Low Interest Rates, Fragility, and the Desertification of Banking

Christopher James*
Nitish Kumar **

August 28, 2025

Abstract

When interest rates are expected to remain low, the opportunity cost of migrating depositors from the interest rate insensitive branch channel to the more volatile digital channel is lower which leads to more branch closures. However, this migration increases bank fragility if rates subsequently rise. Using an instrumental variable approach, we find that persistent low interest rates accelerated technology enabled branch closures. More important, using a difference-in-differences analysis we find that banks that closed more branches due to low interest rates were more adversely affected by subsequent rate increases, highlighting the impact of branch closures on the transmission of monetary policy and 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.

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

*Christopher.james@warrington.ufl.edu
**Nitish.Kumar@business.rutgers.edu

Thanks to seminar participants at Drexel, the University of Florida, and the Essex-Fintex-Washington University conference and especially Sergio Mayordomo, Greg Nini, and Chuck Fang for helpful comments and suggestions.

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 97,000 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] As we discuss later, this transition away from branch banking has potentially important implications for bank value creation, the transmission of monetary policy and banks fragility.[2]

The decline in branch banking has been attributed primarily to technological advancements and evolving customer preferences for internet banking.[3] 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.[4] Moreover, as shown in Figure 2, the move away from brick and mortar to online platforms appears to have started later in banking than in other sectors with significant online activity. Given the timing of these changes, why did it take until 2010 for the number of branches to start declining and why did the number of branches increase again in 2022?[5]

In this paper we present novel evidence that persistently low interest rates hastened the transition from branch to digital banking. We also provide evidence that low-interest-rate-induced reduction in branch banking was associated with a subsequent increase in bank exposure to interest rate risk and an increase in proportion of unbanked households.

[1] See Amberg and Becker (2024).

[2] Egan, Lewellen, and Sunderam (2022) find that deposit productivity is the primary driver of value creation in banking. Moreover, they find that deposit productivity is negatively related to the number of bank branches.

[3] See Keil and Ongena (2024) for a discussion of the possible causes of branch closures. See also Narayanan, Ratnadiwakara, and Strahan (2025) who argue that technology is the primary driver of branch closures.

[4] 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

[5] According to the FDIC number of branches increased in 2023 by 92 (see https://banks.data.fdic.gov/explore/historical/?displayFields=STNAME%2CTOTAL%2CBRANCHES%2CNew_Char&selectedEndDate=2024&selectedReport=CBS&selectedStartDate=1934&selectedStates=0&sortField=YEAR&sortOrder=desc). 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.

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.[6] Moreover, during this period, low interest rates were expected to persist as evidenced by the fact that 10-year treasury rates fell to below 2 percent in November of 2011 (and averaged only about 2.3 percent from 2010-2022).[7]

We present a simple model to show how persistently low interest rates reduce the opportunity cost of transitioning depositors to online banking and how the migration to online banking affects the fragility of the banking sector. The basic idea is that transitioning deposits to digital platforms from branches involves a trade-off: closing branches reduces noninterest operating costs but online deposits are more rate sensitive and fleeting than branch sourced deposits.[8] We argue that when rates are low, there is little difference between the rates paid on internet and branch deposits. As a result, if interest rates are expected to remain low, banks close branches and transition depositors to online banking. However, the transition to online banking may increase bank fragility if interest rates subsequently increase, particularly for banks that traditionally relied heavily on so-called core deposits (transaction and savings) as a source of funding.

While the decline in branching in the U.S. coincided with persistent low interest rates and technological change, 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 low interest rates to study the rise of so-called shadow banks. We take a similar approach but focus on branch closures and use

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[6] 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 (2025).

[7] See https://fred.stlouisfed.org/series/GS10

[8] Transitioning depositors from branches to online banking reduces location-based deposit market power. See Drechsler, Savov, and Schnabl (2017, 2021). In context of the Egan et al. (2022) model, the effect of transitioning to online banking on deposit productivity and the value of the deposit franchise is ambiguous. They argue that more productive banks are able to raise more deposits with the same inputs than less productive banks. However, while digital banking may lower non-interest costs, the shift to online banking may increase the elasticity of deposit supply (and pass through rates) which may reduce deposit productivity.

heterogeneity across banks in their historical reliance on different types of deposit accounts and organizational structures 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.[9] 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 deposits pay higher rates, are more sensitive to changes in the level of interest rates, but they have lower non-interest costs than core deposit 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 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 declines in interest rates.[10] 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 6).

We measure a bank's deposit exposure to interest rate declines as a share-shift or Bartik instrument.[11] Our deposit exposure measure combines pre-GFC deposit account weights with nationwide declines in deposit rates across the different account categories. Specifically, our exposure measure is based on a bank's 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. We focus on a bank's deposit exposure (rather than asset exposure) to interest rate declines because deposit taking is an important source of value in banking

[9] 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.
[10] 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.
[11] 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.

while there is little evidence that reliance on branch banking is related to asset productivity in the cross section.[12]

To illustrate how our share shift instrument works, in Figure 3, 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 the sum of annual branch hazard rates from 2010 to 2022.[13] 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 an important 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 are the cause of branch closures. We address this concern by constructing a bank level measure of exposure to digital innovations. Specifically, we construct a bank level measure of broadband exposure using each bank's historical share of deposits in a county and census tract data from the FCC Form 477 on broadband speeds. Banks with greater broadband exposure are banks

[12] See for example Egan et al. (2022) Table 3.

[13] 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.

with higher historical deposit shares in census tracts with higher average broadband speeds. We refer to these banks as high *Broadband exposure* banks.

As shown in Figure 4 we find virtually no relationship between *Broadband exposure* 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. Moreover, 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 exposure* interacted with *Deposit exposure*, consistent with low interest rates accelerating the impact of technology on branch closures.

To further address concerns that *Deposit exposure* is simply correlated with potentially confounding trends that affected branch closures during the 2010-2022 period, we examine the relation between branch closures and *Deposit exposure* in the rising rate environment between 2022 and 2024. Consistent with low rates contributing to branch closures we find no relationship between branch closures and *Deposit exposure* during the rising rate environment of 2022-2024 while the impact of *Broadband exposure* on branch closure is virtually the same as in 2010 to 2022.

The final section of the paper investigates the impact of low interest driven branch closures on bank interest rate risk exposure and access to bank services. While migrating depositors online lowers operating costs, it likely reduces location-based rents, leading to higher cost and more volatile deposit base in the event that interest rates increase. As a result, the low interest rate induced shift to online deposit taking may increase bank fragility by increasing the sensitivity of the deposit flows to interest rate changes.[14] Furthermore, if branch closures increase the sensitivity of deposit flows to interest rate changes then the move away from branch banking is likely to impact the deposit channel for the transmission of monetary policy (see Drechsler, Savov, and Schnabl (2017) and Erel, Liebersohn, Yannelis and Earnest (2024)). In particular, the reduction in the reliance on sticky core deposits may increase deposit outflows when rates increase thus increasing the real impact of monetary tightening.

[14] This change is likely to lead to less "sleepy" depositors. Hanson, Shleifer, Stein, and Vishny (2015) argue that deposit insurance and a thick equity cushion allow bank depositors to remain "sleepy" in that they do not need to pay attention to transient fluctuations in the value of bank assets. Their focus, however, is on the response of deposit flows to fluctuations in the value of bank assets due to changes in credit risk and not on the sensitivity of deposit flows to interest rate changes.

We investigate the effect of branch closures on bank fragility by examining the relationship between changes in the interest cost of deposits, deposit flows, and bank lending 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. We also find that *Deposit exposure* is negatively related to the growth of small business lending 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 core 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.

We conduct two additional tests to support the claim that branch closures induced by low interest rates increased bank fragility. For the first test, 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 the interest costs, deposit flows and small business lending 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 lending 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 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.

Our second test aims to address the concern that differences in unobservable characteristics between low and high exposure banks drive differences in deposit rate changes, deposit flows, and lending during the interest rate hike of 2022-2023. This test implements a difference-in-differences (DiD) analysis that compares the impact of *Deposit exposure* on changes in deposit yields, deposit flows, and lending across two periods of sharp interest rate increases: the 2004-2006 rate hikes (before the post crisis period of persistently low rates) and the 2022-2023 rates hikes. For this analysis we include bank fixed effects so that identification is through within bank changes in the sensitivity to interest rate increases. Overall, we find significant increases in the sensitivity of deposit yields, deposit flows, and lending to *Deposit exposure* and branch density during the 2022-2023 period than in the precrisis period.

We also examine the impact of branch closures on access to banking services. Branch closures driven by technology versus those driven by low interest rates have potentially different implications for access to banking services. On the one hand, if banks derive market power from their physical proximity to their depositors, such as Drechsler, Savov and Schnabl (2017) and other studies suggest, then technology has the potential to increase competition, lower the cost of financial intermediation and increase access to banking services. On the other hand, low-interest-rate-driven branch closures may lead to regional consolidation that reduces the number of competitors in local banking markets and thus reduces access to banking services. We measure changes in access to banking services using survey FDIC's survey of access to banking services. Specifically, we measure changes in access to banking services by county level changes in the proportion of FDIC survey respondents that report being unbanked over our sample period. Overall, we find low interest rate induced branch closures are associated with an increase in the proportion of unbanked households. In contrast, we find that technology induced branch closures are associated with a decrease in the proportion of unbanked households over our sample period.

We contribute in several ways to the banking 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 the deposit franchise.[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 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 accelerating changes in bank infrastructure that make deposits a less stable source

[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.

of bank funding (see, also, Koont, Santos, and Zingales (2023)) and increase the risk associated with bank maturity transformation. Our paper complements recent research by Erel et al. (2024) who find that transmission of monetary policy on deposit interest rates is more effective for online than traditional banks. In particular, we provide evidence that exogenous shocks to the value of brick-and-mortar branches lead to branch closures and an increase in the within bank deposit rate sensitivity to interest rate changes. We also provide evidence that the increase in the sensitivity of deposits to rate changes is associated with an increase in the sensitivity of bank lending to interest rate changes.

Finally, we provide evidence 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 affect branch closures. This discussion motivates the share shift instrument we use to examine whether low interest rates cause branch closures. In section III we describe our data sources and provide summary statistics. In Section IV we 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

[16] The ability to earn spread income is assumed to arise from local bank market power. However, the source of local 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

interest rates and deposit rates (i.e., the deposit spread) is a function of the degree to which banks pass through changes in market rates to depositors. The deposit pass through rates are often referred to as deposit betas. *Ceteris paribus*, the lower pass-through rates, the higher the deposit spreads 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 non-interest 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

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

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]

Equation (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

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.

[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.

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 to vary inversely with β^D. In short, 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 *Deposit exposure.*

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. One advantage of online banking is the operating costs per dollar of deposits are significantly lower.[18] However, an advantage of brick-and-mortar branches is that deposits are likely to be stickier than deposits 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 importantly, equation (2) suggests that when rates are low, the

[18] 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

incremental interest cost associated with greater reliance on digital distribution are also likely to be low, thus inducing banks to shift to digital distribution.

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*, Drechsler et al. (2017) and Emin et al. (2025) find deposit beta vary widely based on deposit type. For example, Emin et al. (2025) 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 that 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 branch profitability, we use a methodology similar to 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 with 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 $r_s^i - r_{t_0}^i$ 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 consider differences in the speed at which deposit yields fell across categories. 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. Note that we do not construct a panel dataset of bank-level annual (i.e., short-run) exposure measures. Instead, we develop a bank-specific long-run exposure metric designed to capture the cumulative impact of interest rates over the extended period from 2010-2022. Our focus is on banks' responses to persistently low interest rates – both the impact and the consequences are more likely to manifest over longer horizons.

It is also important to note that equation (3) *does not* measure 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).

2.2 Controlling technological change

The focus of our paper is on investigating the impact of low interest rates on branch closures. However, technological change clearly plays 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).[19] 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, 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 low interest rates were not a cause of branch closures. To address the concern *Deposit exposure* may be correlated with technological 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 broadband internet speeds. Specifically, census tracts differ in terms of broadband speeds that are available. We exploit this difference to construct a broadband access measure based on difference between banks in terms of historical branch locations. For each bank b we measure broadband exposure as

$$Broadband\ exposure_{bt} = \sum_j \omega^j_{bt'_0} * Average\ broadbandspeed^j \qquad (4)$$

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 $Average\ broadbandspeed^j$ is broadband speed in census tract j from 2014 to 2021. We obtain census tract level broadband speed data from FCC Form 477. This data is available for the 2014-2021 period, so broadband exposure is measured from 2014-2021. The base year for determining the census tract level deposit weights, $\omega^j_{bt_0}$, is chosen to be 2003.

If *Broadband exposure* 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

[19] 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.

cumulative branch closure hazard and *Broadband exposure*. 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.

We investigate the validity of *Broadband exposure* as a control for the innovations in technology by examining the relationship between *Broadband exposure* and bank spending on IT during the exposure period. In Figure 5 we plot the average cumulative IT spending (defined as bank-level IT spending scaled by assets) from 2014-2022 by *Broadband exposure* quartiles.[20] As shown, the average IT spending is increasing in *Broadband exposure*.[21] Finally, we acknowledge that broadband speed may not fully capture all dimensions of customer digital adoption that could influence bank branch closures. As a robustness check, we use retail store closures as an alternative proxy for customer adoption of digital platforms. Specifically, we construct a county-level net retail store hazard for the period 2010–2022 using data from the Bureau of Labor Statistics and find that our regression results remain qualitatively unchanged under this alternative specification.

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

[20] Data on bank IT spending can be constructed for a limited set of banks using their regulatory filings. See Modi et al. (2022) for details. Their data is available at https://drive.google.com/file/d/1svhNC0n96SskwXgY-xr8-MBy5FVQeBls/view.

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

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.

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. 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 as the branch deposit weighted average broadband speed 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).[22] 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 deserts 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 3,717 banks from 2003 through 2022. Our county level analysis is based on branches operating in 3,032 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.

[22] 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

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

A preliminary look at the relationship between *Deposit exposure* and interest spreads during the exposure period suggests *Deposit exposure* predicts lower spreads. To illustrate this relationship, in Figure 6 we compare average deposit spreads by *Deposit exposure* quartile from 2003-2009 (the pre-exposure period 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 6, the average deposit spread declined substantially between 2003-2009 and 2010-2022 for higher exposure banks than lower 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 7, 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) compared to the sample mean values. 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 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 smaller. 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.[23]

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 (note that we have a balanced panel of banks for the entire 2003-2022 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.[24]

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 does not, suggesting that the trade-off associated with online and branch banking

[23] Benmelech, Yang, and Zator (2023) use changes in branch density to measure the extent to which banks transition depositors from branch on online banking.

[24] 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 could 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 8, 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.[25] 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.[26]

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 a 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 branches—a point we revisit when examining the interplay between low interest rates and

[25] 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.

[26] 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.

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.

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 a couple of ways. First, we examine the relationship between bank level variations in *Broadband exposure* and *Deposit exposure*. In Figure 4 we plot the average *Broadband exposure* for banks belonging to each *Deposit exposure* quartile. Recall that we construct *Broadband exposure* by multiplying the census tract average internet speeds from 2014-2021 with the share of each bank's total deposits in each census tracts-based branch locations in 2003. Thus, *Broadband exposure* measures, based on the location of deposit customers, bank level differences in exposure to technological change based on internet access. As shown in Figure 4, we find little variation in the average *Deposit exposure* across *Broadband exposure* 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 exposure* as a control variable. As shown in columns 3 and 4 of Table 4, controlling for differences in broadband exposure, 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 exposure* absorbs little of the variations in hazard rates or branch density explained by variations in *Deposit exposure*.

We also find a positive and significant relation between cumulative hazard rates (but not changes in deposit density) and *Broadband exposure.* One potential explanation for the positive and significant relation between hazard rates and broadband exposure but no statistically significant relationship between branch density and *Broadband exposure* is differences in deposit growth between low and high *Broadband exposure* banks. We find deposit growth is greater for low than high *Broadband exposure* banks (the mean annual growth in deposits in the first

Broadband exposure quartile was just over 4.2 percent versus 3.3 percent for the highest broadband exposure quartile). This is consistent with customers of high broadband exposure banks being more fintech-savvy and reallocating a portion of their savings from bank deposit accounts to higher yielding investment accounts. In other words, purely technology-driven branch closures reflect a response to reduced demand for deposit and branch-banking services, whereas low-interest rate driven branch closures reflect a supply response to compressed margins rather than diminished demand. Lastly, because broadband exposure and deposit exposure may be related to county level economic and demographic characteristics that could also be correlated with deposit growth, we control for these factors in Section 4.6 by analyzing branch closures at the county level.

4.5 Deposit exposure, technology, and branch closures: 2022-2024

A common concern with share shift instruments is that they may reflect common trends unrelated to causal channel of interest (in our case low interest rates). One obvious candidate is technological changes. While *Broadband exposure* is intended to control for trends in technology, *Broadband exposure* may not fully account for technological change affecting branch closures, resulting in potential omitted variable bias. We address this concern in a couple of ways. First, we examine the relationship between branch closures and *Deposit exposure* during 2022-2024, a period of persistently higher interest rates.[27] Second, as discussed in section 4.6 we examine the relationship between branch closures and *Deposit exposure* at the county level, which allows us to control of local economic and demographic factors that are likely to be related to the adoption of new technologies.

Table 5 provides estimates of the relationship between bank level cumulative net hazard rates over the 2022-2024 period (i.e., the sum of annual net hazard rate over this period) and *Deposit exposure*, *Broadband exposure,* and other controls. As shown, we find a positive and significant relation between cumulative hazard rates and *Broadband exposure* but no significant relationship between closure rates and *Deposit exposure*. Indeed, while the coefficient estimate on *Broadband exposure* is economically comparable (and not significantly different) from the

[27] Short term rates increased beginning in March of 2022 and were expected to be persistently higher than in 2010-2020. For example, the 10-year Treasury rate increases from less than 1 percent in January of 2021 to over 3.5 percent by October of 2022.

coefficient estimate for the 2010-2022 period reported in Table 4, we find the coefficient estimate on *Deposit exposure* is significantly less (at the .05 level) than for the 2010-2022 period.

Importantly, the muted relationship between *Deposit exposure* and branch closures during 2022–2024 is consistent with our interpretation that low interest rates were a key driver of branch closures in the earlier period. When rates rose sharply after 2022, banks saw reduced pressure on deposit funding cost and in some cases even reopened branches or slowed planned closures, despite continued technological adoption. This finding strengthens our interpretation of the results in Table 4: if factors unrelated to interest rates (such as technological change) drove the relationship between *Deposit exposure* and branch closures, the association should remain similar across both periods. Instead, the differential effect suggests that technology and interest rates play distinct roles—technology exerts a relatively steady influence, whereas interest rate–driven pressures on branch viability vary with the interest rate environment. This evidence helps mitigate concerns about omitted variable bias from unobserved trends that coincided with the low-rate environment during 2010-2022 and supports the view that branch closures during 2010-2022 were partly attributable to the prolonged low-rate environment.

4.6 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 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.[28] For this analysis we measure county level Deposit

[28] 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,

exposure and broadband exposure by weighing, for each bank operating in a county, the banks' *Deposit exposure* and *Broadband exposure* measure by the bank's share of county deposits in 2010. Our sample consists of 3,032 counties. We include county level controls for population density, share of college graduates, median income, median age at the start of the exposure period, as well as the growth rate in population and median income from 2010 to 2022.

Estimates of county level branch hazard regressions are presented in Table 6. We use net hazard rates in these regressions and report results using branch closure rates in the Internet Appendix Table A.2.[29] Similar to our bank level findings, we find a positive and significant relation between hazard rates and both *Deposit exposure* and *Broadband exposure.* 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 5.5 percentage points or roughly a 34 percent increase relative to the mean.[30]

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.[31] 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

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.

[29] Net hazard rates are better suited to evaluate the real consequences of *Core 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.

[30] Although broadband speed serves as a reasonable proxy for online platform adoption, we employ retail store closures as an alternative measure. Specifically, we construct a county-level net retail store hazard for the period 2010–2022 and replace broadband exposure with this measure. The results remain qualitatively unchanged under this alternative specification (see Internet Appendix Table A.3).

[31] See for example Benmelech et al. (2023) and Erel et al. (2024). In addition, Emin et al. (2025) 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.

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 exposure.* 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 exposure have larger deposit market shares. As shown in column 3 that is exactly what we find. The coefficient estimate on *Deposit exposure* × *Broadband exposure* variable is positive and statistically significant, indicating closure hazard rates are significantly higher in counties where a greater share of deposits is held by more exposed banks and banks whose customers have better access to broadband internet.

4.7 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.[32] Branches also serve as an important platform for 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 by 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. Drawing on recent research by Dlugosz, Gam, Gopalan, and Skrastins (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

[32] 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).

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 where 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 small business lending and other non-deposit services.

While bank call reports do not provide information on small business lending, since 2010 call reports provide information on a quarterly basis on C&I loans outstanding by loan size. Using loan size as a proxy for small business lending, we find that the proportion of small loans (under $100,000 and under $1,000,000) is significantly greater for decentralized banks (banks with decentralized scores above the median) than centralized banks.[33] For example, the average proportion of loans under $1,000,000 to total loans outstanding was 8.2% for centralized banks and 9.1 % for decentralized banks (the difference is statistically significant at the .01 level).

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 9 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.

Does the effect of low interest rates on branch closures vary by decentralization? 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 exposure* 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 exposure*. Interestingly, the impact of both low interest rates and technology are decreasing in the degree of

[33] While widely used as a proxy for small business lending, loan size is likely a noisy proxy for small business lending. See FDIC Report No. 2020-4 "Measurement of Small Business Lending Using Call Reports: Further Insights from the Small Business Lending Survey"

decentralization. Given the sample difference between the 25th and the 75th 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 75th percentile of decentralization score relative to banks in the 25th 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 branch level decision making and the breadth of activities conducted through brick-and-mortar branches.

V. Branch Closures, Fragility and Access to Banking Services

Why should we worry about branch closures? Don't branch closures simply reflect the substitution of a more cost-effective and potentially more 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 potential cost of greater location-based rents). The transition to online banking, hastened by low interest rates, therefore potentially 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. These concerns are particularly salient in settings where branch closures reflect supply-side pressures (e.g., persistently low interest rates) as opposed to demand-side dynamics (e.g., customer adoption of new technologies). We investigate the impact of low interest rates on bank fragility and access to banking services in the next two subsections.

5.1 Did branch closures 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, the percentage change in deposit volume, and the percentage change in small C&I loans from Q4 of 2021 to Q3 of 2023 when FFRs increase from less than 25 basis points to 525 basis points. We then estimate the relationship between changes in deposit costs, deposit volume, and loan growth and *Deposit exposure*. Since branch closures are more likely to affect small business lending, we focus on growth in small C&I loans during this time period. 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 branch density associated with *Deposit exposure* in a second stage regression relating changes in deposit costs volume and lending to predicted changes in branch density.

Table 8 presents OLS and IV regression results relating changes in deposit costs and fundings and lending 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 percentage change in deposit volume and *Deposit exposure* (column (2)), and between small business lending and *Deposit exposure* (columns (3) and (4)). The economic magnitudes of these changes are large. For example, 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 lending and 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 (5) 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 and small business lending when rates rise, as shown in columns (6)-(8) we find a positive and significant relation between deposit growth, loan growth and instrumented branch density.[34]

Can differences in unobservable characteristics between low and high exposure banks drive differences in deposit rate changes, deposit flows, and lending during the interest rate hike of 2022-2023? To address this concern, we conduct DiD analyses comparing changes in deposit costs, deposit growth and lending during a period of rising interest rates between Q3 2004 through Q2 2006 to changes during the recent increase in interest rates from Q4 2021 through Q3 2023. Both these rate hikes are associated with a sharp increase in FFRs. In particular, the average effective FFR increased roughly 400 basis points (from 1.33% to 5.25%) between 2004 and 2006 compared to a 525-basis point increase (from .08 % to 5.33%) between 2021 and 2023. To account for a somewhat larger increase in FFRs in the post period, we scale each dependent variable by the change in FFRs during each period, so that the coefficient estimates represent the changes relative to a 100-basis point change in FFRs. Unfortunately, quarterly data on small C&I loans is not available during the 2004 through 2006 time period. Given the lack of small loan data, we measure changes in lending by changes in total loans in both time periods.

DiD estimates of changes in deposit costs, deposit and loan growth are presented in Table 9. All estimates include bank fixed effects so that identification is through within bank changes in the impact of *Deposit exposure* on the variables of interest.[35] As shown, consistent with branch closures increasing bank fragility, we find the effect of *Deposit exposure* (in absolute value) is significantly greater in the post period (after the low-rate environment) than before. For instance, a one standard deviation increase in bank-level *Deposit exposure* is associated with an additional 11.9% increase in deposit yield (compared to the sample mean percentage change in deposit yield)

[34] 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 10, between 2010 and 2022 deposits (and assets) grew faster at high exposure banks than low exposure banks.

[35] We also conduct a DiD analysis using instrumented branch density and find results similar to those in Table 9.

in the post period compared to the pre period. In summary, these estimates suggest that branch closures are associated with an increase in the sensitivity of deposits growth and lending to interest rate changes.

5.2 Low interest rates and access to banking services

We investigate whether branch closures caused by low interest rates affect access to banking services differently than technology driven closures. This analysis is motivated by 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 words, we suspect that branch closures caused by low interest are likely to reflect bank exits from local deposit and loan markets and are less likely to reflect the migration of customers to online platforms.[36]

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.[37] We hypothesize 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.[38] Similarly, a potential banking desert is a

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[36] 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/

[37] 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.

[38] 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 11, 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 households reported visiting a branch of the bank where they held their checking or savings account, which suggests that online banking is an imperfect substitute for bank branches.[39]

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 one if the proportion of unbanked households increased between 2009-2021 and the independent variables are *Deposit exposure, Broadband exposure* and a set of bank level controls.[40] 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 10. 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.

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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),

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

[40] 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 exposure,* suggesting that technology-induced branch closures are associated with 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 exposure,* 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 29.2%. In contrast, we find no significant relation between changes in banking deserts and *Broadband exposure.* Column 3 presents estimates of relationship between changes in the county level share of potential banking deserts and *Deposit exposure, Broadband exposure,* 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 exposure.* A one standard deviation increase in *Deposit exposure* increases the change in the county level share of potential banking deserts by 18.2%. 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, a number of years before the decline in branch banking began.

In this paper we provide novel 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 low interest rate induced branch closures are associated with an increase in the sensitivity of deposit growth and lending to changes in interest rates. We also examine the impact of branch closures on bank fragility and the transmission of monetary policy. Using a DiD analysis we find a greater increase in the sensitivity of deposit costs, deposit growth and lending to interest rate changes for banks with greater deposit exposure subsequent to the period of sustained low interest rates.

While all bank customers may eventually adopt some form of digital banking, our evidence suggests 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) suggest that higher interest rates may halt the steep decline in branch banking and potentially improve access to banking services.[41]

[41] 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 exposure**:** 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 time 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 deposit 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*.

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Figures and Tables

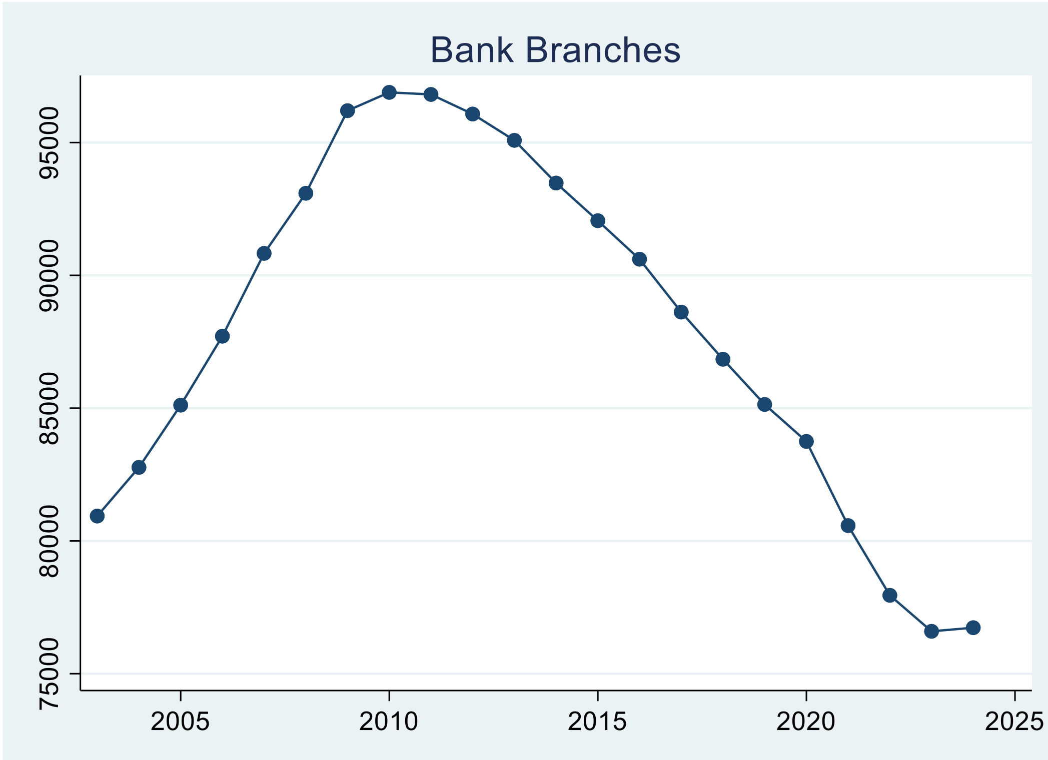

Figure 1: US Bank Branches 2003-2024

This figure plots the number of bank branches of all FDIC-insured institutions in the United States as of June 30th of each year. Data on the number of bank branches is from the Federal Deposit Insurance's Summary of Deposits (SOD).

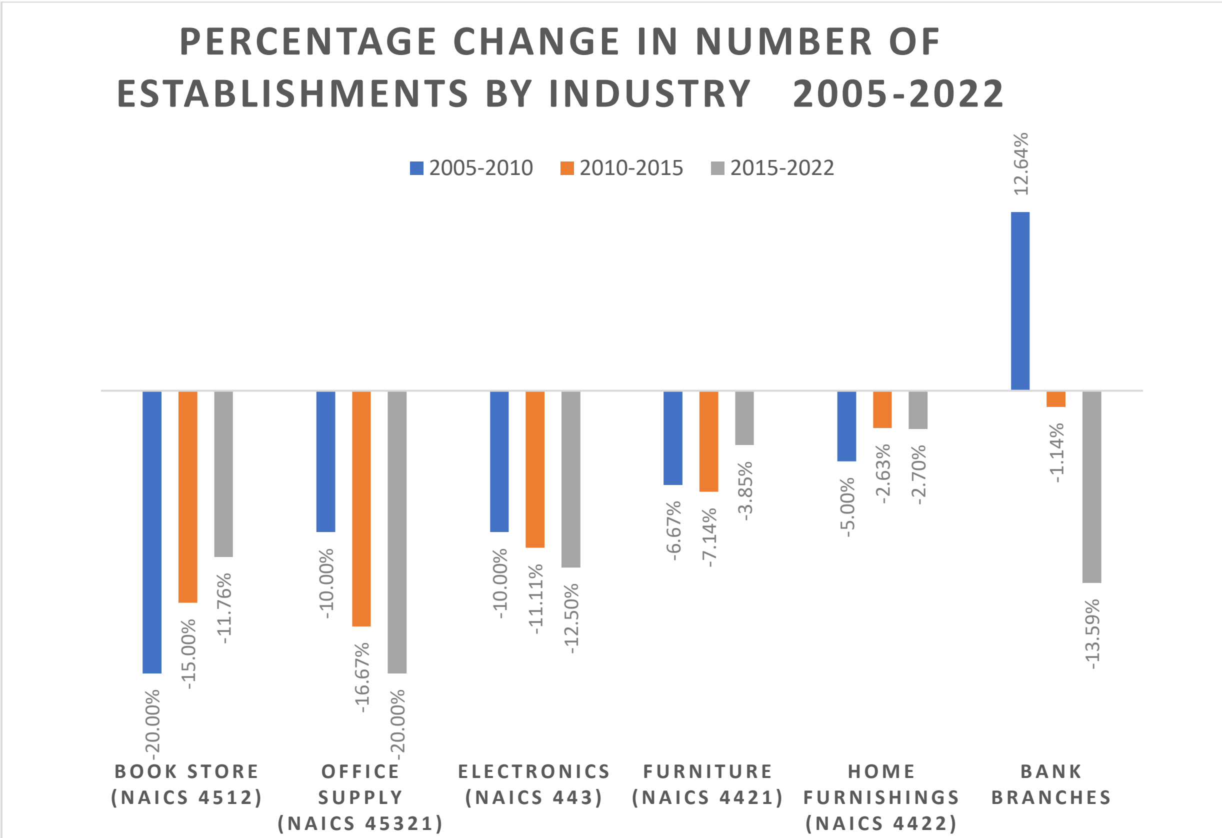

Figure 2 Changes in the Number of Retail Establishments 2005-2022

This figure plots the percentage change in the number bank branches and the percentage change in the number of retail establishments for the top 5 specialty retail sectors with the largest increase in e-commerce sales. Data on the change in the number of establishments is from the Bureau of Labor Statistics' Quarterly Census of Employment and Wages. Data on the number of bank branches is from the Federal Deposit Insurance's Summary of Deposits.

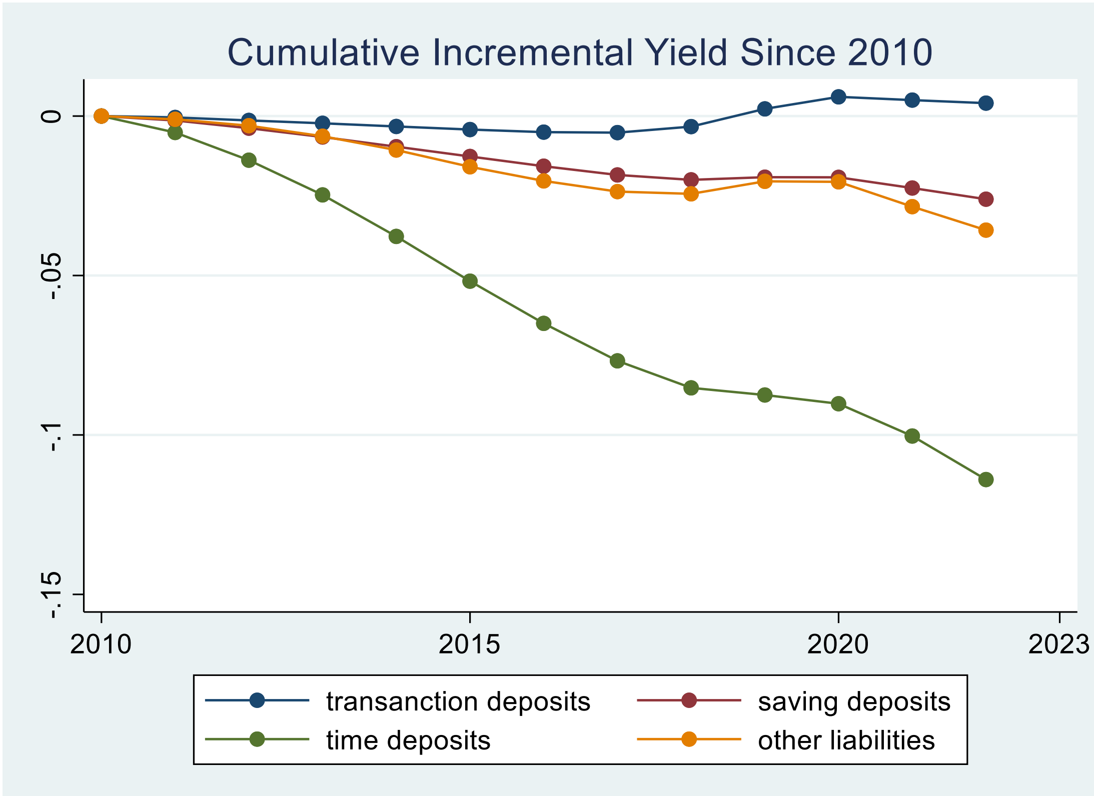

Figure 3: Cumulative Incremental Yields since 2010

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.

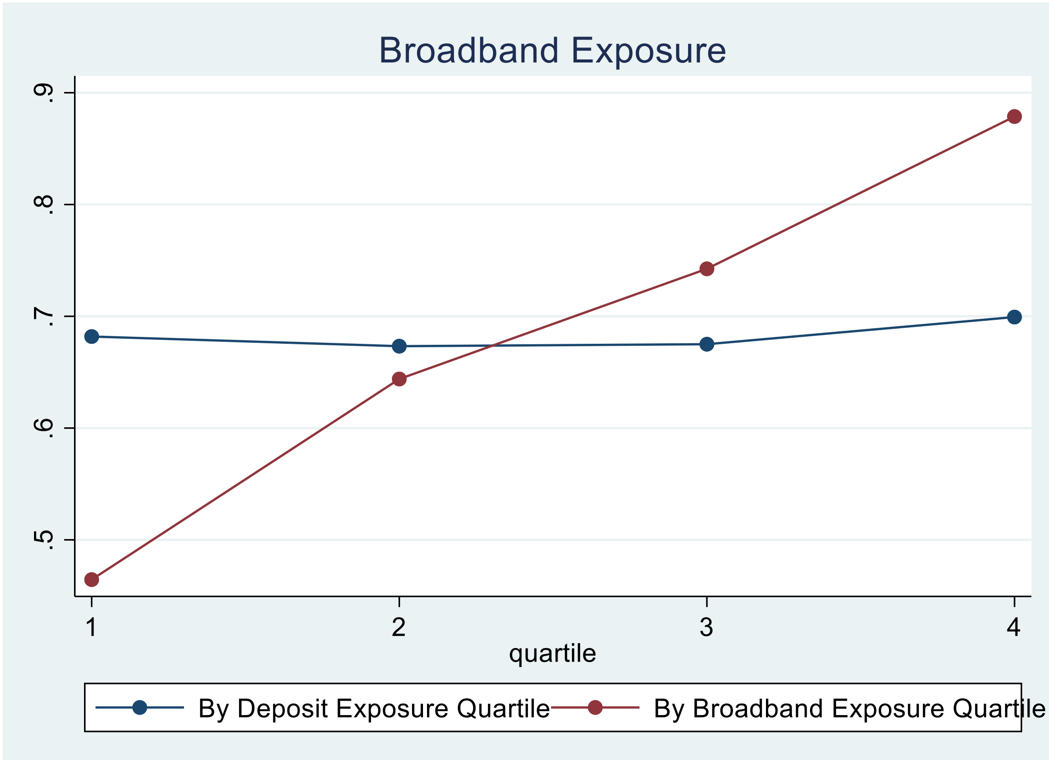

Figure 4: Bank-level Deposit exposure and Broadband Exposure

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

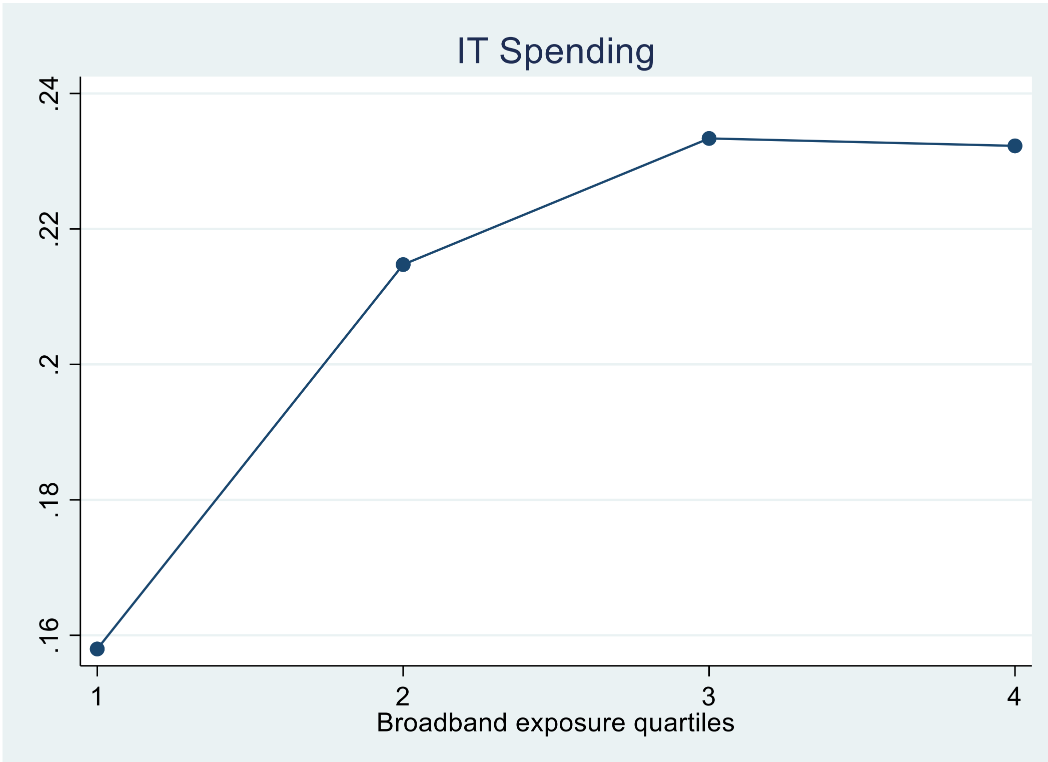

Figure 5: Bank IT Spending by *Broadband Exposure* Quartile
This figure plots average bank-level cumulative IT spending (scaled by assets) from 2014-2022 for banks belonging to the four quartiles of *Broadband exposure*.

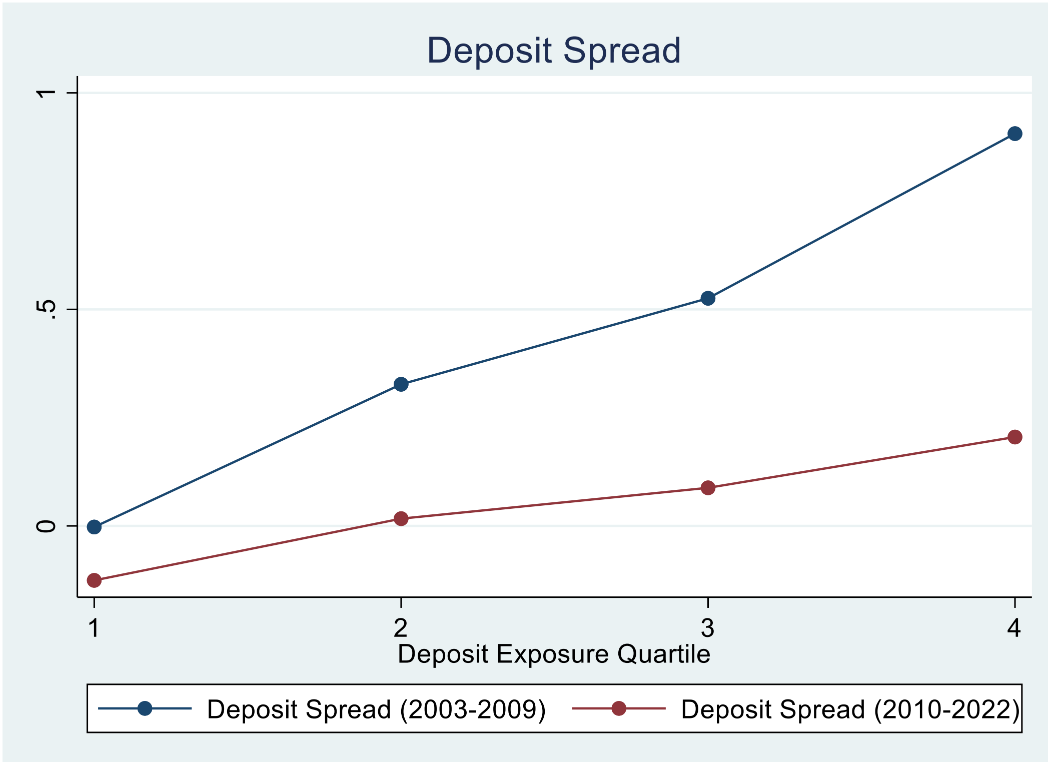

Figure 6: Deposit Spread by Deposit exposure Group

This figure plots average deposit spreads for firms belonging to different *Deposit exposure* quartiles. Deposit spread is defined as the effective federal funds rate minus the deposit yield. The graph shows 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.

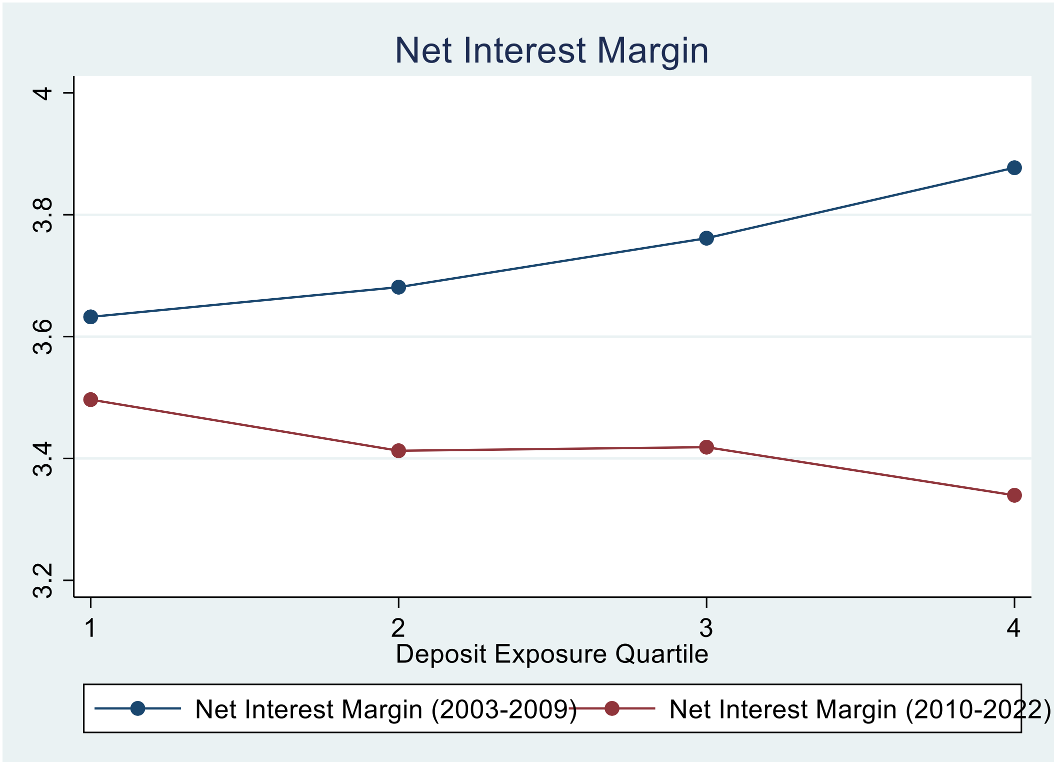

Figure 7: Net Interest Margin by Deposit exposure Quartile

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

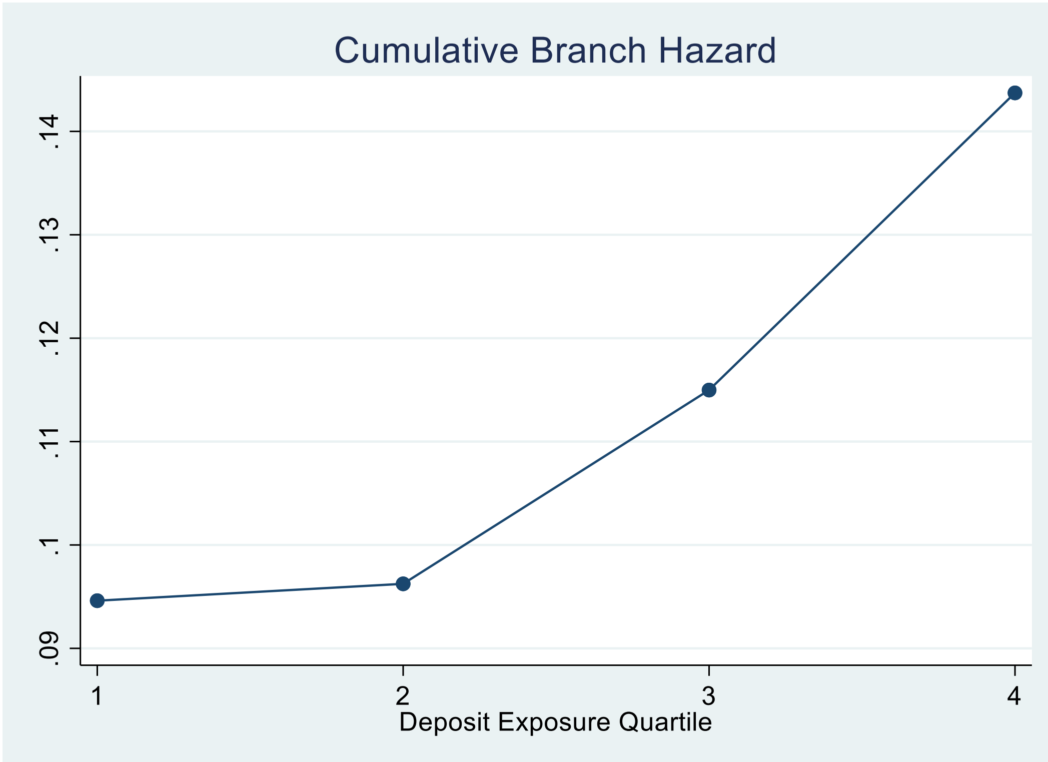

Figure 8: Cumulative Bank-level Branch Hazard by Deposit exposure Quartile
This figure plots the average bank-level cumulative branch hazard rate over 2010-2022 for banks belonging to the four quartiles of *Deposit exposure*.

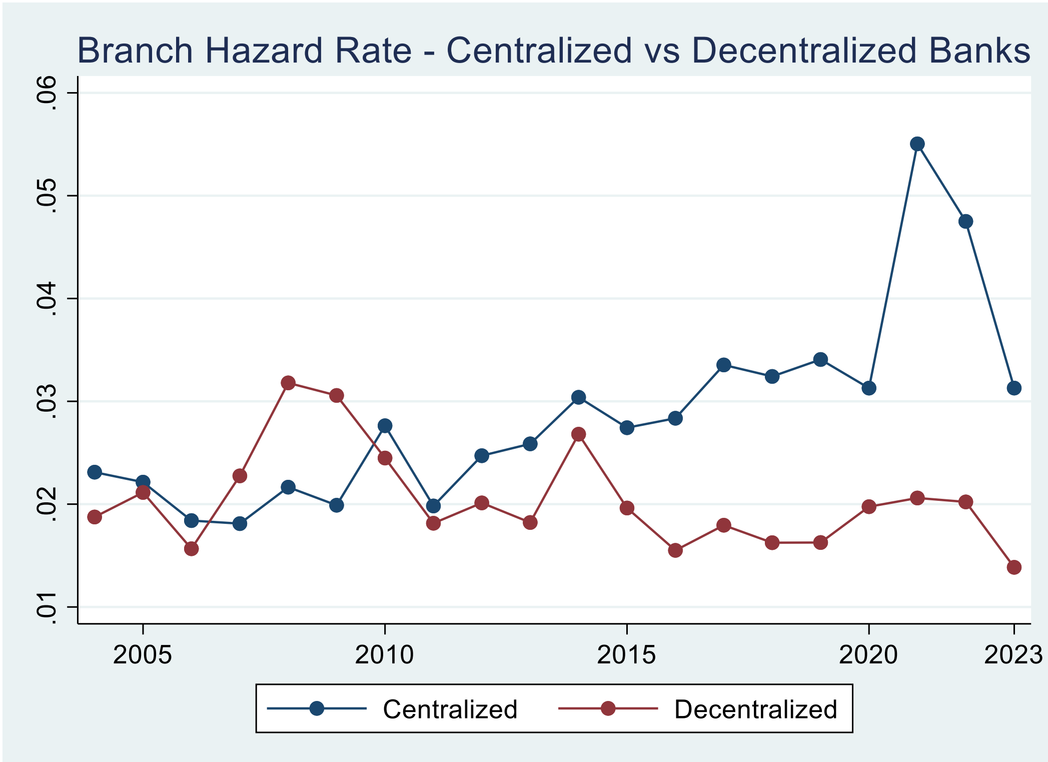

Figure 9: Branch Hazard Rate – Centralized vs. Decentralized Banks

This figure plots the annual branch hazard rate for centralized and decentralized banks. For each group of banks, the branch 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.

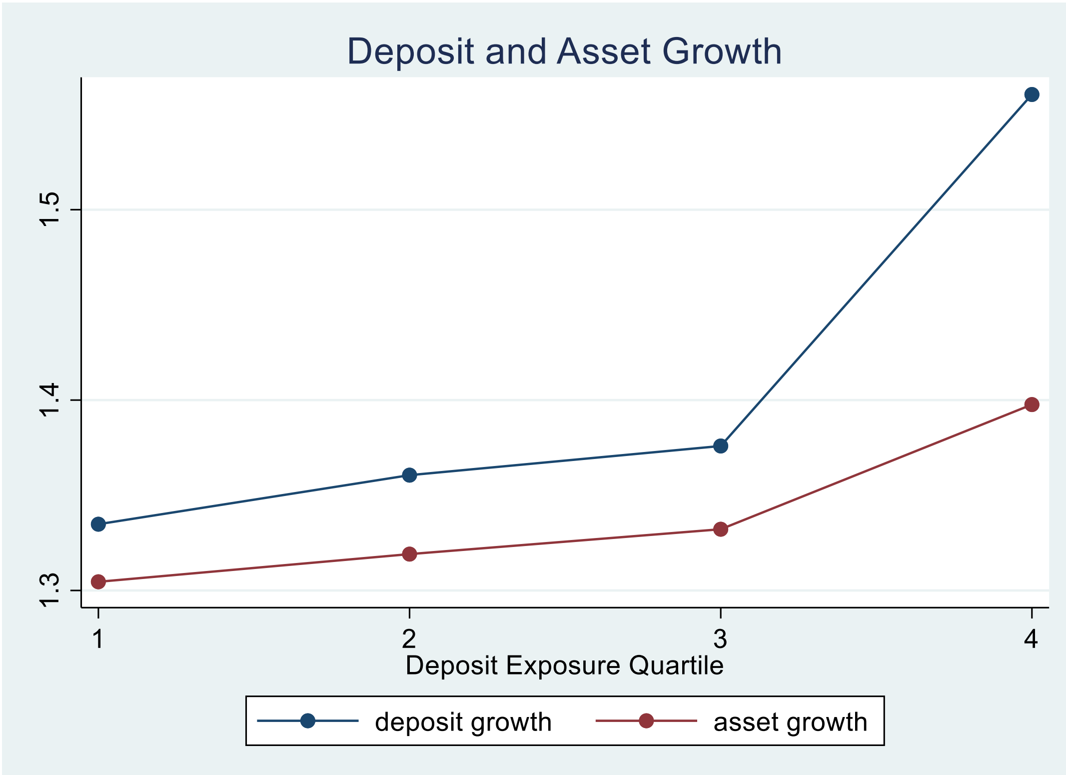

Figure 10: Bank-level Deposit and Asset Growth by Deposit exposure Quartile
This figure plots average bank-level gross deposit and asset growth over 2010-2022 for banks belonging to the four quartiles of *Deposit exposure.*

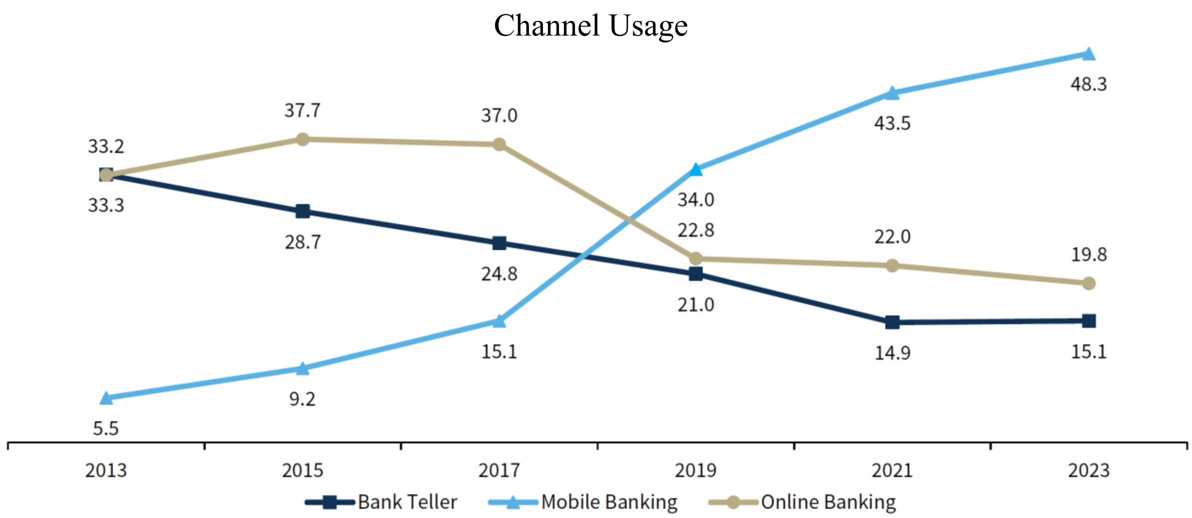

Figure 11: Primary Channel Used to Access Deposit Services.
This figure plots the percentage of bank customers using branch, mobile and online banking as their primary (most common) channel use to access deposit services. Source: FDIC 2023 National Survey of Unbanked and Underbanked Households.

Table 1: Summary Statistics

This table reports summary statistics for variables used in our analysis. In 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 exposure* 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. SBL share (<$1m) is the share of small business C&I loans (<$1m) in total loans whereas SBL share (<$100k) is the share of small business C&I loans (<$100k) in total loans. 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 exposure	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
SBL share (<$1m)	0.03	0.03	0.01	0.02	0.04	3,713
SBL share (<$100k)	0.09	0.06	0.05	0.08	0.11	3,713
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 exposure	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 deposit spreads and average interest earnings to *Deposit exposure* 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 the 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 Exposure*, 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 exposure*. 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 exposure* 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 exposure			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 Exposure, and Cumulative Net Hazard Rate – 2022-2024

This table reports the results of OLS regressions relating branch closure rates to *Deposit exposure* and Broadband Exposure. The dependent variable is the cumulative net branch hazard rate over 2022-2024 for a given bank. *Deposit exposure* for each bank is measured over 2010-2022 period. Broadband exposure 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	(3) Cumulative Net Hazard
Deposit exposure	0.197		0.176
	(0.215)		(0.217)
Broadband Exposure		0.042**	0.042**
		(0.020)	(0.020)
Bank size	0.007***	0.007***	0.006***
	(0.002)	(0.002)	(0.002)
Equity/assets	0.029	0.023	0.026
	(0.047)	(0.049)	(0.049)
Deposit/liability	-0.016	-0.019	-0.018
	(0.030)	(0.030)	(0.030)
Loan/assets	0.002	-0.002	0.001
	(0.020)	(0.020)	(0.021)
Observations	3,533	3,513	3,513
Adj. R-squared	0.002	0.004	0.004

Table 6: *Deposit exposure*, *Broadband Exposure* and Net Cumulative Hazard: County Level Analysis

This table reports the results of OLS regressions relating branch closure rates to deposit exposure and broadband exposure. The dependent variable is the cumulative branch hazard rate over 2010-2022 for a given county. Deposit exposure and Broadband exposure 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, share of population aged 21 and above who are college educated, population growth rate (2010-2022), and household income growth rate (2010-2022). 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	5.256***	5.473***	-0.029
	(0.358)	(0.416)	(2.117)
Broadband exposure		0.199***	0.615***
		(0.036)	(0.161)
Deposit exposure ×			7.695***
Broadband exposure			(2.903)
Population density		0.002	0.002
		(0.002)	(0.002)
Median age		0.002**	0.002***
		(0.001)	(0.001)
Median household income		0.001	0.001
		(0.000)	(0.000)
College education share		-0.101*	-0.101*
		(0.058)	(0.058)
Population growth		-0.267***	-0.268***
		(0.055)	(0.055)
Household income growth		0.055	0.058
		(0.054)	(0.054)
Observations	3,032	3,024	3,024
Adj. R-squared	0.0659	0.0917	0.0935

Table 7: *Deposit exposure*, *Broadband exposure*, 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 exposure	0.096**	-2.365
	(0.041)	(2.623)
Deposit exposure ×	-1.955**	151.958***
Decentralization	(0.831)	(51.794)
Broadband exposure ×	-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 analysis relating changes in deposit yields, deposit flows and changes in lending 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, the dependent variable in column (2) is the bank-level percentage change in deposits between Q4 of 2021 and Q3 of 2023, the dependent variable in column (3) is the bank-level percentage change in small business loans (SBLs) under $1 million, and the dependent variable in column (4) is the bank-level percentage change in SBLs under $100k. *Deposit exposure* for each bank is measured over the 2010-2022 period. In columns (5) - (8), 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* and other control variables, which we report in column (2) of Table 3. We report the results of the second stage in columns (5) - (8), where the dependent variables are those used in columns (1) – (4) 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.

					2SLS			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Δ Deposit Yield	Δ Deposit	Δ SBL (<$1m)	Δ SBL (<$100k)	Δ Deposit Yield	Δ Deposit	Δ SBL (<$1m)	Δ SBL (<$100k)
Deposit exposure	44.247***	-0.905***	-0.916*	-1.493***				
	(4.415)	(0.308)	(0.486)	(0.548)				
Δ Branch Density					-0.281***	0.005***	0.005*	0.010***
					(0.036)	(0.002)	(0.003)	(0.003)
Bank size	1.268***	-0.001	-0.034***	-0.025***	2.088***	-0.016**	-0.050***	-0.052***
	(0.046)	(0.003)	(0.005)	(0.006)	(0.112)	(0.006)	(0.009)	(0.011)
Equity/assets	4.642***	-0.182**	-0.091	-0.153	5.873***	-0.242***	-0.093	-0.108
	(1.182)	(0.082)	(0.162)	(0.186)	(1.554)	(0.089)	(0.163)	(0.192)
Deposit/liability	-0.518	-0.146***	0.007	0.012	1.592	-0.185***	-0.021	-0.048
	(0.711)	(0.050)	(0.085)	(0.097)	(0.998)	(0.057)	(0.087)	(0.102)
Loan/assets	0.053	0.061**	-0.090**	-0.074	-1.716***	0.102***	-0.048	-0.014
	(0.392)	(0.027)	(0.044)	(0.049)	(0.515)	(0.029)	(0.045)	(0.051)
Observations	3,588	3,590	3,485	3,458	3,584	3,586	3,483	3,456

Adj. R-squared	0.241	0.007	0.019	0.010

Table 9: Comparing the Impact of Rate Hikes on Bank Fragility 2004-2006 and 2022-2023

This table reports the results of a DiD analysis of the relationship between changes in deposit yields, deposit flows and changes in lending to *Deposit exposure* pre crisis (Q3 2004 -Q2 2006) and post crisis (Q4 2021 to Q3 2023). The dependent variable in column (1) is the bank-level percentage change in deposit yield in each of the two time periods, the dependent variable in column (2) is the bank-level percentage change in deposits in each period, and the dependent variable in column (3) is the bank-level percentage change in total loans in each period. All dependent variables are scaled by the change in effective fed fund rates over their respective time periods. *Deposit exposure* for each bank is measured over the 2010-2022 period. Post is binary variable equal to 1 if the observation is in the post period. All regressions include bank fixed effects. * p<0.1, ** p<0.05, *** p<0.01.

	(1)	(2)	(3)
	Δ Deposit Yield	Δ Deposit	Δ Loans
Deposit Exposure × Post	9.269***	-0.488***	-0.349***
	(0.878)	(0.107)	(0.104)
Post	1.292***	-0.052***	-0.039***
	(0.053)	(0.006)	(0.006)
Bank FE	Yes	Yes	Yes
Observations	7,170	7,174	7,172
Adj. R-squared	0.445	0.115	0.0722

Table 10: *Deposit exposure*, Branch Closures, and Bank Desertification

This table reports the results of OLS regressions relating branch closure rates to *Deposit exposure* and *Broadband exposure*. 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 exposure* 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, population growth rate (2010-2022), and household income growth rate (2010-2022). 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	5.135**	0.340***	0.363**
	(2.191)	(0.092)	(0.151)
Broadband exposure	-0.554**	-0.003	-0.001
	(0.223)	(0.008)	(0.013)
Population density	-0.038*	-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	0.000	0.000	0.000
	(0.002)	(0.000)	(0.000)
College education share	0.109	-0.047***	-0.076***
	(0.223)	(0.013)	(0.021)
Population growth	-0.441*	-0.012	0.005
	(0.265)	(0.012)	(0.020)
Household income growth	0.159	0.018	-0.012
	(0.298)	(0.012)	(0.020)
Observations	681	3,024	3,024
Adj. R-squared	0.013	0.008	0.007

Internet Appendix

Table A.1: *Deposit exposure*, *Broadband Exposure*, 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 Exposure. 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 exposure 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 exposure		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 exposure*, and Cumulative Branch Hazard: County Level Analysis

This table reports the results of OLS regressions relating branch closure rates to deposit exposure and broadband exposure. The dependent variable is the cumulative branch closure rate over 2010-2022 for a given county. Deposit exposure and Broadband exposure 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, population growth rate (2010-2022), and household income growth rate (2010-2022). 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***	7.633***	-1.064
	(0.474)	(0.574)	(2.944)
Broadband exposure		0.260***	0.916***
		(0.049)	(0.223)
Deposit exposure ×			12.157***
Broadband exposure			(4.037)
Population density		0.004	0.004
		(0.003)	(0.003)
Median age		0.000	0.001
		(0.001)	(0.001)
Median household income		0.000	0.000
		(0.001)	(0.001)
College education share		-0.044	-0.043
		(0.080)	(0.080)
Population growth		-0.217***	-0.217***
		(0.076)	(0.075)
Household income growth		0.160**	0.164**
		(0.075)	(0.075)
Observations	3,022	3,014	3,014
Adj. R-squared	0.0898	0.102	0.104

Table A.3: *Deposit exposure*, Retail Hazard, and Cumulative Net Hazard: County Level Analysis

This table reports the results of OLS regressions relating branch closure rates to liability exposure and retail hazard. The dependent variable is the cumulative branch hazard rate over 2010-2022 for a given county. Deposit exposure at the county level is calculated as weighted average of bank-level Deposit exposure, 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, population growth rate (2010-2022), and household income growth rate (2010-2022). 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	5.830***	2.241**
	(0.454)	(0.942)
Retail Hazard	0.009**	0.125***
	(0.004)	(0.027)
Deposit exposure ×		1.924***
Retail Hazard		(0.443)
Population density	0.003	0.002
	(0.002)	(0.002)
Median age	0.002**	0.002**
	(0.001)	(0.001)
Median household income	0.001	0.001
	(0.000)	(0.000)
College education share	-0.125**	-0.123**
	(0.059)	(0.058)
Population growth	-0.274***	-0.280***
	(0.056)	(0.056)
Household income growth	0.065	0.068
	(0.056)	(0.056)
Observations	2,960	2,960
Adj. R-squared	0.0858	0.0914