The Deposits Channel of Monetary Policy

Itamar Drechsler, Alexi Savov, and Philipp Schnabl*

First draft: November 2014

This draft: March 2016

Abstract

We propose and test a new channel for the transmission of monetary policy. We show that when the Fed funds rate increases, banks widen the interest spreads they charge on deposits, and deposits flow out of the banking system. We present a model in which imperfect competition among banks gives rise to these relationships. An increase in the nominal interest rate increases banks' effective market power, inducing them to increase deposit spreads. Households respond by substituting away from deposits into less liquid but higher-yielding assets. Using branch-level data on all U.S. banks, we show that following an increase in the Fed funds rate, deposit spreads increase by more, and deposit supply falls by more, in areas with less deposit competition. We control for changes in banks' lending opportunities by comparing branches of the *same* bank. We control for changes in macroeconomic conditions by showing that deposit spreads widen immediately after a rate change, even if it is fully *expected*. Our results imply that monetary policy has a significant impact on how the financial system is funded, on the quantity of safe and liquid assets it produces, and on lending to the real economy.

Keywords: Monetary policy, deposits, market power, safe assets, liquidity

---

*New York University Stern School of Business, idrechsl@stern.nyu.edu, asavov@stern.nyu.edu, and pschnabl@stern.nyu.edu. Drechsler and Savov are also with NBER, Schnabl is also with NBER and CEPR. We thank Siddharth Vij for excellent research assistance. We thank Juliane Begenau, Markus Brunnermeier, Douglas Diamond, Eugene Fama, Erik Gilje, Gary Gorton, Anil Kashyap, Arvind Krishnamurthy, Sam Hanson, Daniel Paravisini, David Scharfstein, Philip Strahan, Amit Seru, Adi Sunderam, Amir Sufi, Jeremy Stein, and seminar participants at the AEA Meetings, Berkeley, Boston College, Chicago Booth, Chicago Federal Reserve, Cornell University, Harvard University, IMF/Worldbank Joint Seminar, London School of Economics, London Business School, NBER Asset Pricing, NBER Corporate Finance, NYU-Columbia Junior Meeting, SFS Finance Cavalcade, Stanford University, UCLA, University of Maryland, University of Montreal, and Temple University for helpful comments.

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. These relationships are strong and their aggregate effects are large. Since the financial system relies heavily on deposits, our results imply that monetary policy has a large impact on the cost and composition of the financial system's funding, on the amount of safe and liquid assets it creates, and on the amount of credit it extends to the broader economy.

We argue that the deposits channel is the result of banks' market power over liquidity provision to households. Households value deposits for their liquidity and safety. When interest rates rise, households' alternative sources of liquidity, cash and currency, become more expensive to hold, and this raises banks' effective market power over liquidity provision. Banks take advantage of this greater market power by acting like a monopolist: they maximize profits by raising prices (deposit spreads) and restricting quantities. Households respond to the higher deposit spreads by decreasing their deposit holdings. We identify this mechanism empirically by exploiting geographic variation in competition and branch-level data on deposit spreads and quantities.

Deposits are special for both banks and households. Deposits are an essential source of bank funding that is more stable and dependable than alternative sources, mainly short-term wholesale markets. This stability confers banks with an advantage in investing in risky and illiquid assets (Hanson, Shleifer, Stein, and Vishny 2015). Deposits are also by far the largest source of bank funding, amounting to \$10.2 trillion or 77% of bank liabilities in 2014. Therefore, as banks cut deposits they are also likely to cut lending. Thus, the deposits channel can explain how monetary policy affects bank lending.[1]

Deposits are also the main source of safe and liquid assets for households, and hence a major source of liquidity for the economy as a whole. Therefore, when an increase in the Fed funds rate induces banks to contract deposits, the liquidity premium of all other safe and

[1] In contrast to existing models of the bank lending channel of monetary policy, our proposed explanation does not depend on the quantitatively implausible mechanism of reserve requirements.

liquid assets, such as Treasuries, is expected to rise.[2] In turn, an increase in the liquidity premium has important implications for financial markets and asset prices.

Figure 1 plots the Fed funds rate target, the main instrument of U.S. monetary policy, against the average deposit rate paid on interest checking, money market accounts, and 12-month certificate of deposits. These products are offered in local deposit markets and are targeted primarily at households and small businesses. They are the three most widely-offered products within the three main classes of deposits offered to households: checking, savings, and small time deposits. Checking and savings accounts are demandable and hence highly liquid. In contrast, time deposits are locked in for term and hence relatively illiquid. In 2014 these three classes accounted for \$1.6 trillion, \$6.5 trillion, and \$0.4 trillion, respectively, making up a combined 83% of total deposits.

Figure 1 reveals two important facts. First, the rates paid on deposits are significantly below the Fed funds rate, especially for the more liquid checking and savings deposits. Thus, there is a large and positive spread between Fed funds and deposit rates. Since the Fed funds rate closely tracks the rates investors earn on short-term safe instruments traded in competitive markets, the Fed funds-deposit spread captures the opportunity cost of holding deposits. Figure 1 shows that this opportunity cost is high. In particular, the spread on the highly liquid checking deposits is the largest. It is followed by the spread on the similarly liquid savings deposits, which is also very large, averaging over 200 basis points. In contrast, households incur a substantially lower opportunity cost when they forego the liquidity of savings and checking deposits in favor of time deposits.

Second, deposit spreads are strongly increasing in the Fed funds rate. Therefore, when the Fed funds rate rises, deposits become much more expensive to hold. For instance, as the Fed hiked rates by about 450 basis points in the mid 2000s, the spread on savings and checking deposits increased by 350 and 450 basis points, respectively. While the spread on time deposits also increased, it did so by much less than the two types of liquid deposits. Thus, holding liquid deposits became much more expensive than holding the relatively illiquid time deposits. The same relationship holds throughout the whole sample as the Fed raised and

[2]Krishnamurthy and Vissing-Jorgensen (2012) show that Treasury yields embed a large liquidity premium. Nagel (2014) shows that the premium on "near-money assets" such as Treasuries is strongly positively related to the level of the Fed funds rate.

lowered rates. Thus, Figure 1 makes clear that the liquidity premium on deposits is strongly and positively related to the Fed funds rate.

Figure 2 shows the corresponding changes in the quantities of deposits. It plots the year-over-year change in the Fed funds rate against the percentage growth rate in the aggregate amounts of savings (Panel A), checking (Panel B), and small time deposits (Panel C), as well as their sum (Panel D). The relationships are clear and striking. From Panel A, the growth rate in savings deposits is strongly negatively related to changes in the Fed funds rate. Thus, as the Fed funds rate rises and the cost of holding savings deposits goes up, households reduce their savings deposits holdings. Panel B shows a similar relationship for checking deposits. The effects are large for both classes: year-over-year growth rates vary from −14% to +26%, a very wide range given the enormous size of these asset classes.

In contrast, Panel C shows the opposite relationship for the less liquid time deposits: their growth rate is positively related to changes in the Fed funds rate. As we saw in Figure 1, as the Fed funds rate rises, liquid deposits (savings and checking) become more expensive to hold relative to time deposits. Panel C shows that households respond to this increase in the liquidity premium on deposits by substituting away from liquid deposits into less liquid deposits.

Panel D looks at the sum of checking, savings, and small time deposits. The banking literature refers to this combination as core deposits in recognition of the fact that they represent banks' most stable and dependable source of funding. As the panel shows, core deposit growth is strongly negatively related to changes in the Fed funds rate since outflows from checking and savings deposits greatly exceed inflows into small time deposits. Thus, beyond the reallocation from more to less liquid deposits, core deposits as a whole shrink substantially as the Fed funds rate rises.[3]

We emphasize that Figures 1 and 2 indicate that monetary policy appears to shift banks' *supply* of deposits rather than households' *demand* for deposits because deposit prices (spreads) and quantities move in opposite directions. In contrast, a shift in demand would

[3] In addition to core deposits, which come from households, banks also fund themselves with wholesale deposits, which come from corporate and institutional sources. These include commercial paper and large time deposits. Banks have little market power over wholesale deposits and consequently their rates track the Fed funds rate closely.

cause prices and quantities to move in the same direction. For instance, if households' demand for deposits increases, then they would be willing to pay more for deposits and at the same time hold more of them, in contrast to what we see in the data.

We develop a model that explains the observed relationships and guides our empirical analysis. In the model, households have a preference for liquidity which they obtain from cash and deposits. Cash is fully liquid but pays no interest, while deposits are partially liquid and pay some interest. This interest is determined by a set of monopolistically competitive banks who compete with cash to profit from supplying liquidity to households. Households can always forego liquidity and invest in bonds, which pay a competitive market rate set by the central bank, i.e. the Fed funds rate. Hence, the Fed funds rate represents the opportunity cost of holding cash, and the difference between the Fed funds rate and the deposit rate, the deposit spread, represents the opportunity cost of holding deposits. When the Fed funds rate rises, cash becomes more expensive to hold, and this increases banks' effective market power over liquidity provision. Banks take advantage of this greater market power by charging higher deposit spreads. Households respond to the higher deposit spread by substituting away from liquid deposits into illiquid bonds. This gives rise to the relationships we see in Figures 1 and 2.

We use panel data on U.S. bank branches to test the market power mechanism underlying our theory. This is necessary because the aggregate time series does not reveal why the supply of deposits changes with the Fed funds rate. For instance, it could be that both are responding to changing macroeconomic conditions. Or if lending opportunities deteriorate when the Fed raises rates, then banks would need fewer deposits and this could lead to a reduction in deposit supply even without a direct deposits channel.

We deal with these identification challenges by exploiting geographic variation in competition across U.S. counties, which we measure using the Herfindahl index of banks' local deposit market shares. Our model predicts that an increase in the Fed funds rate has a larger impact on banks' effective market power in areas where competition is low. Thus, following an increase in the Fed funds rate, low-competition counties should see a greater increase in deposit spreads and a greater decrease in deposit quantities than high-competition counties. We find strong support for this prediction using panel data on deposit spreads and quantities.

While this approach controls for changes in aggregate economic conditions, there is still a concern that the sensitivity of local lending opportunities to aggregate economic conditions is correlated with the level of competition. We deal with this concern by comparing the deposit spreads and quantities of different branches that belong to the *same* bank. We do so by estimating panel regressions with bank-time fixed effects. The identifying assumption is that a bank can raise a dollar of deposits at one branch and lend it at another, effectively decoupling the local lending and deposit-taking decisions. Under this assumption, our within-bank estimation controls for changes in banks' lending opportunities and identifies differential changes in deposit supply that are due to differences in competition across counties.

We find that following a 100 basis point increase in the Fed funds rate branches in low-competition counties increase savings deposit spreads by 15 basis points, and time deposits spreads by 8 basis points, relative to branches in high-competition counties. We also find that branches in low-competition counties experience deposit outflows that are 86 basis points larger than branches in high-competition markets. These numbers imply an elasticity of deposits with respect to spreads of -7.0, which is comparable to the -5.4 elasticity implied by the aggregate time series.

To further establish a direct effect of monetary policy on deposits, we use weekly data to conduct an event study of the precise timing of changes in deposit spreads. We find that deposit spreads react immediately (within a week) to changes in the Fed funds rate, and that the difference between more and less competitive counties emerges at exactly the same time. There is no effect in the weeks before a Fed funds rate change. This precise timing provides strong evidence that monetary policy has a direct effect on deposit pricing that varies across markets with different levels of competition.

While the event study supports our model's prediction that banks change deposit spreads in response to changes in the Fed funds rate, it remains possible that they are actually responding to new information about economic conditions that the Fed releases at the same time as it changes rates. Ruling out this information release hypothesis is a pervasive and difficult challenge for empirical studies of monetary policy because any rate change could be associated with an information release. We are uniquely able to hold information fixed and thereby tackle this challenge by testing whether deposit spreads respond differentially even to fully *expected* changes in the Fed funds rate, which we isolate from Fed funds futures prices. While in most settings expected rate changes have no effect because asset prices react only to news, in our setting deposit spreads should react to both. The reason is that deposits (specifically checking and savings) have zero maturity, hence they should not price in a rate change until it is actually realized, even when it is fully expected.

We find that our results are unchanged when we replace realized Fed funds changes with expected Fed funds changes. This demonstrates that the differential response of deposit spreads to Fed funds changes by level of competition is driven by the change in the Fed funds rate itself and not by the release of new information. It also provides further evidence that our results cannot be explained by changes in macroeconomic conditions because news of such changes would have to exactly coincide and be correlated with Fed funds changes that are anticipated in advance.

We conduct several additional tests. First, we show that proxies for financial literacy (age, income, and education) have similar effects as our Herfindahl measure of competition, although our measure remains significant in regressions that include both. Since limited financial literacy is a plausible source of market power for banks, this result is in line with our channel. Second, our results hold for both small and large banks, which is consistent with the large aggregate effects we see. Third, we show that our results hold for a variety of deposit products beyond the most-widely offered products in each category. Fourth, our results are not sensitive to how we specify the size of a local deposit market, which we show by computing Herfindahl indexes within two and five miles of a given branch. Fifth, our results are robust to using alternative measures of competition such as measures based on historical, time-varying, and branch-level market shares. And sixth, we find similar results if we estimate our deposit spreads regressions in levels instead of changes, which indicates that we are picking up long-lived effects in deposit pricing.

We highlight two important implications of the deposits channel. The first is that the deposits channel can explain how monetary policy affects bank lending without relying on reserve requirements. Under the deposits channel, an increase in the Fed funds rate induces banks to restrict deposit supply in order to increase profits, even if this comes at the cost of decreasing lending. In contrast, the traditional explanation for the bank lending channel works through reserve requirements, an increasingly implausible mechanism in recent decades as required reserves and the open market operations that change their supply have become too small to impact bank lending.

We provide evidence for the implications of the deposits channel for bank lending using data on all U.S. commercial banks. We first show that our branch-level results aggregate up to the bank level with little change in magnitudes. We then show that the changes in deposits induced by changes in the Fed funds rate affect the rest of bank balance sheets. Specifically, when the Fed funds rate rises, banks that operate in less competitive markets not only shrink their deposits but also expand their wholesale funding relative to banks that operate in more competitive markets. This result has implications for financial stability since wholesale funding markets are recognized as less resilient in times of stress. We further show that the substitution to wholesale funding does not fully offset the contraction in deposits, leading to a reduction in total bank assets including loans to the real economy.

The second implication we highlight is that the deposits channel can explain how monetary policy affects the liquidity premium in financial markets. As Nagel (2014) shows, there is a strong positive relationship between the Fed funds rate and measures of the liquidity premium in Treasury and other markets. For such a strong relationship to exist, monetary policy must induce large shifts in the supply of liquid assets in the economy. As noted above, changes in required reserves are too small to fulfill this role. The deposits channel offers an alternative mechanism: as the Fed funds rate rises and deposits, which are large, shrink by a large amount, the overall supply of liquid assets shrinks. As the supply of liquid assets shrinks their price, the liquidity premium, increases, which is what we see in the data.

In turn, the liquidity premium plays an important role in the financial system. Drechsler, Savov, and Schnabl (2015) provide a theory where it affects the cost of leverage for financial institutions who hold large amounts of liquid assets to insure against a loss of funding. Through its effect on the cost of leverage, the liquidity premium affects risk taking and risk premia, and by extension asset prices and investment.

II. Related literature

Our paper connects to the large literatures on the transmission of monetary policy, the bank lending channel, and liquidity provision. Bernanke (1983) argues that bank lending is an important source of propagation and amplification of shocks. Bernanke and Gertler (1995) and Kashyap and Stein (1994) formalize the bank lending channel. Bernanke and Gertler (1989) and Bernanke, Gertler, and Gilchrist (1999) develop the broader balance sheet channel which works through the scarcity of equity capital in the financial sector. More recently, He and Krishnamurthy (2013) and Brunnermeier and Sannikov (2014) present fully dynamic macroeconomic models in the tradition of the balance sheet channel.

On the empirical side, Bernanke and Blinder (1992) and Kashyap, Stein, and Wilcox (1993) show that an increase in the Fed funds rate is associated with a decrease in deposits and bank lending, and an increase in unemployment. Kashyap and Stein (2000) show that lending falls most among small banks. Jiménez, Ongena, Peydró, and Saurina (2014) and Dell'Ariccia, Laeven, and Suarez (2013) extend these results by exploiting within-borrower variation in lending around interest rate changes. Scharfstein and Sunderam (2014) show that market power in mortgage lending affects its sensitivity to monetary policy.

Diamond and Dybvig (1983) and Gorton and Pennacchi (1990) interpret deposits as a source of liquidity for households. Stein (1998) argues that deposits are also a special, hard-to-replace funding source for banks. Kashyap, Rajan, and Stein (2002) emphasize the complementarities between lending and deposit taking and Stein (2012) presents a model of how monetary policy can be used to regulate deposit taking in the interest of financial stability. Krishnamurthy and Vissing-Jorgensen (2012, 2013) show that bank balance sheets absorb changes in the liquidity premium induced by changes in the supply of Treasuries. Sunderam (2015) shows that the shadow banking system also responds to changes in the liquidity premium.

In the literature on deposit markets, Neumark and Sharpe (1992) and Hannan and Berger (1991) argue that deposit rates are downward-rigid and upward-flexible as a result of market power. Driscoll and Judson (2013) show that average deposit rates adjust asymmetrically to interest rate changes. Acharya and Mora (2015) and Egan, Hortacsu, and Matvos (2015) document large reallocation of deposits across banks during the financial crisis. Gilje, Loutskina, and Strahan (2013) and Ben-David, Palvia, and Spatt (2015) show that banks channel deposits to branches located in areas with high loan demand.

A branch of the empirical literature on monetary policy and asset prices uses event studies. Bernanke and Kuttner (2005), Hanson and Stein (2015), Nakamura and Steinsson (2013), and Gertler and Karadi (2015) show that nominal rates have large effects on risky assets such as stocks, long-term bonds, and credit spreads.

Within this context, the contribution of our paper is to show that banks transmit changes in monetary policy to the real economy through the supply of deposits, and that they do so as a result of market power in deposit markets.

The rest of this paper is organized as follows: Section III presents our model, Section IV summarizes our data, Section V presents our results, and Section VI concludes.

III. A model of the deposits channel

We present a simple model of the relationship between market power, deposits, and the Fed funds rate. For simplicity, the economy lasts for one period and there is no risk. We think of it as corresponding to a regional market or a county in the context of our empirical analysis. The county's representative household maximizes utility, which is defined 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, in monetary economics it arises from a cash-in-advance constraint (see Galí 2009). In other models it arises 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 in turn 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 representative of the relatively liquid types of household deposits such as savings accounts.[4] Because cash and deposits both provide liquidity, it is natural to view them as 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 $1/N$ and produces deposits at a rate D_i, resulting in an amount 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.[5]

In addition to cash and deposits, households can invest in bonds, which provide no liquidity (or at least less liquidity than cash or deposits). Bonds pay an interest rate, f, which is set by the central bank. In other words, f is the Fed funds rate.

Deposits pay an interest rate $f - s_i$, where s_i is the spread that bank i charges on its deposits. This spread measures the opportunity cost of holding deposits in terms of foregone interest. Let $s \equiv \frac{1}{N}\sum_{i=1}^{N} \frac{D_i}{D} s_i$ be the weighted average deposit spread. Then the household's budget equation can be written simply as

$$W = W_0(1+f) - Mf - Ds. \tag{4}$$

[4] We model a single type of deposits for simplicity. It is straight-forward to extend the model to allow for multiple deposits with varying degrees of liquidity.

[5] 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 prefers to hold deposits in whichever bank is most convenient. As a result, the representative household substitutes deposits imperfectly across banks and prefers to distribute them evenly as in (3).

Households earn the gross interest rate $1 + f$ on their initial wealth W_0, while foregoing the net interest rate f on their cash holdings M and the deposit spread s on their deposits D.

The solution to the household's problem can be summarized by three first-order conditions. The first is that the household must be indifferent between banks at the margin:

$$\frac{D_i}{D} = \left(\frac{s_i}{s}\right)^{-\eta}. \tag{5}$$

As bank i increases its deposit spread relative to other banks, the household reduces its deposits at bank i at the rate η, the elasticity of substitution across banks. The second condition is that the household must be indifferent between cash and deposits at the margin:

$$\frac{D}{M} = \delta^{\epsilon}\left(\frac{s}{f}\right)^{-\epsilon}. \tag{6}$$

When deposit spreads are high, households substitute away from deposits into cash at the rate ϵ, the elasticity of substitution between cash and deposits. Finally, the household must also be indifferent between liquidity and bonds at the margin:

$$\frac{l}{W} = \lambda^{\rho} s_l^{-\rho}, \tag{7}$$

where $s_l \equiv \frac{M}{l} f + \frac{D}{l} s$ is the weighted average foregone interest or premium that households pay to obtain liquidity.[6] When the Fed funds rate f and deposit spread s are high, liquidity is more expensive and households substitute away from liquid assets into bonds.

Banks invest the deposits they raise in bonds, earning the bond rate f. More broadly, we can think of them as having a portfolio of loans and securities whose risk-adjusted return is the competitive market rate f. Bank i sets its deposit spread s_i to maximize its profits $D_i s_i$. The resulting profit-maximizing condition is

$$\frac{\partial D_i / D_i}{\partial s_i / s_i} = -1. \tag{8}$$

At the optimum, the elasticity of demand for bank i's deposits is -1 so that further increasing

[6] Using (6), we can write it solely in terms of f and s as $s_l^{1-\epsilon} \equiv f^{1-\epsilon} + \delta^{\epsilon} s^{1-\epsilon}$.

the spread cannot increase profits. We can use the interbank margin (5) to calculate the elasticity in (8). In a symmetric equilibrium ($D_i = D$ and $s_i = s$) it is given by

$$\frac{\partial D_i/D_i}{\partial s_i/s_i} = \frac{1}{N}\left(\frac{\partial D/D}{\partial s/s}\right) - \eta\left(1 - \frac{1}{N}\right). \tag{9}$$

As bank i increases its spread s_i, it faces outflows from two sources. The first is an aggregate effect: the increase raises the average deposit spread s, making deposits more expensive and leading to outflows from deposits to other assets. This effect diminishes as banks become more numerous (N rises) because each individual bank becomes less important. The second source of outflows comes from inter-bank competition: raising s_i makes bank i's deposits expensive relative to other banks. In particular, when s_i rises by one percent, the average spread s goes up by $1/N$ percent, and hence the price of bank i's deposits increases by $1-1/N$ percent relative to the average bank. This induces outflows from bank i at a rate η, the elasticity of substitution across banks. Substituting (9) into (8), we get the equilibrium condition

$$\frac{1}{N}\left(\frac{\partial D/D}{\partial s/s}\right) - \eta\left(1 - \frac{1}{N}\right) = -1. \tag{10}$$

Whereas the interbank effect (second term) does not depend on monetary policy (f), the aggregate effect (first term), which is due to competition between deposits and other assets, does. Specifically, we can combine (4), (6), and (7) to write the aggregate effect as

$$-\frac{\partial D/D}{\partial s/s} = \left[\frac{1}{1+\delta^{\epsilon}\left(\frac{f}{s}\right)^{\epsilon-1}}\right]\epsilon + \left[\frac{\delta^{\epsilon}\left(\frac{f}{s}\right)^{\epsilon-1}}{1+\delta^{\epsilon}\left(\frac{f}{s}\right)^{\epsilon-1}}\right]\left(\frac{\rho + \frac{ls_l}{W}}{1+\frac{ls_l}{W}}\right). \tag{11}$$

Households substitute deposits with either cash or bonds and hence both represent sources of competition for banks. When the Fed funds rate is low, cash is cheap and this makes it an attractive source of liquidity. For a given average spread s, the elasticity of deposit demand is then close to ϵ, the elasticity of substitution between deposits and cash, which is high. Hence, banks face strong competition from cash. Conversely, when the Fed funds rate is high, cash is expensive and relatively unattractive as a source of liquidity. As such it provides little competition for banks. Banks' competition instead comes from bonds, which are not a good substitute for deposits because they are illiquid ($\rho < \epsilon$). In this case, the elasticity of deposit demand is close to a value between ρ and 1 (the last term in parentheses), which is less than ϵ. Thus, when rates are high banks face an inelastic demand curve, increasing their effective market power over the provision of liquidity to households.

We can solve for spreads in closed form in the case when liquidity demand is small compared to total wealth ($\lambda \to 0$):[7]

Proposition 1. *Let $\rho < 1 < \epsilon, \eta$. Also let $\mathcal{M} \equiv 1 - (\eta - 1)(N - 1)$, which captures the market power of banks over deposits. Consider the limiting case $\lambda \to 0$. If $\mathcal{M} < \rho$ then the deposit spread is zero. Otherwise, the deposit spread is given by*

$$s = \delta^{\frac{\epsilon}{\epsilon-1}} \left(\frac{\mathcal{M} - \rho}{\epsilon - \mathcal{M}} \right)^{\frac{1}{\epsilon-1}} f. \tag{12}$$

The deposit spread:

(i) increases with banks' market power $\mathcal{M}$, which is itself decreasing in the number of banks N and elasticity of substitution across banks η;

(ii) increases with the Fed funds rate f;

(iii) increases more with the Fed funds rate f when banks' market power $\mathcal{M}$ is higher.

Proof of Proposition 1. It follows from (10) that when banks are at an interior optimum, the aggregate deposit elasticity satisfies $-\frac{\partial D/D}{\partial s/s} = 1 - (\eta - 1)(N - 1) = \mathcal{M}$. Substituting (11) into this expression and letting $\lambda \to 0$ gives (12). The relationship between s and $\mathcal{M}$ is $\frac{\partial s}{\partial \mathcal{M}} = s(\epsilon - 1)^{-1} (\epsilon - \mathcal{M})^{-2}$. Thus s increases in $\mathcal{M}$ provided that $\epsilon > 1$. Moreover, $\mathcal{M}$ decreases in N and η provided N, $\eta > 1$. Using $\frac{\partial^2 s}{\partial \mathcal{M} \partial f} = \frac{1}{s} \frac{\partial s}{\partial f} \frac{\partial s}{\partial \mathcal{M}}$ and $\frac{\partial s}{\partial f} > 0$ gives (iii). □

Competition among banks causes the banking sector as a whole to have market power given by the endogenous quantity $\mathcal{M}$. Intuitively, we can think of replacing the N banks with a representative bank with market power equal to $\mathcal{M}$. This market power is lower when there is more inter-bank competition, either because there are more banks (N is higher) or because deposits are more easily substituted across banks (η is larger). When there is only one bank, or individual banks' deposits are poor substitutes ($\eta \to 1$), $\mathcal{M} = 1$ (its largest

[7] We can also do this in the case $\rho \to 1$. The formulas are identical.

possible value). In this case the representative bank acts like a pure monopolist and charges a high deposit spread. In contrast, when N is large or banks' deposits are good substitutes (η is large), $\mathcal{M}$ is small and the deposit spread is small.

Proposition 1 shows that the deposit spread rises with the Fed funds rate. When the Fed funds rate is high, cash is an expensive source of liquidity and hence an expensive substitute for bank deposits. The representative bank's competition comes mostly from bonds, a relatively poor substitute for deposits due to their illiquidity ($\rho < \epsilon$). Hence, the representative bank faces a relatively inelastic demand curve and therefore charges more for deposits. In contrast, when the Fed funds rate is low the representative bank faces more competition from cash, which is highly substitutable with deposits ($\epsilon > 1$). It therefore faces a relatively elastic demand curve and charges little for deposits. Monetary policy thus affects banks' effective market power over the provision of liquidity to households.[8]

Finally, Proposition 1 shows that the effect of the Fed funds rate on the deposit spread is larger when competition is low. When competition is high, spreads are low regardless of the Fed funds rate and the opportunity cost of holding cash. In contrast, when competition is low, cash is a more important alternative to bank deposits, and hence the effect of the Fed funds rate on deposit spreads is larger. This result is captured by the cross-partial comparative static in part (*iii*) of Proposition 1. It corresponds empirically to the interaction coefficient between market power and changes in the Fed funds rate which we estimate below.

IV. Deposits data and summary statistics

We build a novel data set at the bank-branch level that includes information on deposit quantities, deposits rates, branch, bank, and county characteristics.

The data on deposit quantities is from the Federal Deposit Insurance Corporation (FDIC), which provides annual branch-level data on total deposits from June 1994 to June 2014. The data set has information on branch characteristics such as the parent bank, address, and ge-

[8]There is evidence that Proposition 1 is consistent with how banks set their deposit rates in practice. The practitioner literature explicitly recommends taking into account the demand elasticity of deposits (Ke 2012). Industry consultants offer advice on how to estimate this elasticity and how to use it to increase profits (PricewaterhouseCoopers 2011). Scharfstein (2015) presents a case study where banks facing less competition increase their deposit rates by less as interest rates rise.

ographic coordinates. It covers the universe of bank branches in the U.S. and contains a unique branch identifier, bank identifier, and county identifier. We use these identifiers to match it with other data sets.

The data on deposit rates is from Ratewatch, covering the period from January 1997 to December 2014. Ratewatch collects weekly branch-level data on deposit rates by product. The quality of the data is high as it is used by both banks and regulators such as the FDIC. The data is a sample of U.S. branches covering 54% of all U.S. branches in 2008. We merge the Ratewatch data with the FDIC data using the FDIC branch identifier. We are able to match 85.4% of the Ratewatch data. The data reports whether a branch actively sets deposit rates ("rate-setting") or whether the branch uses rates that are set by another branch ("non rate-setting"). We focus our analysis on rate-setting branches to avoid duplication of observations.[9]

The Ratewatch data reports a deposit rate for every deposit product offered at a given branch. This deposit rate is the one offered for new accounts at that branch. We focus our analysis on the two deposit products that are most commonly offered across all branches, money market 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).[10] These two products are representative of the two main types of deposits, savings and time. As we show below, our results also hold for other deposit products and account sizes.

We collect data on bank characteristics from the U.S. Call Reports from January 1986 to December 2014, which we obtain from the Federal Reserve Bank of Chicago. The Call Reports 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 unique FDIC bank identifier.

We collect data on county characteristics from the 2000 U.S. Census. We use data on total population, share of individuals over age 65, median household income, share of individuals with a college degree, and county size. We merge these county characteristics with the

[9]There is about two non-rate-setting branches for each rate-setting branch. Non-rate-setting branches are typically smaller and are geographically close to the rate-setting branch.

[10]Money market accounts should not be confounded with money market mutual fund shares. Money market accounts are saving deposit accounts. Money market mutual fund shares are shares in a money market mutual fund.

deposit data using the FDIC county identifier.

We measure the stance of monetary policy using the Fed funds rate. Given that there is no variation in the Fed funds rate after December 2008, we restrict the analysis to the period before December 2008. We also drop the second half of 2008 because the U.S. financial crisis triggered deposit flows that were unrelated to market power. Our sample period is therefore for from June 1994 (FDIC data) or January 1997 (Ratewatch data) until June 2008.[11]

We download the daily Fed funds target rate from the St. Louis Federal Reserve Economic Database and we use it to compute weekly and quarterly changes.[12] We also download the one-year T-Bill rate, which we use when analyzing 12-month CDs. In some tests we distinguish between expected and unexpected changes in the Fed funds rate. At the weekly frequency, we use the estimates from Kuttner (2001). At the quarterly frequency, we compute the expected change in the Fed funds rate as the difference between the three-month Fed funds futures rate and the Fed funds target rate at the beginning of each quarter. The unexpected change is the total realized change minus the expected change.

Our main measure of deposit competition is the deposit Herfindahl index at the county level. It is widely used by regulators and practitioners to evaluate the level of competition between banks.[13] We compute the Herfindahl index in the standard way, by summing the squared deposit market shares of all banks with branches in a given county in a given year and then averaging over the years in the sample. In the robustness section we also analyze historical as well as yearly versions of the Herfindahl index, as well as versions constructed within two or five miles of a given branch.

Figure 3 shows a map of competition by county using the deposit Herfindahl measure. A Herfindahl of one indicates complete concentration in which a single bank has all the deposits in a given county, whereas lower values indicate less concentration and hence more competition. As shown in the figure, there is significant variation across counties, ranging

[11] Our analysis of deposits spreads and deposit growth is robust to including the second half of 2008.

[12] We use the Fed funds target rate to avoid occasional end-of-month spikes in the effective Fed funds rate. Our results are robust to using the average effective Fed funds rate during the last week or month of a quarter.

[13] The Federal Reserve and the U.S. Department of Justice, Antitrust Division, use deposit Herfindahl indexes to analyze the effects of bank mergers and acquisitions on competition under the Bank Holding Company Act. The Federal Reserve Bank of St. Louis provides provides MSA-level and county-level deposit Herfindahl indexes at `https://cassidi.stlouisfed.org/`.

from competitive counties with a minimum Herfindahl of 0.06 to uncompetitive counties with a maximum Herfindahl of 1. The figure does not reveal any obvious regional clustering. Consistent with this interpretation, we show below that our analysis is unaffected by controlling for regional trends.

Panel A of Table 1 provides summary statistics at the county level. The data is for all counties with at least one bank branch, which yields 3,104 observations. We provide a breakdown of county characteristics split by the median Herfindahl index. Low-Herfindahl counties (high competition) are larger than high-Herfindahl counties (low competition) with a median population of 25,981 versus 13,097. They also have a higher median household income, \$37,611 versus \$32,242, a lower share of individuals over the age of 65, 14.2% versus 15.4%, and a higher share of individuals with a college degree, 18.7% versus 14.3%.

Panel B of Table 1 provides summary statistics on deposit quantities at the branch level. The data is annual from June 1994 to June 2008 covering all bank branches, which yields 906,125 observations. Total deposits per branch are \$56.9 million and their growth rate is 8.85%. Panel C provides summary statistics on deposit spreads at the branch level. The data is quarterly from January 1997 to June 2008 and covers all rate-setting branches. The change in the deposit spread is computed as the change in the Fed funds rate minus the change in the deposit rate over a quarter. The average change for savings deposits (25K money market accounts) and time deposits (10K 12-month CDs) are −3 and −1 basis points, respectively. The average change in the Fed funds and T-Bill rates is −8 basis points.

Panel D of Table 1 provides summary statistics at the bank level. The data is quarterly from June 1994 to June 2008 covering all commercial banks, which yields 424,606 observations. We compute a bank's deposit Herfindahl index as the deposit-weighted average of its one-quarter lagged branch-level Herfindahl indexes. The average bank has \$825 million in assets and total liabilities of \$750 million. The main funding source are domestic core deposits, which account for 80.6% of total liabilities. Checking deposits account for 26.1%, savings deposits account for 22.8%, and small time deposits account for 31.5%. The other main liabilities are large time deposits and other wholesale funding, accounting for 13.4% and 5.9%, respectively.[14]

[14]We refer to transaction deposits as checking deposits, which include demand deposits and other checkable

V. Testing the deposits channel

A. Main identification strategy

The goal of our empirical analysis is to estimate the effect of monetary policy on the supply of deposits. As we saw in Figure 1, the spreads between deposit rates and the Fed funds rate widen as the Fed funds rate increases. As we saw in Figure 2, there is a contemporaneous outflow from checking and savings deposits (Panels A and B) and an inflow into small time deposits (Panel C). The net effect is an aggregate outflow of core deposits from the banking system (Panel D). This aggregate evidence is consistent with the hypothesis that monetary policy affects the supply of deposits.

However, establishing that monetary policy *causes* the supply of deposits to change is challenging due to the potential influence of omitted variables such as changes in economic conditions.[15] Moreover, if raising the Fed funds rate causes lending opportunities to decline, then this could explain why deposits shrink without an independent deposits channel. We must therefore control for changes in economic conditions and lending opportunities in order to establish a direct causal effect of monetary policy on deposit supply.

We address this identification challenge by using geographic variation in deposit market competition. Our model predicts that an increase in the Fed funds rate leads to larger increases in deposit spreads and greater outflows of deposits in areas where competition is low. We test these predictions using panel data on deposit spreads and flows at the county level. This approach allows us to control for changes in *aggregate* economic conditions.

Yet this approach does not fully solve the identification challenge because it could be that economic conditions change differentially across counties with different levels of competition. For instance, if lending opportunities decline by more in less competitive counties following an increase in the Fed funds rate, then the supply of deposits would decline by more in these counties without a direct deposits channel.

deposits. Other wholesale funding consists of foreign deposits, Fed Funds purchased, and other borrowed money.

[15] As monetary policy typically tightens when the economy is booming, we would expect rising rates to coincide with high loan growth and hence an increasing supply of deposits, contrary to what we see in the aggregate time series. Nevertheless, we design our empirical strategy so that it fully controls for changes in economic conditions at both the aggregate and local level.

We address this more refined version of the identification challenge by using geographic variation in deposit market competition across branches of the *same* bank. This approach is best illustrated with an example. Consider a bank that runs two branches, one in a competitive county and one in an uncompetitive county. Since the bank can move deposits from one branch to the other, the decision of how many loans to make at one branch is independent of the decision of how many deposits to take in at that branch. In other words, we can control for differential changes in lending opportunities across counties by comparing deposit spreads and quantities across branches of the same bank located in different counties. We refer to this approach as within-bank estimation.

The identifying assumption behind the within-bank estimation is that banks equalize the marginal return to lending across branches. This assumption holds as long as banks can freely allocate resources internally. The banking literature indicates that this is indeed the case by showing that banks channel deposits to areas with high loan demand (e.g. Gilje, Loutskina, and Strahan 2013). Even if banks' internal capital markets have frictions, this strategy controls for changes in lending opportunities as long as the frictions are uncorrelated with local deposit market competition.

We implement our identification strategy in two stages. First, we examine whether the patterns in the aggregate time series are stronger cross-sectionally in less competitive counties. We do this by running simple time series regressions at the branch level that use all of the variation in the data. Second, we implement the within-bank estimation by running panel regressions with bank-time fixed effects, which uses only variation within multi-branch banks. By comparing results across progressively more restrictive specifications, we can evaluate the magnitude, robustness, and external validity of our findings.

B. Branch-level time-series regressions

We start by analyzing the sensitivity of deposits to monetary policy at the branch level. Specifically, for each branch i we estimate the following time-series regression:

$$\Delta y_{it} = \alpha_i + \beta_i \Delta FF_t + \varepsilon_{it}, \tag{13}$$

where Δy_{it} is either the change in the deposit spread or the log change in total deposits (deposit flows) of branch i from date t to $t+1$ and ΔFF_t is the change in the Fed Funds target rate from t to $t+1$. The estimation is quarterly for deposit spreads (Ratewatch data) and annual for flows (FDIC data). For deposit spreads we include all rate-setting branches in the Ratewatch data. For flows we include all branches in the FDIC data. We refer to β_i as the "deposit beta" of branch i because it captures the sensitivity of branch i's deposit spread and flows to changes in the Fed funds rate.[16]

To examine the role of competition, we average deposit betas by county, winsorizing at the 1%-level to minimize the effect of outliers. We then sort counties into twenty equal groups by level of competition (about 131 counties per group) and plot the average deposit beta for each group. The results are presented in Figure 4.

Panel A of Figure 4 shows that the spreads on savings deposits (25K money market accounts) increase more with the Fed funds rate in counties with less competition. The result is robust as the relationship between deposit betas and competition is roughly linear across all groups. The average deposit beta is 0.66 in high-competition counties (Herfindahl below 10th percentile) and 0.76 in low-competition counties (Herfindahl above 90th percentile). Hence, a 100 basis point increase in the Fed Funds rate raises savings deposit spreads in low-competition counties by 10 basis points relative to high-competition counties.

Panel B shows the results for the spreads on time deposits (10K 12-month CDs). For this plot we use the one-year T-Bill rate instead of the Fed funds rate to match the maturity of time deposits.[17] Similar to the results for savings deposits, we find that the time deposits spread increases more with the T-Bill rate in counties with less deposit competition. The average deposit beta is 0.19 in high-competition counties (Herfindahl above 10th percentile) and 0.26 in low-competition counties (Herfindahl below 90th percentile). Hence, a 100 basis point increase in the T-Bill rate raises time deposit spreads by 7 basis points in low-competition counties relative to high-competition counties.[18]

[16] We use the deposit spread as the outcome variable because it measures the price of deposits in terms of foregone interest. 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 $1 - \beta_i$.

[17] The cross-sectional results are similar if we use the Fed funds rate instead.

[18] The average deposit beta for time deposits is smaller than for savings deposits. This is consistent with the aggregate results in Figure 1 which show that the spread on more liquid deposits such as savings deposits increases relative to the spread on less liquid deposits such as time deposits.

Panel C shows the results for deposit flows. We find the opposite relationship from the one for deposit spreads: deposit flows are on average negative after an increase in the Fed funds rate. More importantly, they are more negative in counties with less competition. The average deposit beta is about 0.18 in high-competition counties (Herfindahl below 10th percentile) and −0.53 in low-competition counties (Herfindahl above 90th percentile). Hence, a 100 basis point increase in the Fed funds rate leads to deposit outflows of 71 basis points in low-competition counties relative to high-competition counties.

Taken together, Figure 4 shows that the aggregate time series results from Figures 1 and 2 are stronger cross-sectionally in counties with less competition. Specifically, an increase in the Fed funds rate leads to a larger increase in deposit spreads (prices) and a larger decrease in deposit flows (quantities) in counties with less competition relative to counties with more competition. This suggests that monetary policy shifts the deposit supply curve. In contrast, under a shift in the demand curve, prices and quantities would move in the same direction. For example, if an increase in the Fed funds rate led households to demand more deposits, it would result in higher deposit spreads and higher deposit growth, contrary to what we see. Thus, our results are inconsistent with a demand-driven explanation for the relationship between monetary policy and deposits.

C. Within-bank estimation

In this section we implement the within-bank estimation strategy to control for changes in banks' lending opportunities. We do so by including bank-time fixed effects, among others, in the following ordinary least squares regression:

$$\Delta y_{ijct} = \alpha_i + \delta_{jt} + \zeta_c + \lambda_{st} + \gamma \Delta FF_t \times HHI_c + \varepsilon_{ijct}, \tag{14}$$

where Δy_{ijct} is either the change in the deposit spread or deposit flows at branch i of bank j in county c from date t to $t+1$, ΔFF_t is the change in the Fed funds rate from t to $t+1$, HHI_c is the deposit Herfindahl of county c, δ_{jt} are bank-time fixed effects, and α_i, ζ_c, and λ_{st} are branch, county, and state-time fixed effects, respectively. We cluster standard errors by county because this is the level of variation of our variable of interest, HHI_c.

The key set of controls are the bank-time fixed effects, which absorb all time-varying differences across banks. This controls for changes in lending opportunities. Intuitively, the regression with bank-time fixed effects compares two branches of the same bank and measures the extent to which, following an increase in the Fed funds rate, the branch in a less competitive county raises its deposit spread and experiences lower deposit growth relative to the branch in a more competitive county.

The other sets of fixed effects serve as additional controls. State-time fixed effects control for state-level changes in deposit markets (e.g., because of changes in state-level bank regulation). Branch time fixed effects control for branch-specific trends (e.g., because of local branch management). County fixed effects control for time-invariant county characteristics (e.g., county size).[19] Quarter fixed effects control for average changes in deposit spread and average deposit growth.[20] We also run specifications with different combinations of fixed effects to gauge their effects and the robustness of our results.

Estimating our regressions in first differences imposes the strict timing assumption that changes in deposit spreads and quantities occur in the same period as changes in the Fed funds rate. This approach is preferable to estimation in levels from an identification standpoint because it controls for other variables that may vary with monetary policy over longer periods of time or with a lag. To capture slower adjustments that can be missed by a first differences specification, we also run levels regressions as a robustness test below.

We use the Ratewatch data for our analysis of deposit spreads and the FDIC data for our results on deposit growth. The data is at the quarterly level for deposit spreads and at the annual level for deposit growth. We note that the analysis does not include data after 2008 because there was no variation in the Fed funds rate in this period.[21] We include all banks with branches in at least two counties because the coefficient of interest (γ) is not identified

[19]The branch and county fixed effects are highly collinear in joint specifications as very few branches (0.6%) ever change counties. We include the county fixed effects in a specification without branch fixed effects to absorb differences in county characteristics and gauge the robustness of our estimates.

[20]We include quarter fixed effects in all regressions. They are collinear with bank-time and state-time fixed effects in joint specifications.

[21]This does not mean that the deposits channel has been less important since 2008. To the contrary, we think of the period after 2008 as exemplifying how the deposit channel works. Our model predicts that when the Fed funds rate is close to zero, banks' market power over liquidity provision is greatly diminished, hence deposit spreads should be low and deposit quantities should be high. This is indeed what we see in the data.

for single-county banks in the presence of bank-time fixed effects. For comparison, we also provide estimates for the full sample of banks but without bank-time fixed effects.[22]

Panel A of Table 2 presents the results for the spreads on savings deposits (25K money market accounts). We find that deposit spreads increase more with the Fed funds rate in counties with less deposit competition. Column 1 presents our preferred specification with the full set of fixed effects. A 100 basis point increase in the Fed funds rate raises spreads in low-competition counties by 15 basis points relative to high-competition counties. The coefficient is highly significant. Column 2 omits the state-time fixed effects, which gives a significant coefficient of 11 basis points. Column 3 features only county and time fixed effects, which also gives a similar result. Columns 4 to 6 estimate the same specifications as in Columns 1 to 3 for the full sample, without bank-time effects. The coefficients are slightly larger across all specifications and continue to be statistically significant.

Panel B of Table 2 presents the results for the spreads on time deposits (10K 12-month CDs). As with the branch-level time-series regressions, we replace the Fed funds rate with the one-year T-Bill rate to match the maturity of time deposits.[23] Column 1 shows that a 100 basis point increase in the T-Bill rate leads to an increase in time deposit spreads in low-competition counties by 8 basis points relative to high-competition counties. 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 deposits, the coefficients for the full sample without bank-time fixed effects (Columns 4 to 6) are slightly larger.

Table 3 presents the results for deposit flows. Column 1 shows that a 100 basis point increase in the Fed funds rate leads to 0.86% lower deposit growth in low-competition counties relative to high-competition counties. The effect is slightly larger if we estimate the specification without state-time fixed effects (Column 2) and using only county and time fixed effects (Column 3). The effect is similar if somewhat larger for the full sample without bank-time fixed effects (Columns 4 to 6).

The magnitude of our estimates is significant and consistent with the aggregate time series. In the aggregate time series, a 100 basis point increase in the Fed funds rate is

[22]By construction, if we include bank-time fixed effects the coefficients in the full sample are identical to the ones in the sample of banks with branches in at least two counties.

[23]The results are similar if we use the Fed funds rate.

associated with a 54 basis point increase in the savings deposit spread and a 2.9% decrease in savings deposit growth. These numbers imply a price elasticity of deposits equal to −5.4. The elasticity is −7.0 in the cross section, which is similar. Hence, cross-sectional variation in competition generates a response of deposit quantities to prices that is comparable to the one observed in the time series.[24]

Our estimates are also consistent with profit maximization, as predicted by the model. Bank profits from supplying deposits equal deposit revenues (deposit spread × deposit quantity) minus operating costs. Assuming that operating costs do not change, deposit profits and deposit revenues change by the same percentage. The percentage change in deposit revenues is equal to the sum of the percentage changes of deposit spreads and quantities. Our estimates imply that the average percentage change in deposit spreads is 13.3% and the average percentage change in deposit quantities is −0.86% per 100 basis points in the Fed funds rate. The sum of these two numbers is positive, which indicates that revenues, and hence profits, increase with the Fed funds rate.[25]

Overall, our results show a strong and robust effect of competition on the transmission of monetary policy to deposit prices and quantities. The coefficients are similar across different specifications and samples, and their magnitude is consistent with the branch-level time-series regressions. The effect of monetary policy on deposit supply is independent of changes in local lending opportunities, state-level regulation, and other factors. The results are likely to have a high degree of external validity as they are estimated among the large majority of U.S. bank branches.

[24]For the aggregate elasticity, we use the Call Reports to compute an aggregate savings deposit spread and savings deposits growth and regressing them on the Fed funds rate at the quarterly frequency from 1986 to 2007. (The savings deposit spread can only be computed from the Call Reports starting 2001. We find a similar estimate using Ratewatch data.) To compute the cross-sectional elasticity, we divide the coefficient in Column 1 of Table 3 by the weighted average of the coefficients in Column 1 of Panels A and B of Table 2, using the aggregate shares of savings and small time deposits as the weights.

[25]We compute the percentage change in deposit spreads as the weighted average of the coefficients in Column 1 of Panels A and B of Table 2 divided by the corresponding average spreads. The percentage change in deposit quantities is from Column 1 of Table 3. We also estimate the effect of monetary policy on deposit revenues directly in the bank-level regressions and find similar results (see Table 11, Column 6).

D. *Event study analysis*

In this section we exploit the weekly frequency of the Ratewatch data to conduct an event study of the response of deposit spreads to changes in the Fed funds rate. Every six weeks or so, the Federal Reserve's Open Market Committee (FOMC) announces an updated target for the Fed funds rate. Looking at a narrow window around FOMC announcements allows us to pinpoint a direct effect of monetary policy on deposit spreads. This helps to further rule out changes in economic conditions as an alternative explanation for our results as long as they do not perfectly coincide with FOMC announcements.[26]

We run the event study on the set of all branches in the Ratewatch data by estimating the following OLS regression:

$$\Delta y_{ijct} = \alpha_t + \beta_c + \sum_{\tau=-5}^{5} \gamma_\tau HHI_c \times \Delta FF_{t-\tau} + \varepsilon_{ijct}, \tag{15}$$

where Δy_{ijct} is the change in the deposit spread of branch i of bank j in county c from week t to $t+1$, $\Delta FF_{t-\tau}$ is the change in the Fed funds target rate from week $t-\tau$ to $t-\tau+1$, HHI_c is the Herfindahl index of county c, α_t are time fixed effects, and β_c are county fixed effects. We include five leads and lags of changes in the Fed funds rate to capture its potentially dynamic effect on deposit spreads within the typical six-week FOMC window. We plot 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-competition counties. We also include the associated 95% confidence intervals, which take into account the covariances between the underlying coefficients.

Panel A of Figure 5 shows results for savings deposits (25K money market accounts).[27] There are no differential changes in deposit spreads by level of competition in the weeks leading up to a Fed funds rate change. In contrast, in the week of the rate change deposit spreads increase by 7 basis points in low-competition counties relative to high-competition

[26]It remains possible that FOMC announcements coincide with the release of new information about macroeconomic conditions. We address this possibility below by distinguishing between expected and unexpected changes in the Fed funds rate.

[27]We focus on savings deposits because the long maturity of time deposits implies that their rates should adjust ahead of actual rate changes.

counties. The effect is statistically significant. It accumulates to about 11 basis points over the next two weeks and remains constant thereafter.

This finding provides strong evidence for a direct effect of monetary policy on deposit pricing that varies with competition. The quick response of deposit spreads to Fed funds rate changes is unlikely to be explained by changes in economic conditions. The magnitude of the response is also very close to the quarterly regression estimates in Table 2, which is consistent with a permanent effect of monetary policy on deposit supply.

E. Expected rate changes

The results of the event study establish a direct effect of monetary policy on deposit pricing. We now examine the precise mechanism behind this effect. Recall that in our model deposit spreads depend on the Fed funds rate itself. Yet empirically it remains possible that the Fed releases private information about the economy whenever it changes interest rates, and that it is this information that is somehow responsible for the differential response of deposit supply by level of competition. Private information could arise from the Fed staff's superior ability to forecast economic activity or from their access to proprietary information stemming from the Fed's role as a regulator. It could be communicated through the official press releases that follow FOMC meetings or through other channels, or it could be embedded as a signal in the Fed funds rate itself.

Disentangling the effect of a rate change from a coinciding release of information is difficult, especially if the information is conveyed through the rate change itself. This issue confounds nearly all empirical studies of monetary policy. In contrast, 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 information releases. This technique is not applicable in other settings because most assets (e.g., stocks and bonds) are long-lived. Long-lived assets incorporate information about future rates in advance and hence react only to unexpected rate changes. Most deposits, on the other hand, have zero maturity and should therefore react to a rate change at the time it is enacted and not before, regardless of whether the rate change is expected or unexpected.

Thus, the zero maturity of deposits allows us to disentangle the effect of a Fed funds rate change from any confounding release of private information.

We implement this approach by decomposing Fed funds rate changes into expected and unexpected components using data on Fed funds futures. We compute the expected rate change over the next quarter as the difference between the three-month Fed funds futures rate and the Fed funds target rate at the beginning of the quarter. The unexpected rate change is the difference between the realized rate change and the expected rate change. This decomposition follows the event study literature (e.g. Kuttner 2001). We then estimate regression (14), allowing for separate coefficients for the expected and unexpected rate change components. We focus on savings deposits because of their zero maturity.

Panel A of Table 4 presents the results. From Column 1, the preferred specification with the full set of fixed effects shows that a 100 basis point *expected* increase in the Fed funds rate raises deposits spreads in low-competition counties by 22 basis points relative to high-competition counties. The effect of an *unexpected* increase in the Fed funds rate is slightly smaller at 15 basis points, but the difference is not statistically significant. The results are similar in specifications without state-time fixed effects (Column 2) and with only county and time fixed effects (Column 3). The coefficients on expected and unexpected rate changes are slightly larger in the full sample across all specifications (Columns 4 to 6).

We also examine the precise timing of the response of deposit spreads to expected and unexpected rate changes using weekly data. To do so we estimate the event study regression (15) used to produce Panel A of Figure 5, replacing the total Fed funds rate change with the expected change (Panel B) and the unexpected change (Panel C). We follow Kuttner (2001) in computing the expected and unexpected Fed funds rate change at the weekly level.[28]

Panel B of Figure 5 plots the results for expected rate changes. As with total rate changes in Panel A, expected rate changes have no effect on deposit spreads prior to their enactment. At the time of enactment, a 100 basis point expected increase in the Fed funds rate raises the deposit spread by 6 basis points in low-competition counties relative to high-competition counties. The effect grows to about 11 basis points in the following week and remains constant thereafter. Panel C of Figure 5 plots the results for unexpected rate changes.

[28]Specifically, we use the estimates available on Kenneth N. Kuttner's website as of August 18, 2014.

Deposits spreads rise by about 10 basis points in the week of a 100 basis point unexpected rate increase. The spread increases by another 3 basis points in the following two weeks and remains constant thereafter.[29]

These results demonstrate that deposit spreads react similarly to both expected and unexpected rate changes. This indicates that monetary policy affects deposit pricing through the Fed funds rate itself and not through the release of private information, which is consistent with our model. The observed response to expected rate changes also further strengthens our identification strategy by fully controlling for news about economic conditions that might coincide with a rate change.

Our results also relate to the large literature that studies the effect of monetary policy on asset prices. This literature relies on correlations between asset prices and unexpected rate changes, typically on the day of an FOMC announcement (e.g. Kuttner 2001, Bernanke and Kuttner 2005). Yet these tests cannot rule out the possibility that the observed changes in asset prices are due to a release of private information by the Fed instead of monetary policy per se. To the best of our knowledge, our paper is the first to solve this problem by using expected rate changes to identify the effects of monetary policy.[30]

F. The role of financial literacy

Our tests so far exploit geographic variation in competition using market concentration as a proxy. At the same time, the household finance literature suggests that financial literacy is another important determinant of competition. Households with low financial literacy might not be aware of the price of deposits at their bank relative to other banks and relative to other financial products. This has the effect of increasing banks' market power for a given level of concentration.[31] Thus, under the deposits channel the effect of monetary policy on deposit supply should be stronger in areas with lower levels of financial literacy.

[29] The standard errors for unexpected rate changes are larger than the standard errors for expected rate changes becomes the Fed funds rate reacts slowly to changes in its target. Sunderam and Stein (2015) provide a model of gradualism in monetary policy.

[30] Kuttner (2001) examines the effect of expected Fed funds rate changes on Treasury yields as a placebo and finds no significant result. This is consistent with our paper because Treasury bonds are long-lived.

[31] In the context of our model, we can think of η, the elasticity of substitution across banks, as a proxy for financial literacy. When η is low, banks' market power $\mathcal{M}$ is high.

We test this prediction within our empirical framework by using three common proxies for financial literacy that are available at the county level: age (share of individuals over 65), income (natural logarithm of median household income), and education (share of college graduates). These measures enter into our benchmark regression (14) for deposit spreads and flows in the same way as the Herfindahl index.

Panel A of Table 5 presents the results for savings deposit spreads (25K money market accounts). Columns 1 to 3 include the full set of fixed effects and find no statistically significant effects for the three financial literacy variables. The effect of the Herfindahl index remains statistically significant and is similar in magnitude to the benchmark estimates. The effects of the financial literacy variables become statistically significant in the full sample where only county and time fixed effects are included (Columns 4 to 6). In addition to being statistically significant, the coefficients have the expected sign. The effect of the Herfindahl index is slightly smaller but remains statistically significant.[32]

Panel B of Table 5 presents the results for deposit flows. Column 1 to 3 show that the financial literacy variables have statistically significant effects and the expected signs in regressions with the full set of fixed effects. The effects of income and education become insignificant in the full sample with only county and time fixed effects. The effect of the Herfindahl index remains robust and statistically significant in all specifications.

These results suggest that financial literacy affects the transmission of monetary policy to deposit supply. They are consistent with the deposits channel based on the interpretation that low financial literacy limits competition in the banking sector.

G. *The role of bank size*

We examine whether our main findings vary with bank size. This helps to evaluate the extent to which market power can account for aggregate changes in deposit supply. We measure bank size with indicator variables for whether a bank is in the 50^{th}, 75^{th}, or 90^{th} percentile of the size distribution by assets in a given year. We then add these variables to regression (14) as a triple interaction with competition and changes in the Fed funds rate (we also include

[32]The statistical significance of the financial literacy variables varies when we add state-time fixed effects and branch fixed effects. The Herfindahl index is statistically significant across all specifications.

the various two-way interactions and main effects).[33]

Panel A of Table 6 presents the results for savings deposit spreads (25K money market accounts) and time deposit spreads (12-month CDs). For savings deposits, the triple interaction coefficient is statistically insignificant for all three size cutoffs (Columns 1 to 3). For time deposits (Columns 4 to 6), the coefficients are statistically insignificant except for the specification using the 50^{th} percentile cutoff, which is positive, indicating a stronger effect among larger banks. Panel B shows the results for deposit flows. The coefficients on the triple interactions are statistically insignificant and their signs vary.

In sum, we find no evidence that the effect of monetary policy differs significantly by bank size. These results indicate that monetary policy affects the supply of deposits for banks across the size spectrum, which is consistent with substantial aggregate effects.

H. Other deposit products

So far we have focused on the most widely offered savings and time deposit products (25K money market accounts and 10k 12-month CDs). The advantage of doing so is that we can compare the price of exactly the same product across all branches. To ensure that our results apply more generally, we also estimate our benchmark regression (14) for the second- and third-most widely offered savings and time deposit products (2.5K and 10K money market accounts and 10K 3-month and 6-month CDs).

Panel A of Table 7 present the results for savings deposits. Column 1 presents the benchmark specification for 10K money market accounts with the full set of fixed effects and shows that a 100 basis point increase in the Fed funds rate raises deposit spreads in low-competition counties by 13 basis points relative to high-competition counties. The estimate is nearly identical to the one for 25K money market accounts. Columns 2 and 3 present estimates for the full sample without bank-time fixed effects (Column 2) and with only county and time fixed effects (Column 3) and find similar results. Columns 4 to 6 present the same specifications for 2.5K money market accounts and also find similar results. Panel B of Table 7 presents the results for 10K 3-month CDs (Column 1 to 3) and 10K 6-month

[33]The results are similar if we use a continuous measure such as the natural logarithm of total assets.

CDs (Column 4 to 6).[34] The coefficients are similar to the ones estimated for 10K 12-month CDs. We conclude that our results are robust to using alternative deposit products.

I. *Alternative definitions of a local market*

Our results so far are based on deposit competition at the county level. This definition of a local market follows the literature on bank concentration. Yet it is possible that the relevant set of competitors for a given branch are located within a smaller geographic area. This could be because there are significant costs of traveling to branches that are far away, especially if households make frequent use of the services available at their local branch. To examine this question, we use the geographic coordinates provided by the FDIC to compute alternative Herfindahl indexes based on market shares within a 2- and 5-mile radius of each branch. We then estimate the benchmark regression (14), replacing the county-level Herfindahl index with the 2- and 5-mile Herfindahl indexes.

Panel A of Table 8 presents the results for saving deposits spreads (25K money market accounts). For the benchmark specification with the full set of fixed effects we find a statistically significant coefficient on the interaction of changes in the Fed funds rate and deposit competition in a 2-mile radius (Column 1). We find similar results for the full sample using the full set of fixed effects (Column 2) and using only county and quarter fixed effects (Column 3). The coefficient is smaller than the one for the county-level Herfindahl but since the standard deviation of the 2-mile Herfindahl is larger, the effect of a one-standard deviation change in Herfindahl is similar for both sets of measures. The results are similar for the 5-mile Herfindahl (Columns 4 to 6). Panel B presents results on deposit flows and finds statistically significant effects for both the 2-mile Herfindahl (Columns 1 to 3) and the 5-mile Herfindahl (Columns 4 to 6). Taken together, the results indicate that our main findings are robust to alternative definitions of a local market.

[34] We use the one-year T-Bill rate for consistency with the results for 12-month CDs. The results are similar using the Fed funds rate.

J. Measuring competition

Our results are based on the average Herfindahl index in a county over the sample. As an alternative, one may want to ignore variation in the Herfindahl index during the sample period to rule out reverse causality. We do so by instrumenting for the average Herfindahl with the Herfindahl at the start of the dataset (historical HHI). As shown in Panel A of Table 9, the results are almost identical to the ones in Table 2.

Alternatively, one may want to exploit yearly variation in competition to get the most up-to-date measure at each point in time. We do so by replacing the Herfindahl with the time-varying Herfindahl, lagging it by one quarter. As shown in Panel B of Table 9, the results are once again unchanged from the ones in Table 2.

Finally, it is possible that local deposit competition is driven by branch managers that maximize branch revenue. In this case, the relevant competition is across branches instead of across banks. We therefore compute an alternative measure of competition based on branch market shares (as opposed to bank market shares). As shown in Panel C of Table 9, this does not affect our results.

K. Estimation in levels

Our results so far are estimated in first differences, implicitly imposing the strict timing assumption that changes in deposit supply occur in the same period as changes in the Fed funds rate. This assumptions strengthens the identification of our results because the effects are estimated solely off variation within a narrow window of a rate change and therefore they are less likely to be contaminated by other factors. Yet the timing assumption also potentially ignores long-lived effects. We explore this issue by running regressions in levels instead of first differences. We do so by estimating the benchmark regression (14), replacing the changes in the deposit spread and the Fed funds rate with their respective levels.

Panel A of Table 10 presents the results for savings deposits (25K money market accounts). Columns 1 to 3 include the specifications with bank-time fixed effects. The coefficients are similar and slightly larger than those obtained using first differences. Columns 4 to 6 present the results for the full sample without bank-time fixed effects, which are very similar. Panel B of Table 10 looks at time deposits (10K 12-month CDs). The effects are again very similar to our earlier estimates.

The levels regressions indicate that our main findings are robust to alternative timing assumptions. They also indicate that the effect of monetary policy on deposit pricing is long-lived. This is consistent with the predictions of our model, with the aggregate time series of deposit rates, and with the results of the event study.

VI. Implications of the deposit channel

A. *Effects on bank lending*

In this section we complement our branch-level analysis with bank-level results, which allows us to assess the robustness of our main findings. It also allows us to examine the impact of the deposits channel on the asset side of bank balance sheets.[35] While bank-level regressions do not control for changes in lending opportunities, they are standard in the literature on the bank lending channel, allowing us to compare our results with prior studies (e.g. Kashyap and Stein 2000).[36]

We construct a measure of deposit competition for a given bank as the weighted average of the county Herfindahl indexes associated with each of the bank's branches, using branch deposits as weights. This bank-level Herfindahl index captures the average level of competition across all markets where a bank operates. We estimate the bank-level analog to the branch-level regressions using the following OLS specification:

$$\Delta y_{ijct} \quad = \quad \alpha_i + \delta_t + \beta HHI_{it-1} + \gamma \Delta FF_t \times HHI_{it-1} + \varepsilon_{ijct}, \tag{16}$$

where y_{ijct} is the change in a bank-level outcome variable (e.g. assets, deposits, loans, or the deposit spread) of bank i from date t to $t+1$, ΔFF_t is the change in the Fed funds rate from t to $t+1$, HHI_{it-1} is the deposit Herfindahl of bank i at $t-1$, α_i are bank fixed effects

[35]There is no meaningful way to examine bank assets at the branch-level since it would require assigning assets to specific branches.

[36]Recall that our branch-level results are robust across specifications with and without bank-time fixed effects. This finding provides support for the identification assumption implicit in bank-level regressions.

and δ_t are time fixed effects. We cluster standard errors at the bank level.

Table 11 presents the results for banks' core deposits, which represent 81% of bank liabilities. Columns 1 presents the results for total core deposits and finds a negative and statistically significant effect: a 100 basis point increase in the Fed funds rate leads to deposit outflows off 88 basis points for banks in low-competition markets relative to banks in high-competition markets. The coefficient is almost identical to the one estimated at the branch level. Columns 2 to 4 find similar results for all three types of core deposits: checking deposits, savings deposits, and small time deposits. Column 5 finds a positive coefficient of 8.8 basis points for the deposit spread, which is very close to the branch-level estimates. Column 6 find a positive coefficient for deposit revenues (deposit spread times the quantity of deposits), which indicates that banks are able to increase profits by reducing the quantity of deposits and raising their spread.[37]

Table 12 examines the extent to which banks replace core deposits with other sources of funding. Column 1 looks at total liabilities and finds a similar coefficient to the one estimated for core deposits. There are two countervailing effects that generate this result. As Column 2 shows, banks located in low-competition markets experience lower inflows of large time deposits than banks in high-competition markets.[38] As Column 3 shows, banks in low-competition markets increase wholesale funding relative to banks in high-competition counties to offset this effect. The net effect is close to zero, which is why total liabilities behave similarly to core deposits. Column 4 finds no effect on other liabilities. Columns 5 finds some substitution to subordinated debt, which is concentrated among large banks.[39] Overall, there is evidence of some substitution to other sources of funding, especially for large banks with access to wholesale markets, but the net effect remains negative.

[37]The number of observations in Column 6 is smaller than in the other columns because deposit spreads are sometimes negative when the Fed funds rate is low, in which case we cannot compute revenue growth. As an alternative, we can use an augmented deposit spread equal to the actual spread plus 100 basis points. This procedure avoids dropping observations and yields a similar coefficient as in Column 6.

[38]This result suggests that banks have some market power over large time deposits. Consistent with this interpretation, we find that the spread on large time deposits increases with the Fed funds rate. This effect is stronger for small banks, which tend to source large time deposits locally through their branch network. In contrast, large banks source most of their large time deposits though wholesale funding markets where they have no market power and charge no spread. The data does not distinguish between these two types of large time deposits but this result suggests that locally-sourced large time deposits are similar to core deposits while wholesale-sourced large time deposits are a type of wholesale funding.

[39]The number of observations is smaller in this regression because most banks have no subordinated debt.

Next, we turn to the asset side of bank balance sheets. Table 13 presents the results. Column 1 shows that a 100 basis point increase in the Fed funds rate lowers assets by 98 basis points for banks in low-competition markets relative to banks in high-competition markets, which is in line with the estimated effect on deposits and total liabilities.

Banks often use liquid assets to absorb shocks and mitigate their impact on lending. The main sources of liquid assets are cash & reserves and securities, which account for 4.8% and 25.8% of bank assets, respectively. Columns 2 and 3 show that a 100 basis point increase in the Fed funds rate leads banks in low-competition markets to reduce cash & reserves by 247 basis points and securities by 74 basis points relative to banks in high-competition markets.

The two main categories of loans are real estate loans and commercial & industrial (C&I) loans, accounting for 37.7% and 10.1% of bank assets, respectively. Columns 4 and 5 show that a 100 basis point increase in the Fed funds rate leads banks in low-competition markets to reduce real estate loans by 53 basis points and C&I loans by 66 basis points relative to banks in high-competition markets. These results indicate that the changes in deposit funding that arise from a change in the Fed funds rate affect bank lending.

The takeaway from these results is that when the Fed funds rate rises, banks partially offset the contraction in deposits with other sources of funding. However, the offset is incomplete and so banks also reduce lending. This indicates that the deposits channel has real effects. These effects arise from the influence of monetary policy on the tradeoff banks face between maximizing the profits they make on deposits and financing a large balance sheet. The effect on lending is also consistent with the large literature on the bank lending channel, which argues that monetary policy affects bank lending. In contrast to existing models of the bank lending channel, the deposits channel does not depend on reserve requirements.[40] Rather, it works through banks' market power over deposits.

B. Effects on the liquidity premium

The deposit channel also has important general equilibrium implications. Figure 1 and 2 document large aggregate changes in the price and quantity of deposits. Since deposits are

[40] Reserve requirements are widely considered an implausible mechanism because open market operations are small relative to bank balance sheets and because most deposits are not subject to reserve requirements.

the main source of liquid assets for households, these changes are expected to propagate to the prices of other liquid assets such as Treasuries. Thus, the deposits channel has implications for the liquidity premium in financial markets. As interest rates rise and the supply of deposits shrinks, the liquidity premium is expected to rise.

The liquidity premium is a macro variable, hence we cannot test this prediction with cross-sectional tests like the ones we have presented so far. Nevertheless, it is instructive to plot measures of the liquidity premium against the price of deposits in the time series. We do so using a proxy for the liquidity premium which is given by the Fed funds-T-Bill spread. Both Fed funds loans and T-Bills are extremely safe short-term securities but T-Bills provide a higher level of liquidity services to a broader range of investors.[41] Against this measure of the liquidity premium we plot the aggregate deposit spread, which we compute from the Call Reports. Figure 6 plots the two series from 1986 to 2007 and shows that there is a striking positive relationship between them with 90% correlation and strong co-movement both in the cycle and in the trend.

This result is consistent with a large effect of deposit supply on the liquidity premium. 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 mutual funds. As the liquidity premium rises and the cost of holding a liquid asset buffer increases, these institutions are expected to decrease their risk taking, resulting in higher risk premia and a higher cost of capital (Drechsler, Savov, and Schnabl 2015). This general equilibrium effect of the deposits channel is in addition to the bank-level effect on lending discussed above.

VII. 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 is high, the spread between the Fed funds rate and the deposit rate is high. This makes deposits expensive to hold. The higher price

[41]Nagel (2014) looks at alternative measures of the liquidity premium and also finds that they are highly correlated with the Fed funds rate.

is associated with large outflows of deposits.

We argue that the effect of monetary policy on deposit supply can be explained by banks' market power over deposit creation. When rates are low, banks face competition from cash, which forces them to charge low spreads. When rates are high, competition is mainly from other banks, allowing banks in concentrated markets to increase spreads. Households respond by decreasing their deposit holdings. We call this the deposits channel of monetary policy.

We provide evidence for this mechanism by examining the cross section of deposit rates and flows. We control for changes in banks' lending opportunities by comparing branches of the same bank located in markets with different levels of competition. We find that when the Fed funds rate rises, branches located in less competitive markets raise their deposit spreads and experience outflows relative to branches located in more competitive markets. We also find that the differential effect of higher rates on deposit spreads occurs within a week or two of a Fed funds rate increase. It also occurs even when the change is expected, consistent with a direct causal effect of interest rates on deposit supply.

Deposits are the primary source of funding for banks. Their stability makes them particularly well-suited for funding risky and illiquid assets. As a result, the deposits channel has implications for bank lending. Deposits also represent the primary source of safe and liquid assets for households. As a result, the deposits channel also has implications for the overall supply of safe and liquid assets in the economy and for the price of liquidity in financial markets.

References

Acharya, Viral V., and Nada Mora, 2015. A crisis of banks as liquidity providers. The Journal of Finance 70, 1–43.

Ben-David, Itzhak, Ajay Palvia, and Chester Spatt, 2015. Banks internal capital markets and deposit rates. Discussion paper, National Bureau of Economic Research.

Bernanke, Ben, and Mark Gertler, 1989. Agency costs, net worth, and business fluctuations. The American Economic Review 79, 14–31.

Bernanke, Ben S, 1983. Nonmonetary effects of the financial crisis in the propagation of the great depression. The American Economic Review 73, 257–276.

——— , and Alan S Blinder, 1992. The federal funds rate and the channels of monetary transmission. The American Economic Review 82, 901–921.

Bernanke, Ben S, and Mark Gertler, 1995. Inside the black box: The credit channel of monetary policy. The Journal of Economic Perspectives 9, 27–48.

——— , and Simon Gilchrist, 1999. The financial accelerator in a quantitative business cycle framework. Handbook of Macroeconomics 1, 1341–1393.

Bernanke, Ben S, and Kenneth N Kuttner, 2005. What explains the stock market's reaction to federal reserve policy?. The Journal of Finance 60, 1221–1257.

Brunnermeier, Markus K., and Yuliy Sannikov, 2014. A macroeconomic model with a financial sector. American Economic Review 104, 379–421.

Dell'Ariccia, Giovanni, Luc Laeven, and Gustavo Suarez, 2013. Bank leverage and monetary policy's risk-taking channel; evidence from the united states. IMF Working Papers 13/143 International Monetary Fund.

Diamond, Douglas W, and Philip H Dybvig, 1983. Bank runs, deposit insurance, and liquidity. The Journal of Political Economy 91, 401–419.

Drechsler, Itamar, Alexi Savov, and Philipp Schnabl, 2015. A model of monetary policy and risk premia. Journal of Finance forthcoming.

Driscoll, John C, and Ruth A Judson, 2013. Sticky deposit rates. Federal Reserve Board Working Paper.

Egan, Mark, Ali Hortacsu, and Gregor Matvos, 2015. Deposit competition and financial fragility: Evidence from the us banking sector. Chicago Booth Working Paper.

Galí, Jordi, 2009. Monetary Policy, Inflation, and the Business Cycle: An Introduction to the New Keynesian Framework Princeton University Press.

Gertler, Mark, and Peter Karadi, 2015. Monetary policy surprises, credit costs, and economic activity. American Economic Journal: Macroeconomics 7, 44–76.

Gilje, Erik, Elena Loutskina, and Philip E. Strahan, 2013. Exporting liquidity: Branch banking and financial integration. Working Paper 19403 National Bureau of Economic Research.

Gorton, Gary, and George Pennacchi, 1990. Financial intermediaries and liquidity creation. Journal of Finance 45, 49–71.

Hannan, Timothy H., and Allen Berger, 1991. The rigidity of prices: Evidence from the banking industry. The American Economic Review 81, 938–945.

Hanson, Samuel, Andrei Shleifer, Jeremy C. Stein, and Robert W. Vishny, 2015. Banks as patient fixed-income investors. Journal of Financial Economics 117, 449–469.

Hanson, Samuel Gregory, and Jeremy C Stein, 2015. Monetary policy and long-term real rates. Journal of Financial Economics 111, 429–448.

He, Zhiguo, and Arvind Krishnamurthy, 2013. Intermediary asset pricing. American Economic Review 103, 732–70.

Jiménez, Gabriel, Steven Ongena, José-Luis Peydró, and Jesús Saurina, 2014. Hazardous times for monetary policy: What do twenty-three million bank loans say about the effects of monetary policy on credit risk-taking?. Econometrica 82, 463–505.

Kashyap, Anil K, Raghuram Rajan, and Jeremy C Stein, 2002. Banks as liquidity providers: An explanation for the coexistence of lending and deposit-taking. The Journal of Finance 57, 33–73.

Kashyap, Anil K., and Jeremy C. Stein, 1994. Monetary policy and bank lending. in Monetary PolicyNBER Chapters . pp. 221–261 National Bureau of Economic Research, Inc.

——— , 2000. What do a million observations on banks say about the transmission of monetary policy?. American Economic Review 90, 407–428.

Kashyap, Anil K, Jeremy C. Stein, and David W. Wilcox, 1993. Monetary policy and credit conditions: Evidence from the composition of external finance. American Economic Review 83, 78–98.

Ke, Wei: Snowman. Ben; Pham, Ada; Baumgarten Jens, 2012. Optimising retail deposit pricing. Risk Magazine 25, 55–57.

Krishnamurthy, Arvind, and Annette Vissing-Jorgensen, 2012. The aggregate demand for treasury debt. Journal of Political Economy 120, 233–267.

——— , 2013. Short-term debt and financial crises: What we can learn from us treasury supply. Discussion paper, Citeseer.

Kuttner, Kenneth N, 2001. Monetary policy surprises and interest rates: Evidence from the fed funds futures market. Journal of Monetary Economics 47, 523–544.

Nagel, Stefan, 2014. The liquidity premium of near-money assets. NBER Working Papers 20265 National Bureau of Economic Research, Inc.

Nakamura, Emi, and Jón Steinsson, 2013. High frequency identification of monetary non-neutrality. Discussion paper, National Bureau of Economic Research.

Neumark, David, and Steven A. Sharpe, 1992. Market structure and the nature of price rigidity: Evidence from the market for consumer deposits. Quarterly Journal of Economics 107, 657–680.

PricewaterhouseCoopers, 2011. When cash isn't king: Driving deposit value in a world of excess liquidity. available at https://www.pwc.com/us/en/financial-services/publications/viewpoints/driving-deposit-value-in-excess-liquidity.html (last accessed on March 5, 2016).

Scharfstein, D., 2015. Novantas and deposit funding at first regional bank. Harvard Business School Case, N9-215-054.

Scharfstein, David, and Adi Sunderam, 2014. Market power in mortgage lending and the transmission of monetary policy. HBS Working Paper.

Stein, Jeremy C, 1998. An adverse-selection model of bank asset and liability management with implications for the transmission of monetary policy. RAND Journal of Economics 29, 466–486.

———, 2012. Monetary policy as financial stability regulation. The Quarterly Journal of Economics 127, 57–95.

Sunderam, Adi, 2015. Money creation and the shadow banking system. Review of Financial Studies 28, 939–977.

Sunderam, A., and Jeremy C Stein, 2015. The fed, the bond market, and gradualism in monetary policy. Working Paper, Harvard University.

Figure 1: **Deposit rates and monetary policy**

The figure plots the Fed funds rate and the rates paid on each of the three main types of deposits held by households (checking, savings, and small time deposits). We use the most widely-offered deposit product and the most common account size for each deposit type (interest checking, money market accounts, and 12-month CDs). The underlying data is from RateWatch. The sample is from January 1997 to June 2008.

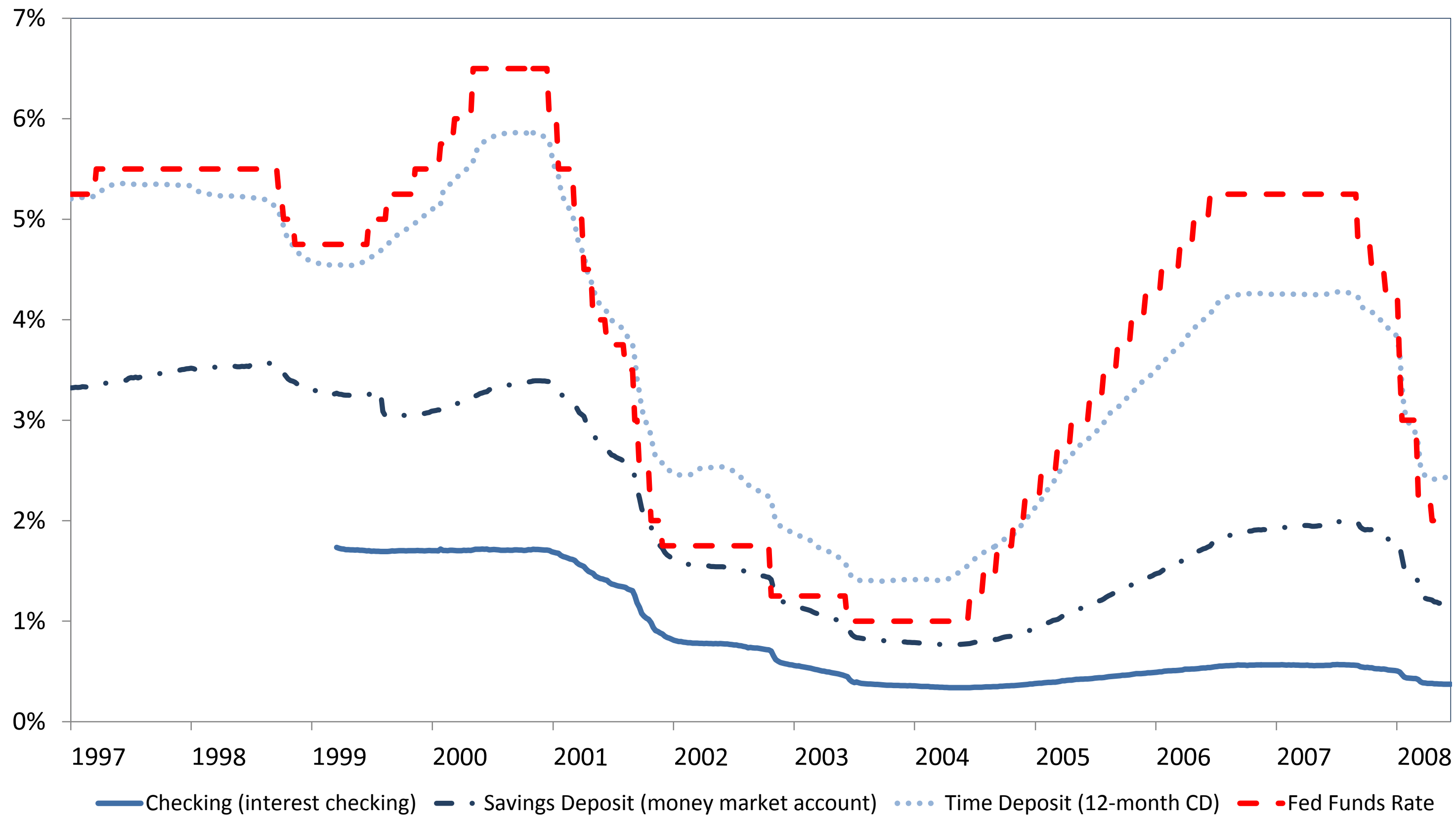
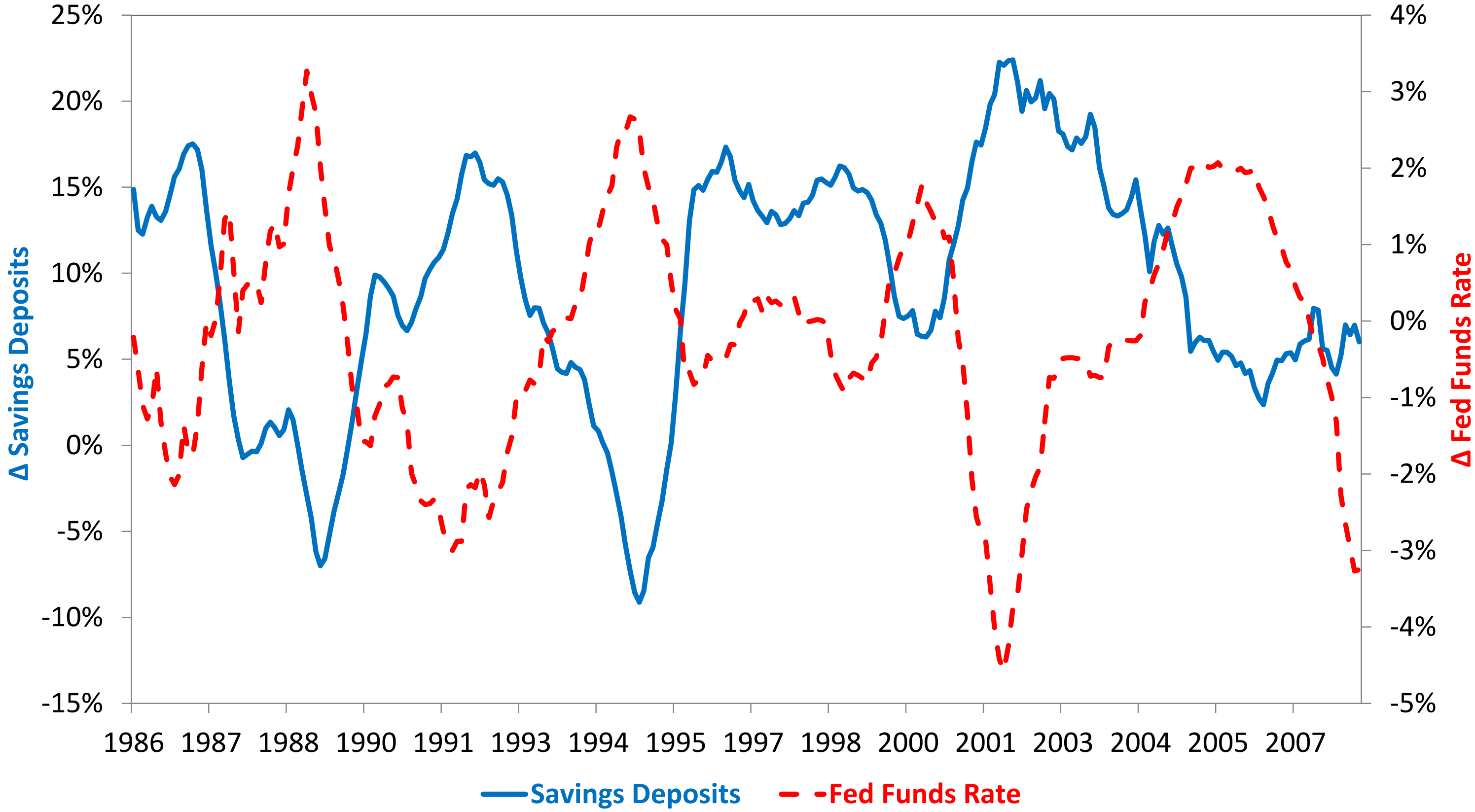


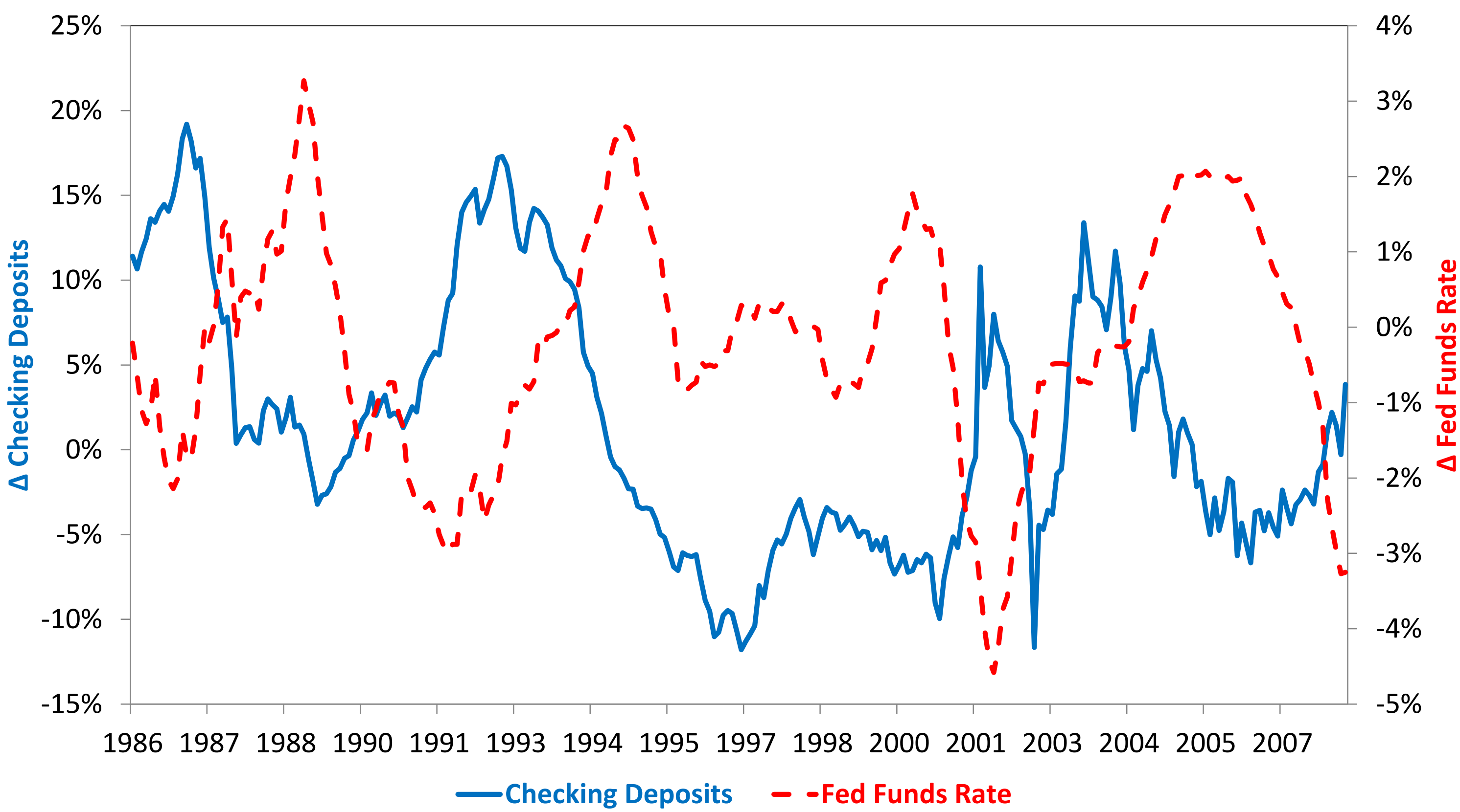
Figure 2: **Deposit growth and monetary policy**

This figure plots year-over-year changes in savings deposits (Panel A), checking deposits (Panel B), small time deposits (Panel C), and total core deposits (Panel D) against year-over-changes in the Fed funds rate. Total core deposits are the sum of checking, savings, and small time deposits. The data is from the Federal Reserve Board's H.6 release. The sample is from January 1986 to June 2008.

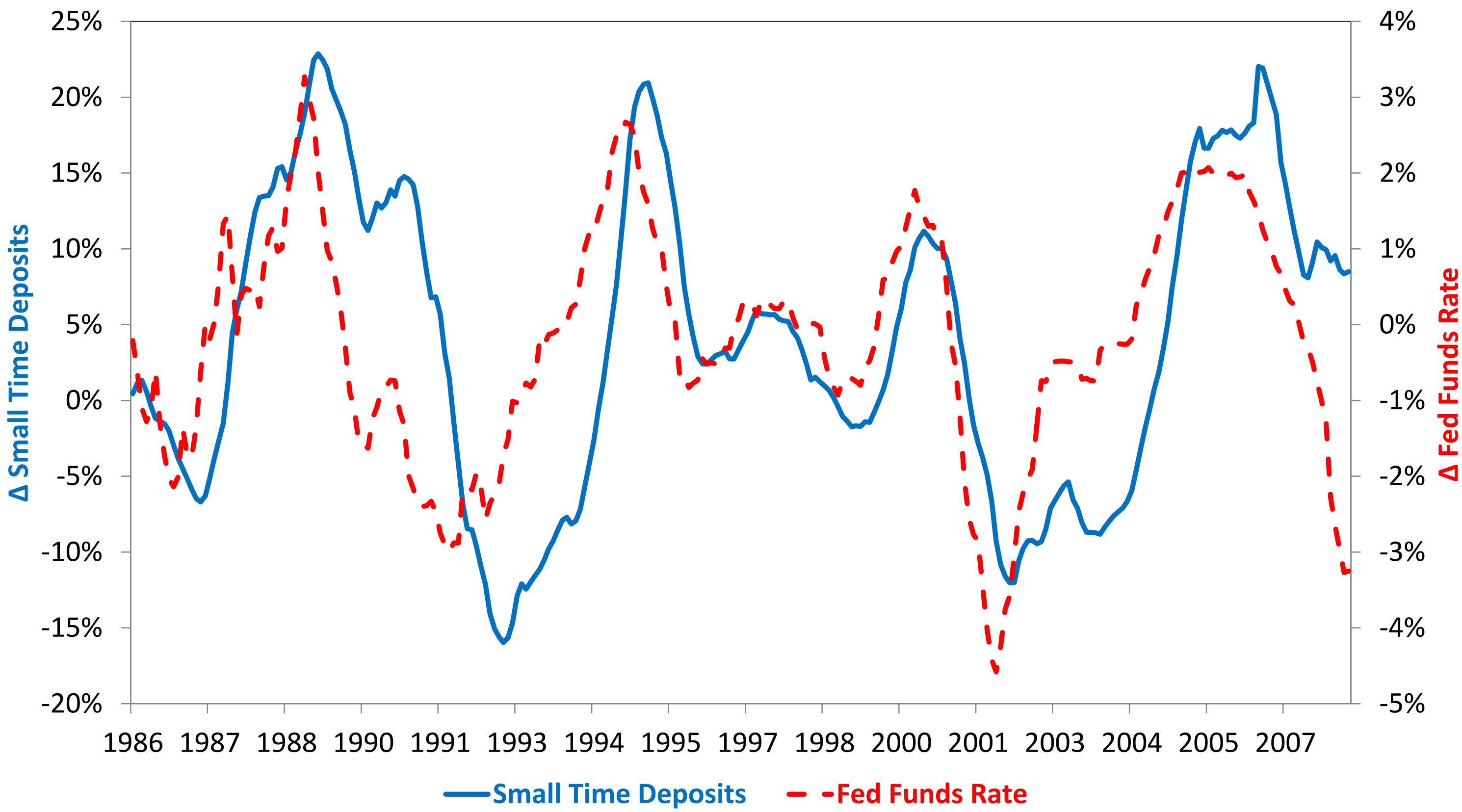
Panel A: Savings Deposits



Panel B: Checking deposits



Panel C: Small time deposits



Panel D: Total core deposits (checking + savings + small time deposits)

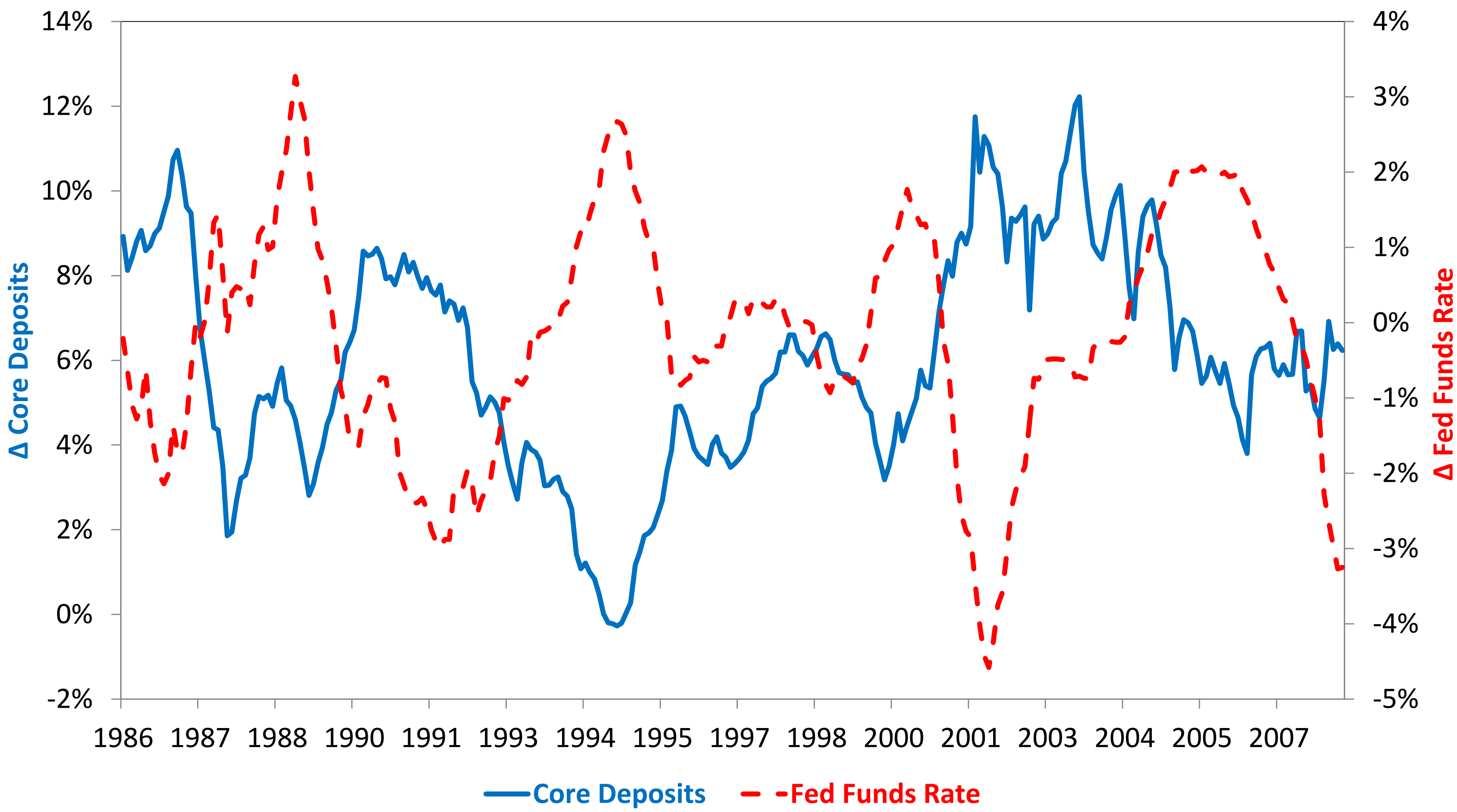


Figure 3: **Deposit competition**

This map shows the average 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 2008. The underlying data is from the FDIC.

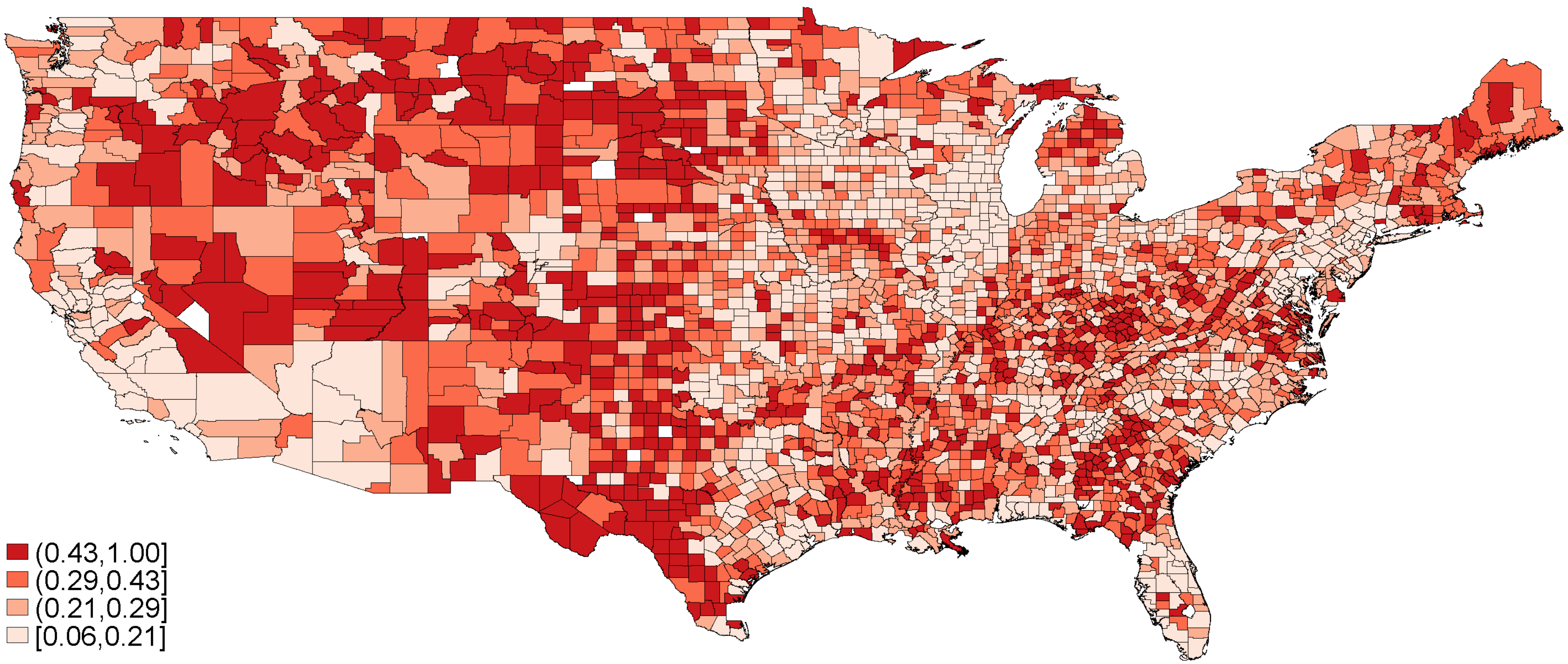


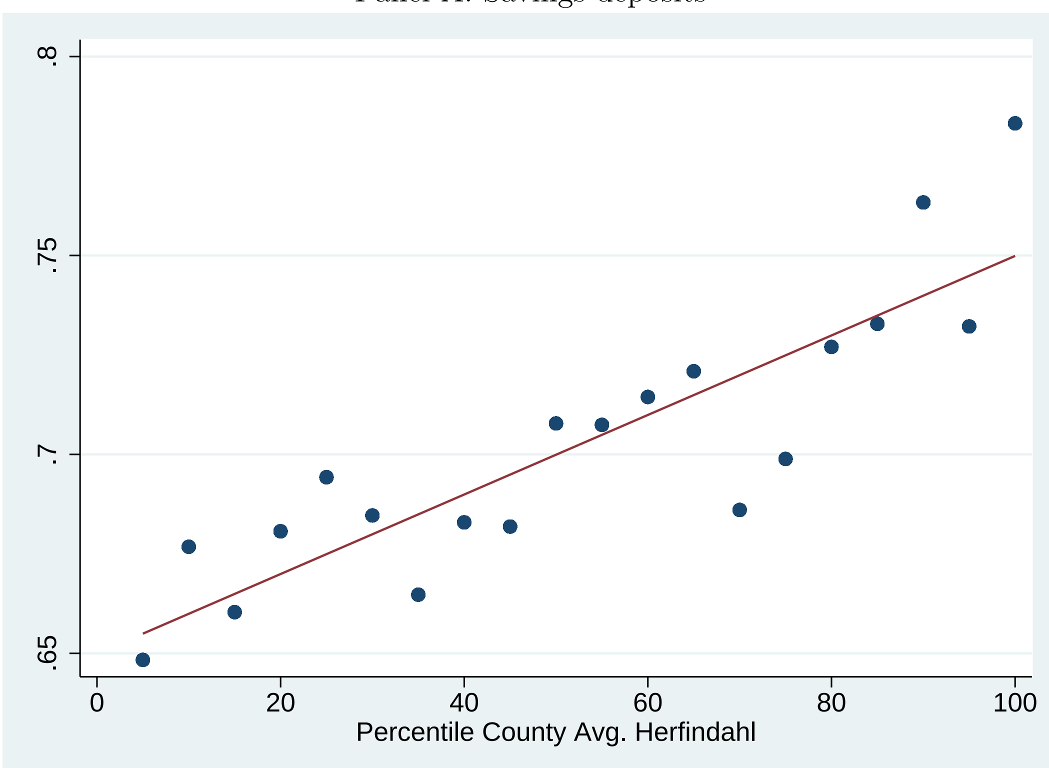
Figure 4: **Deposit competition and monetary policy**

This figure shows the relationship between deposit competition and the sensitivities of deposit spreads and growth to changes in the Fed funds rate ("deposit betas"). The figures are constructed in two steps. The first is to estimate branch-specific deposit betas using a time-series regression for each branch i:

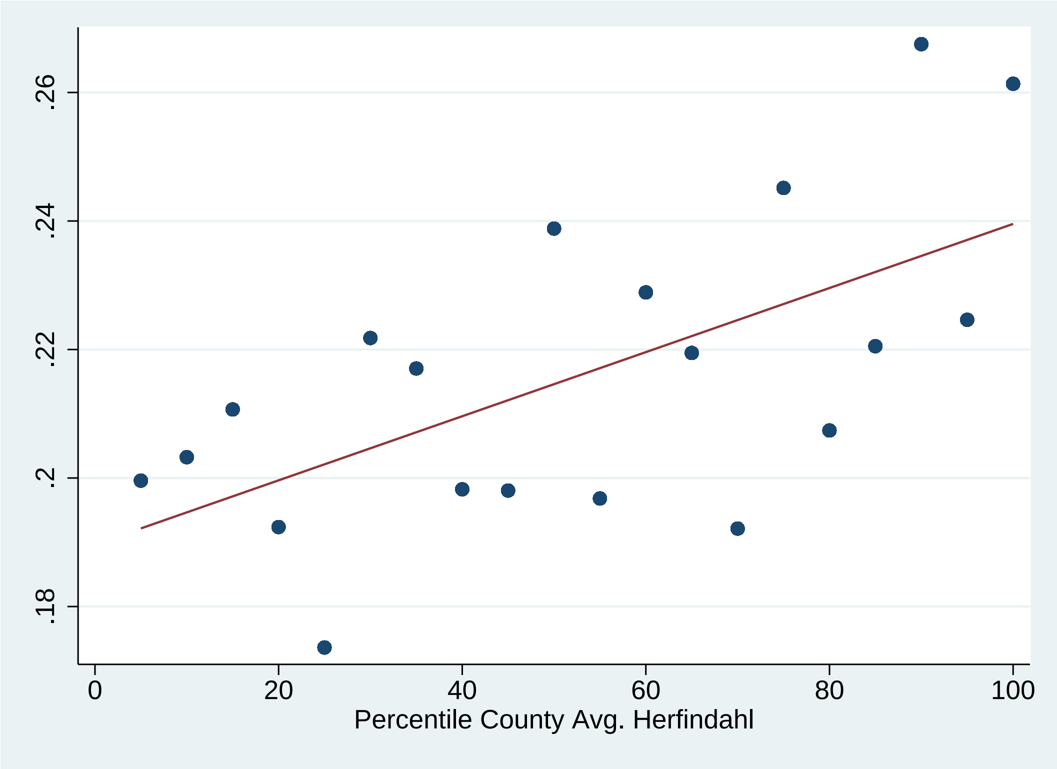
$$\Delta y_{it} \quad = \quad \alpha + \beta_i \Delta FF_t + \varepsilon_{it}.$$

where Δy_t is either the change in the deposit spread or the deposit growth (log change in deposits) from date t to $t+1$ and ΔFF_t is the change in the Fed funds target rate from t to $t+1$. For deposit spreads the data is quarterly from January 1997 to June 2008 and includes all branches in the Ratewatch data. For deposit growth the data is annual from June 1994 to June 2008 and includes all branches in the FDIC data. The second step is to average deposit betas by county, sort counties into twenty groups by Herfindahl index, and report average deposit betas by group. Panel A shows the results for savings deposits (25K money market accounts), Panel B shows the results for time deposits (12-month CDs), and Panel C shows the results for deposit flows.

Panel A: Savings deposits



Panel B: Time deposits



Panel C: Deposit growth

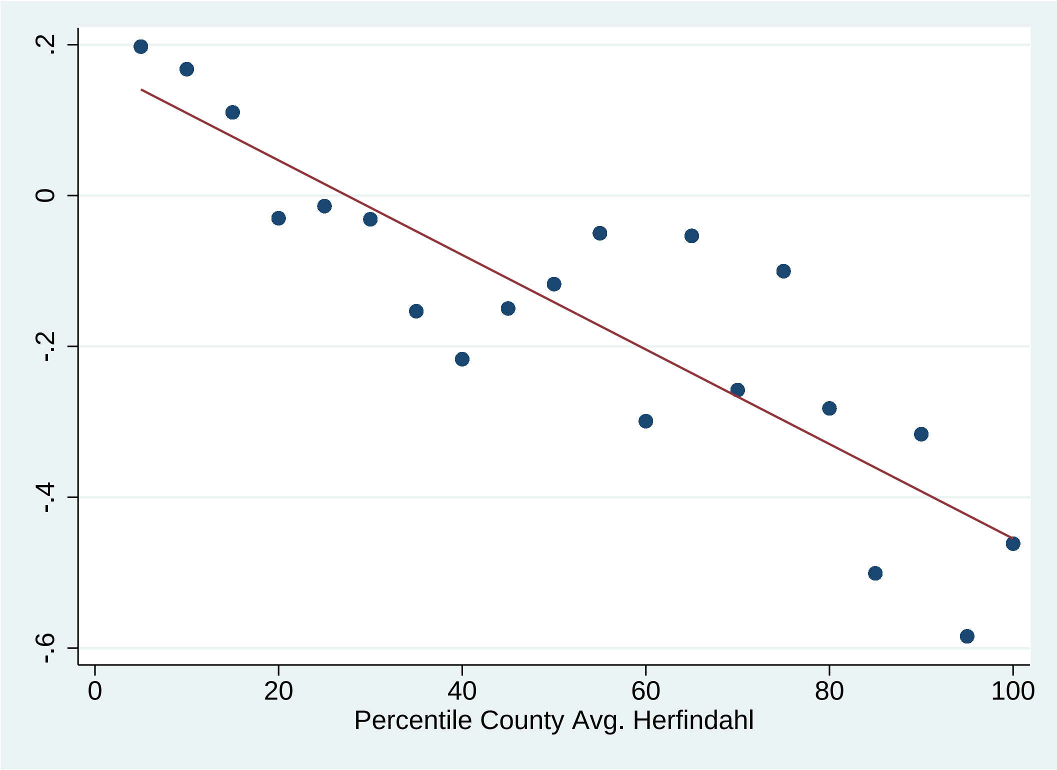
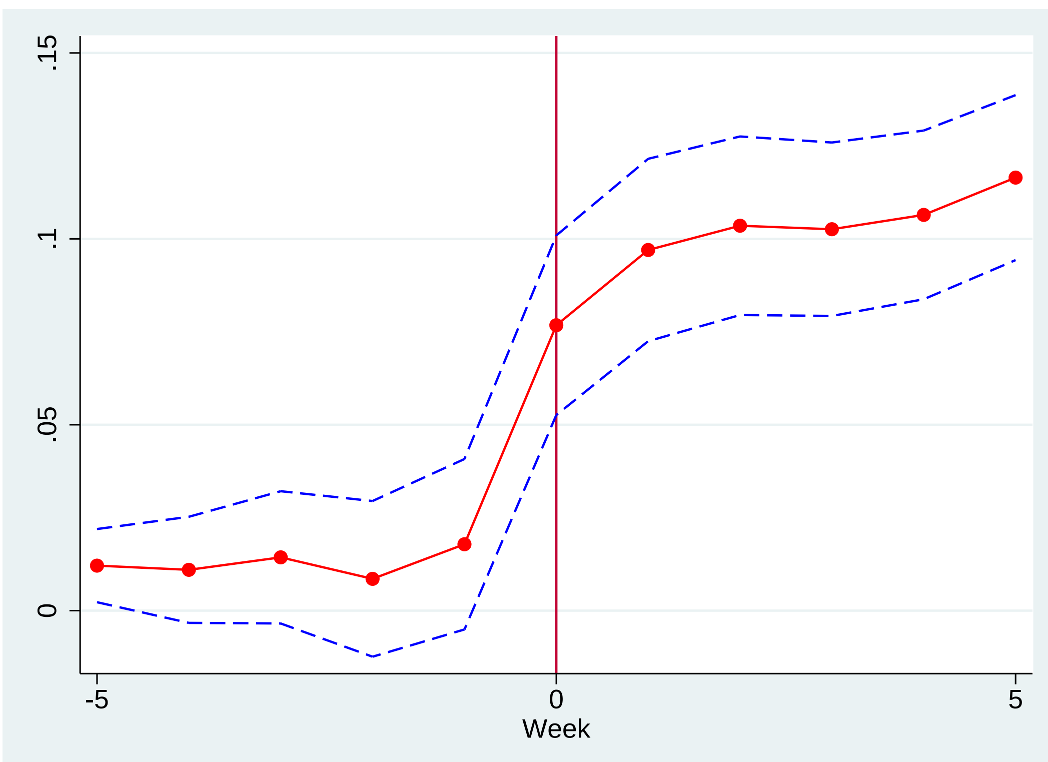


Figure 5: **Deposit spreads and monetary policy, event study**
The panels in this figure plot the coefficient sums $\sum_{-5}^{t} \gamma_\tau$, $t = -5, \ldots, 5$ (week 0 corresponds to an FOMC meeting), and associated 95% confidence intervals, estimated from the regression

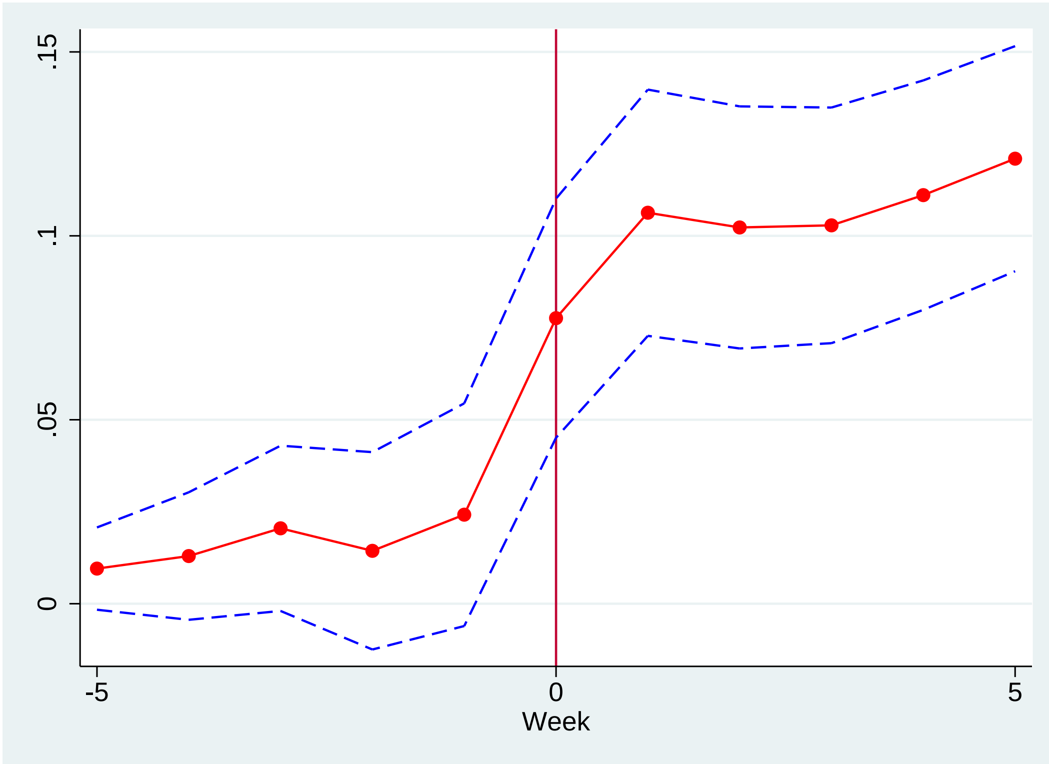
$$\Delta Spread_{ijct} \quad = \quad \alpha_t + \delta_c + \sum_{\tau=-5}^{5} \gamma_\tau HHI_c \times \Delta FF_{t-\tau} + \varepsilon_{ijct}.$$

where $\Delta Spread_{ijct}$ is the weekly change in the deposit spread (the Fed funds rate minus the deposit rate) on savings deposits (25K money market accounts), HHI$_c$ is the average county-level Herfindahl index computed from banks' deposit market shares, and ΔFF$_t$ is the weekly change in the Fed funds target rate. The sample are all branches in the Ratewatch data from January 1997 to June 2008. Panel A uses the realized change in the Fed funds target rate, Panel B uses the expected change, and Panel C uses the unexpected change. The expected and unexpected changes in the Fed Funds rate are obtained from Fed funds futures as in Kuttner (2001).

Panel A: Total ΔFF



Panel B: Expected ΔFF



Panel C: Unexpected ΔFF

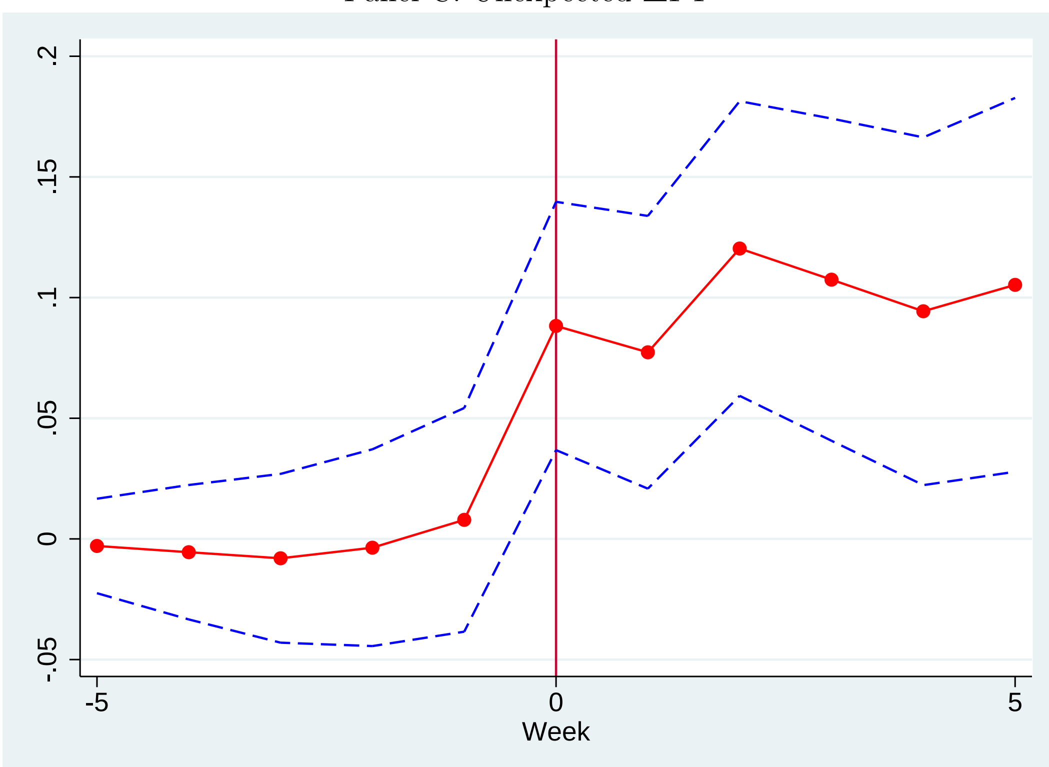


Figure 6: **The aggregate deposit spread and the liquidity premium**

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 3-month T-Bill rate. Both the Fed funds rate and T-Bill rate are calculated as quarterly averages. The data is from 1986 to 2007.

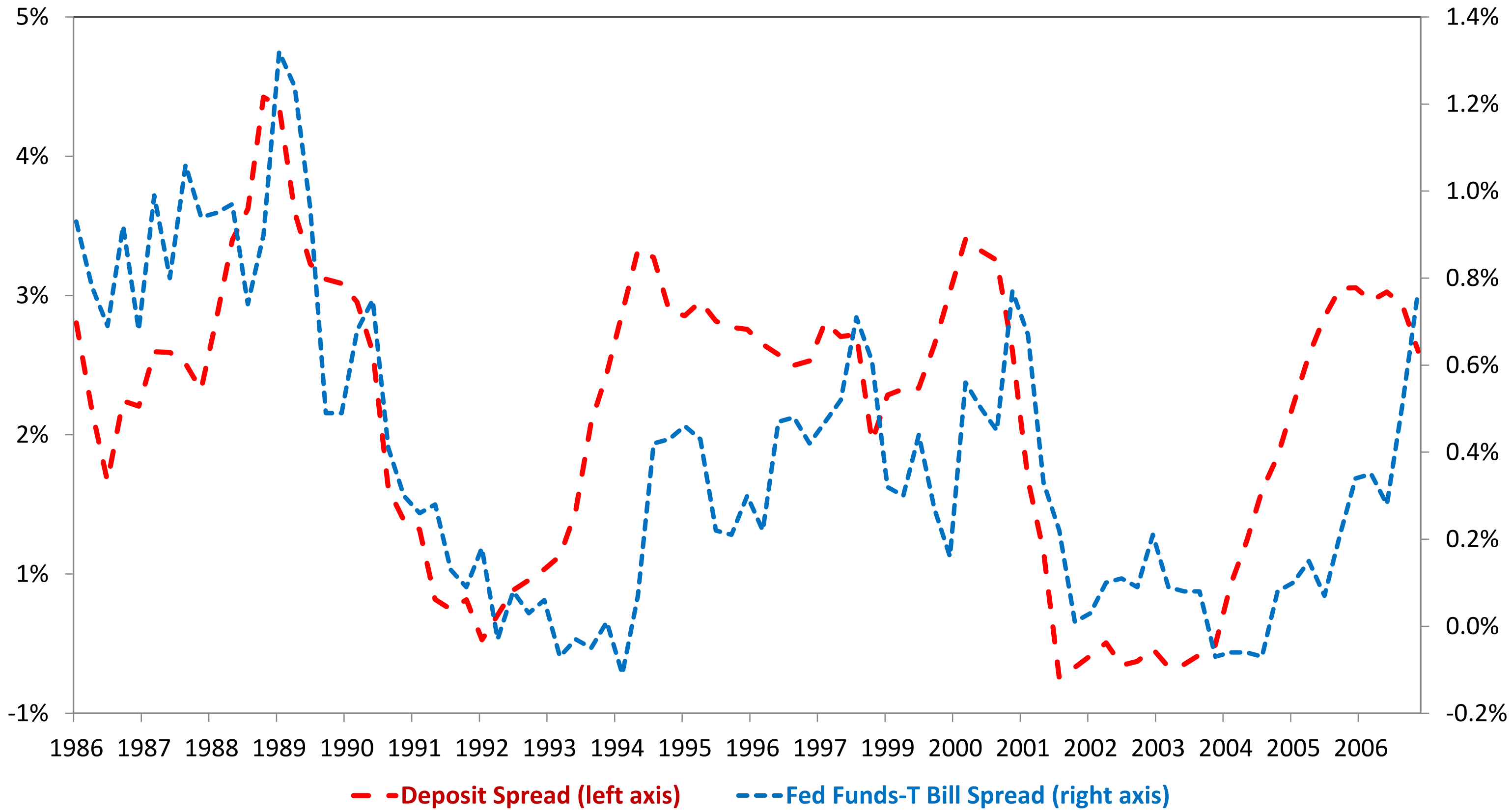


Table 1: **Descriptive statistics**

This table provides summary statistics at the county, branch, and bank levels. Panel A presents county characteristics for all U.S. counties with at least one bank branch. The underlying data is from the 2000 Census. Panel B presents branch characteristics. The underlying data is from the FDIC from June 1994 to June 2008. Panel C presents additional branch characteristics. The underlying data is from Ratewatch from January 1997 to June 2008. Panel D presents bank characteristics for all U.S. commercial banks. The underlying data is from the U.S. Call Reports from June 1994 to June 2008.

Panel A: County characteristics (2000 Census)

	All			Low Herfindahl			High Herfindahl		
	Mean	Median	St. Dev.	Mean	Median	St. Dev.	Mean	Median	St. Dev.
Population	90,845	25,329	294,719	150,081	25,981	394,457	28,717	13,097	85,292
Area (sq. mile)	1,057	613	2,484	903	619	1,279	1,217	605	3,299
Median income	36,406	34,787	8,990	39,332	37,611	9,467	33,343	32,242	7,302
Over age 65 (in %)	14.78	14.4	4.14	14.22	13.9	4.03	15.35	14.9	4.17
College degree (in %)	16.55	14.5	7.81	18.69	16.2	8.49	14.3	12.8	6.28
Herfindahl	0.36	0.29	0.21	0.21	0.21	0.05	0.51	0.44	0.21
Obs. (counties)		3,104			1,589			1,515	

Panel B: Branch characteristics (FDIC)

	All			Low Herfindahl			High Herfindahl		
	Mean	Median	St. Dev.	Mean	Median	St. Dev.	Mean	Median	St. Dev.
Deposits (mill.)	56.92	28.16	547.33	53.01	30.81	223.54	60.82	25.68	741.04
Deposit growth (in %)	8.85	3.79	41.26	10.05	4.28	43.48	7.65	3.35	38.87
Δ FF	−0.20	0	1.66	−0.20	0	1.67	−0.19	0	1.65
Herfindahl	0.22	0.19	0.11	0.15	0.15	0.03	0.29	0.26	0.11
Obs. (branch×year)		906,125			453,058			453,067	

Panel C: Branch characteristics (Ratewatch)

	All			Low Herfindahl			High Herfindahl		
	Mean	Median	St. Dev.	Mean	Median	St. Dev.	Mean	Median	St. Dev.
Δ Spread (savings)	−0.03	0	0.53	−0.03	0	0.53	−0.03	0	0.53
Δ Spread (time)	−0.01	0	0.36	−0.01	0	0.36	−0.01	0	0.36
Δ FF	−0.08	0	0.56	−0.08	0	0.56	−0.08	0	0.55
Δ T-Bill	−0.08	−0.01	0.56	−0.08	−0.01	0.57	−0.08	−0.01	0.56
Herfindahl	0.22	0.2	0.09	0.15	0.16	0.03	0.29	0.27	0.07
Obs. (branch×quarter)	287,928			143,207			144,721		

Panel D: Bank characteristics (Call Reports)

	All			Low Herfindahl			High Herfindahl		
	Mean	Median	St. Dev.	Mean	Median	St. Dev.	Mean	Median	St. Dev.
Assets (mill.)	825	88	14,959	797	94	12,706	853	82	16,914
Liabilities (mill.)	750	79	13,708	727	85	11,669	774	73	15,482
Core deposits/liabilities (in %)	80.56	97.04	7.4	80.48	82.65	11.58	80.63	82.30	10.56
Checking deposits/liabilities (in %)	26.13	25.62	10.43	25.49	24.75	10.87	26.77	26.32	9.94
Savings/liabilities (in %)	22.79	20.55	11.38	24.54	22.28	11.85	21.05	18.88	10.6
Small time/liabilities (in %)	31.47	31.95	12.07	32.69	33.12	11.18	32.69	33.12	11.18
Large time/liabilities (in %)	13.40	11.82	8.06	13.27	11.50	8.32	13.52	12.12	7.78
Wholesale/liabilities (in %)	5.92	2.94	7.32	6.1	3.19	7.43	5.74	2.7	7.2
Other liabilities/liabilities (in %)	0.88	0.75	0.58	0.86	0.74	0.58	0.89	0.76	0.59
Cash/assets (in %)	4.85	3.92	3.61	4.86	3.91	3.69	4.84	3.93	3.53
Securities/assets (in %)	25.79	23.98	14.22	24.81	22.91	14.3	26.77	25.03	14.08
Real estate loans/assets (in %)	37.7	37.31	15.97	39.93	39.46	16.04	35.48	35.15	15.58
C&I loans/assets (in %)	10.11	8.54	6.9	10.7	9.11	7.26	9.52	8.05	6.48
Herfindahl	0.24	0.21	0.14	0.15	0.16	0.04	0.34	0.29	0.14
Obs. (bank×quarter)	424,606			212,303			212,303		

Table 2: **Deposit spreads and monetary policy**

This table estimates the effect of Fed funds rate changes on deposit spreads. 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 data is quarterly from January 1997 to June 2008. Δ Spread is the change in the deposit spread, which is equal to the Fed funds target rate minus the deposit rate. Herfindahl is the average county-level Herfindahl index computed from banks' deposit market shares. Δ FF is the change in the Fed funds target rate. Δ T-Bill is the change in the one-year T-Bill rate. Panel A reports the results for savings deposits (25K money market accounts). Panel B reports the results for time deposits (12-month CDs). The data is from RateWatch. Fixed effects (f.e.) are denoted at the bottom of each panel. Standard errors are clustered by county.

Panel A: Savings deposits

	Δ Spread					
	≥ 2 Counties			All		
	(1)	(2)	(3)	(4)	(5)	(6)
Δ FF × Herfindahl	0.153***	0.106***	0.112***	0.208***	0.163***	0.168***
	[0.037]	[0.036]	[0.043]	[0.031]	[0.029]	[0.029]
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	84,282	84,282	84,282	275,451	275,451	275,451
R^2	0.780	0.767	0.499	0.607	0.598	0.589

Panel B: Time deposits

	Δ Spread					
	≥ 2 Counties			All		
	(1)	(2)	(3)	(4)	(5)	(6)
Δ T-Bill × Herfindahl	0.076***	0.084***	0.168***	0.163***	0.136***	0.135***
	[0.027]	[0.027]	[0.037]	[0.027]	[0.025]	[0.024]
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	86,928	86,928	86,928	287,928	287,928	287,928
R^2	0.853	0.844	0.595	0.664	0.649	0.646

Table 3: **Deposit growth and monetary policy**

This table estimates the effect of Fed funds rate changes on deposit growth. 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. The data is annual from June 1994 to June 2008. Deposit growth is the log change in deposits at the branch level. Herfindahl is the average county-level Herfindahl index computed from banks' deposit market shares. Δ FF is the change in the Fed funds target rate. The data is from the FDIC. Fixed effects are denoted at the bottom of the table. Standard errors are clustered by county.

	Deposit growth					
	≥ 2 Counties			All		
	(1)	(2)	(3)	(4)	(5)	(6)
Δ FF × Herf.	−0.863***	−1.256***	−1.298***	−2.290***	−2.399***	−1.369***
	[0.273]	[0.334]	[0.240]	[0.215]	[0.252]	[0.208]
Bank × qtr. f.e.	Y	Y	N	N	N	N
State × qtr. 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	779,096	779,096	779,096	906,125	906,125	906,125
R^2	0.390	0.380	0.023	0.286	0.275	0.022

Table 4: **Deposit spreads and expected changes in monetary policy**

This table estimates the effect of *expected* Fed funds rate changes on deposit spreads. The data is quarterly from January 1997 to June 2008. 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 (25K money market accounts) because they have zero maturity. Δ Spread is the change in the deposit spread, which is equal to the Fed funds target rate minus the deposit rate. Herfindahl is the average county-level Herfindahl index computed from banks' deposit market shares. Δ Exp. 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. Δ Unexp. FF is the unexpected change in the Fed funds rate, computed as the difference between the realized change and the expected change. Fixed effects are denoted at the bottom of each panel. Standard errors are clustered by county.

	Δ Spread					
	≥ 2 Counties			All		
	(1)	(2)	(3)	(4)	(5)	(6)
Δ Exp. FF × Herfindahl	0.211***	0.154**	0.171**	0.235***	0.173***	0.179***
	[0.078]	[0.075]	[0.073]	[0.047]	[0.046]	[0.045]
Δ Unexp. FF × Herf.	0.155*	0.089	0.049	0.265***	0.204***	0.210***
	[0.086]	[0.080]	[0.088]	[0.054]	[0.049]	[0.048]
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	86,368	86,368	86,368	275,451	275,451	275,451
R^2	0.780	0.767	0.499	0.607	0.598	0.589

Table 5: **Deposit spreads, deposit growth, and financial literacy**

This table estimates the effect of financial literacy on deposit spreads and deposit growth. The data is quarterly from January 1997 to June 2008. 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. Age is the county share of the population aged 65 or older. Income is the county log median household income. Education is the county share of the population with a college degree. All other variables are defined in Table 2. Panel A reports results on deposit spreads (25K money market accounts). Panel B reports results for deposit growth. "All f.e." includes bank-time, state-time, branch, and county fixed effects. "Time + cnty. f.e." includes time and county fixed effects. Standard errors are clustered by county.

Panel A: Δ Spread

	≥ 2 Counties			All		
	(1)	(2)	(3)	(4)	(5)	(6)
Δ FF × Herfindahl	0.135***	0.138***	0.132***	0.124***	0.059*	0.066**
	[0.039]	[0.041]	[0.040]	[0.031]	[0.033]	[0.032]
Δ FF × age	0.182			0.434***		
	[0.114]			[0.076]		
Δ FF × income		−0.020			−0.104***	
		[0.020]			[0.015]	
Δ FF × education			−0.060			−0.297***
			[0.040]			[0.037]
All f.e.	Y	Y	Y	N	N	N
Time + cnty. f.e.	Y	Y	Y	Y	Y	Y
Observations	77,745	77,745	77,745	275,451	275,451	275,451
R^2	0.780	0.780	0.780	0.589	0.589	0.589

Panel B: Deposit growth

	≥ 2 Counties			All		
	(1)	(2)	(3)	(4)	(5)	(6)
Δ FF × Herfindahl	−0.538**	−0.639**	−0.821***	−1.110***	−1.551***	−1.438***
	[0.268]	[0.291]	[0.303]	[0.231]	[0.248]	[0.246]
Δ FF × age	−5.836***			−4.164***		
	[0.830]			[0.804]		
Δ FF × income		0.416***			−0.157	
		[0.213]			[0.148]	
Δ FF × education			0.431			−0.110
			[0.367]			[0.371]
All f.e.	Y	Y	Y	N	N	N
Time + cnty. f.e.	Y	Y	Y	Y	Y	Y
Observations	761,754	761,754	761,754	898,311	898,311	898,311
R^2	0.390	0.390	0.390	0.022	0.022	0.022

Table 6: **Deposit spreads, deposit growth, and monetary policy (bank size)**
This table estimates the effect of monetary policy on deposit spreads and deposit growth by bank size. The data is quarterly from January 1997 to June 2008. The variables 90^{th}, 75^{th}, and 50^{th} pct are indicator variables equal to one if a bank is in the $90^{th}, 75^{th}$ and 50^{th} percentile of the asset distribution in each year, and zero otherwise. All other variables are defined in Table 2. In Panel A the sample is all banks with branches in two or more counties. Column 1 to 3 reports results on savings deposits (25K money market accounts). Column 4 to 6 report results on time deposits (12-month CDs). Panel B reports results for deposit growth. 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. All specifications include two-way interactions and main effects (coefficients not shown). "All f.e." includes bank-time, state-time, branch, and county fixed effects. "Quarter + cnty. f.e." includes time and county fixed effects. Standard errors are clustered by county.

Panel A: Δ Spread

	Savings			Time		
	(1)	(2)	(3)	(4)	(5)	(6)
Δ FF × Herf. × 90^{th} pct	−0.018			−0.005		
	[0.079]			[0.058]		
Δ FF × Herf. × 75^{th} pct		−0.140			−0.003	
		[0.093]			[0.057]	
Δ FF × Herf. × 50^{th} pct			−0.123			0.125**
			[0.100]			[0.060]
All f.e.	Y	Y	Y	Y	Y	Y
Two-way interactions	Y	Y	Y	Y	Y	Y
Observations	83,491	83,491	83,491	86,061	86,061	86,061
R^2	0.779	0.779	0.779	0.854	0.854	0.854

Panel B: Deposit growth

	≥ 2 Counties			All		
	(1)	(2)	(3)	(4)	(5)	(6)
Δ FF × Herf. × 90^{th} pct	0.272			−1.526		
	[1.389]			[1.284]		
Δ FF × Herf. × 75^{th} pct		0.640			−0.913	
		[0.682]			[0.844]	
Δ FF × Herf. × 50^{th} pct			0.644			0.722
			[0.793]			[0.579]
All f.e.	Y	Y	Y	N	N	N
Time + cnty. f.e.	N	N	N	Y	Y	Y
Two-way interactions	Y	Y	Y	Y	Y	Y
Observations	769,897	769,897	769,897	896,262	896,262	896,262
R^2	0.390	0.390	0.390	0.028	0.028	0.028

Table 7: **Deposit spreads and monetary policy (other products)**
This table estimates the effect of Fed funds rate changes on deposit spreads using alternative deposit products. The data is quarterly from January 1997 to June 2008. Columns 1 to 3 and 4 to 6 of Panel A report results for 10K money market accounts and 2.5K money market accounts, respectively. Columns 1 to 3 and 4 to 6 of Panel B report results for 10K 3-month CDs and 10K 6-month CDs, respectively. In Columns 1 and 4 the sample consists of all banks with branches in two or more counties. In Columns 2, 3, 5, and 6 the sample consists of all banks. All variables are defined in Table 2. Fixed effects are denoted at the bottom of each panel. Standard errors are clustered by county.

Panel A: Savings deposits

	Δ Spread					
Product	10K Money market			2.5K Money market		
Counties	≥ 2	All	All	≥ 2	All	All
	(1)	(2)	(3)	(4)	(5)	(6)
Δ FF × Herfindahl	0.134***	0.198***	0.156***	0.089***	0.115***	0.053**
	[0.036]	[0.029]	[0.026]	[0.030]	[0.024]	[0.022]
Bank × quarter f.e.	Y	N	N	Y	N	N
State × quarter f.e.	Y	Y	N	Y	Y	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	83,997	274,906	274,906	82,205	268,280	268,302
R^2	0.812	0.663	0.647	0.886	0.788	0.783

Panel B: Time deposits

	Δ Spread					
Product	10K 3-Month CD			10K 6-Month CD		
Counties	≥ 2	All	All	≥ 2	All	All
	(1)	(2)	(3)	(4)	(5)	(6)
Δ T-Bill rate × Herf.	0.068**	0.064**	0.066***	0.074**	0.112***	0.102***
	[0.032]	[0.027]	[0.025]	[0.030]	[0.026]	[0.024]
Bank × quarter f.e.	Y	N	N	Y	N	N
State × quarter f.e.	Y	Y	N	Y	Y	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	84,007	267,553	267,553	86,927	287,938	287,938
R^2	0.766	0.509	0.687	0.484	0.355	0.323

Table 8: **Deposit spreads, deposit growth, and monetary policy (market size)** This table estimates the effect of monetary policy using alternative measures of market size. In Columns 1 to 3 and Columns 4 to 6 the Herfindahl index is computed from banks' deposit market shares within 2 and 5 miles of a given branch, respectively. In Columns 1 and 4 the sample consists of banks with branches in two or more counties. In Columns 2, 3, 5, and 6 the sample consists of all banks. All other variables are defined in Table 2. Panel A reports results for savings deposits (25K money market accounts). Panel B reports results for deposit growth. Fixed effects are denoted at the bottom of each panel. Standard errors are clustered by county.

Panel A: Δ Spread

Market size	2 miles			5 miles		
Counties	≥ 2	All	All	≥ 2	All	All
	(1)	(2)	(3)	(4)	(5)	(6)
Δ FF × Herfindahl	0.044***	0.080***	0.075***	0.040**	0.093***	0.084***
	[0.016]	[0.008]	[0.008]	[0.019]	[0.009]	[0.008]
Bank × quarter f.e.	Y	N	N	Y	N	N
State × quarter f.e.	Y	Y	N	Y	Y	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	80,495	266,418	266,418	80,495	266,418	266,418
R^2	0.802	0.650	0.634	0.802	0.651	0.634

Panel B: Deposit growth

Market size	2 miles			5 miles		
Counties	≥ 2	All	All	≥ 2	All	All
	(1)	(2)	(3)	(4)	(5)	(6)
Δ FF × Herfindahl	−0.939***	−0.168**	−0.841***	−1.496***	−0.559***	−1.124***
	[0.077]	[0.082]	[0.079]	[0.082]	[0.092]	[0.079]
Bank × quarter f.e.	Y	N	N	Y	N	N
State × quarter f.e.	Y	Y	N	Y	Y	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	716,922	843,435	843,435	716,922	843,435	843,435
R^2	0.297	0.4079	0.022	0.297	0.407	0.023

Table 9: **Deposit spreads and monetary policy (competition measure)**
This table estimates the effect of Fed funds rate changes on deposit spreads using alternative competition measures. Historical Herfindahl is the Herfindahl index at the start of the dataset (Panel A). Time-varying Herfindahl is the one-quarter lagged Herfindahl index (Panel B). Branch Herfindahl is based on branch market shares (Panel C). All other variables are defined in Table 2. Fixed effects are denoted at the bottom of each panel. Standard errors are clustered by county.

Panel A: Historical competition

	Δ Spread					
	≥ 2 Counties			All		
	(1)	(2)	(3)	(4)	(5)	(6)
Δ FF × historical Herf.	0.164***	0.114**	0.125**	0.188***	0.129***	0.138***
	[0.049]	[0.046]	[0.051]	[0.038]	[0.033]	[0.032]
Bank × quarter f.e.	Y	Y	N	N	N	N
State × quarter	Y	N	N	Y	N	N
Branch f.e.	Y	Y	N	Y	Y	N
Other f.e.	Y	Y	Y	Y	Y	Y
Observations	84,282	84,282	84,282	275,451	275,451	275,451
R2	0.799	0.787	0.543	0.648	0.639	0.631

Panel B: Time-varying competition

	Δ Spread					
	≥ 2 Counties			All		
	(1)	(2)	(3)	(4)	(5)	(6)
Δ FF × lagged Herf.	0.127***	0.088***	0.097**	0.184***	0.151***	0.155***
	[0.034]	[0.033]	[0.040]	[0.027]	[0.025]	[0.025]
Bank × quarter f.e.	Y	Y	N	N	N	N
State × quarter	Y	N	N	Y	N	N
Branch f.e.	Y	Y	Y	Y	Y	Y
Other f.e.	Y	Y	Y	Y	Y	Y
Observations	84,270	84,270	84,270	275,427	275,427	275,427
R2	0.799	0.787	0.543	0.648	0.639	0.631

Panel C: Branch competition

	Δ Spread					
	≥ 2 Counties			All		
	(1)	(2)	(3)	(4)	(5)	(6)
Δ FF × branch Herf.	0.157***	0.120***	0.164***	0.293***	0.238***	0.251***
	[0.043]	[0.043]	[0.048]	[0.032]	[0.031]	[0.031]
Bank × quarter f.e.	Y	Y	N	N	N	N
State × quarter	Y	N	N	Y	N	N
Branch f.e.	Y	Y	Y	Y	Y	Y
Other f.e.	Y	Y	Y	Y	Y	Y
Observations	84,282	84,282	84,282	275,451	275,451	275,451
R2	0.799	0.787	0.543	0.648	0.639	0.631

Table 10: **Deposit spreads and monetary policy (levels)**
This table estimates the effect of Fed funds rate changes on deposit spreads using estimation in levels. The data is quarterly from January 1997 to June 2008. 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. Δ Spread is the change in the deposits spread, calculated as the difference between the Fed funds rate and the deposit rate. All variables are defined in Table 2. Panel A reports results on deposit spreads (25K money market accounts). Panel B reports results for time deposits (10K 12-month CDs). Fixed effects are denoted at the bottom of each panel. Standard errors are clustered by county.

Panel A: Savings deposits

	Spread					
	$\geq$ 2 Counties			All		
	(1)	(2)	(3)	(4)	(5)	(6)
FF × Herfindahl	0.239***	0.156***	0.131***	0.250***	0.198***	0.190***
	[0.046]	[0.043]	[0.039]	[0.029]	[0.028]	[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	90,404	90,404	90,404	290,481	290,481	290,481
R^2	0.842	0.833	0.733	0.834	0.814	0.709

Panel B: Time deposits

	Spread					
	$\geq$ 2 Counties			All		
	(1)	(2)	(3)	(4)	(5)	(6)
FF × Herfindahl	0.166***	0.115***	0.074**	0.129***	0.096***	0.070***
	[0.020]	[0.020]	[0.019]	[0.028]	[0.032]	[0.029]
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	92,977	92,977	92,977	303,019	303,019	303,019
R^2	0.793	0.760	0.627	0.779	0.758	0.633

Table 11: **Bank core deposits and monetary policy**

This table estimates the effect of Fed funds rate changes on bank deposits. The sample consists of commercial banks from the Call Reports from January 1994 to June 2008. The bank-level Herfindahl is calculated as the weighted average of the county-level Herfindahl indexes of a bank's branches using lagged branch deposits as weights. Δ FF is the change in the Fed funds target rate. Δ Total deposits, demand, savings, and time is the quarterly growth (log change) in core deposits, checking deposits, savings deposits, and small time deposits, respectively. Δ Spread is the change in the Fed funds target rate minus the change in the deposit rate (computed as total deposit expense divided by total domestic deposits) over a quarter. Δ Deposit revenue is the log quarterly growth in deposit revenue (computed as deposit spread $\times$ total domestic deposits). The regression includes the main effect of the one-quarter lagged Herfindahl index (coefficient not shown). All regressions include bank and quarter fixed effects. Standard errors are clustered by bank.

	Δ Core	Δ Checking	Δ Savings	Δ Small time	Δ Spread	Δ Revenue
	(1)	(2)	(3)	(4)	(5)	(6)
Δ FF $\times$ Herfindahl	−0.884***	−0.895***	−0.571**	−1.829***	0.088***	7.023***
	[0.151]	[0.216]	[0.252]	[0.203]	[0.010]	[1.709]
Bank f.e.	Y	Y	Y	Y	Y	Y
Quarter f.e.	Y	Y	Y	Y	Y	Y
Observations	426,620	426,620	426,620	426,620	426,620	323,212
R-squared	0.147	0.101	0.075	0.148	0.388	0.557

Table 12: **Bank liabilities and monetary policy**

This table estimates the effect of Fed funds rate changes on bank liabilities. The sample consists of commercial banks from the Call Reports from January 1994 to June 2008. The bank-level Herfindahl is calculated as the weighted average of the county-level Herfindahl indexes of a bank's branches using lagged branch deposits as weights. Δ FF is the change the Fed funds target rate. Total liabilities are total bank liabilities. Non-deposit liabilities are total liabilities excluding deposits. Wholesale funding is total non-deposit funding minus subordinated debt and other liabilities. All outcome variables are computed as the log change over a quarter. The regression includes the main effect of the Herfindahl index (coefficient not shown). All regressions include bank and quarter fixed effects. Standard errors are clustered by bank.

	Δ Total liabilities (1)	Δ Large time deposits (2)	Δ Non-deposit liabilities (3)	Δ Wholesale funding (4)	Δ Other liabilities (5)	Δ Subordinated debt (6)
Δ FF × Herfindahl	−1.039***	−2.989***	3.564***	3.466***	−0.145	4.773*
	[0.143]	[0.403]	[0.986]	[0.969]	[0.520]	[2.435]
Bank f.e.	Y	Y	Y	Y	Y	Y
Quarter f.e.	Y	Y	Y	Y	Y	Y
Observations	426,620	426,620	426,620	426,620	426,620	11,522
R-squared	0.171	0.046	0.028	0.056	0.071	0.113

Table 13: **Bank assets and monetary policy**

This table estimates the effect of Fed funds rate changes on bank assets. The sample consists of commercial banks from the Call Reports from January 1994 to June 2008. The bank-level Herfindahl is calculated as the weighted average of the county-level Herfindahl indexes of a bank's branches using lagged branch deposits as weights. Δ FF is the change the Fed funds target rate. All outcome variables are computed as the log growth over a quarter. RE loans and C&I loans are real estate loans and commercial and industrial loans, respectively. The regression includes the main effect of the Herfindahl index (coefficient not shown). All regressions include bank and quarter fixed effects. Standard errors are clustered by bank.

	Δ Assets	Δ Cash & reserves	Δ Securities	Δ RE loans	Δ C&I loans
	(1)	(2)	(3)	(4)	(5)
Δ FF $\times$ Herfindahl	−0.979***	−2.470***	−0.742**	−0.528**	−0.656*
	[0.126]	[0.615]	[0.361]	[0.220]	[0.385]
Bank f.e.	Y	Y	Y	Y	Y
Quarter f.e.	Y	Y	Y	Y	Y
Observations	426,620	426,620	426,620	426,620	426,620
R-squared	0.169	0.055	0.057	0.152	0.047