Low Interest Rates, Technology, and the Desertification of Banking

Abstract

The decline in branch banking is typically attributed to technological change. While the so-called digital disruption has reduced the need for brick-and-mortar branches, we find that persistently low interest rates have also played a key role. When interest rates are low, cheap deposit financing contributes less to bank profitability, leading to lower deposit franchise values. This, in turn, lowers the opportunity cost of shifting depositors from the interest rate insensitive branch channel to more volatile digital channel. As a result, when low rates are expected to persist, banks close branches. We test whether low interest rates caused branch closures using a share shift instrument based on historical differences among banks in their reliance on interest rate sensitive deposits and the average nationwide change in deposit yields since 2010. We control for changes in technology by calculating a bank level measure of exposure to innovations in broadband access and speeds. We find that low interest rates are significantly related to branch closures and that persistent low interest rates accelerated technology enabled branch closures. In addition, we find that banks that closed more branches due to low interest rates were more adversely affected by subsequent rate increases, highlighting concerns about bank fragility. Finally, we find that branch closures due to low interest rates, but not technology, are related to an increase in the proportion of the population that identify as unbanked and to the expansion of banking deserts.

Keywords: Branch closures, banking deserts, technology, low interest rates
JEL: D22, G21, G32

Introduction

Branch banking started declining in the United States in 2010. As shown in Figure 1, the number of bank branches in the United States peaked in 2010 at over 9,700 and declined steadily at an average annual rate of about 3% through 2022. In other countries de-branching has progressed further. For example, in OECD countries the number of branches fell by almost 30% from a peak in 2008 through 2022.[1] The steady decline in the number of branches is broadly seen as fundamentally changing the bank infrastructure, leading to an increase in the physical distance between bankers and their customers.

The decline in branch banking has been attributed primarily to technological advancements and evolving customer preferences for internet banking.[2] However, online banking has been around since at least the early 1990's and by 2000, an estimated 80 percent of banks in the U.S. offered online banking services.[3] Given the timing of these innovations, why did it take until 2010 for the number of branches to start declining and why did the number of branches start increasing again in 2023?[4]

We provide evidence in this paper that persistently low interest rates contributed to the decline in branch banking and hastened the transition from branch to digital banking. Our study is motivated by the fact that the global financial crisis (GFC) ushered in a period of persistently low interest rates. For example, between 2010 and 2022 effective Federal Funds Rates (FFRs) were consistently below the "so called" reversal rate of two percent.[5] The average effective FFR during this period was 63 basis points and was below 25 basis points for 32 out of 48 quarters. Since deposit rates are bounded by zero, it is difficult to offset declines in interest earnings by further

---

[1] See Amberg and Becker (2024).

[2] See Keil and Ongena (2024) for a discussion of the possible causes of branch closures.

[3] In 1994, Stanford Federal Credit Union became the first financial institution in the United States to offer online banking services to all its customers. In 2001, Bank of America was the first financial institution to gain more than 3 million online banking customers, about 20 percent of its customer base. Mobile banking was first introduced in early 2007 and Bank of America was the first large bank to offer mobile banking in 2007. See https://www.nasdaq.com/articles/how-online-banking-evolved-mainstream-financial-tool-2014-11-09?utm

[4] According to the FDIC number of branches increased in 2023 by 91. As we discuss later, closure rates peaked in 2020 during the pandemic and have decreased since then. This decline was accompanied by a number of banks announcing plans to expand their branch networks. For example, JP Morgan Chase recently announced plans to open over 500 new branches and to renovate approximately 1,700 locations by 2027. See https://media.chase.com/news/chase-makes-multi-billion-dollar-investment-in-its-branch-network?utm.

[5] The reversal rate is the interest rate at which accommodative monetary policy reverses and becomes contractionary for lending. The reversal rate also refers to the rate below which the relationship between changes in bank equity values and of changes in Federal funds rates reverses from negative to positive, which most studies find is around 2 percent. See Adadi, Brunnermeier, and Koby (2023), Wang, Whited Wu, and Xiao (2022) and Emin, James, and Li (2024).

reducing deposit rates when short term rates are as low as they were after the GFC. We present a simple model to show how persistently low interest rates reduce the profitability of the deposit franchise and lead to branch closures. Low interest rates also reduce the opportunity cost of transitioning depositors to online banking. The basic idea is that transitioning deposits to digital platforms from branches involves a trade-off. While closing branches reduces noninterest operating costs, online deposits are more rate sensitive and fleeting than branch sourced deposits.[6] Moreover, when rates are low, the difference between the rates paid on internet deposits and branch deposits is less. As a result, if interest rates are expected to remain low, banks close branches and transition depositors to online banking.

While the decline in branching in the U.S. coincided with persistent low interest rates, the empirical challenge is to establish a causal link between low interest rates and branch closures. We address this challenge by drawing on recent empirical work by Sarto and Wang (2023) who exploit heterogeneity in bank exposures to lower interest rates to test whether persistent low rates contributed to the rise of so-called shadow banks. We take a similar approach but focus on branch closures and use heterogeneity across banks in their historical reliance on different types of deposit accounts (time, savings and transaction accounts) to identify the effect of low interest rates on branch closures.

Our identification strategy is motivated by the observation that the sensitivity of the rate paid on deposits to changes in interest rates (so called deposit pass-through rates or deposit betas) differs across deposit accounts and the channel through which deposits are acquired.[7] For example, transaction accounts typically pay low rates (or none at all) and the rates offered are relatively insensitive to changes in market interest rates. In contrast, time and savings deposits pay higher rates, their rates are more sensitive to changes in the level of interest rates, but they have lower non-interest costs than transaction accounts. This implies that when interest rates decline, more of the decrease is passed through to depositors in terms of lower deposit rates on time and savings accounts than on transaction accounts. As a result, banks that rely more heavily on deposits with low pass-through accounts are *ceteris paribus* more exposed to declines in earnings caused by

[6] Transitioning depositors from branches to online banking reduces location-based deposit market power. See Drechsler, Savov, and Schnabl (2017, 2021).

[7] The deposit pass through rate is the portion of market interest rate changes that is passed through to depositors in terms of rates paid on deposits.

declines in interest rates.[8] This exposure, as we discuss later, is reflected in a larger decline in the average deposit spread (the difference between FFRs and deposit rates) for banks that rely more heavily on low pass-through accounts (see Figure 5).

We construct a measure of a bank's deposit cost exposure to interest rate declines as a share-shift or Bartik instrument.[9] Specifically, we construct a deposit exposure measure by combining pre-GFC deposit account weights with nationwide declines in deposit rates across the different account categories. Our exposure measure relies on call report information concerning a bank's historical liability structure from 2003 (before interest rates declined) and nationwide changes in average deposit rates in different account categories during the 2010 to 2022-time period. Importantly, our measure *does not* include any bank specific changes in deposit rates or deposit account weights during the period of interest and therefore doesn't capture any bank specific responses to low rates.

To provide some intuition on how our share shift instrument works, in Figure 2, we plot the cumulative change in deposit yields since 2010 for each of the deposit categories in our deposit exposure measure. As shown, cumulative yields (the sum of the annual change relative to 2010) dropped by more than 10 percent for time deposits and around 2.5 percent for savings deposits. In contrast, there was virtually no change in the cumulative yield on transaction accounts. As a result, banks that historically relied heavily on transaction accounts were more exposed to a decline in interest rates since their deposit spreads and gross profits from providing deposit services are likely to be more significantly impacted compared to banks that relied heavily on time and savings deposits. We define banks with high historical weights in low-interest rate pass through accounts as high *Deposit exposure* banks.

If low interest rates cause branch closures, we expect a positive relation between cumulative branch closure rates and *Deposit exposure*. We obtain information on bank branch closures from the FDIC's Summary of Deposits and define the cumulative branch hazard rate as

---

[8] Banks with liabilities that are more exposed to declines in interest rates may hedge potential exposure to lower rates by structuring their earning assets so that interest earnings on assets are less sensitive to interest rate declines than banks with liabilities that are less exposed to declines in interest rates. Nevertheless, as discussed later, persistently low rates ceteris paribus adversely affect the profitability of brick-and-mortar branches more for banks with lower average pass-through rates on deposits.

[9] Share shift instruments have been used in a number of recent studies to test for causal links. For example, see Autor, Dorn, and Hanson (2013). Goldsmith-Pinkham, Sorkin, and Swift (2020) provide an excellent discussion regarding the conditions affecting the plausibility of share shift instruments.

the sum of annual branch hazard rates from 2010 to 2022.[10] Overall, we find a positive and statistically significant relation between cumulative branch closure rates and *Deposit exposure*. The effect of low interest rates on bank closures is economically large with, at the bank level, a 100-basis point increase in exposure leading to an increase in the cumulative branch hazard of 79 basis points (or roughly 50 percent of the mean cumulative closure rate from 2010 through 2022).

While our findings suggest that low interest rates affect branch closure rates, technological change also plays a role. Indeed, we argue low interest rates may have accelerated technologically driven closure rates. This raises the obvious concern that our deposit exposure measure may be correlated with technological change and that changes in technology and not low interest rates caused banks to close branches. We address this concern by constructing a bank level measure of exposure to digital innovations. Specifically, we construct bank level measure of broadband penetration using each bank's historical share of deposits in a county and census tract data from the FCC Form 477 on the evolution of broadband speeds.[11] Banks exposed to greater broadband penetration are banks with higher historical deposit shares in census tracts with the greater broadband penetration. We refer to these banks as high *Broadband penetration* banks.

As shown in Figure 3 we find virtually no relationship between *Broadband penetration* and *Deposit exposure*. In addition, consistent with prior research (see for example Jiang, Yu, and Zhang (2022)) we find a positive and significant relation between cumulative branch closure rates and our measure of changes in technology. In addition, when we include both variables in the hazard regression, we find both are positively and significantly related to branch closures. Finally, and most interesting, at the county level, we find a positive relation between closure hazard rates and *Broadband penetration* interacted with *Deposit exposure*, consistent with that low interest rates accelerating the impact of technology on branch closures.

To explore further the reasons for branch closures, we investigate the relationship between branch closures and the organizational structure of the banks in our sample. We use bank branch managers' ability to set deposit and loan rates locally as a measure of the extent decision making is delegated to the branch level. Following Dlugosz, Gam, Gopalan, and Skrastins (2024) we use

[10] Annual branch hazard rate equals number of branches closed during a year scaled by the total number of branches at the beginning of the year. We also examine net closure rates defined as the change in the number of branches scaled by total number of branches at the beginning of the year.
[11] We measure broadband penetration from 2014-2022. We start in 2014 because that is the first year data from FCC Form 477 is available.

data from Ratewatch to identify loan and deposit rate setting branches. We then calculate a decentralization score as the ratio of the number of counties in which a bank has at least one rate setting branch to the total number of counties in which the bank has branches. Higher decentralization scores are assumed to be associated with greater delegation of decision making to the branch level. We hypothesize more decentralized banks engage in more localized, personal interaction with their customers through their branches and are therefore less likely to close branches. We refer to this as the *delegated decision-making hypothesis*. Consistent with this hypothesis we find a negative and significant relation between cumulative branch hazard rates and decentralization scores. Moreover, we find that decentralization serves to mitigate the impact of low interest rates and broadband penetration on branch closures.

The final section of the paper investigates the impact of branch closures on bank fragility and access to banking services. The concern with branch closures arises because branch banking and the accompanying close geographic proximity of banks to their customers has traditionally been seen as a core part of the business of banking. Proximity, the argument goes, is critical for the collection of soft information, the development of banking relationships and the ability of banks to screen and monitor borrowers.[12] Distance may also matter in deposit taking and the provision of liquidity services. Deposits are by far the largest source of bank financing (representing on average 80 percent of bank funding) and the deposit franchise is a principal source of bank value.[13] More important, deposit supply has an important local component. For example, Drechsler, Savov, and Schnabl (2017) find that local deposit market concentration is significantly related to deposit spreads, consistent with the localized nature of deposit taking. In addition, Gilje, Loutskina, and Strahan (2016) show branch networks play an important role in integrating local credit markets, particularly for smaller community and regional banks.

If distance matters, de-branching represents a potential paradigm shift in the business of banking. Moreover, technology versus low-interest rate driven closures potentially have different implications for deposit market competition and access to banking services. On the one hand, if banks derive market power from their physical proximity to their borrowers and depositors, as

[12] There is a large literature documenting the importance of local finance. See for example, Petersen and Rajan (1994, 2002), Berger et al. (2005), Gilje (2012) and more recently Granja, Leuz, and Rajan (2022). Consistent with the importance of geographic proximity several recent studies find that branch closures are associated with a significant decrease in lending to small and medium size businesses (SME's). See Amberg and Becker (2024) and Nguyen (2019).
[13] For example, Egan, Lewellen, and Sunderam (2022) find that deposit productivity is responsible for two thirds of the value of the median bank and most of the cross-sectional variation in bank values.

several studies suggest, then technology has the potential to increase competition and lower the cost of financial intermediation. On the other hand, the rates paid on deposit tend to be stickier when acquired through branches, thus de-branching raises fragility concerns. In addition, there is the concern that some bank customers have limited access to digital services and that for some types of lending in person interaction is still important. As a result, branch closures may have adverse distributional consequences.

We investigate the effect of branch closures on bank fragility and access to banking services. We begin by examining the relationship between changes in the interest cost of deposits and *Deposit exposure*, as well as between deposit flows and *Deposit exposure* during the interest rate hikes from 2022-2023. We find that in the cross-section of banks, *Deposit exposure* is positively associated with increases in deposit yields and negatively related to increases in deposit volume during 2022-2023. We argue that this increase in deposit funding volatility for high *Deposit exposure* banks is related to branch closures and the associated transition of deposits from brick-and-mortar branches to online platforms. This aligns with recent work by Benmelech et al. (2023), who argue that low branch density banks have more volatile deposit funding.

To test this hypothesis, we use *Deposit exposure* as an instrument for changes in branch density from 2010-2022. We then estimate second stage instrumental variable (IV) regressions relating changes in deposit interest costs and deposit flows to changes in branch density. We find a negative and significant relation between changes in deposit interest costs and low interest rate induced changes in branch density. In addition, we find a positive and significant relation between the change in deposit volume and changes in branch density during the interest rate hikes in 2022-2023. The economic effect of low interest rate induced changes in branch density on deposit costs and flows is economically large. For example, a one standard deviation reduction in low interest rate induced branch density is associated with about a 60 percent increase in the deposit interest costs relative to the mean increase. Overall, we find that low interest rates are associated with reductions in locally sourced branch deposits which, in turn led to more rate sensitive deposit financing when interest rates subsequently increased.

We next turn to investigating the effect of branch closures on access to bank services. For this investigation we employ two commonly used access measures. The first measure is county level changes in the proportion of FDIC survey respondents that report being unbanked over our sample period. We conjecture that closures caused by low interest rates are more likely to lead to a higher proportion of unbanked respondents than closures caused by broadband penetration. The idea is that closures motivated by technology are likely to be associated with greater local access to digital substitutes for in-person banking and thus less likely to leave households unbanked. Consistent with this conjecture we find a positive relationship between increases in the proportion of households that report being unbanked and our deposit exposure measure. In contrast we find a *negative* and significant relation between proportion of unbanked households and the county level proportion of deposits held by high technology penetration banks. This latter result suggests that improvements in internet access increase access to banking services.

Our second access measure is based on changes in the number of banking deserts; defined as census tracts without a bank, savings and loan and credit union branch within a fixed radius distance from that population center of the tract.[14] In particular, we use the definition of banking deserts used by bank regulatory agencies and define a banking desert as urban, suburban and rural census tracts without a branch within a two-, five- or 10-mile radius of the population center of the census tract. Consistent with low interest rates leading to desertification, we find a positive and significant relation between the changes in county level banking deserts and *Deposit exposure*. However, we find no significant relationship between changes in our access measures and *Broadband penetration*. Overall, our findings suggest that branch closures caused by low interest rates and not technology reduce access to banking services.

We contribute in several ways to the literature. First, while a number of recent studies have examined the impact of low interest rates on the effectiveness of monetary policy and the growth of "shadow banking", to our knowledge ours is the first study to examine the impact of low interest on branch closures.[15] We provide novel evidence that low interest rates reduce branch franchise value, cause branch closures, and contribute to the so-called digital revolution by reducing the opportunity cost of transitioning depositors from branches to more transparent and competitive digital platforms.

Second, we add to the literature investigating the impact of online banking and reductions in branch density on bank fragility and the effectiveness of monetary policy. Specifically, we show

[14] See Barca and Hou (2024) for a discussion of definition of banking deserts and potential banking deserts used by bank regulators.

[15] For example, Sarto and Wang (2023) analyze whether low interest rates caused the growth of "shadow banks". See Wang et. al. (2022) for an analysis of the impact of low interest rates on bank deposit market power and the effectiveness of monetary policy.

that persistent low interest rates accelerated the shift to lower branch density which in turn is associated with less stable deposit financing. Our findings suggest that low interest rates can affect bank fragility by causing long term changes in bank infrastructure that make deposits a less stable source of bank funding.

Finally, our findings suggest that technology driven branch closures impact access to banking services differently than low-interest rate driven closures. Specifically, we find that low interest rates are associated with branch closures that reduce access to banking services and increase desertification. We find no evidence that technology driven closures adversely affect access to banking services. This finding is perhaps not surprising given that new technologies provide substitutes (albeit potentially imperfect ones) for branches in the provision of banking services while low-interest rate driven branch closures make access to branch services more difficult.

The rest of the paper is organized as follows. In the next section we discuss the potential mechanisms through which low interest rates and technological change may affect branch closures. This discussion motivates the share shift instrument we use to examine whether low interest rates cause of branch closures. In section III we describe our data sources and provide summary statistics. In Section IV present our empirical findings on the causes of branch closures and in Section V we examine the relation between branch closures, bank fragility and access to banking services. In the last sections we provide concluding remarks.

II. Empirical Framework

2.1 Deposit franchise value and interest rates

The value of the deposit franchise is generally assumed to arise from banks being able to pay interest rates on deposits that are below market interest rates.[16] The spread between market interest rates and deposit rates (i.e., the deposit spread) is a function of the degree to which banks

[16] The ability to earn spread income is assumed to arise from bank market power. However, the source of market power in banking is debated. Drechsler, Savov, and Schnabl (2017, 2021) provide evidence that deposit spreads are related to local deposit market concentration. However, Begenau and Stafford (2023) and d'Avernas et al. (2023) find that many banks engage in uniform pricing suggesting that differences in the degree of competition across local markets do not explain deposit spreads. Rather, they argue market power arises from banks offering differentiated deposit products, which allows some banks to offer lower deposit rates but better liquidity services (such as better on-line and ancillary services). Differences in customer preferences and technology in turn drives where banks locate branches and therefore geographical differences in deposit rates.

pass through changes in market rates to depositors. The deposit pass through rate is often referred to as the deposit beta. *Ceteris paribus*, the lower the pass-through rate, the higher the deposit spread and the more valuable the deposit franchise. In short, low pass-through rates are one reason deposits are a low cost and stable source of funding for banks.

To motivate our empirical analysis, we draw on recent work by Drechsler et al. (2021) to illustrate the relationship between the value of the deposit franchise and the level of interest rates. Assume that the bank offers I_D types of deposit accounts that differ in terms of the rates they pay, the liquidity services they provide and their noninterest costs. Assume for simplicity that the bank invests deposits proceeds in short term investment that earn a market rate of r_f. Define β^i as the deposit beta or pass through rate associated with account type i so that the average deposit beta for the bank is simply

$$\beta^D = \sum_{i \in I_D} \omega^i * \beta^i, \tag{1}$$

where ω^i is the proportion of deposits in category i to total deposits.

The per period income generated from a bank's deposit franchise is

$$Inc_t^D = D(\left(1 - \sum_{i \in I_D} \omega^i * \beta^i\right) r_f - \sum_{i \in I_D} \omega^i * c^i) \tag{2}$$

where c^i is the per dollar non-interest operating costs associated with deposit type i.

Deposit accounts vary in terms of the liquidity they provide, interest rates offered, deposit insurance coverage and the channel through which they are acquired. The pass-through rates and the non-interest operating costs are likely to vary by the type of deposit account (i.e., time, savings, and transaction account) and, as we discuss later, the channel through which the account was acquired (i.e., online versus branch network).[17]

Equations (2) illustrates how a decline in market interest rates affects the profitability of the deposit franchise and the channel through which low rates may lead to branch closures. A reduction in interest rates reduces both the revenue earned on deposit funded investments and the interest cost of deposits. However, the magnitude of the reduction in the interest cost of deposits depends on β^D. The higher β^D, the greater the reduction in the interest cost of deposits when rates decline and therefore the smaller the decline in the earnings (i.e., the deposit spread). As a result, the sensitivity of earnings to changes in interest rates is expected vary inversely with β^D. In short,

[17] The Call Report provides bank level information on interest expense and deposit volume for time, savings, and transaction accounts. Unfortunately, branch level interest expense and deposit volume by type of account is not provided in the Call Report or in the FDIC's Summary of Deposits reports.

high pass-through rates cushion the adverse effects of lower interest rates on margins but serve to dampen the gains in margins when rates increase. We refer to banks with low $\beta^D s$ as high *Deposit exposure* banks because their earnings on their deposit franchise are more exposed to *declines* in interest rates.

When interest rates approach the zero lower bound it is likely to be more difficult for banks to hedge against further declines in interest rates by adjusting the rates on deposits or changing the composition of deposits. Whether high *Deposit exposure* leads to a decline in bank net interest margins will depend on the extent banks can hedge deposit exposure by matching the rate sensitivity of their deposits and assets. Drechsler et al. (2021) find that banks on average hedge interest rate by matching the rate sensitivity of their assets and liabilities. However, their sample begins in 1984 and ends in 2016 and therefore is heavily weighted towards a period when interest rates were above the reversal rate. When short-term interest rates remain low for a considerable time, it becomes harder for banks to use long-term assets to hedge the negative effect on deposit income. Consistent with the lack of a complete hedge, as discussed later, we find a negative and significant relationship between changes in net interest margins and our *Deposit exposure.* Note that regardless of the extent of hedging, low interest rates diminish the profitability of branch-deposit business and lower the opportunity cost of shifting depositors from relatively rate insensitive branch channel to more rate sensitive digital platforms.

We identify the impact of low interest rates on branch closures by exploiting differences in the exposure of bank deposit franchise values to interest rate declines. Heterogeneity in exposure, in turn, is a function of differences in pass through rates across categories of deposits. Consistent with heterogeneity in deposit exposure, Drescher et al. (2017) and Emin et al. (2024) find deposit beta vary widely based on deposit type. For example, Emin et al. (2024) find the average time deposit beta from 1997 through 2023 was .35 versus only .08 for transaction accounts. As a result, the deposit franchise earnings of banks that rely heavily on transaction accounts are expected to decline more when rates decrease than banks the rely more heavily on time deposits as a funding source.

Obviously, the reliance on various types of deposits for funding is endogenous and is likely to depend on both the interest cost of various types of deposits as well as the differences in account operating costs. As a result, a bank's exposure to low interest rates at given point in time is likely to be a function of a variety of factors including the current and expected future level of interest rates, deposit market competition, technology, and demographic characteristics of the markets in which the bank operates and the bank's lending and investment opportunities.

Given that the composition of deposits is endogenous; to identify the effect of low interest rates on the branch profitability, we use a methodology like the one used in Sarto and Wang (2023). Specifically, following Sarto and Wang (2023) we construct a share shift or Bartik instrument using bank deposit weights in 2003 (before the decline in interest rates following the GFC) to measure a bank's exposure to low interest rates. We then interact each bank's historical deposit weights with the change over time in the national average rate paid on deposits in each category. Specifically, for each bank *b* we measure deposit exposure as

$$Deposit\ exposure_{bt} = \sum_{i \in I_D} \omega^i_{bt'_0} \ * \ \int_{t_0}^{t} (r^i_s - r^i_{t_0}) ds \tag{3}$$

where $\omega^i_{bt'_0}$ is bank *b*'s balance sheet weight of liability category *i* calculated at base year t'_0 (2003), and r^i_t is the national deposit yield (rate) for deposit category *i* at time *t*. For example, for time deposits, r^i_t corresponds to the deposit yield on time deposits over time period *t*. Our deposit exposure measure is based on four categories of liabilities: transaction deposits, saving deposits, time deposits, and other liabilities. We calculate the cumulative deposit exposure from t_0 to *t* for bank *b* by integrating $r^i_s - r^i_{t_0}$ from 2010 through 2022. Note that integrating over the path of decline in deposit yields, as opposed to taking the difference between the end points, allows us to take into account differences in the speed at which deposit yields fell across categories. As emphasized by Sarto and Wang (2023), this methodology captures the fact that a bank would be more affected by a 100 bps decline in yield in a deposit category if most of the decline happened around 2010, and less affected if most of the decline occurred closer to 2022.

It is important note that equation (3) *does not* measure of how the cost of deposit funding actually changed for bank *b* from 2010 through 2022. Deposit exposure is intended to instrument for changes in deposit costs but will differ from the actual change in the cost of deposits for at least two reasons. First, *Deposit exposure* is calculated using changes in the *national average rate paid* for each category of deposits and not the actual change in rates paid by bank *b*. This corrects for potential endogeneity arising from bank level changes in deposit rates due to changes in a bank's customer base, market power or changes in the technology platform the bank uses. Second, *Deposit exposure* is based on fixed pre- GFC deposit weights which accounts for potential endogeneity arising from changes in the composition of deposits in response to a change in interest rates. In other words, the *Deposit exposure* measures the potential impact of low interest rates which in turn is expected to be related to the ex-post actions banks take in response to low interest rates (such as adjusting the composition of their deposit portfolio or closing branches).

Our deposit exposure measure is based on the idea that the primary driver of deposit franchise value is the spread earned on deposits. However, local bank branches may add value by facilitating lending and in particular by SME lending based on so called "soft" information. Soft information is typically defined as credit risk relevant information that is qualitative, subjective, and not easily quantifiable or verifiable by others. Thus, the ability to produce and utilize soft information is likely to depend on close interactions between bank lenders and their customers through the branch network and the extent to which lending decisions are made at the local level.[18] As a result, branches may add value through facilitating soft information-based lending and monitoring.[19]

There is likely considerable heterogeneity among and even within banks in terms of their reliance on brick-and-mortar branches as a lending platform. In addition, as we discuss in the next section, the importance of branches for lending has likely changed over time as technology enables the hardening of soft information and lowers the cost of transmitting soft information over long distances (for example the use of Zoom to conduct loan interviews).[20]

We conjecture that the reliance on branches as lending platform will vary with the extent to which pricing decisions are delegated to branch managers. Drawing on recent research by Dlugosz et al. (2024) we use information from Ratewatch to identify rate setting branches. Ratewatch conducts a weekly survey of bank branches in terms of the interest rates branches offer on loan and deposit products. In addition to collecting information on interest rates, Ratewatch identifies branches with rate setting authority and branches that follow rates set elsewhere in the bank. We use branch level rate setting information to construct a bank level decentralization score

[18] Stein (2002) argues that co-locating decision rights with the production of soft information enhances an agent's incentive to produce and utilize soft information.

[19] There is a substantial literature on the importance in distance in small business lending. These studies assume that the main repository of soft information is branch office and therefore measure distance by how far a loan customer is from the nearest branch. For example, see Petersen and Rajan (2002), Agarwal and Hauswald (2010), Berger and Udell (2002) and more recently Granja, Leuz, and Rajan (2022).

[20] Petersen and Rajan (2002) argue that the steady improvement in IT technology has allowed lenders to substitute away from local interaction leading to an increase in the distance between borrowers and lenders.

which is intended to measure the extent to which decision making is delegated to branch level. We compute a bank level decentralization score by calculating the number of counties the bank has at least one rate setting branch divided by the total number of counties in which the bank operates branches. We assume higher decentralization scores indicate greater branch level decision making and therefore the higher the likelihood the bank uses its branches as a platform for lending and other non-deposit services. We expect more decentralized banks to be less likely to close branches when interest rates are low.

2.2 Branch closures and technological change

The focus of our paper is on investigating the impact of low interest rates on branch closures. However, technological change is also likely to play a role in branch closures. Technology reduces the need for branches by reducing the relative costs of collecting deposits and servicing depositors through mobile and on-line platforms versus brick-and-mortar branches. There are at least a couple of reasons to suspect technological changes was an important driver of branch closures during our sample period. First, aggregate deposits grew in real terms by 4.5% from 2010 through 2022, in large part through the growth of transaction deposits. The growth in deposits was accompanied by a decrease in branch density (defined as the number of bank branches per $1 billion dollars of deposits).[21] Thus branch closures did not lead to a decline in the aggregate deposits. Second, the decline in interest rates after the GFC coincided with the expansion of 3G networks, which facilitated the use of smart phones and other devices for mobile banking. Consistent with this argument, Jiang, Yu, and Zhang (2022) find a positive and significant relation between the county level deployment of 3G networks and branch closures.

It is important to emphasize, however, that technology and low interest rates are not mutually exclusive explanations for bank closures – each can independently and simultaneously contribute to branch closures. Moreover, as we discuss later, low interest rates may accelerate the adoption of cost saving technologies and the transition to digital banking.

However, the concern here is that our deposit exposure measure may be correlated with technological change and that changes in technology and not low interest rates caused banks to close branches. To address the concern deposit exposure may be correlated with technological

[21] According to data from the Federal Reserve Economic Data (FRED), total deposits in all commercial banks increased from approximately $8.5 trillion in January of 2010 to $19.2 trillion by December 2022.

change and to investigate the incremental effects of low interest rates and technology on branch closures, we control for technological innovation by exploiting differences across census tracts in the evolution of internet speeds. Specifically, census tracts differ in terms of broadband speeds that are available and the evolution of broadband speeds over time. We exploit these differences to construct a broadband penetration measure based on difference between banks in terms of historical branch locations. For each bank *b* we measure broadband penetration or exposure as

$$Broadband\ penetration_{bt} = \sum_j \omega_{bt_0'}^{j} \ * \ \int_{t_0}^{t} census\ tract\ broadband_s^j\ ds \qquad (4)$$

where $\omega_{bt_0'}^{j}$ is bank *b*'s branch deposit in census tract j in base year t_0' divided by total bank branch deposits across all branches of the bank in base year t_0', and $census\ tract\ broadband_s^j$ is broadband speed in census tract j in year t. We obtain census tract level broadband speed data from FCC Form 477. This data is available for the 2014-2021 period so broadband penetration is measured from 2014-2021. The base year for determining the census tract level deposit weights, $\omega_{bt_0}^{j}$, is chosen to be 2003.

If *Broadband penetration* is related to the propensity of banks to substitute digital distribution of deposit services for brick-and-mortar branches, we expect a positive relationship between the cumulative branch closure hazard and *Broadband penetration*. More important, if low interest rates and technology are separate channels affecting branch closures, we expect both to be positive and significant when included together in the closure regression.

The advantage of *Broadband penetration* as a control is that it is calculated using deposit weights in 2003 and thus mitigates concerns that it may be correlated with changes in the deposit funding caused by low interest rates. Nevertheless, we investigate the validity of *Broadband penetration* as a control for the innovations in technology by examining the relationship between *Broadband penetration* and bank spending on IT during the exposure period. In Figure 4 we plot the average cumulative IT spending (defined as bank-level IT spending scaled by assets) from 2014-2022 by *Broadband penetration* quartiles. As shown the average IT spending is increasing in *Broadband penetration*.[22]

[22] We also regress IT spending on *Broadband penetration* and find a positive and significant (at the .01 level) relationship.

Finally, equation (2) illustrates how low interest rates may incent banks to transition depositors to online banking. One advantage of online banking is the operating costs per dollar of deposits are significantly lower.[23] However, an advantage of brick-and-mortar branches is that deposits are likely to be stickier than deposit from online accounts. For example, Erel et al. (2024) find that passthrough rates on deposits are 17 to 36 basis points higher at online banks than at traditional banks. In addition, Benmelech et al. (2023) find a negative relation between average deposit yields and branch density. This suggests a trade-off when considering whether to close a branch; online platforms involve lower operating costs but higher interest costs. More important, equation (2) suggests that when rates are low, the incremental interest cost associated with greater reliance on digital distribution are also likely to be low, thus inducing banks to shift to digital distribution.

III. Data and Summary Statistics

3.1 Data Sources

We use several datasets in our analysis. The central focus of our paper is to examine whether exposure to persistent low interest rates led banks to close brick and mortar branches. In order to test this hypothesis, we obtained data on bank branches and branch-level deposits from the FDIC Summary of Deposit (SOD). The FDIC collects these pieces of information from all FDIC-insured institutions as of June 30 each year. Our main analysis on branch closures uses data from 2010 to 2022. We begin in 2010 as this was the year with the highest number of bank branches according to SOD before the low-interest rate environment triggered branch closures.

We obtain quarterly bank balance sheet and income statement data from Consolidated Reports of Condition and Income (also known as Call Reports) from 2003 to 2022. This dataset is hosted by the Federal Financial Institutions Examination Council (FFIEC) Central Data Repository's Public Data Distribution. This dataset covers every national bank, state member bank, insured state non-member bank, and savings association in the U.S. We use this data to calculate bank weights and yields for various liability categories. The cumulative yields are calculated over 2010-2022 while bank-specific weights for each liability category are calculated as of 2003.

[23] According to SouthBank, a service provider for community banks, direct operating costs of servicing deposits online is about 33 percent lower than through brick-and-mortar branches. See https://southstatecorrespondent.com/banker-to-banker/deposits/deposit-profitability-the-operating-cost-of-your-deposits

We obtain branch-level deposit pricing and decision-making data from Ratewatch. Ratewatch collects deposit and loan product interest rates at the bank branch level. Ratewatch structures its dataset by rate-setting branches and rate-following branches. Weekly deposit rates for different deposit products are quoted by the rate setting branches. A separate linking file contains the list of rate-following branches that follow each rate-setting branch. We use this dataset to construct bank and bank-county level measures of delegated decision making.

We obtain fixed broadband deployment data from Federal Communications Commission (FCC) Form 477. All fixed broadband providers are required to file data with the FCC twice a year on where they offer internet access service at speeds exceeding 200 kbps in at least one direction. The dataset provides advertised downstream speed/bandwidth at the census tract level. We drop information on broadband speed available to businesses and focus on broadband speed available to household consumers. Each year, all bank branches in a given census tract are assigned the advertised downstream speed for that census tract. We then construct bank-county level exposure to broadband penetration in a given year as branch deposit weighted average broadband speed at the branch level for all bank branches within a county.

We use the FDIC Household Survey data on unbanked and underbanked to calculate changes in unbanked rate over our analysis period. The survey was conducted biennially by the FDIC in partnership with the U.S. Census Bureau from 2009 to 2021.

We use bank branch information from S&P Global Market Intelligence SNL US Bank Branch Data Set to construct measures of banking desert at the census tract level. We closely follow the methodology of Barca and Hou (2024) to construct this measure. In particular, we include all brick-and-mortar, non-in-store, full service, and retail branches. We include branches from all types of banks and credit unions. Although there is no standard definition, banking deserts are a common metric used to measure branch access. We define a banking desert based on the methodology for "areas with very low branch access" introduced in the CRA NPR, such that a banking desert is a census tract that has no bank branch within a defined radius from the population center of the tract (two miles in urban areas, five miles in suburban areas, and 10 miles in rural areas).[24] The different distance thresholds account for variation in spatial density across these different types of geographies. We follow this methodology to construct a measure of banking

[24] See Interagency Notice of Proposed Rulemaking to Implement the CRA for details at: https://www.federalreserve.gov/consumerscommunities/files/cra-npr-fr-notice-20220505.pdf

desert at the census tract level in 2010 and in 2022. In order to relate county level deposit exposure to county level bank desertification, we calculate the share of census tracts within a county classified as banking desert. We then calculate the change in this county-level desertification measure from 2010 to 2022 to examine the effect of deposit exposure to low interest rate on bank desertification.

Lastly, we obtain information on the daily Effective Federal Funds Rates (series DFF) from the Federal Reserve Economic Data (FRED). County-level demographics information comes from the Bureau of Economic Analysis (BEA) and the Census Bureau.

3.2 Summary Statistics

Table 1 provides summary statistics for the banks in our sample. Panel A provides bank level summary statistics and Panel B provide county level summary statistics. Our sample consists of a balanced panel of 3717 banks from 2003 through 2022. Our county level analysis is based on branches operating in 3032 counties at the start of the exposure period (about 97 percent of the counties in the U.S). The average size of the banks in our sample (in 2010) is $2.3 billion, and the average number of branches was 18.

As shown, the bank level average cumulative hazard is 11.2 percent over the exposure period (2010-2022). However as shown, the median hazard rate is zero, indicating the majority of the banks in our sample did not shrink their branch network. However, given the growth in deposits most banks experienced a decline in branch density with the mean and median branch density declining by -12.76 and -10.35 respectively.

As discussed later, centralized banks, defined as banks with a decentralization score below the median, closed more branches than decentralized banks. In particular, the average cumulative hazard for centralized banks is 14.8 while the average hazard for decentralized banks is only 7.7 percent. Given the decline in interest rates during most of the sample period, not surprisingly, the mean and median of *Deposit exposure* are negative.

At the county level both the mean and median cumulative hazard are about 16 percent consistent with most counties experiencing some branch closures during the sample period. Even though most counties experienced branch closures, the share of census tracts designated as banking desert within a county increased by only about 1 percent during the exposure period.

IV. Determinants of Branch Closures

4.1 The low-interest rate channel

As discussed in Section II, we hypothesize that high deposit exposure banks are more likely to close branches when interest rates are low because, given their reliance on low pass-through deposits, their deposit spreads (i.e., gross profits from deposits) fall relatively more when rates fall than banks that rely more heavily on high deposit beta funding. In other words, the assumed mechanism leading to higher cumulative hazard rates for high exposure banks is a negative relationship between deposit exposure and changes in the interest cost of deposits.

A preliminary look at the relationship between *Deposit exposure* and subsequent interest spreads during the exposure period suggests *Deposit exposure* predicts lower spreads. To illustrate this relationship, in Figure 5 we compare average deposit spreads by deposit exposure quartile from 2003-2009 (when the average FFR was about 3 percent) to averages during the exposure period (when the average FFR was .63 percent).

As shown, in Figure 5 the average deposit spread declined substantially more between 2003-2009 and 2010-2022 for high exposure banks than low exposure banks. For banks in the lowest exposure quartile, the average deposit spread declined by only about 10 basis points (bps) versus almost 70 bps for banks in the highest exposure quartile. Recall that deposit spread is defined as the difference between the quarterly average effective FFR and the interest cost of deposits, so that the larger decrease in the average deposit spread for the most exposure banks indicates a greater hit to the earnings on deposits (this is also evident from Equation (2), where change in earnings equals change in deposit spread, holding non-interest cost of deposits fixed).

High exposure banks were unable to offset declines in deposit spreads with increased interest earnings on assets. As shown in Figure 6 lower interest rates are associated with substantially lower net interest margins, and the decline in margins was greater for high deposit exposure banks. For example, for banks in the highest (lowest) exposure quartile, the average net interest margin declined 50 (10) bps between 2003-2009 and 2010-2022.

We empirically confirm the relationship between changes in interest earnings and *Deposit exposure* during our exposure period, which was characterized by an overall decline in interest rates. Specifically, we estimate the relationship between changes in deposit spreads between 2003-2009 and 2010-2022 and *Deposit exposure*. We also estimate the relationship between changes in its NIM and *Deposit exposure*. Estimates of these relationships are reported in Table 2. Consistent with more exposed banks suffering greater declines in earnings, we find a negative and significant relation between changes in average deposit spreads and *Deposit exposure*. We find a similar negative relationship between changes in net interest margins and *Deposit exposure*. The economic magnitude of the changes is large, with a one standard deviation change in exposure associated with a 59 (50) percent change in average deposit spread (net interest margin). Overall, the results in Table 2 indicate more exposed banks' interest earnings declined more when interest rates fell after the GFC.

4.2 The deposit rate- technology trade-off

Branch closures involve a trade-off. Closing branches and transitioning depositors to online platforms, as we discuss later, potentially reduces operating costs but exposes banks to increased competition by reducing location-based rents. In addition, when rates are low, the difference between the rates paid on internet deposits and branch deposits is less. As a result, if interest rates are expected to remain low, banks close branches and transition depositors to online banking. A bank level measure of reliance on brick-and-mortar branches for deposits used in the literature is branch density, defined as the number of branches per $1 billion in deposits.[25]

A comparison of deposit yields and non-interest expense yields at high and low branch density banks illustrates the trade-offs we have in mind. In Table 3 we split the banks in our sample into two groups based on whether they are above or below the sample average branch density over the 2003-2022-time period. Next, we compare deposit yields and noninterest expense for high and low branch density banks in high and low-interest rate periods (defined as whether the average effective FFR is above or below the sample average value of FFR). Deposit yields are simply the interest expense on deposits divided by the average deposit balance and noninterest expense yields are noninterest expenses divided by average deposit balances [26]

As shown, deposit interest costs are on average higher for low density than high branch density banks but non-interest costs per dollar of deposits are lower. More important, the difference between deposit rates at low- and high-density banks varies with interest rates while the difference in operating costs do not, suggesting that the trade-off associated with online and branch banking

[25] Benmelech, Yang, and Zator (2023) use changes in branch density to measure the extent to which banks transition depositors from branch on online banking.
[26] Non-interest yields include non-interest expense not related to the operation of branches and thus may lead to an understatement of the differences in noninterest expenses between high and low branch density banks.

varies with the level of interest rates and that persistent low interest rates would accelerate the transition from branch banking to online banking.

4.3 Deposit exposure, technology, and branch closures: Bank level regressions

If low interest rates are causally linked to branch closures and reductions in branch density, we expect a positive and significant relation between cumulative branch closure rates during 2010-2022 and *Deposit exposure*. Consistent with this prediction, as shown in Figure 7, the average cumulative hazard for the highest quartile banks is over 50 percent greater than the cumulative hazard for banks in the lowest exposure quartile.

We formally test the relationship between branch closure rates and *Deposit exposure* by regressing, at the bank level, cumulative hazard rates (2010 to 2022) on *Deposit exposure* including controls for bank characteristics at the start of the exposure period.[27] Consistent with more exposed banks closing more of their branches, as shown in column 1 of Table 4, the coefficient estimate on *Deposit exposure* is positive and statistically significant at the .01 level. The economic effect of exposure is also large. The coefficient estimate indicates a one standard deviation increase in exposure is associated with an 0.8 percentage point increase in the cumulative branch closure hazard or about a 7.2 percent increase relative to the mean.[28]

An alternative measure of changes in branch network infrastructure is changes in branch density. Inasmuch as changes in branch density indicate reduction in the number of branches per $ billion in deposits, declines in branch density will reflect both the effect of branch closures as well as a possible increase in deposit volume. As shown in Column 2 of Table 4 we find a negative and significant relationship between changes in branch density and *Deposit exposure*. The negative relationship suggests that banks with greater *Deposit exposure* experienced larger decline in branch density. The fact that branch closures for high *Deposit exposure* banks are accompanied by increases in branch density suggests these banks did not lose significant deposits by closing

[27] Our findings are similar when we examine cumulative net hazard rates (i.e., reduction in number of branches scaled by total number of branches at the beginning of year). We report those results in Internet Appendix Table A.1. A concern with using net hazard rates to investigate the impact of low interest rates on branch closures is that bank-level net hazard rates could be driven by mergers and acquisitions rather than branch closures.
[28] Note that the exposure measure is calculated for banks that existed over the entire 2003-2022 time period. Hence, our measure is calculated for banks that survived the persistent low-interest rate regime and the disruptive technology adoption. Consequently, our reported economic magnitudes may under-estimate the effect of low interest rates and technology on branch closures.

branches—a point we revisit when examining the interplay between low interest rates and technology-enabled branch closures. Overall, the positive relationship between branch closure rates and *Deposit exposure* and the negative relationship between changes in branch density and *Deposit exposure* are consistent with a causal link between changes in bank branch infrastructure and declines in interest rates.

As discussed earlier, technological change is likely an important determinant of branch closures. Indeed, we argue that low interest rates accelerated the adoption of digital banking. This, however, raises the concern that *Deposit exposure* may simply reflect variations across banks in exposure to changes in technology. We address this concern in couple of ways. First, we examine the relationship between bank level variations in *Broadband penetration* and *Deposit exposure*. In Figure 3 we plot the average *Broadband penetration* for banks belonging to each *Deposit exposure* quartile. Recall that we construct the *Broadband penetration* by multiplying the census tract evolution in internet speeds from 2014-2022 with the share of each bank's total deposits in each census tracts-based branch locations in 2003. Thus, *Broadband penetration* measures, based on the location of deposit customers, bank level differences in exposure to technological change based on internet access. As shown in Figure 3, we find little variation in the average *Deposit exposure* across *Broadband penetration* quartiles suggesting that *Deposit exposure* does not simply reflect differences among banks in their exposure to technological change.

Our second test involves including in the hazard and branch density regressions *Broadband penetration* as a control variable. As shown in columns 3 and 4 of Table 4, controlling for differences in broadband penetration, we continue to find a positive and significant relation between cumulative hazard rates and *Deposit exposure* as well as a negative and significant relationship between changes in branch density and *Deposit exposure*. Moreover, the coefficient estimates for *Deposit exposure* are similar in magnitude and significance as those reported in columns 1 and 2, suggesting *Broadband penetration* absorbs little of the variations in hazard rates or branch density explained by variations in *Deposit exposure*.

As shown in columns 3 and 4 of Table 4 we find a positive and significant relation between cumulative hazard rates (but not changes in deposit density) and *Broadband penetration.* One potential explanation for the positive and significant relation between hazard rates and broadband penetration but no statistically significant relationship between branch density and *Broadband penetration* is differences in deposit growth between low and high *Broadband penetration* banks.

We find deposit growth is greater for low than high *Broadband penetration* banks (the mean annual growth in deposits in the first *Broadband penetration* quartile was just over 4.2 percent versus 3.3 percent for the highest broadband penetration quartile). While our technology change measure is similar to ones used in the literature, bank level changes in technology are based on a deposit weighted measure of county level average broadband speeds.[29] Local innovations in broadband speeds in turn may be related to country level economic and demographic characteristics that may be correlated with deposit growth. To control for these factors, in the next section, we analyze county level branch closures.

4.4 Deposit exposure, technology, and branch closures: County level regressions

Branch closures are likely to vary with deposit market size, local economic and demographic factors as well as internet access. For example, Fuster, Plosser, Schnabl, and Vickery (2019) find technology adoption (measured by propensity to borrow from FinTech lenders) is greater in census tracts with populations that are younger and more highly educated. They also find FinTech lending is greater in higher income and more densely populated census tracts. Another example is research by Saka et al. (2022) who find that bank customers with better ex-ante internet coverage are more likely to shift to online banking in response to epidemic induced reductions in the demand for in-person banking services.

To control for county level differences in the access and receptiveness of bank customers to new technologies as well as other county level factors that might affect bank branch closure rate, we analyze county level net hazard rates.[30] For this analysis we measure county level deposit exposure and broadband penetration by weighing, for each bank operating in a county, the banks' *Deposit exposure* and *Broadband penetration* measure by the bank's share of county deposits in 2010. Our sample consist of 3032 counties. We include county level controls for population density, share of college graduates, median income, and median age at the start of the exposure period.

[29] See for example, Saka, Einchengreen, and Aksoy (2022), Sarto and Wang (2023) and Jiang et al. (2022)

[30] Changes in branch density at the county level is difficult to measure. The difficulty stems from the fact that while we can identify branch closures at the county level, we don't have information on where the deposits at the closed branch go. In particular, we don't know the proportion of deposits that are retained by the bank closing a branch, and, if retained, how the deposits are accounted for in SOD data. For these reasons, our county level analysis focuses on net hazard rates and not changes in branch density.

Estimates of county level branch hazard regressions are presented in Table 5. We use net hazard rates in these regressions and report results using branch closure rates in the Internet Appendix Table A.2.[31] Similar to our bank level findings, we find a positive and significant relation between hazard rates and both *Deposit exposure* and *Broadband penetration.* The economic magnitude of the effect of *Deposit exposure* on county hazard rates is similar to the impact of *Deposit exposure* at the bank level. For example, the coefficient estimate reported in column (2) suggests that a one standard deviation increase in *Deposit exposure* is associated with an increase in the hazard rate of about 5 percentage points or roughly a 30 percent increase relative to the mean.

Did low interest rates accelerate technology driven branch closures? The decision to invest in and deploy technology-based delivery systems depends in part on the receptiveness of bank customers to technology and the cost of the new technology. As discussed in section 2, a potential additional cost of substituting technology for brick-and-mortar branches is the need to pay higher rates on deposits due to a reduction in location-based market power. Several recent studies find that online banks and banks with low density branch networks pay higher rates on deposits than banks that rely more heavily on branch networks.[32] As a result, reducing reliance on branches involves a potential trade-off; higher deposit rates for lower operating costs. We show later that this trade-off varies with the level of interest rates so that when rates are low, the incremental cost of reducing branch density in terms of higher deposit rates is also low. Thus, low interest rates are likely to accelerate the adoption of digital banking.

We test whether technological change and low interest rates complement one another by interacting *Deposit exposure* with *Broadband penetration.* If technology and low interest rates are complements to one another in their impact on branch closures, we expect low interest rates to have the greatest impact on bank hazard rates in counties where banks with greater broadband penetration have larger deposit market shares. As shown in column 3 that is exactly what we find. The coefficient estimate on *Deposit exposure* * *Broadband penetration* variable is positive and statistically significant, indicating closure hazard rates are significantly higher in counties where a

[31] Net hazard rates are better suited to evaluate the real consequences of *Deposit exposure* on banks and their customers. In addition, mergers and acquisitions do not contaminate measures of county-level changes in branches as they do for bank level net hazards.
[32] See for example Benmelech et al. (2023) and Erel et al. (2024). In addition, Emin et al. (2024) find that the sensitivity of pass-through rates to changes in interest rates varies inversely with branch density, indicating that low branch density banks gain less in terms of spread income when rates increase.

greater share of deposits is held by more exposed banks and banks whose customers have better access to broadband internet.

4.5 Decentralized banking and branch closures.

Banks do more in their branches than simply service depositors. For example, branches are an important conduit for SME lending and branches are where relationship based small business lending decisions are often made.[33] Branches also serve as an important platform for making consumer and mortgage loans as well as providing advisory and other services to bank customers. In addition, there is likely to be significant heterogeneity among and within banks in terms of whether decision rights over pricing, services offered and how activities are performed are delegated to local branches. If low interest rates cause branch closures through reducing the value of the bank's branch-based deposit franchise, we expect branch hazard rates to vary inversely with the breadth of activities offered through branches.

Unfortunately, to the best of our knowledge, other than deposit volume, there is no branch level reporting of other services provided. Given the lack of data, we use bank branch managers' ability to set deposit and loan rates as proxy for the breadth of banking services provided at the branch. Note that differences in local rate setting authority may also reflect variation in customer preferences for interpersonal interaction as well as local variations in the importance of relationship banking. Thus, decentralization may serve as a proxy for customer demand for other banking services. For these reasons we expect the likelihood of branch closures to be lower in counties with at least one rate setting branch and lower for more decentralized banks (i.e., banks with a higher proportion of rate setting branches).

We begin by investigating whether bank level cumulative hazard rates vary by the degree decentralized. For this analysis we divide the banks in our sample into two groups based on their decentralization scores in 2003 and define decentralized and centralized banks as banks with decentralization scores below and above the sample median. In Figure 8 we compare branch hazard rates of decentralized banks to centralized banks from 2003-2022. As shown, beginning in 2010, annual branch closure rates are consistently higher for centralized than for decentralized banks.

---

[33] As discussed earlier, most academic studies of the importance of distance in small business lending, use the location of the closest branch to measure the distance between the bank and its borrowers.

To examine whether branch closures vary with the degree of decentralized decision making we conduct two tests. First, we examine whether the propensity to close branches is lower in counties with rate setting branches controlling for bank and county level factors. Specifically, we estimate at the branch-year level, a linear probability model relating the likelihood of closure to whether the branch is located in a county where the bank also has a rate setting branch. The regression also includes bank-year and county-year fixed effects, essentially controlling for all time-varying bank and county level factors. As shown, in column 1 of Table 6 we find the likelihood of branch closure is significantly lower for branches located in counties with a rate setting branch.

The second test involves examining the relationship between bank-county closure hazards and bank-level decentralization scores. In this regression we include county-year fixed effects to control for local economic and demographic factors that may affect branch closures as well as bank level controls. This approach allows us to compare branch closures across banks within the same county and year. As shown in column 2, we find a negative and significant relation between bank county hazard rates and *Decentralization*, indicating branch closure hazards are lower at decentralized banks.

Does the effect of low interest rates on branch closures vary by decentralization? As discussed earlier, we suspect this might be the case if decentralized banks provide a greater array of services at each of their branches. To investigate this issue, we interact *Deposit exposure* with *Decentralization* and then include the interaction variable in our regressions. We also interact *Broadband penetration* with *Decentralization* to investigate whether impact of technology on branch closures varies with the degree of decentralization. The results of these analyses are presented in Table 7.

As shown, consistent with the findings reported in Table 4 we find a positive and significant relation between cumulative hazard rates and both *Deposit exposure* and *Broadband penetration*. Interestingly, the impact of both low interest rates and technology are decreasing in the degree of decentralization. Given the sample difference between the 25^{th} and the 75^{th} percentile of decentralization score is about .62, the coefficient estimate on the *Deposit exposure* interaction term indicates the economic impact of low interest rates on branch hazard rates is about eighty four percent lower for banks in the 75^{th} percentile of decentralization score relative to banks in the 25^{th} percentile. The effect of low interest rates on branch density is also significantly lower for more decentralized banks. Overall, these findings suggest the impact of low interest rates on bank branch infrastructure varies with the breadth of activities conducted through brick-and-mortar branches.

V. Branch Closures, Fragility and Access to Banking Services

Why should we worry about de-branching? Don't branch closures simply reflect the substitution of a more cost efficient and convenient digital channel for branch banking? In addition, substituting online platforms for brick-and-mortar branches may reduce deposit market entry barriers, leading to an increase in competition.

Branch closures, however, raise two potential concerns. First, deposits acquired through brick-and-mortar branches tend to be less sensitive to interest rate changes than online deposits and thus represent a more stable source of bank funding (albeit at the cost of greater location-based rents). The transition to online banking, hastened by low interest rates, therefore exposes banks to higher deposit costs and lower deposit growth during periods of tightening monetary policy. A second concern is that closures may reduce access to banking services, particularly among low income and older customers with limited access to alternative banking platforms. We investigate the impact of low interest rates on bank fragility and access to banking services in the next two subsections.

5.1 Did Deposit exposure increase bank fragility?

As discussed earlier, the expectation of persistently low interest rates may lead banks to close branches as they trade lower non-interest operating costs for potentially higher deposit costs. While the trade-off is an attractive one when rates are low, greater reliance on online deposits exposes banks to significantly higher deposit costs if rates increase.

The sharp increase in interest rates in 2022-2023 represents an opportunity to test whether low interest rate induced branch closures lead to greater volatility in deposit costs in a rising rate environment. For this test we calculate the percentage change in deposit interest costs and the percentage change in deposit volume from Q4 of 2021 to Q3 of 2023 when FFRs increase from around 25 basis points to 525 basis points. We then estimate the relationship between changes in deposit costs, deposit volume and *Deposit exposure*. Since the mechanism leading to higher deposit costs is an increase in the reliance of high exposure banks on digital platforms, we also instrument for changes in branch density using *Deposit exposure* and use the predicted change in deposit density associated with *Deposit exposure* in a second stage regression relating changes in deposit costs and volume to predicted changes in branch density.

Table 8 presents OLS and IV regression results relating changes in deposit costs and fundings to *Deposit exposure* and predicted changes in branch density. The coefficient on *Deposit exposure* in column (1) indicates a positive and significant relation between the percentage change in deposit costs and deposit exposure. A one standard deviation increase in *Deposit exposure* is associated with a percentage increase in deposit costs of 57 percent. In contrast, we find a negative relation between changes in deposit volume and *Deposit exposure*. A one standard deviation increase in *Deposit exposure* reduces deposit growth by 12.6 percent. Overall, these findings indicate that high exposure banks experienced a greater increase in deposit costs and smaller changes in deposit volume during the rapid increase in interest rates in 2022-2023.

In Section 4 we showed that high exposure banks reduced their reliance on brick-and-mortar branches more during 2010-2022 time-period. We conjecture that this reduction led banks to substitute more volatile online deposits for stickier branch sourced deposits, thereby exposing high exposure banks to subsequent increases in interest rates. To test this conjecture, we adopt a two-stage regression framework where in the first stage we extract the variation in change in branch density explained by variation in deposit exposure. In the second stage, we use this predicted change in branch density to explain changes in deposit costs and funding. We have already reported the first stage result in column (2) of Table 4. Consistent with this conjecture, as shown in the second-stage regression results in column (3) of Table 8, we find a negative and significant (at the .01 level) relationship between changes in deposit costs and predicted changes in branch density. Moreover, consistent with low interest rates reducing branch density and causing smaller deposit growth when rates rise, we find a positive and significant relation between deposit growth and instrumented branch density.

The results in Table 8 are consistent with persistent low rates leading banks to close branches and shift deposits to online platforms leading to a reduction in branch density and greater bank fragility. An alternative potential mechanism is that greater earning declines at high *Deposit exposure* banks lead these banks to reduce their deposit growth more than low exposure banks and slower deposit (and asset growth) was the reason for branch closures. This does not appear to be the case. As shown in Figure 9, between 2010 and 2022 deposits (and asset) grew faster at high exposure banks that low exposure banks.

5.2 Low interest rates and access to banking services

We conjecture that branch closures caused by low interest rates affect access to banking services differently than technology driven closures. This conjecture is based on the idea that technology driven branch closures are more likely to be associated with increased competition through the entry of on-line banks, shadow banks and broader geographical reach of traditional banks than branch closures caused by low interest rates. In other word, we suspect that branch closures caused by low interest are likely to reflect banks exiting from local deposit and loan markets and are less likely to reflect the migration of customers to online platforms.[34]

We investigate the impact of branch closures on access to banking services using two commonly used access measures. The first measure is county level changes in the proportion of FDIC survey respondents that report being unbanked over our sample period. The FDIC defines a household as unbanked if no one in the household had a checking or a savings account with a bank or credit union.[35] We conjecture that closures caused by low interest rates are more likely to result in an increase in the proportion of unbanked households than closures associated with broadband innovations.

Our second measure of banking access is based on the CRA/NPR definition of banking deserts and potential banking deserts. In particular, the Federal Reserve Board and OCC define banking deserts as a census tract with no bank, savings and loan or credit union branch within a defined radius from the population center of the tract.[36] Similarly, a potential banking desert is a

[34] JD Powers conducts an annual "The Financial Brand" survey of retail customer satisfaction with banking services, channel usage (website, mobile app, phone, and branch) and reason customers use different channels. See https://thefinancialbrand.com/news/customer-experience-banking/slips-in-customer-service-can-prove-extra-costly-now-j-d-power-survey-shows-161972/

[35] The FDIC also reports the proportion of households that are underbanked. A household is considered underbanked if "… it had a checking or savings account at a bank or credit union but in the past 12 months had used at least one of eight nonbank financial services (NBFSs). These NBFSs include three transaction services (nonbank money orders, check cashing, and international remittances) and five alternatives to mainstream credit (rent-to-own services and payday, pawn shop, auto title, and tax refund anticipation loans). Such NBFSs historically have been used disproportionately by unbanked households to meet their transaction or credit needs" See FDIC 2023 Survey of Unbanked and Underbanked.

[36] Bank deserts are defined based on a methodology for identifying areas of low financial services access introduced in the CRA, Notice of Proposed Rule Making (NPR). As of 2022, banking deserts are defined as urban, suburban, and

census tract that will become a banking desert if one bank, savings and loan or credit union branch closes within the same defined radius from the population center of the tract. We measure changes in banking deserts and potential banking deserts as the change in the share of bank desert census tracts and potential bank desert census tracts, respectively, in the county between 2010 and 2022.

One potential criticism of using a geographic based access measure is that channel usage has shifted over time from branches to online and mobile apps and thus the importance of geographic proximity has declined over time. This seems likely since as shown in Figure 10, the proportion of bank customers that use branches as their primary source of banking services has declined over the last decade. Nevertheless, older, less educated, and lower income households are likely to be more reliant on branch access. Moreover, according to the 2016 Survey of Consumer Finances (SCF), 84 percent of household reported visiting a branch of the bank where they held their checking or savings account, suggests that online banking is an imperfect substitute for bank branches.[37]

The FDIC Survey of Unbanked and Underbanked Households is based on a survey of Core-based statistical areas, which we map to 681 counties. We examine the relationship between changes in the proportion of unbanked households and branch closures by estimating linear probability model in which the dependent variable equals 1 if the proportion of unbanked households increased between 2009-2021 and the independent variables are *Deposit exposure*, *Broadband penetration* and a set of bank level controls.[38] As in the county level analysis of bank hazard rates, independent variables are constructed by weighing bank level measures by a bank's share of county level deposits in 2010.

An estimate of the linear probability model relating increases in unbanked to *Deposit exposure* is reported in column 1 of Table 9. Consistent with our conjecture that low interest rate induced closures adversely affect access, we find a positive and statistically significant relation between the likelihood of an increase in the proportion of unbanked households and *Deposit exposure*. The coefficient estimate for *Deposit exposure* indicates that a one standard deviation increase in county-level deposit exposure is associated with about a 30 percent higher likelihood of an increase in unbanked households relative to the mean.

rural census tracts without a bank branch within two, five and 10 miles of the population center of the tract. See Barca and Hou (2024),

[37] See Anenberg, Chang, Grundi, Moore, and Windle (2018).

[38] Change in unbanked is measured between 2009-2021 because the FDIC survey is Biennial and was started in 2009.

In contrast to the impact of *Deposit exposure*, we find a negative and significant coefficient on *Broadband penetration,* suggesting that branch closures associated with technological change led to a *reduction* in unbanked households. This finding is consistent with the argument that technology enables broader access to banking services, as reflected in the increase in use of online and mobile banking services.

In column (2) we present estimates of relationship between changes in the county level share of banking deserts and *Deposit exposure, Broadband penetration,* and bank level controls. Similar to our findings concerning changes in unbanked households, we find a positive relation between changes in banking deserts and *Deposit exposure.* The impact of *Deposit exposure* is substantial with a one standard deviation increase in deposit exposure associated with an increase in the county level share of banking deserts by 29.8%. In contrast, we find no significant relation between changes in banking deserts and *Broadband penetration.* Column 3 presents estimates of relationship between changes in the county level share of potential banking deserts and *Deposit exposure, Broadband penetration,* and bank level controls. We again find a positive and statistically significant relationship between changes in potential banking deserts and *Deposit exposure*, and no relationship between changes in potential banking deserts and *Broadband penetration.* A one standard deviation increase in *Deposit exposure* increases the change in the county level share of potential banking deserts by 16.4%. Overall, these findings indicate that the effect of branch closures on access to banking services is different for closures caused by low interest rates than closures associated with technological advances.

VI. Summary and Conclusion

The decline in the importance of "physical" banking has been attributed primarily to technological advancements and evolving customer preferences for internet banking. However, online banking has been around since at least the early 1990's and mobile banking was introduced in early 2007. Given this timing, why did the decline in bank branches start in 2010, and why as discussed earlier did a number of banks begin expanding their branch networks in 2022?

In this paper we provide new evidence linking branch closures to low interest rates. We argue that the substitution of online and mobile banking for branches involves a trade-off. On the one hand, operating costs associated with digital banking are significantly lower per dollar of deposits than brick and mortar branches. On the other hand, digital banking lowers switching costs which reduces location-based bank market power, leading to higher deposit pass through rates. Consistent with this argument, online banks pay higher rates on deposits and among traditional banks deposit rates are negatively related to branch density. Moreover, deposits rates are more sensitive to changes in market rates for banks with less dense branch networks. Low interest rates change the digital-branch trade-off by lowering the cost of transitioning depositors to online banking. This is because when rates are low the difference in deposit rates between high and low pass-through accounts is also low, leading banks to close branches.

We test whether low interest rates are a cause of branch closures by exploiting ex-ante heterogeneity in bank exposure to declines in interest rates. We use differences in pass through rates to construct a share shift instrument to identify the effect of low interest rates. Consistent with a causal link between branch closures and low interest rates, we find a positive and significant relationship between branch closure rates and bank ex-ante exposure to low interest rates. We also find a positive and significant relation between increases in county level proportions of unbanked households and the proportion of counties with banking deserts and county level bank exposure to low interest rates.

While all bank customers may eventually adopt some form of digital banking, our evidence suggest that the persistent low interest rates accelerated the transition period. Our findings together with surveys indicating bank customers continue to value access to physical branches (particularly for financial advice) suggests that higher interest rates may halt the steep decline in branch banking and potentially improve access to banking services.[39]

[39] In announcing expansion of its brick-and-mortar branches (referred to as financial centers) a Bank of America spokesman explained *"We are reaching more and more clients through the expansion and modernization of our financial centers.…While most clients are using our digital capabilities for their everyday banking, they are visiting our centers for in-person conversations about their more complex financial needs and advice on their life priorities and financial goals."* *See https://newsroom.bankofamerica.com/content/newsroom/press-releases/2024/09/bofa-to-open-more-than-165-financial-centers-by-end-of-2026.html?utm*

Variable Definitions

***Average IT spending*:** mean bank-level IT spending scaled by assets over the 2014-2022-time period. Information on IT spending is reported in Call Reports only if it is among the top three items within non-interest expenses. We obtain this data from Yannick Timmer's website: https://sites.google.com/site/timmeryannick/research

***Branch density*:** # of branches per billion dollars of deposit at the bank level.

***Broadband penetration*:** measures access to broadband internet for bank's deposit customers. For each bank b:

$$broadband\ penetration_{bt} = \sum_j \omega^j_{bt'_0} * \int_{t_0}^{t} census\ tract\ broadband^j_s\, ds$$

where $\omega^j_{bt'_0}$ is bank b's branch deposit in census tract j in base year t'_0 divided by total bank branch deposits across all branches of the bank in base year t'_0, and $census\ tract\ broadband^j_s$ is broadband speed in census tract j in year t. We obtain census tract level broadband speed data from FCC Form 477. This data is available for the 2014-2021 period. The base year for determining the census tract level deposit weights, $\omega^j_{bt_0}$, is chosen to be 2003.

***Decentralization score*:** a bank's decentralization score equals #counties with at least one rate setting branch divided by total #counties with bank branches.

Deposit spread: effective federal fund rate minus the deposit yield.

Deposit yield: interest expense on all deposits in year *t* divided by the average of total deposits (i.e., domestic and foreign deposits) in *t*-1 and *t*.

***Hazard rate*:** a bank's hazard rate equals total number of branches closed in a year scaled by the total number of branches in existence at the beginning of the year.

***Deposit exposure*:** calculated following Sarto and Wang (2023). Deposit exposure to interest rate measures a bank's exposure to changes in effective federal fund rates and the resulting changes in yields on various liabilities. For each bank b:

$$deposit\ exposure_{bt} = \sum_{i \in I_D} \omega^i_{bt'_0} * \int_{t_0}^{t} (r^i_s - r^i_{t_0})ds$$

where $\omega^i_{bt'_0}$ is bank b's balance sheet weight of liability category i calculated at base year t'_0, and r^i_t is the national average of category i's yield at time t. For instance, for time deposits, r^i_t corresponds to the deposit yield on timed deposits over time period *t*. Four liability categories are used: transaction deposits, saving deposits, time deposits, and other liabilities. The above expression will calculate the cumulative deposit exposure from t_0 to *t* for bank *b*. The base year for determining the fixed balance sheet weights, $\omega^i_{bt_0}$, is chosen to be 2003. The interest rate exposure is calculated over 2010-2022.

***Net interest margin (NIM)*:** interest income minus interest expense on all deposits in year *t* divided by the average of total assets in *t*-1 and *t*.

Non-interest expense yield: non-interest expense in year *t* divided by the average of total deposits (i.e., domestic and foreign deposits) in *t*-1 and *t*.

Rate setter branch: an indicator that takes the value of one if the branch sets deposit rates for one or more branches of the bank, and zero otherwise.

References

Adadi, J., M. Brunnermeier, and Y. Koby, 2023, The Reversal Interest Rate, American Economic Review 113 (8), 2084-2120.

Agarwal, S., and R. Hauswald, 2010, Distance and Private Information in Lending, Review of Financial Studies 23 (7), 2757-2788.

Amberg, N., and B. Becker, 2024, Banking Without Branches, Sveriges Riksbank Working Paper 430.

Anenberg, E., A. Chang, S. Grundi, K. Moore, and R. Windle, 2018, The Branch Puzzle: Why are there Still Bank Branches? FEDS Notes, Board of Governors of the Federal Reserve System.

Autor, D. H., Dorn, D., and Hanson, G. H., 2013, The China Syndrome: Local Labor Market Effects of Import Competition in the United States, American Economic Review 103(6), 2121-2168.

Barca, A., and H. Hou, 2024, U.S. Bank Branch Closures and Banking Deserts, Federal Reserve Bank of Philadelphia.

Begenau, J., and E. Stafford, 2023, Uniform Rate Setting and the Deposit Channel, Harvard Business School Working Paper.

Benmelech, E., J. Yang and M. Zator, 2023, Bank Branch Density and Bank Runs, NBER Working paper 31462.

Berger, A. N. Miller, M. Petersen, R. Rajan, and J. Stein, 2005, Does Function Follow Oranizational Form? Evidence from the Lending Practices of Large and Small Banks, Journal of Financial Economics 76, 237-260.

Berger, A., and G. Udell, 2002, Small Business Credit Availability and Relationship Lending: The Importance of Bank Organisational Structure, The Economic Journal 112, F32-F53.

Buchak, `G., G. Matvos, T. Piskorski, and A. Seru, 2018, Fintech, regulatory arbitrage, and the rise of shadow banks, Journal of Financial Economics 130 (3), 453-483.

Claessen, S., N. Coleman, and M. Donnelly, 2018, Low for Long Interest Rates and Bank Interest Margins and Profitability, Journal of Financial Intermediation 35, 1-16

d'Averanas, A. A. Eisfelt, C. Huang, R. Stanton, and N. Wallace, 2023 The Deposit Business at Large and Small Banks, NBER Working Paper 31865.

Di Maggio, M., and M. Kacperczyk, 2017, The Unintended Consequences of the Zero Lower Bound Policy, Journal of Financial Economics 123, 59-80.

Dlugosz, J., Y.K. Gam, R. Goplan, and J. Skrastins, 2024, Decision-making Delegation in Banks, Management Science 70 (5), 3281-3301.

Drechsler, I., A. Savov, and P. Schnabl, 2017, The Deposit Channel of Monetary Policy, Quarterly Journal of Economics 132, 189-1876.

Drechsler, I., A. Savov, and P. Schnabl, 2021, Banking on Deposits: Maturity Transformation Without Interest Rate Risk, Journal of Finance 76, 1091-1143.

Egan, M., S. Lewellen, and A. Sunderam, 2022, The Cross-Section of Bank Value, Review of Financial Studies 35, 2101-2143.

Emin M., C. James, and T. Li, 2024, Variable Betas and Bank Interest Rate Risk Exposure, Working Paper University of Florida

Erel, I., J. Liebersohn, C. Yannelis, and S. Earnest, 2024, Monetary Transmission Through Online Banks, Fisher School Working paper.

Fuster, A., M. Plosser, P. Schnabl, and J. Vickery, 2019, The Role of Technology in Mortgage Lending, Review of Financial Studies 32(5), 1854-1899.

Gilje, E. 2019, Does Local Access to Finance Matter? Evidence from U.S. Oil and Natural Gas Booms, Management Science 65(1), 1-18.

Gilje, E., E. Loutskina, and P. Strahan, 2016, Exporting Liquidity: Branch Banking and Financial Integration, Journal of Finance 71(3), 1159-1184.

Goldsmith-Pinkham, P., I. Sorkin, and H. Swift, 2020, Bartik Instruments: What, When, Why and How, American Economic Review 110(8), 2586-2624.

Gopal, M., and P. Schnabl, 2022, The Rise of Finance Companies and FinTech Lenders in Small Business Lending, Review of Financial Studies 35(11), 4859-4901.

Granja, J., C. Leuz, and R. Rajan, 2022, Going the Extra Mile: Distance Lending and Credit Cycles, Journal of Finance 77(2), 1259-1324.

Hannan, T.H., and A.N. Berger, 1991, The Rigidity of Prices: Evidence from the Banking Industry, American Economic Review 81(4), 938–945.

Haendler, C., 2022, Keeping up with the Digital Era: How Mobile Technology is Reshaping the Banking Sector, Working paper Boston College.

Jayarante, J., and P.E Strahan, 1997, The Benefits of Branching Deregulation, Economic Policy Review, 3.

Jiang, E. X., G. Y. Yu, and J. Zhang, 2022, Bank Competition Amid Digital Disruption: Implications for Financial Inclusion, Working Paper University of Southern California.

Kang-Lansberg, A., and M. Plosser, 2022, How do Deposit Rates Respond to Monetary Policy? Federal Reserve Bank of New York: Liberty Street Economics.

Kang-Lansberg, A., A. Luck, and M. Plosser, 2023, Deposit Betas: Up, Up and Away, Federal Reserve Bank of New York: Liberty Street Economics.

Keil, J., and S. Ongena, 2024, The Demise of Branch Banking- Technology, Consolidation, Bank Fragility. Journal of Banking and Finance 158.

Lopez, J.A., A. K. Rose, and M.M. Siegel, 2018, Why Have Negative Nominal Rates Had Such a Small Effect on Bank Performance? NBER Working Paper No. 25004.

Nguyen, H., 2019, Are Credit Markets Still Local? Evidence from Bank Branch Closings, American Economic Journal: Applied Economics 11(1), 1-32.

Petersen, M.A., and R.G Rajan, 1994, The Benefits of Lending Relationships: Evidence from Small Business Data, Journal of Finance 49, 3-37.

Petersen, M.A., and R.G Rajan 2002, Does Distance Still Matter? The Information Revolution in Small Business Lending, Journal of Finance 57, 2533-2570.

Saka, O., B. Einchengreen, and C.G. Aksoy 2022, Epidemic Exposure, Financial Technology, and the Digital Divide. Journal of Money Credit and Banking 54 (7), 1913-1940.

Sarto, A., and O. Wang, 2023, The Secular Decline in Interest Rates and the Rise of Shadow Banking, Working paper.

Stein, J., 2002, Information Production and Capital Allocation: Decentralized vs. Hierarchical Firms, Journal of Finance 57, 1891-1921.

Wang, Y., T.M. Whited, Y. Wu, and K. Xiao, 2022, Bank Market Power and Monetary Transmission: Evidence from a Structural Estimation, Journal of Finance 77, 2093-2141.

<u>Figures and Tables</u>

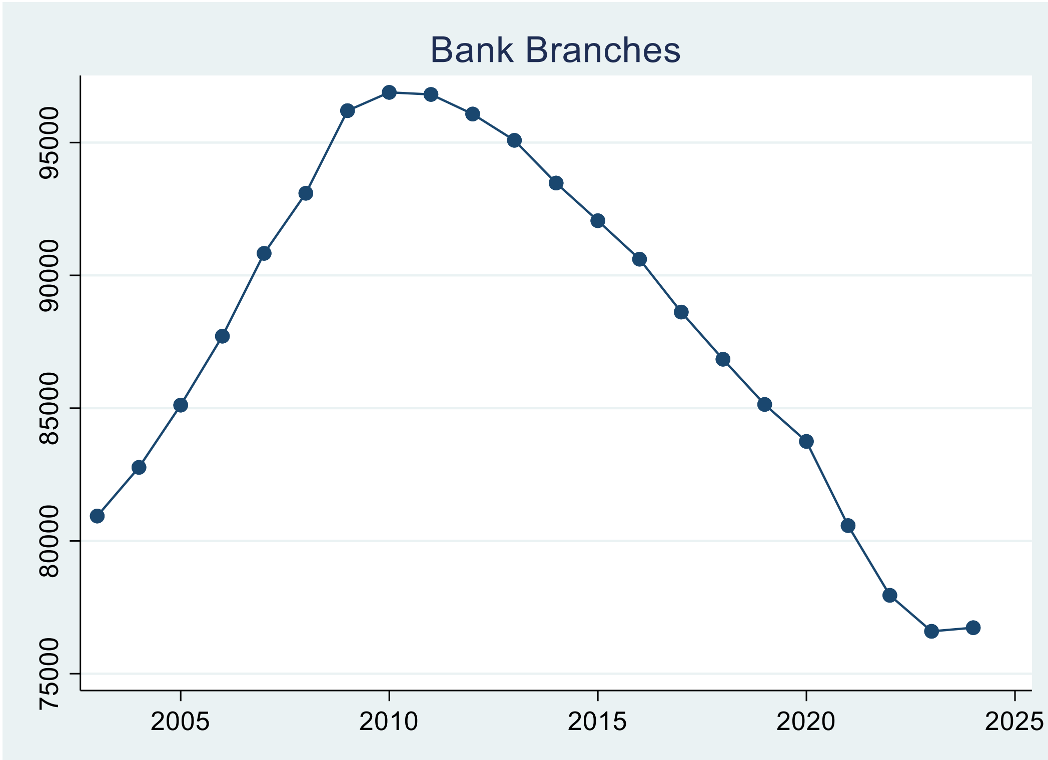

Figure 1: US Bank Branches 2003-2024

This figure plots the number of bank branches of all FDIC-insured institutions in the United States as of June 30th of each year.

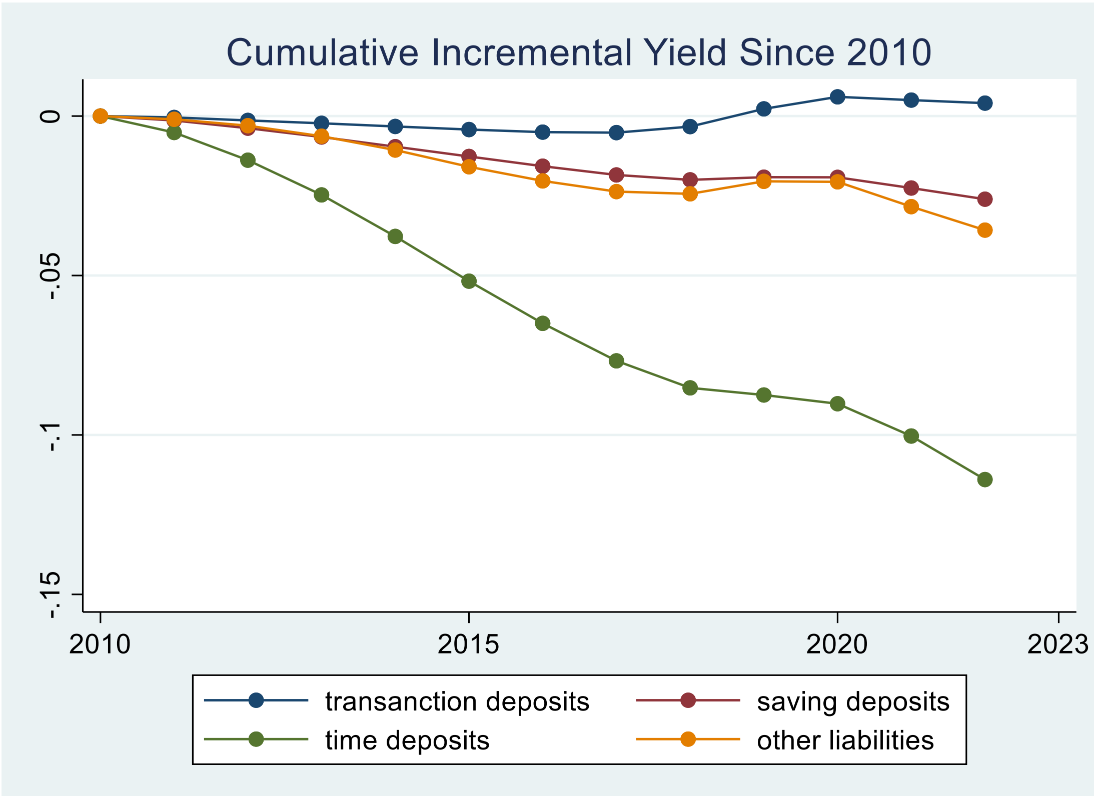

Figure 2: Cumulative Incremental Yields since 2010

This figure plots the cumulative incremental yield since 2010 for the aggregate banking sector for four bank liability categories – transaction deposits, saving deposits, time deposits, and other bank liabilities. For each liability category, aggregate banking sector yield in a year is calculated by aggregating interest expenses across banks for the liability category and dividing by aggregate balance sheet value of that liability category. Cumulative incremental yield since 2010 is calculated by summing up the incremental yields each year since 2010.

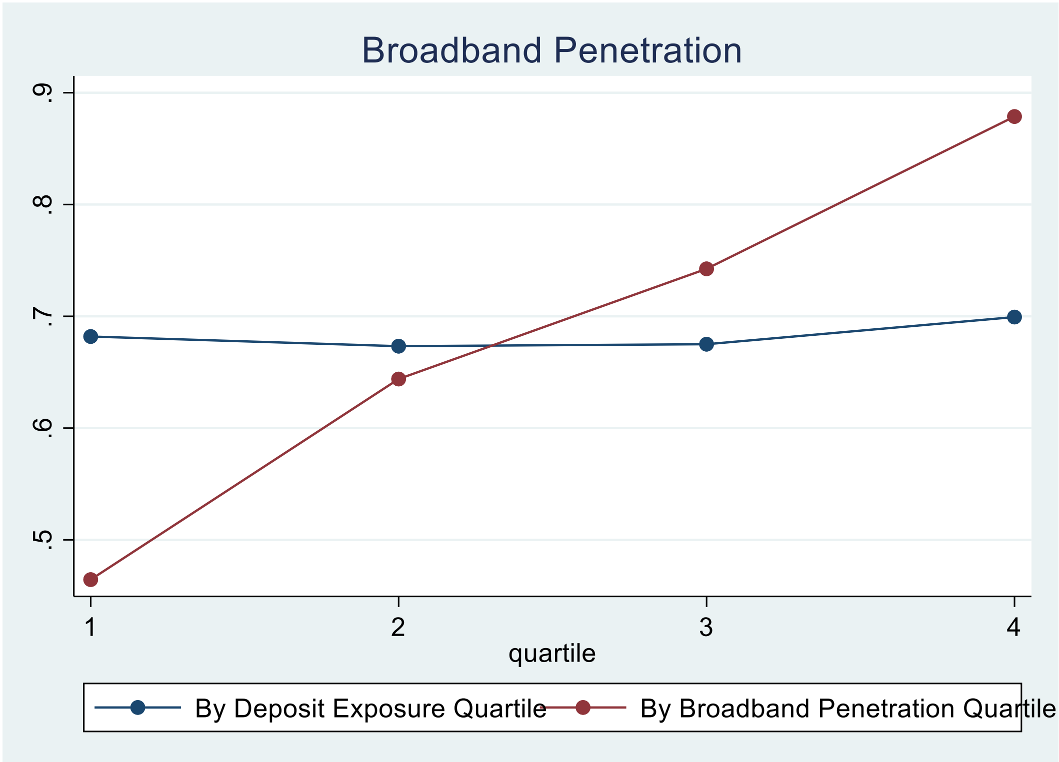

Figure 3: Bank-level Deposit Exposure and Broadband Penetration

This figure plots average broadband penetration for banks belonging to the four quartiles of *Deposit exposure* and the four quartiles of *Broadband penetration.*

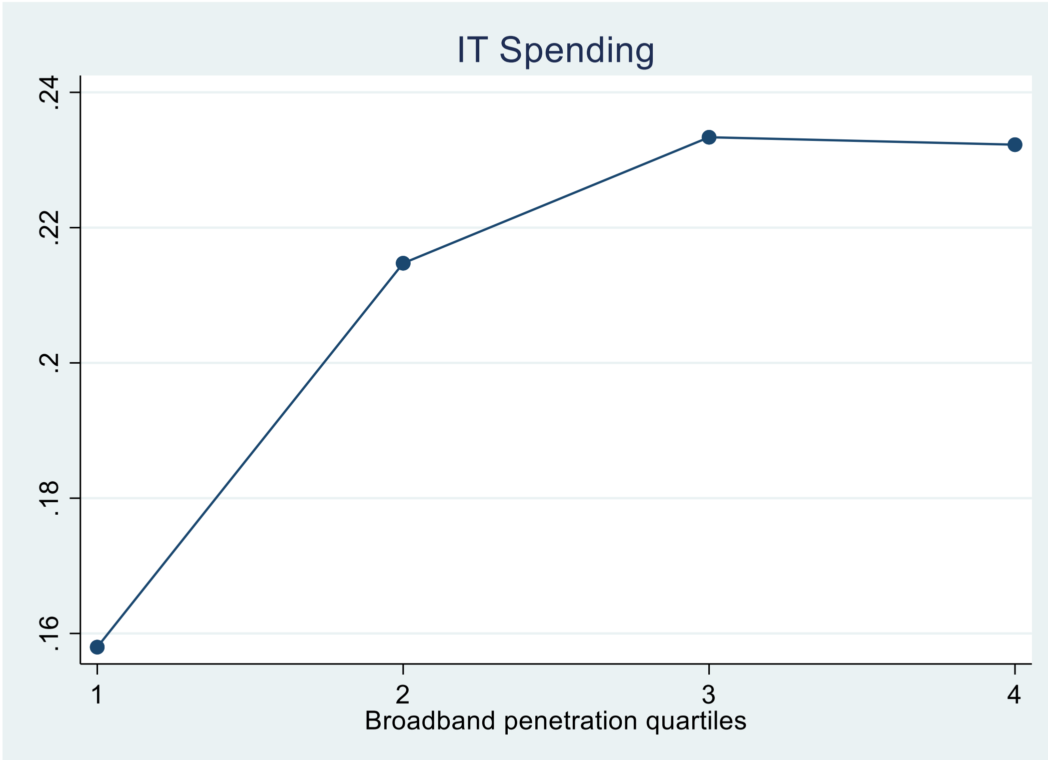

Figure 4: Bank IT Spending by *Broadband Penetration* Quartile
This figure plots average bank-level cumulative IT spending (scaled by assets) from 2014-2022 for banks belonging to the four quartiles of *Broadband penetration*.

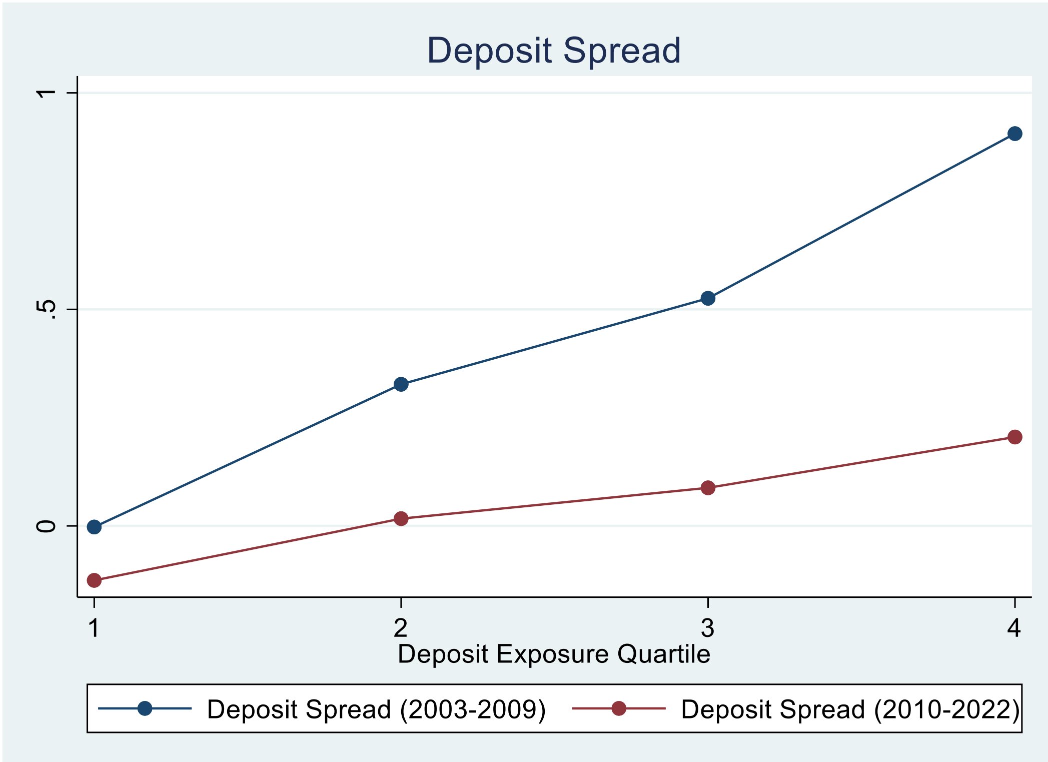

Figure 5: Deposit Spread by Deposit Exposure Group

This figure plots average deposit spreads for firms belonging to different *Deposit exposure* quartiles. Deposit spread is defined as effective federal funds rate minus the deposit yield. The graph plots the average deposit spread during the pre-period (2003-2009) and during the exposure period (2010-2022) for banks belonging to the four *Deposit exposure* quartiles.

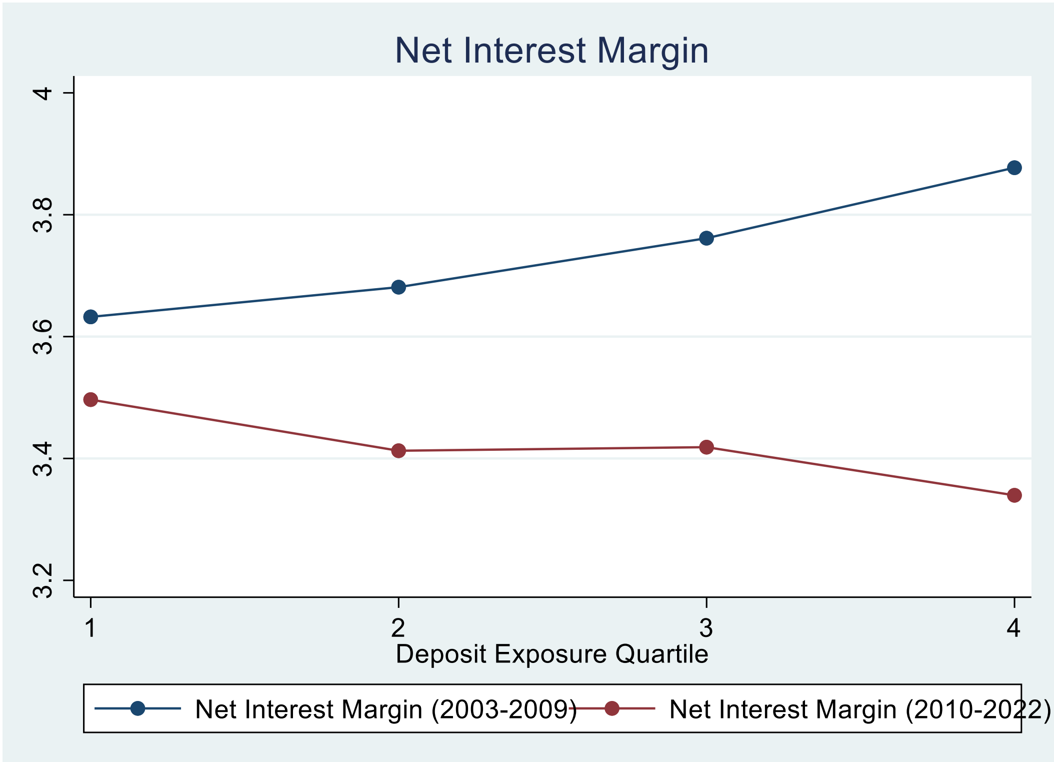

Figure 6: Net Interest Margin by Deposit Exposure Quartile

This figure plots average net interest margin (NIM) for firms belonging to different *Deposit exposure* quartiles. The graph plots the average NIM during the pre-period (2003-2009) and during the exposure period (2010-2022).

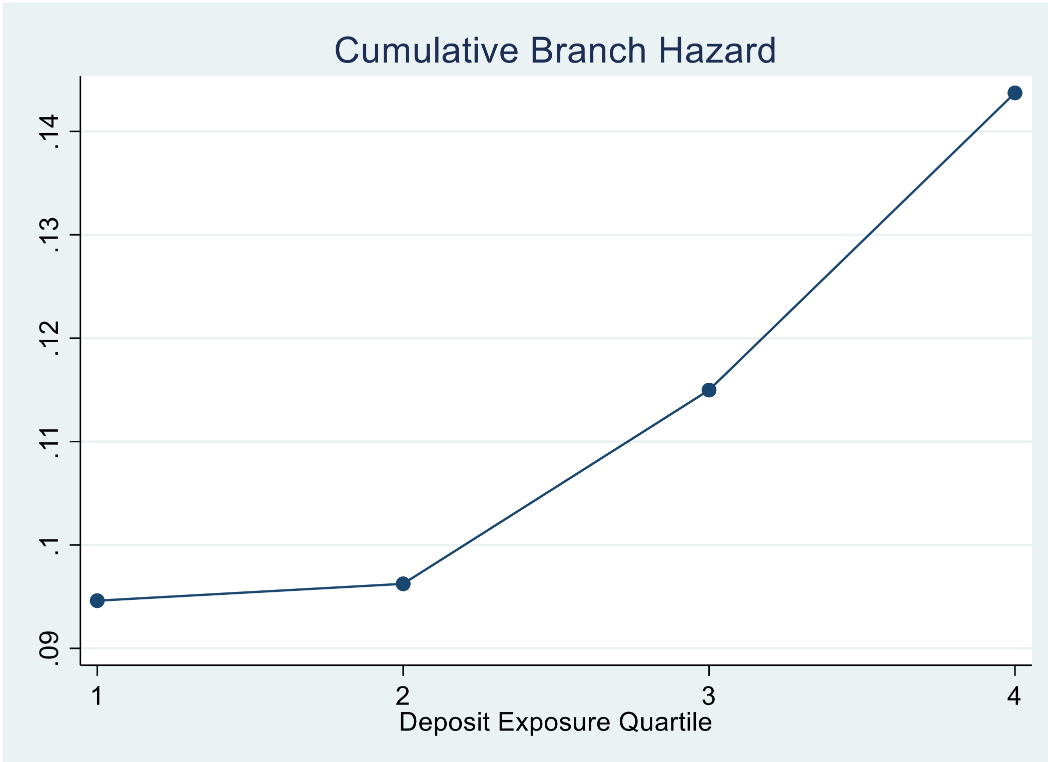

Figure 7: Cumulative Bank-level Branch Hazard by Deposit Exposure Quartile
This figure plots average bank-level cumulative branch hazard rate over 2010-2022 for banks belonging to the four quartiles of *Deposit exposure*.

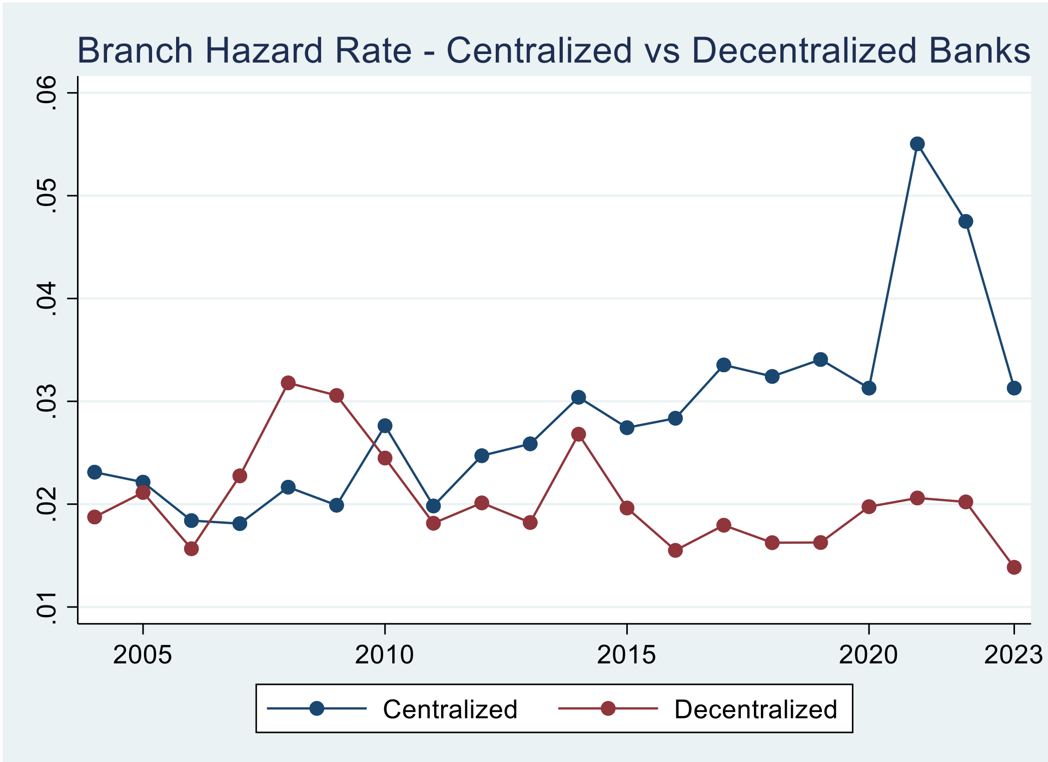

Figure 8: Branch Hazard Rate – Centralized vs. Decentralized Banks

This figure plots the annual branch hazard rate for centralized and decentralized banks. For each group of banks, hazard rate equals total number of branches closed in a year scaled by the total number of branches in existence at the beginning of the year. A bank's decentralization score is calculated as the share of counties with branch presence that have at least one rate setting branch in the county. We use each bank's decentralization score as of 2003 to divide banks into two groups based on the median value of their decentralization score. Banks with a decentralization score above the median value are labeled "Decentralized" while those with score below the median are labeled "Centralized." Information on rate setting versus rate following branch comes from Ratewatch.

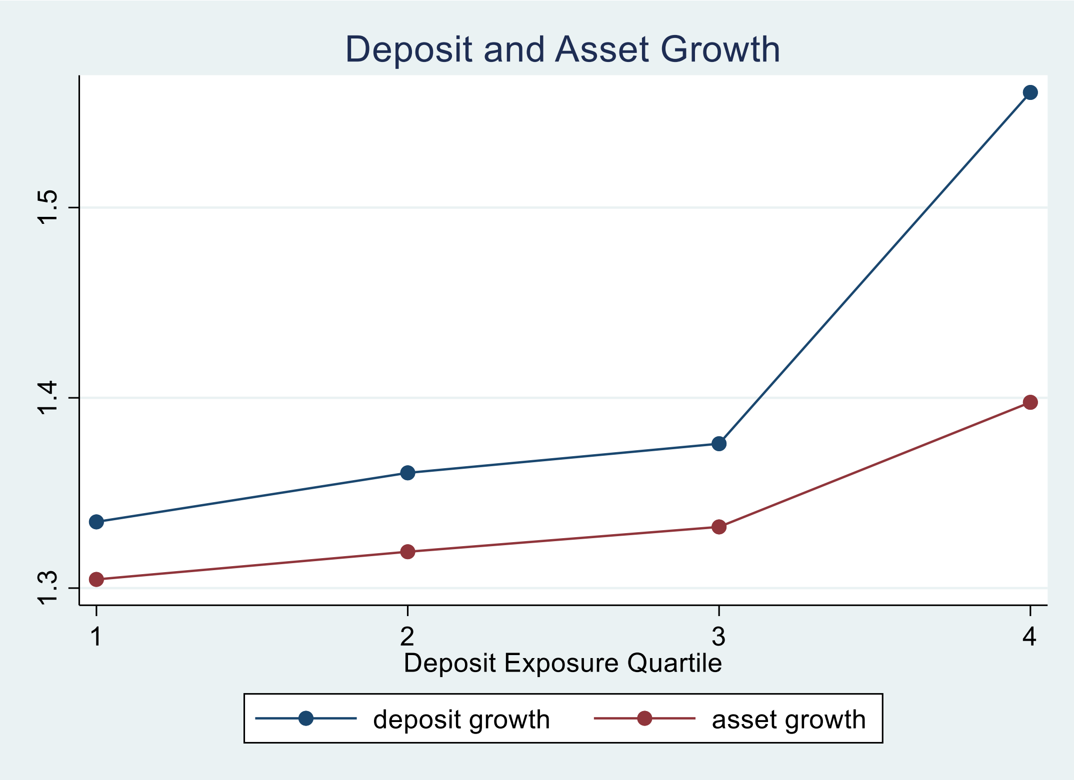

Figure 9: Bank-level Deposit and Asset Growth by Deposit Exposure Quartile
This figure plots average bank-level gross deposit and asset growth over 2010-2022 for banks belonging to the four quartiles of *Deposit exposure*.

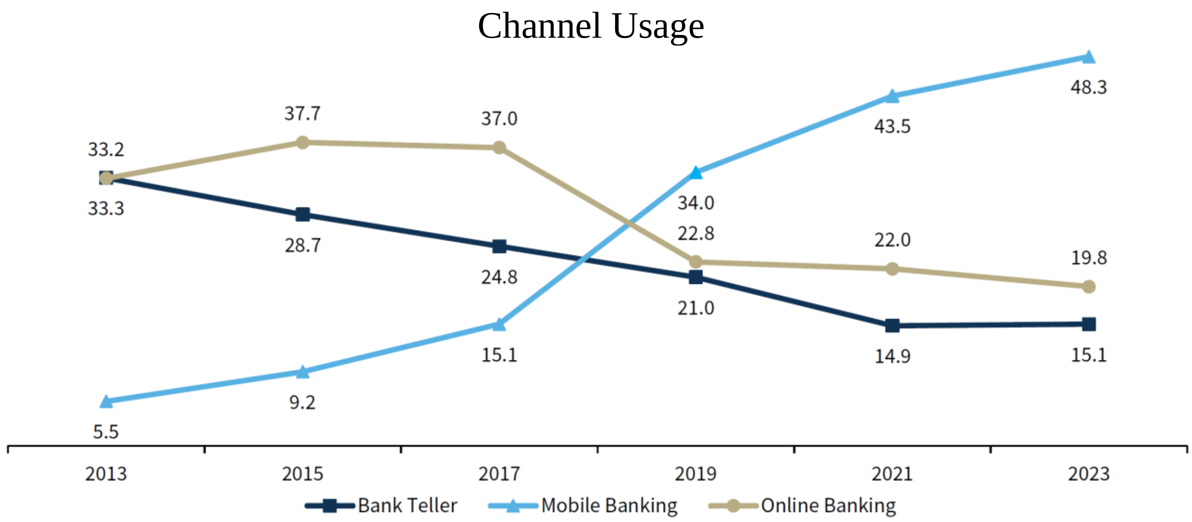

Figure 10: Primary Channel Used to Access Deposit Services.

This figure plots the percentage of bank customers using branch, mobile and online banking as their primary (most common) channel use to access deposit services. Source: FDIC 2023 National Survey of Unbanked and Underbanked Households.

Table 1: Summary Statistics

This table reports summary statistics for variables used in our analysis. Panel A we tabulate statistics at the bank level whereas panel B tabulates statistics at the county level. *Deposit exposure* each bank is measured over 2010-2022 period, *Broadband penetration* is measured over 20014-2022, Δ Branch density is the change in branch density from 2010 to 2022, Δ Deposit spread is the change in deposit spread from 2010 to 2022, Δ NIM is the change in net interest margin from 2010 to 2022, and Δ Non-interest expense yield is the change in non-interest expense yield from 2010 to 2022. Average IT spending is multiplied by 100 for ease of representation. *Decentralization score* equals #counties with at least one rate setting branch divided by total #counties with bank branches. *Unbanked* is an indicator that takes a value of one if the proportion of FDIC Unbanked Survey respondents in county reporting being unbanked increased from 2009 to 2021, and zero otherwise.

Panel A. Exposure and Outcome Variables (Unit of observation: Bank)

	Mean	Standard Deviation	25th Percentile	Median	75th Percentile	Observations
Deposit exposure	-0.058	0.013	-0.067	-0.059	-0.051	3,717
Broadband penetration	0.681	0.167	0.580	0.691	0.786	3,698
Cumulative hazard	0.112	0.178	0	0	0.200	3,717
Δ Branch density	-12.76	11.54	-16.98	-10.35	-5.51	3,716
Δ Deposit spread	-0.39	0.39	-0.61	-0.37	-0.15	3,717
Δ NIM	-0.32	0.50	-0.61	-0.29	-0.01	3,717
Δ Non-interest Expense Yield	-0.281	1.206	-0.666	-0.293	0.072	3,717
Average IT spending	0.210	0.547	0	0	0.070	3,867
Decentralization score	0.661	0.314	0.379	0.625	1.000	3,541
Bank size (million)	2,378.8	44,974.7	74.4	152.6	342.0	3,717
Equity/assets	0.112	0.053	0.089	0.102	0.121	3,717
Deposit/liability	0.931	0.087	0.902	0.955	0.990	3,717
Loan/assets	0.617	0.150	0.534	0.637	0.722	3,717

Panel B: County-level Descriptive Statistics

	Mean	Standard Deviation	25th Percentile	Median	75th Percentile	Observ ations
Cumulative hazard	0.166	0.201	0.000	0.167	0.292	3,032
Deposit exposure	-0.047	0.010	-0.052	-0.041	-0.039	3,032
Broadband penetration	0.726	0.107	0.706	0.737	0.776	3,032
Decentralization score	0.145	0.280	0.000	0.007	0.112	3,032
Population density (1,000 persons/sq. mi.)	0.282	1.879	0.017	0.045	0.121	3,098
Median age	39.9	4.9	37.0	40.0	43.0	3,098
Median household income ($000s)	43.19	10.75	36.17	41.28	47.77	3,097
College education share	0.191	0.087	0.131	0.169	0.226	3,098
Δ Banking desert	0.01	0.04	0	0	0	3,098
Δ Potential banking desert	0.02	0.07	0	0	0	3,098
Unbanked	0.158	0.365	0	0	0	690

Table 2: Exposure and Changes in Interest Earnings

This table reports the results of OLS regressions relating changes in average interest earnings between 2003-2009 and 2010-2022. The dependent variable in column (1) is the change in the deposit spreads. Similarly, the dependent variable in column (2) is the change in net interest margins. *Deposit exposure* for each bank is measured over 2010-2022 period. Other controls include bank size (log total assets in millions USD), equity/assets, deposit/liability, and loan/assets, which are measured as of beginning of 2010. Standard errors are reported below the coefficients in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

	(1) Δ Deposit Spread	(2) Δ NIM
Deposit exposure	-17.988***	-12.607***
	(0.385)	(0.605)
Bank size	0.045***	0.025***
	(0.004)	(0.006)
Equity/assets	-0.385***	-1.045***
	(0.100)	(0.157)
Deposit/liability	-0.150**	-1.097***
	(0.062)	(0.097)
Loan/assets	0.442***	0.290***
	(0.034)	(0.054)
Observations	3,717	3,717
Adj. R-squared	0.430	0.162

Table 3: Branch Density, Interest Rate Environment, and Cost of Deposits

This table reports deposit yields and non-interest expense yields for banks with low and high branch density over the 2003-2022 period. Branch density is defined as number of branches per billion dollars of deposit at the bank level. Banks with average branch density below the median value are classified as low-density banks. We also report the difference in the mean value of deposit yields and non-interest expense yields for each group, as well as t-statistics of the difference. We perform this analysis separately for low- and high- interest rate environment. We divide the sample period from 2003-2022 into periods of low- and high- interest rates based on the sample median federal fund effective rate (FFEF). * p<0.1, ** p<0.05, *** p<0.01.

	Low FFEF environment		**High FFEF environment**	
	Deposit Yield	Non-Interest Expense Yield	Deposit Yield	Non-Interest Expense Yield
low branch density	0.703	3.365	1.762	3.449
high branch density	0.664	3.792	1.669	3.882
diff (low-high)	0.039***	-0.428***	0.093***	-0.433***
t-stat	4.29	-8.11	6.63	-8.52
differences-in-difference: high FFEF environment - low FFEF environment				
diff-in-diff	0.055***	-0.005		
t-stat	6.448	-0.195		

Table 4: *Deposit Exposure*, *Broadband Penetration*, Cumulative Branch Hazard, and Changes in Branch Density: Bank Level Analysis

This table reports the results of OLS regressions relating branch closure rates and branch density to *Deposit Exposure* and Broadband Penetration. The dependent variable in columns (1) and (2) is the cumulative branch hazard rate over 2010-2022 for a given bank. The dependent variable in columns (3) and (4) is the change in branch density from 2010 to 2022 for a given bank. *Deposit Exposure* for each bank is measured over 2010-2022 period. Broadband penetration for each bank is measured over 2014-2021 period. Other controls include bank size (log total assets in millions USD), equity/assets, deposit/liability, and loan/assets. Standard errors are reported below the coefficients in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

	(1) Cumulative Hazard	(2) Δ Branch Density	(3) Cumulative Hazard	(4) Δ Branch Density
Deposit exposure	0.670***	-162.928***	0.673***	-165.649***
	(0.248)	(15.963)	(0.248)	(16.017)
Broadband penetration			0.029**	1.311
			(0.015)	(1.150)
Bank size	0.045***	2.943***	0.045***	2.909***
	(0.002)	(0.188)	(0.002)	(0.189)
Equity/assets	-0.057	6.378	-0.059	5.494
	(0.055)	(6.870)	(0.057)	(7.103)
Deposit/liability	-0.029	7.947**	-0.028	8.354**
	(0.039)	(3.731)	(0.039)	(3.717)
Loan/assets	0.042**	-6.356***	0.039*	-6.510***
	(0.020)	(1.504)	(0.020)	(1.505)
Observations	3,717	3,713	3,695	3,691
Adj. R-squared	0.131	0.109	0.132	0.109

Table 5: ***Deposit Exposure*****,** ***Broadband Penetration*****, Cumulative Net Hazard, and Changes in Branch Density: County Level Analysis**

This table reports the results of OLS regressions relating branch closure rates to liability exposure and broadband penetration. The dependent variable is the cumulative branch hazard rate over 2010-2022 for a given county. Liability exposure and Broadband penetration at the county level is calculated as weighted average of their bank-level measures, with bank deposits in the county in 2010 acting as weights. Other controls include population density, median age, income per capita, and share of population aged 21 and above who are college educated. Standard errors are reported below the coefficients in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

	(1) Cumulative Net Hazard	(2) Cumulative Net Hazard	(3) Cumulative Net Hazard
Deposit exposure	5.055***	4.927***	-0.666
	(0.346)	(0.397)	(1.904)
Broadband penetration		0.185***	0.617***
		(0.036)	(0.148)
Deposit exposure X *Broadband penetration*			7.911***
			(2.634)
Population density		0.003	0.003
		(0.002)	(0.002)
Median age		0.002***	0.002***
		(0.001)	(0.001)
Median household income		-0.000	-0.000
		(0.000)	(0.000)
College education share		-0.150***	-0.150***
		(0.058)	(0.058)
Observations	3,032	3,032	3,032
Adj. R-squared	0.0655	0.0791	0.0815

Table 6: Branch Hazard rate – Centralized vs Decentralized banks

This table reports the results of OLS regressions relating branch closure rates to organizational structure of banks. The dependent variable is either an indicator denoting whether a bank branch gets closed in a given year (column (1)) or branch closure rate at the bank-county level (column 2). A bank's *decentralization score* equals #counties with at least one rate setting branch divided by total #counties with bank branches. *Local rate setter* is a dummy that equals one if the bank has at least one rate setting branch in the county. Other controls include bank size (log total assets in millions USD), equity/assets, deposit/liability, and loan/assets. All regressions are estimated with heteroscedasticity robust standard errors that are clustered by bank and county and are reported below the coefficients in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

	(1) closed	(2) bank-county hazard
Local rate setter	-0.003***	
	(0.001)	
Decentralization score		-0.010***
		(0.002)
Bank size		0.002***
		(0.000)
Equity/assets		0.031
		(0.019)
Deposit/liability		0.011
		(0.018)
Loan/assets		-0.001
		(0.006)
FE	Bank-year; County-year	county-year
Observations	932,536	265,262
Adj. R-squared	0.0748	0.00672

Table 7: *Deposit Exposure*, *Broadband Penetration*, Decentralization, Cumulative Branch Hazard, and Changes in Branch Density

This table reports the results of OLS regressions relating branch closure rates to organizational structure of banks. The dependent variable is the cumulative branch hazard rate over 2010-2022 for a given bank. A bank's *decentralization score* equals #counties with at least one rate setting branch divided by total #counties with bank branches. Other controls include bank size (log total assets in millions USD), equity/assets, deposit/liability, and loan/assets. All regressions are estimated with heteroscedasticity robust standard errors that are clustered by bank and county and are reported below the coefficients in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

	(1) Cumulative Hazard	(2) Δ Branch Density
Deposit exposure	2.181***	-283.865***
	(0.671)	(38.642)
Broadband penetration	0.096**	-2.365
	(0.041)	(2.623)
Deposit exposure ×	-1.955**	151.958***
Decentralization	(0.831)	(51.794)
Broadband penetration ×	-0.087*	3.265
Decentralization	(0.050)	(3.468)
Decentralization	-0.110*	18.420***
	(0.061)	(3.927)
Bank size	0.036***	4.554***
	(0.003)	(0.227)
Equity/assets	-0.076	1.759
	(0.060)	(7.824)
Deposit/liability	-0.078*	12.255***
	(0.041)	(3.893)
Loan/assets	0.029	-4.695***
	(0.021)	(1.504)
Observations	3,521	3,518
Adj. R-squared	0.144	0.187

Table 8: *Deposit Exposure* and Bank Fragility

This table reports the results of OLS regressions relating changes in deposit yield and deposit flows to *Deposit exposure*. The dependent variable in column (1) is the bank-level percentage change in deposit yield between Q4 of 2021 and Q3 of 2023, while the dependent variable in column (2) is the bank-level percentage change in deposits between Q4 of 2021 and Q3 of 2023. *Deposit Exposure* for each bank is measured over 2010-2022 period. In columns (3) and (4), we run a two-stage instrumental variable regression where in the first stage we regress the change in branch density from 2010 to 2022 for a given bank against its *Deposit Exposure*, which we report in column (2) of Table 3. We report the results of the second stage in columns (3) and (4), where the dependent variables are change in deposit yields and deposit flows, respectively, and the key explanatory variable is the predicted change in branch density obtained from the first stage regression. Other controls include bank size (log total assets in millions USD), equity/assets, deposit/liability, and loan/assets. Standard errors are reported below the coefficients in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

	(1) Δ Deposit Yield	(2) Δ Deposit	(3) Δ Deposit Yield	(4) Δ Deposit
Deposit exposure	44.247***	-0.905***		
	(4.415)	(0.308)		
Δ Branch Density			-0.281***	0.005***
			(0.036)	(0.002)
Bank size	1.268***	-0.001	2.088***	-0.016**
	(0.046)	(0.003)	(0.112)	(0.006)
Equity/assets	4.642***	-0.182**	5.873***	-0.242***
	(1.182)	(0.082)	(1.554)	(0.089)
Deposit/liability	-0.518	-0.146***	1.592	-0.185***
	(0.711)	(0.050)	(0.998)	(0.057)
Loan/assets	0.053	0.061**	-1.716***	0.102***
	(0.392)	(0.027)	(0.515)	(0.029)
Observations	3,588	3,590	3,584	3,586
Adj. R-squared	0.241	0.00737		

Table 9: *Deposit Exposure*, Branch Closures, and Bank Desertification

This table reports the results of OLS regressions relating branch closure rates to *Deposit exposure* and *Broadband penetration*. The dependent variable in column (1) is an indicator that takes a value of one if the proportion of FDIC Unbanked Survey respondents in county reporting being unbanked increased from 2009 to 2021, and zero otherwise. The dependent variable in columns (2) and (3) are the changes in share of census tracts classified as banking desert and potential banking desert, respectively, within each county from 2010 to 2022. *Deposit exposure* and *Broadband penetration* at the county level is calculated as weighted average of their bank-level measures, with bank deposits in the county in 2010 acting as weights. Other controls include population density, median age, income per capita, and share of population aged 21 and above who are college educated. Standard errors are reported below the coefficients in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

	(1) Δ Unbanked	(2) Δ Banking desert	(3) Δ Potential banking desert
Deposit exposure	4.616**	0.346***	0.327**
	(2.159)	(0.087)	(0.143)
Broadband penetration	-0.532**	-0.002	-0.002
	(0.224)	(0.008)	(0.013)
Population density	-0.032	-0.000	-0.000
	(0.023)	(0.000)	(0.001)
Median age	0.001	0.000	0.000*
	(0.004)	(0.000)	(0.000)
Median household income	-0.001	0.000	0.000
	(0.002)	(0.000)	(0.000)
College education share	0.066	-0.046***	-0.077***
	(0.223)	(0.013)	(0.021)
Observations	681	3,032	3,032
Adj. R-squared	0.005	0.008	0.007

Internet Appendix

Table A.1: *Deposit Exposure, Broadband Penetration*, and Cumulative Net Branch Hazard: Bank Level Analysis

This table reports the results of OLS regressions relating cumulative net branch hazard rates to *Deposit Exposure* and Broadband Penetration. The dependent variable is the cumulative net branch hazard rate over 2010-2022 for a given bank. Annual branch hazard rate is calculated for each bank as decrease in # of branches scaled by total # of branches at the beginning of year. Cumulative net hazard rate for each bank is calculated by aggregating the annual net hazard rates over 2010-2022. *Deposit Exposure* for each bank is measured over 2010-2022 period. Broadband penetration for each bank is measured over 2014-2021 period. Other controls include bank size (log total assets in millions USD), equity/assets, deposit/liability, and loan/assets. Standard errors are reported below the coefficients in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

	(1) Cumulative Net Hazard	(2) Cumulative Net Hazard
Deposit exposure	2.732***	2.793***
	(0.759)	(0.763)
Broadband penetration		0.069
		(0.057)
Bank size	-0.008	-0.010
	(0.008)	(0.008)
Equity/assets	0.097	0.114
	(0.214)	(0.224)
Deposit/liability	0.378***	0.404***
	(0.140)	(0.141)
Loan/assets	-0.194***	-0.211***
	(0.064)	(0.064)
Observations	3,717	3,695
Adj. R-squared	0.0113	0.0127

Table A.2: *Deposit Exposure*, *Broadband Penetration*, and Cumulative Branch Hazard: County Level Analysis

This table reports the results of OLS regressions relating branch closure rates to liability exposure and broadband penetration. The dependent variable is the cumulative branch closure rate over 2010-2022 for a given county. Liability exposure and Broadband penetration at the county level is calculated as weighted average of their bank-level measures, with bank deposits in the county in 2010 acting as weights. Other controls include population density, median age, income per capita, and share of population aged 21 and above who are college educated. Standard errors are reported below the coefficients in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

	(1) Cumulative Hazard	(2) Cumulative Hazard	(3) Cumulative Hazard
Deposit exposure	8.193***	7.212***	-1.373
	(0.474)	(0.544)	(2.632)
Broadband penetration		0.261***	0.921***
		(0.049)	(0.204)
Deposit exposure ×			12.135***
Broadband penetration			(3.640)
Population density		0.005*	0.004
		(0.003)	(0.003)
Median age		0.000	0.000
		(0.001)	(0.001)
Median household income		0.000	-0.000
		(0.001)	(0.001)
College education share		-0.057	-0.056
		(0.080)	(0.079)
Observations	3,022	3,022	3,022
Adj. R-squared	0.0898	0.0981	0.101