DESTABILIZING DIGITAL "BANK WALKS"

Naz Koont
Columbia University

Tano Santos
Columbia University and NBER

Luigi Zingales
University of Chicago and NBER

June 13, 2023

Abstract

We study the impact of digital banking on the value of the deposit franchise and the stability of the banking sector. Using the classification of digital banking in Koont (2023), we find that when the Fed funds rate increases deposits flow out faster and the cost of deposits increases more in banks with a digital platform. The results are similar for insured and non-insured deposits. Using the model of Drechsler et al. (2023c), we find that correcting for digital betas and deposit outflows results in a deposit franchise value that is 40% lower for digital-broker banks relative to a traditional bank without digital platform. We apply this analysis to Silicon Valley Bank (SVB) and find that the reduced value of the deposit franchise explains why SVB was insolvent in early March 2023, even before the bank run occurred.

1 Introduction

Banks are in the business of maturity transformation (Diamond and Dybvig (1983), Kashyap et al. (2002), and Hanson et al. (2015)). This business exposes them to liquidity and interest rate risk. The main reason why banks can bear this risk is that deposits are "sticky", i.e. they are not very sensitive to movements in the monetary policy rate (Drechsler et al. (2017)). This stickiness of deposits gives rise to what is referred to as banks' deposit franchise value. This has important implications for bank valuation and stability: even when a rise in interest rates makes the market value of assets fall below the level of liabilities, a bank can survive as long as this shortfall does not exceed the value of the deposit franchise.

As Drechsler et al. (2023c) argue, the value of the deposit franchise is a function of the stickiness of deposits: how much (and for how long) depositors are willing to tolerate a remuneration of deposits much below the policy rate. This stickiness, in turn, is driven by many factors: what deposits are used for, how sophisticated the depositors are, etc. Ceteris paribus, however, technology is an important factor. Since the Great Financial Crisis, over half of the roughly 4,000 existing banks have introduced a mobile app (Koont (2023)). Thus, moving money from a deposit to a money market fund can be done with a single mouse click without leaving your sofa. As a result, it is reasonable to expect that the demand for bank deposits has become much more sensitive to the interest rates offered by alternative forms of liquidity storage (like money market funds), especially in banks with well-functioning digital platforms.

In this paper, we study how the introduction of mobile banking has changed the stickiness of deposits and how this change in stickiness has reduced the franchise value of deposits and consequently the stability of the banking sector.

We start by documenting that on average deposits have become more sensitive to changes in the federal funds rate in the last decade. While the time series evident is consistent with the digitalization hypothesis, it does not prove it. To shed more light on this hypothesis we turn to the cross section of banks. We find that this sensitivity is particularly pronounced for banks with a digital platform and banks with a brokerage account. We find that a 400bps increase in the Fed funds rate, roughly what the Fed increased rates in 2022, leads to a differential drop in deposit growth of 6.4% for non-digital banks without a brokerage and of 11.6% for digital banks with a brokerage.

The fact that a bank has a digital application or a brokerage account may correlate with other characteristics that lead to differential deposit outflows. To dispel this possibility we consider deposit flows within-bank-year, looking at variation across their branch networks. Specifically, for a given bank, we look at whether deposit flows are more sensitive in counties that have higher internet usage, depending on whether the bank is digital or not. Internet usage proxies for the extent to which local customers make use of digital banking. We find that banks' deposit outflows are more pronounced in markets with higher internet usage, but that this is only the case for digital banks (regardless of whether they report brokerage fees or not). County-level deposit outflows are 18% larger, and rate increases are 54% larger for a given digital bank that reports brokerage fees in counties with 100% household internet usage when compared to counties with no internet usage whatsoever.

As a second step, we analyze the beta of deposits, that is, how much the remuneration of deposits increases with the federal fund rate. We find that in recent years the beta of digital-broker banks is significantly higher, at 0.402 compared to the beta of non-digital banks (0.348).

Having obtained an estimate for two of the key parameters of the Drechsler et al. (2023c) model of the value of deposit franchise, we can estimate that the value of deposit franchise is 40% lower in digital banks. We then compare the market value of SVB assets as of December 2022 with its liabilities. If we use the estimates in DSS to compute the value of the deposit franchise, the market value of SVB assets exceeded the value of its liabilities by $2bn. By contrast, if we use the value of the parameters of a digital bank (as SVB was), the market value of SVB assets was $5bn short of the value of liabilities, thus SVB was insolvent. This example illustrates how more fragile the banking system has become and the additional challenges to monetary policy that digitalization brings.

Related Literature.

Interest rates on deposits do not adjust one to one to the return depositors can obtain elsewhere (Berger and Hannan (1989), Diebold and Sharpe (1990), Hannan and Berger (1991), Neumark and Sharpe (1992), Driscoll and Judson (2013), and Drechsler et al. (2017, 2021)). Much of this literature attributes this limited passthrough to imperfect competition.[1] We show a different dimension of limited passthrough: technology. Digitalization affects how banks adjust deposit rates, say, in the presence of of an increase in the Fed fund rate and as well as deposit outflows when there is an imperfect passthrough of that increase. We build on Koont (2023), who docu-

[1]For an early review of the empirical literature on competition in banking see Degryse and Ongena (2008).

ments that banks' digital platform adoption leads to compositional changes in funding towards less stable deposits that require higher interest rates and are more sensitive to bank risk. We follow Drechsler et al. (2021)'s empirical methodology closely and re-estimate the sensitivity of deposit rates to shocks in the Fed funds rate depending on whether banks have digital platforms and offer their customers brokerage services.

The stickiness of deposits is an important source of value for banks: The ability of the bank to retain deposits at rates below those depositors could in principle obtain elsewhere is potentially a significant component of the equity market value. Hutchison and Pennacchi (1996, p. 401) were the first to write a simple model to estimate what they referred to as the "a bank's monopoly rent from issuing retail deposits." More recently, Drechsler et al. (2023c, p. 9) have referred to the difference between the book and market value of deposits as the deposit franchise value of the bank. This value is of course directly related to the sensitivity of deposit rates to other rates available to depositors. Our paper is the first to use this framework to assess the effect of digitalization on the value of the deposit franchise. We argue that digitalization lowers this value and that this has important consequences for financial stability.

More broadly, these findings are important because they speak to the sensitivity of bank profitability to interest rate changes and overall financial stability.[2] In particular, our work connects to Egan et al. (2017) and Jiang et al. (2023). Egan et al. (2017) explore the financial stability consequences of uninsured depositors sensitivity to bank distress. Uninsured depositors are more likely to withdraw in the presence of an increase in the CDS spreads, for instance; the more sensitive uninsured depositors are to distress, the higher the interest rates that banks have to offer depositors, which lowers profitability and makes the existence of a run equilibrium more likely. Jiang et al. (2023) explore the financial stability consequences associated with the losses in the banks' hold-to-maturity portfolios. These losses are the result of the unprecedented speed of interest rate rises by the Federal Reserve throughout 2022 (see also Drechsler et al. (2023b)). If

[2]Samuelson (1945) is an early reference in the literature; see also Hancock (1985). Flannery (1981, 1983) finds that bank profitability have a low exposure to interest rate changes, the reason being that "large banks have effectively hedged themselves against market rate risk by assembling asset and liability portfolios with similar average maturities." English (2002) presents some international evidence consistent with this lack of exposure of bank profitability to interest rates. A more recent literature explores banks' exposure, or the lack thereof, to interest rates shocks using balance sheet data; see for instance Begenau et al. (2015), amongst others. Finally, another literature looks at changes in bank equity valuation due to shocks in interest rates. See, for example, English et al. (2018), who use high frequency data to assess the effect of FOMC announcements on bank stock valuation.

interest rate increases are small, so are the losses and a run equilibrium does not exist, whereas it does if the rate hike is large enough. Acharya et al. (2023) are concerned with the instability of deposit funding associated with the expansion and contraction of the Fed's balance sheet during QE and QT (quantitative tightening) episodes: Banks finance reserve holdings with deposits but do not shrink them when they lose them as the Fed pivots away from QE to QT .

Finally, there is a small but rapidly growing literature on the effect of digitalization on banks.[3] In a contemporaneous piece Erel et al. (2023) study online banks' deposit flow sensitivity to changes in the federal fund rates. Their focus is on banks that interact with customers mostly or entirely online. Their sample comprises seventeen banks that represent about 5% of total system deposits. They find that online banks increase interest rates significantly more than traditional banks but do not experience deposit outflows. We focus on banks with digital platforms, not just online banks, and find that they increase rates more than banks with no digital platforms and in addition they experience greater deposit outflows. Jiang et al. (2022) explores the effects of bank competition in the era of digital banking on financial inclusion. Haendler (2022) documents the effects of mobile banking competition on the business models of small community banks. Hong et al. (2019) show that the digitalization of asset management can lead to highly synchronized investor behavior. Curi et al. (2023) show that the digitalization of banking has been a significant factor in market valuation, especially during the Covid-19 shock. Related to the recent banking crisis, Cookson et al. (2023) document the role of social media, specifically Twitter, in fueling the bank run at SVB. Our work is most closely related to Koont (2023), who traces out the effects of endogenous adoption of digital platforms on the industrial organization of the banking sector and the effects on financial stability. We focus on the effect of digitalization on the stickiness of the deposits and the value of the deposit franchise.

2 Data and Definitions

Digital Banks. Our data on banks' digital platforms comes from Koont (2023), who constructs a data set related to the introduction of digital banking platforms for the universe of more than 4,000 US banks. Specifically, our baseline measure of banks' digital presence is based on the release dates of banks' earliest mobile applications on either the Apple or Android App Store. In order to

[3] See Stulz (2019) for a discussion of how digitalization and FinTech threaten banks' business models.

focus our analysis on banks with significant usage of digital platforms, we leverage information on the number of reviews that these applications receive, and we take a higher number of reviews to correlate with significant use of the digital platform. Throughout the paper, we define a bank to be *Digital* if it has a digital platform with at least 300 reviews. Table 1 panel A tabulates the number of digital banks in 2022, and Table 1 panel B repeats the tabulation focusing only on banks with between $1 and $250 billion in asset size.[4]

Brokers. In addition to identifying digital banks, we categorize banks depending on whether or not they have a brokerage. In order to do so, we collect banks' income in fees and commissions from securities brokerage from the FFIEC Consolidated Reports of Condition and Income, generally referred to as Bank Call Reports. These regulatory filings provide quarterly bank-level information for every U.S. commercial bank. We find that 10% of banks report non-zero brokerage income in 2022. Throughout the paper, we define a bank to be a *Broker* if it reports non-zero brokerage income. Table 1 panel A tabulates the number of banks that are brokers and that have digital applications in 2022, and Table 1 panel B repeats the tabulation focusing only on banks with between $1 and $250 billion in asset size.

Bank Deposits. We construct various categories of bank deposits, as following. First, we consider bank-level deposits, which we take to be the sum of savings deposits, demand deposits, and time deposits from banks' Call Reports. Second, we consider bank-level Core deposits, which are defined by the FDIC as the sum of savings deposits, demand deposits, and small time deposits below $250,000 from the FDIC Statistics of Deposit Institutions (SDI).[5] Third, we consider bank-level estimated insured deposits from the FDIC SDI. Finally, at the bank-branch level, we obtain deposits from the FDIC Survey of Deposits (SOD).

Additional Data Sources. We thank Jiang et al. (2023) for providing data and measures on banks' marked-to-market securities losses in 2022. We further collect additional bank balance sheet quantities from banks' Call Reports. We augment this data with branch-level bank deposit rate information from RateWatch. Additionally, for our within-bank analysis, we obtain annual

[4]From Table 1, it is clear that banks with larger asset size tend to adopt digital platforms. For more on banks' endogenous digital platform adoption decisions, see Koont (2023).

[5]See https://www.fdic.gov/regulations/reform/coredeposit-study.pdf

branch locations from the FDIC Survey of Deposits. We collect the proportion of households in a county that have internet subscriptions from the 2019 Census American Community Survey, using the 5-year estimates. We hand-collect information from SVB's consolidated quarterly reports. Aggregate time-series data on nominal commercial bank deposits, GDP, and the effective federal funds rate come from FRED. Throughout the paper we refer to the effective federal funds rate as the "Fed funds" rate. Table 1 panel C provides summary statistics on balance sheet quantities and deposit rates.

3 Deposit walks and interest expense betas

3.1 Deposits and interest rates: Time series evidence

The stability of deposits plays a central role in the banking literature. Other than their payment needs, and abstracting from the possibility of undesirable bank runs, depositors may withdraw funds either because they are concerned about the health of the bank and they hold uninsured deposits or because they hope to obtain higher interest rates on their funds than those paid by the bank on their deposits. Our focus is on this last source of deposit sensitivity. In particular, it is the stickiness of deposits that is the source of the banks' deposit franchise value: The component of the value of the bank that is due to the fact that deposits remain with the bank even when interest rates go up by more than the interest on deposits. Increases in interest rates may result in higher net interest margins if banks have a sizable portfolio of adjustable interest rate loans and rates on deposits increase by less. These gains partially compensate for the losses borne by banks on the assets, such as securities and fixed rate loans, held in the balance sheet. Thus if deposits become less sticky, the value of the deposit franchise is lower and so is the value of the bank.

To begin exploring whether bank deposits have become more sensitive to interest rate shocks we estimate a simple time series regression of changes in normalized deposits to changes in the Fed funds rate. Specifically, for each decade in the sample we run the following time series regression with quarterly data from 1973 to 2023,

$$\Delta\left(\text{Deposits/GDP}\right)_{t,t-1} = \beta_0 + \beta_1 \times \Delta FFR_{t,t-1} \times \text{Decade}_t + \varepsilon_t, \tag{1}$$

where $\Delta\left(\text{Deposits/GDP}\right)_{t,t-1}$ is the level change in the ratio of nominal deposits to nominal GDP from quarter $t-1$ to quarter t, $\Delta FFR_{t,t-1}$ is the level change in the Fed funds rate between quarter $t-1$ and t, and Decade_t is an indicator variable for each decade.[6]

Table 2 reports the results. Figure 1 Panel B suggests that the elasticity of deposits as a share of GDP with respect to increases in Fed funds rate is much higher in recent years. Table 2 shows time series evidence that is consistent with this hypothesis: Deposit outflows in the presence of interest rate increases were more pronounced staring in the first two decades of the 21st century than in the last third of the 20th. In the first decade of the current century, a 100 bps increase in the Fed funds rate was associated with a 0.5% decrease in deposits to GDP, which is statistically significant, but not economically large. In the last decade, however, a 100 bps increase in the Fed funds rate is associated with a 3.6% decrease in the deposit-to-GDP ratio.

Obviously, this regression simply reports a correlation and does not speak to the channel that is our concern: Whether deposits have become more sensitive to interest rate changes. In general, there are several reasons why the sensitivity of deposits to the Fed funds rate might be greater in the last 25 years. First, money market funds were created only in 1971 and started to be massively diffused only at the end of the 1990s. Second, the 1999 repeal of Glass Steagall allowed banks to own brokerage accounts and integrate them in their services. Third, the diffusion of the internet has facilitated the discovery of alternatives to deposits offering better rates. Last but not least, Koont (2023) documents that since the Great Financial Crisis, over half of the roughly 4,000 existing banks have introduced a mobile app, further facilitating moving funds from bank deposits to money markets. As a result, moving money from a deposit to a money market fund can be done with a single mouse click without leaving the living room sofa. Thus, it is reasonable to expect that the demand for bank deposits has become much more sensitive to the interest rates offered by alternative forms of liquidity storage (like money market funds), especially in banks with well-functioning digital platforms.

Unfortunately, in the last 15 years interest rate hikes have coincided with periods of quantitative tightening, so it is impossible to identify the effects of these regulatory and technological changes in the time series. For this reason, we resort to the cross section of banks.

[6]Given data availability, the 1970 decade ranges from 1973 through 1979, and the 2010+ decade includes 2010 through 2023.

3.2 Digital Banking and the sensitivity of deposits to interest rates

3.2.1 Digital banking, brokerage and deposit outflows in 2022 and 2023

Figure 3 Panel A plots the quarterly growth rate in deposits (the sum of demand, savings, and time deposits) averaged across banks for digital and non-digital banks.[7] We focus on mid-sized banks, those between $1B and $250B in assets, as they have been at the center of much of the turmoil in early 2023. Table 1 panel B documents that 64% of these mid-sized banks are digital.

The analysis is restricted to the period of monetary tightening and thus we start the plot in the third quarter of 2021. In the third quarter of 2022, the rate of growth of deposits for digital and non-digital banks diverges as the pace of Fed funds rate increases accelerates. In fact, digital banks start experiencing deposit outflows in the fourth quarter of 2022. In the debate following the collapse of SVB, much has been made of the differential behavior of insured versus uninsured deposits. We restrict our attention to banks' estimated insured deposits as reported to the FDIC in panel B. While the overall growth trends are more muted, the divergence in rates of growth for digital and non-digital banks is even larger at the end of 2022. Whatever happened in the banking system in late 2022 and early 2023 was not just about the flight of uninsured deposits.

In addition, banks that supply brokerage services facilitate transferring deposits to other accounts, such as money market mutual funds. To explore this channel, we further split banks depending on whether they report non-zero income due to fees and commissions from securities brokerage, as described in Section 2. There are thus four types of banks, banks that have neither a digital platform nor report brokerage fees, banks that have no digital platform but offer brokerage services, banks that have digital platforms but no brokerage services and finally banks that offer both digital banking as well as brokerage. To simplify our terminology, we refer throughout as banks that have neither digital apps nor report brokerage fees as "traditional banks". 31% of mid-sized banks are digital-brokers, as documented in Table 1 panel B. Figure 3 Panel C shows that brokerage makes difference: Independently of whether the bank has a digital platform or not, they experienced deposit outflows in the second quarter of 2022. Notice that in the case of non-digital

[7] This figure differs slightly from Figure 1 in our blog post in the Promarket website. In this paper we use a consistent definition of digital banks to be those that have greater than 300 reviews on their mobile application. There, we had excluded banks below $5B in asset size, and given the sample of larger banks, had used a stricter definition of digital banks to be those that had (in logs) a number of reviews to deposits in the top quartile of the distribution and greater than 300 reviews. See https://www.promarket.org/2023/04/04/destabilizing-digital-bank-walks/

banks, the rate of growth of deposits bounced back, whereas it did not for digital banks. Finally, in panel D we consider estimated insured deposits, we find that traditional banks maintain stable insured deposit growth through the end of 2022 while digital-broker banks experience nearly a 3% decline in their insured deposit growth throughout 2022.

3.2.2 Bank-level panel regressions

To formalize the findings in Figure 3 we estimate a panel regression of the form,

$$\begin{aligned} \frac{\mathrm{Y}_{b,t} - \mathrm{Y}_{b,t-1}}{\mathrm{Y}_{b,t-1}} = \alpha_b \quad &+ \quad \beta_1 \, \Delta FFR_{t,t-1} + \beta_2 \, \Delta FFR_{t,t-1} \times \mathrm{Digital}_{b,t} \\ &+ \quad \beta_3 \, \Delta FFR_{t,t-1} \times \mathrm{Broker}_{b,t} \\ &+ \quad \beta_4 \, \Delta FFR_{t,t-1} \times \mathrm{Digital}_{b,t} \times \mathrm{Broker}_{b,t} + \varepsilon_t, \end{aligned} \tag{2}$$

where $\mathrm{Y}_{b,t}$ is the outcome variable of interest in each specification. We expand our analysis to the universe of banks annually between 2010 and 2022. The main explanatory variable is thus $\Delta FFR_{t,t-1}$, the change in the Fed funds rate between years $t-1$ and year t, retrieved from FRED, in percentage points, interacted with the corresponding indicator variables. $\mathrm{Digital}_{b,t}$ is an indicator variable that takes the value one if bank b has a digital platform in year t and $\mathrm{Broker}_{b,t}$ is an indicator variable that takes the value one if bank b has a brokerage in year t. We additionally include a bank fixed-effect, α_b, to absorb out the average growth for each bank, including effects driven by average differences in size.

Table 3 reports the estimates for different outcome variables of interest. In column (1) the dependent variable is the annual proportional change in deposits (including savings, time and demand deposits as reported in the Call Reports). An increase in the Fed funds rate of 100 bps decreases deposit growth in a traditional bank (those with neither a brokerage nor a digital application) by 1.6%. It decreases further by another .6% if the bank has a digital platform and .7% if the bank offers brokerage services. Thus, banks with both digital and brokerage services decrease deposit growth rates in the presence of a 100 bps increase in the Fed funds rate by an additional 1.3%. That is, the presence of digital platforms and brokerage services almost doubles the slowdown in deposit growth relative to that experienced by traditional banks.

In column (2) the dependent variable is the annual proportional change in Core deposits, i.e. where we now exclude uninsured time deposits over $250,000. The effects look very similar, despite the intention that Core deposits should include “deposits that are stable and lower cost and that reprice more slowly than other deposits when interest rates rise".[8] This again confirms that the outflow of deposits from the banking sector is not driven solely by those deposits classified by regulators to be "flightier".

In column (3) the dependent variable is the annual proportional change in savings and demand deposits, excluding time deposits. In the case of time deposits, clients bear additional costs of withdrawing funds before maturity, which of course makes them "sticky" in the short run. Consistent with this intuition, when we exclude them from the estimation, we find that an increase in the Fed funds rate by 100 bps decreases deposit growth for a traditional bank by 3.9%. For digital-broker banks the overall decrease becomes 5.5%, where much of the differential effect is coming from the presence of a broker which leads to a 1.2% additional slowdown in deposit growth.

In column (4) the dependent variable is the annual proportional change in banks' estimated insured deposits, as reported to the FDIC. We find that a 100 bps increase in the Fed funds rate decreases insured deposit growth for a traditional bank by 1.4%, but by 1.7% for a digital bank, regardless of whether or not it offers brokerage services. Thus, although the magnitudes are muted for estimated insured deposits, the differential trends across digital and non-digital banks remain.

The results in columns (1)-(4) speak of the effect of shocks to the Fed funds rate on deposits, but in principle shocks to the Fed funds rate may also an effect on the composition of deposits depending on whether the bank has a digital application or offer brokerage services. We estimate equation (2), but using as a dependent variable the annual proportional change in the ratio of interest bearing deposits to overall deposits. The results are shown in column (5). An increase in the Fed funds rate of 100 bps increases the ratio of interest bearing deposits by .5% for a bank with neither a brokerage nor a digital application. The effect increases to 1.1% for a bank that has both a brokerage and a digital application.

In sum then, a 100 bps increase in the Fed funds rate reduces the rate of growth of deposits by 2.9% for banks with digital platforms and brokerage services, whereas it is only 1.6% for traditional banks. At the same time, a 100 bps increase in the Fed funds rate alters the composition of deposits towards those that bear interest by 1.1% for digital-broker banks, whereas it only does so by .5% for traditional banks.

[8]See https://www.fdic.gov/regulations/reform/coredeposit-study.pdf

3.2.3 Within-bank-year panel regression

The fact that a bank has a digital platform or offers its clients brokerage services may correlate with other characteristics that make deposits and rates behave differently in the presence of shocks to the Fed funds rate. To dispel that possibility we estimate the following regression,

$$\begin{aligned}\frac{\mathrm{Y}_{b,c,t} - \mathrm{Y}_{b,c,t-1}}{\mathrm{Y}_{b,t-1}} &= \alpha_{bt} + \alpha_{ct} + \beta_1 \; \Delta FFR_{t,t-1} \times \text{Internet}_c \times \text{Digital}_{b,t} \\ &+ \beta_2 \; \Delta FFR_{t,t-1} \times \text{Internet}_c \times \text{Broker}_{b,t} \\ &+ \beta_3 \; \Delta FFR_{t,t-1} \times \text{Internet}_c \times \text{Digital}_{b,t} \times \text{Broker}_{b,t} + \varepsilon_t\end{aligned} \tag{3}$$

We estimate this bank-county-year panel between 2010 and 2022. We include a bank-year fixed effect α_{bt}, thereby restricting variation to be across different counties that a bank operates in when it faces a shock to the Fed funds rate, where the “treatment intensity” is determined by each county’s internet usage, Internet_c. We further include a county-year fixed effect α_{ct}, taking out the county-level average effect in a given year and looking at variation across types of banks, depending on whether or not they are digital and offer brokerage services. The main explanatory variable now is thus $\Delta FFR_{t,t-1} \times \text{Internet}_c$, which is the level change in the Fed funds rate in percentage points, interacted with county-level proportion of households that have internet subscriptions, which is a variable that ranges from 0 to 1. We further interact this explanatory variable with the indicator variables for bank categories, $\text{Digital}_{b,t}$ and $\text{Broker}_{b,t}$, which were defined above.

In table 4 column (1) the dependent variable is the proportional change in deposits of bank b in county c across year t, and we only include the indicator variable $\text{Digital}_{b,t}$. Bank b’s deposits in a given county c are calculated as the sum of all deposits accruing to branches of bank b within the county c. We find that for a given 100 bps increase in the Fed funds rate, banks with digital platforms face more pronounced outflows in markets with high internet usage: their differential deposit growth is 18% lower in counties that have full internet usage relative to counties with no internet usage, after controlling for the average yearly growth rate of each county with the county-year fixed effect. In column (2) we repeat the analysis including indicator variables for broker banks, and find no significant differential effect for these banks.

Notice that this analysis allows us to rule out two key identification concerns. The bank-year and county-year fixed effects together controls for time-varying differences in banks’ investment opportunities and overall depositor clientele. For instance, it may be that the investment opportunities of banks with digital platforms deteriorate when the Fed funds rate increases by more than those of banks with no digital platform. As a result, banks with digital platform may underwrite a lower amount of loans and create less deposits. However, deposits are fungible across counties and can be invested at the bank-level, thus this alternative story does not explain why digital banks would suffer larger deposit outflows in counties with greater internet usage. If local loan growth varies across counties, leading to differential deposit growth, it should not vary differently for digital banks relative to non-digital banks within the same county.

Second, it may be that depositors of digital banks are flighty for a reason orthogonal to the existence of a digital platform. For instance, it may be that digital bank depositors work in cyclical industries, which requires them to dip further into their savings during periods of economic downturn. These exposed industries may be concentrated in certain counties that correlate to some extent with county-level internet usage. However, this alternative story does not explain why digital banks would suffer differentially larger deposit outflows in counties with greater internet usage relative to non-digital banks in those same counties.

Thus, through the inclusion of bank-year and county-year fixed effects, we are able to cleanly identify that digital platforms do indeed lead to greater deposit outflows in response to changes in the Fed funds rate, and that this is accompanied by a differential proportional increase in banks' deposit savings rates as they try to hold on to these "walking" depositors.

In sum, we find that banks' deposit outflows are more pronounced in markets with higher internet usage, but that this is only the case for digital banks, regardless of whether they report brokerage fees or not. This supports the interpretation that digital banking has led to a higher sensitivity of deposits to shocks in the Fed funds rate and, potentially, a decrease in the franchise value of deposits. We explore in Section 4 the implications of this observation for financial stability and the banking crisis of 2023.

3.3 Deposit rates, interest expense betas and digital banking

So far the focus has been on how deposits react to increases in the Fed funds rate. In Table 3 we documented that digital banks experience greater deposit outflows in the cross-section of banks, and in Table 4 columns (1) and (2) we showed that within-bank, digital banks face greater deposit outflows in counties with greater internet usage in the presence of increases in the fed funds rate. The question is of course whether digital banks try to steam deposit flight through increases in deposit rates.

To start answering this question, Table 4 columns (3) and (4) show the results of estimating the within-bank specification, Equation (3), but now using as a dependent variable the proportional change in the insured deposit savings rate of bank b in county c across year t. In column (3) we only include the indicator variable $\text{Digital}_{b,t}$; column (4) includes indicator variables for broker banks. The insured deposit savings rate is calculated as the average savings rate for deposit volumes below \$100,000 across the branches of bank b in county c, where the data come from RateWatch. We find that for a given 100 bps increase in the Fed funds rate, banks with digital platforms increase their deposit rates in markets with high internet usage: their deposit rates increase by 54% in counties that have full internet usage relative to counties with no internet usage. Column (4) shows that there are no significant differential effect for banks which offer brokerage services.

Next, we turn to calculating a bank-level measure of banks' sensitivity of interest rates to changes in the Fed funds rate. Drechsler et al. (2021) suggest a bank-level estimation technique for what they refer to as banks' interest expense beta.[9] Specifically they suggest the following specification

$$\Delta \textit{IntExp}_{bt} = \alpha_b + \sum_{\tau=0}^{3} \beta_{b,\tau}^{\text{Exp}} \Delta FFR_{t-\tau} + \varepsilon_{bt}, \tag{4}$$

and define the bank-specific interest expense beta as $\sum_{\tau=0}^{3} \beta_{b,\tau}^{\text{Exp}}$ "to capture the cumulative effect of Fed funds rate changes over a full year".[10] We follow this methodology, but estimate a single average interest expense beta for the panel of banks in our sample rather than bank-specific betas. In this section we follow the convention in Drechsler et al. (2023c) of reporting the Fed funds rate, FFR, in decimals so that .01 is 1 percentage point. Table 5 reports the results of our replication along with several other specifications, and additionally reports the sum of the coefficients as the interest expense beta at the bottom of each column. In column (1), we reproduce the average interest expense beta found by Drechsler et al. (2021), using their time sample of 1983 through 2017. We find an average expense beta of 0.364, which is very close to their estimate of 0.345. As they state, an increase of 100 bp in the Fed funds rate results in an increase of about 35 bp in an

[9]See also Kang-Landsberg et al. (2023), who also calculate the cumulative change in deposit rates relative to the cumulative change in the fed funds rate over several tightening cycles.

[10]See Drechsler et al. (2021, p. 1112) equation (9) and the discussion around it.

average bank's interest expense. Column (2) repeats the exercise for the sample period between 2010 to 2017, the period of the digital banking revolution, which we again stop at the last year of the sample period considered by Drechsler et al. (2021). We find a similar interest expense beta of 0.352 in this time period.

In Table 5 column (3), we now consider the differential interest expense beta of digital banks. In order to do so, we estimate the following regression specification,

$$\Delta \mathit{IntExp}_{bt} = \alpha_b + \sum_{\tau=0}^{3} \beta_{\tau}^{\text{Exp}} \Delta FFR_{t-\tau} + \sum_{\tau=0}^{3} \beta_{\tau}^{\text{Digi Exp}} \Delta FFR_{t-\tau} \times \text{Digital}_{b,t} + \varepsilon_{bt}, \quad (5)$$

and calculate the digital interest expense beta to be the sum of statistically significant coefficients $\sum_{\tau=0}^{3} \beta_{b,\tau}^{\text{Exp}} + \beta_{b,\tau}^{\text{Digi Exp}}$, whereas the interest expense beta for a traditional bank remains the sum of statistically significant coefficients $\sum_{\tau=0}^{3} \beta_{b,\tau}^{\text{Exp}}$. We find that the interest expense beta for digital banks is significantly higher than that of traditiona banks, at 0.397 relative to 0.343.

Finally, in Table 5 column (4), we consider the differential interest expense beta of digital-broker banks. We estimate now the following,

$$\begin{aligned} \Delta \mathit{IntExp}_{bt} = \alpha_b \; &+ \; \sum_{\tau=0}^{3} \beta_{\tau}^{\text{Exp}} \Delta FFR_{t-\tau} \\ &+ \; \sum_{\tau=0}^{3} \beta_{\tau}^{\text{Digi-Broker Exp}} \Delta FFR_{t-\tau} \times \text{Digital}_{b,t} \times \text{Broker}_{b,t} + \varepsilon_{bt}, \end{aligned} \quad (6)$$

and calculate the digital interest expense beta to be the sum of statistically significant coefficients $\sum_{\tau=0}^{3} \beta_{b,\tau}^{\text{Exp}} + \beta_{b,\tau}^{\text{Digi-Broker Exp}}$, whereas the interest expense beta for a bank that does not have both a digital platform and brokerage services is calculated to be the sum of statistically significant coefficients $\sum_{\tau=0}^{3} \beta_{b,\tau}^{\text{Exp}}$. Again, we find that the interest expense beta for digital-brokers is significantly higher, at 0.402 compared to an average beta of 0.348.

Thus far we have stopped the sample at 2017, consistent with the sample period considered in Drechsler et al. (2021). Next, in Table 6, we repeat the analyses and extend the sample through 2022. Column (1) reports the average interest expense beta during the period 2010 through 2022 to be 0.268, which is lower than the values reported for the sample ending in 2017. As these authors themselves note in a recent brief note, the estimates of interest expense beta have come down in the last part of the sample.[11] Further, the components of $\sum_{\tau=0}^{3} \beta_{b,\tau}^{\text{Exp}}$ appear to

[11] See Drechsler et al. (2023a). In particular they reference a short note by Harris (2023), though no empirical

exhibit mean-reversion, with $\beta_{b,2}^{\text{Exp}}$ equal to -0.596 and $\beta_{b,3}^{\text{Exp}}$ equal to 0.620. It is likely that the quantitative easing and tightening surrounding the Covid-19 pandemic biases the estimation of interest expense betas during this time period. However, columns (2) and (3) reports differential interest expense betas for digital banks and digital-broker banks respectively, and these betas remain elevated relative to that of the average bank even during this abnormal time period.

Overall, the evidence in this section is consistent with the hypothesis that digital banks do indeed try to slow their "deposit walk" through increasing the rates that they offer to their depositors, resulting in higher interest expense betas relative to traditional banks.

4 The banking crisis of 2023

We have established that digital banking increases the sensitivity of deposits to interest rate shocks, and that banks increase their deposit rates, consistent with an attempt to stem this "deposit walk". What are the implications of this decreased deposit stickiness for financial stability? In this section, first we demonstrate that there are limits to the extent that banks can increase the interest that they offer to depositors without impairing their profitability (subsection 4.1). Second, we combine the evidence on deposit sensitivity and interest expense betas to provide a simple estimate of the effect that digital banking has on banks' deposit franchise value (subsection 4.2). We conclude this section by zeroing on Silicon Valley Bank, which is perhaps the most salient of the episodes in the banking crisis of 2023, and highlighting the lessons of our analysis for individual bank performance (subsection 4.3).

4.1 Constraints on the ability to raise interest rates

We have already demonstrated in Section 3.3 that digital banks do raise their interest rates by more as is reflected in their interest expense betas; nevertheless they lose more deposits. We take this as evidence of the mobility of deposits in digital banks. To reiterate: Digital banks do not have to lose deposits as they can in principle match, one-to-one, any increase in the Fed funds rate. But, of course, this can only come at the expense of their profitability. Consider as an example

results are reported there.

SVB. On March 8th, 2023, SVB gave a mid quarter presentation[12] in which they updated their expectations regarding deposits for the quarter, which stood in the $167bn-$169bn range (news account suggest that the drop in deposits was much higher than anticipated). In 2022 SVB had $173.1 billion in deposits and reports $2.2 billion in pre-tax income in its consolidated statements of income. Thus, if the bank had paid 125 bps more on its deposits, its net profits would have gone to zero.[13] The ability of SVB to raise interest rates on deposits without suffering operating income losses was not that large. Figure 4 Panel A does this for the universe of banks in 2022. Specifically, for each bank we compute the increase in the deposit rate, expressed in basis points, which when applied to all the deposits would eliminate the bank's 2022 operating income. As we can see from the figure, over 40% of banks would become unprofitable if they had raised the interest on deposits by 150 bps or more. It is useful to put this number in perspective. As shown by Kang-Landsberg and Plosser (2022), in the first figure of their note, the spread between the Fed funds rate and interest-bearing deposit rates is not large by historical standards. Our point is that the presence of digital platforms and the bundling of brokerage services have made deposits more sensitive to increases in the deposit spread than before.[14]

In Figure 4 Panel B we repeat the same exercise restricting our attention to the banks that have losses in their held-to-maturity assets that exceed their book value of equity. For the estimate of the losses in the HTM portfolio, we rely on Jiang et al. (2023). As Jiang et al. (2023) shows, there are roughly 2,300 banks that are technically insolvent if the franchise value of their deposits is zero. Of these banks, 248 cannot raise their deposits rate by more than 75 bps, otherwise they will become unprofitable. Note that since the beginning of December 2022, the Fed Funds rate has increased by 100 bps.

Obviously, the Fed Funds rate increases will over time increase the return on bank assets as well. Thus, the shortfall in profitability is only temporary. Nevertheless, these calculations suggest that increased sensitivity of deposits to the Fed Funds rate places banks in a difficult position: If they do not increase rates, they run the risk of losing so many deposits that they have to realize large losses. If they do not want to lose deposits, they need to increase the deposit rate,

[12]This presentation can be found at https://s201.q4cdn.com/589201576/files/doc_downloads/2023/03/Q1-2023-Mid-Quarter-Update-vFINAL3-030823.pdf

[13]SVB's interest on deposits jumped from $ 62 million in 2021 to $862 million in 2022.

[14]Admittedly, the speed of the increase in the Fed funds rate may have been an additional factor, as it made the increases even more salient.

undermining, at least in the short run, their profitability and showing to the market the reduced value of their deposit franchise, precisely when the rate hikes have weakened their balance sheet.

4.2 Digital banking and deposit franchise values

How do digital banks' magnified deposit flow sensitivity to interest rates, together with higher interest expense betas, combine to affect the value of their deposit franchise? This is a difficult question given that there is no direct way to measure a bank's deposit franchise value. In a recent piece Drechsler et al. (2023c) build on their influential work to suggest a simple expression for the value of the deposit franchise, which they denote by DF:

$$DF(f) = D(1 - w(s, f))\left(1 - \beta - \frac{c}{f}\right) \tag{7}$$

The deposit franchise $DF(f)$ is assumed to be an increasing function of the Fed funds rate[15] now denoted by f. It depends on the level of deposits D, and the one minus the deposit beta net of the capitalized costs of servicing a dollar of deposits, c. Deposits are scaled by what these authors refer to as the outflow rate, $w(s, f)$, which is increasing in the deposit spread $s \equiv (1 - \beta) f$ (in what follows we write $w(f)$ for short).[16] The interpretation of $w(f)$ is the fraction of the deposits that carry no franchise value. Given that it is increasing in the spread, relative to the original level of deposits, the fraction of deposits with a franchise value decreases with the spread. Intuitively, other things equal, the higher the outflow rate the lower the franchise value of deposits.

We are interested in evaluating the deposit franchise value of a bank at the end of 2022, and examining how it varies if we treat it to be traditional bank versus a digital-broker bank. To do so, we need estimates of c, β, and $w(f)$. We take the estimate provided by Drechsler et al. (2023c) for operating costs c to be 0.02. We use our estimates for banks' interest expense betas from Table 5 for β: namely, we set β to be 0.345 for traditional banks[17], 0.397 for digital banks without brokerage services, and 0.402 for digital-broker banks.

The calculation of the outflow rate $w(f)$ is more involved. Outflow rates will also differ between traditional and digital-broker banks because the ease of moving deposits is higher for the

[15](Drechsler et al., 2023c, p. 12). Once again, we follow the convention in Drechsler et al. (2023c) of reporting the Fed funds rate f in decimals so that .01 is 1 percentage point.

[16]In their paper, the outflow rate is also a (decreasing) function of the Fed funds rate itself.

[17]This number is the midpoint of the average interest expense beta reported in columns (3) and (4) of Table 5.

latter than for the former: for a given increase in the spread, we expect outflows to be larger for digital-broker banks than for traditional banks.[18] Accordingly, we need to estimate two functions for $w(f)$, one for traditional banks and the other for digital-broker banks. We consider a linear approximation as in

$$w(f_1) \approx w'(f_0) \times (f_1 - f_0) \tag{8}$$

for $f_0 = 0$ and where we have assumed that $w(0) = 0$. This assumption boils down to assuming that when the Fed funds rate is 0, all deposits of the bank carry franchise value.[19] Thus, given that we have the level of the Fed funds rate at the end of 2022 to be $f_1 - f_0 = .04$, all that remains is to estimate $w'(f_0)$ for traditional and digital-broker banks. Our deposit outflow estimation reported in Table 3 column (1) provides an estimate of $w'(f_0)$ to be 1.6% for traditional banks, and 2.9% for digital-broker banks. This reduced-form estimation of $w'(f_0)$ accounts for both the different betas across traditional and digital-broker banks, as well as the different sensitivity of depositors to these betas resulting from the differing ease of moving traditional vs. digital deposits.

Using (7) along with our estimates of β and $w(f)$ at the end of 2022, when $f = .04$, we are able to calculate how much lower a bank's deposit franchise value is once we recognize that it is digital. We calculate the proportional change in a bank's deposit franchise value, and find that correcting for digital betas and outflows results in a deposit franchise value that is 40% lower for digital-broker banks relative to if the bank had the same quantity of deposits but was a traditional bank.

While we have adjusted the outflows and beta of digital banks, we have not altered the operating costs c. As discussed in Drechsler et al. (2023c), significant operating costs c are crucial in this model to generate a deposit franchise value that is increasing in the Fed funds rate f. However, Koont (2023) estimates the cost functions of digital banks in detail and provides evidence that service provision via digital platforms reduces bank costs relative to services provided via brick-and-mortar branches, particularly by increasing the economies of scale. Thus, as digital services become even more ubiquitous going forward, it is likely that c will tend to a lower value, which will increase the deposit franchise value per equation (7).[20] Given that banks are

[18]There can be further differences in outflow sensitivity due to differences in depositor clientele across digital and non-digital banks. Koont (2023) documents that digital banks attract demand from flightier depositors.

[19]Notice however that for f near 0, the deposit franchise value in equation (7) is very low due to the cost c of servicing deposits, as described in Drechsler et al. (2023a).

[20]However, as c tends to 0, banks' deposit franchise value becomes decreasing in the Fed funds rate f, contrary

only in a state of transition towards digital service provision, and continue to operate large branch networks, it is a reasonable approximation that the value of c has not yet decreased significantly. Further, as interest rates increase, the present value of the future reduction in costs is lower and thus present costs loom larger.

The implications for financial stability of these findings are in our view important. Regulators and bank supervisors might think banks are solvent when considering the value of the deposit franchise. Our point is that the value of the deposit franchise for a given level of deposits is much lower on account of digitalization and that this can have serious consequences for solvency, particularly in the face of high marked-to-market asset losses.

4.3 Silicon Valley Bank

Silicon Valley Bank (SVB), which was put into receivership by FDIC in early 2023, was the first and (so far) most salient episode of the banking crisis of 2023. SVB was the principal subsidiary of SVB Financial Group and it specialized in meeting the financial needs of the private equity venture capital community, particularly in the areas of technology and life sciences space.[21] The other three segments were SVB Private, the private banking and wealth management arm, SVB Capital, which was in charge of VC and credit investments, and SVB Securities, an investment bank. The bank had been founded in 1983 and from its early steps focused on the needs of start-ups; it opened its first office in San Jose, CA, but soon opened branches as well in Massachusetts to service the needs of the "Route 128 tech" community. It's business model, as it was widely reported in the press after its collapse, combined traditional commercial banking functions with bespoke banking services for entrepreneurs and venture capitalists with investment in this space on behalf of third party limited partners.

Figure 2 Panel A shows the evolution of deposits at this institution since the first quarter of 2002 in billions of dollars.[22] SVB lost 25 billion dollars throughout 2022, or about 13% of its

---

to the interest rate hedging role of deposits for traditional banks.

[21] But not only: perhaps of more immediate concern to the finance academic profession, they were also one of the leading providers of financial services to the premium wine community in the Napa Valley.

[22] We extracted these numbers from the quarterly reports of SVB Financial, the parent company of the Silicon Valley Bank, which was SVB Financial's most important subsidiary. When we compare total deposits as well as other magnitudes from those of the call reports, or the numbers provided in the corresponding footnotes, we obtain very similar patterns. For instance, the consolidated balance sheet reports total deposits at the end of of $173.1bn,

deposits. This quick drop in deposits masks interesting changes in the composition of deposits throughout 2021 and 2022. Panel B of the same figure shows the changes in the composition in deposits. It reports the fraction of deposits that are non-interest bearing, which hovers above 60% throughout; the rapid increase in the volume of deposits associated with the pandemic has no discernible impact on it. But starting in the first quarter of 2022, this fraction starts dropping rapidly, falling from 67% to 47% a drop of 20 percentage points. SVB tried to hold on to its deposit base by shifting its composition and compensate depositors for the increasing opportunity costs associated with the Fed fund rate hikes, as documented in column (5) of Table 3. As a result its interest expense went from $.1bn to $1.2bn in the span of a year (see Table 5).

Additionally, there is the issue of the losses in the hold-to-maturity portfolio. Figure 2 Panel C shows the evolution of these losses for SVB. There were some small gains in the portfolio during the pandemic quarters, but they reverse dramatically starting in 2022, peaking at $16b in the third quarter 2023, which, by perhaps an unfortunate coincidence, is almost identical to the total SVB Financial Group equity.

SVB was the ultimate digital-broker bank: It did not only have digital platforms, and brokerage services; its clients were precisely savvy tech entrepreneurs and investors. If there was a bank that was sensitive to the type of effects discussed in this paper it was SVB. Indeed, when we calculate SVB's deposit franchise value following the methodology in Section 4.2 and combine it with information on SVB's marked-to-market losses provided by Jiang et al. (2023), we find that if SVB were evaluated as if it were a traditional bank, it would have a high enough deposit franchise value to remain solvent: its equity and deposit franchise value less its marked-to-market losses remains positive at around $3B. However, once we recognize that SVB is a digital-broker bank and adjust the valuation of its deposit franchise, it becomes insolvent: its equity and deposit franchise value less its marked-to-market losses becomes negative at around -$5B.

5 Conclusions

The stability of deposits, the franchise value of deposits, plays an important role in the way we think about and regulate banks. We show that banks that have digital platforms and offer brokerage services to their clients face higher sensitivity of deposits to changes in the Fed funds rate.

whereas the total (average) deposits as reported in the Operating Segment Results of the FY2022 Annual Report was $172bn; see page 62 of the report.

This effect is statistically significant and most importantly economically large: The sensitivity for digital-broker banks more than doubles relative to traditional commercial banks, those without digital platforms or brokerage services. As digital platforms become more pervasive and customers more accustomed to moving funds across alternatives, the stability of deposits may erode further. We think this finding has important regulatory implications.

Indeed, much of bank regulation is based on the presumption that deposits are stable, but digitalization has made deposits much less sticky. We argue that for a given level of deposits this has led to a drop in the franchise value of deposits. Bank supervisors counting on a high deposit franchise value when evaluating solvency might be relying on outdated estimates of deposit betas and outflows, those from a pre-digital world.

Many, including the Fed, see the failure of SVB and Signature Bank as aberrations, failures that are the result of poor risk management at these two banks rather than structural changes in the banking system. Our analysis suggests that more may be at work here than idiosyncratic incompetence. The additional mobility of deposits associated with the digital-brokerage world, the fact that deposits now can flow easily to money market funds, say, has decreased the value of the deposit franchise. The market is realizing this reduced value at the same time as it is realizing the magnitude of losses hidden in the banks' hold-to-maturity portfolios. The combination of these two factors can make several banks insolvent or close to insolvency. This insolvency risk cannot be addressed with simple injections of liquidity by the Fed, if this liquidity is priced at market rates. It is a difficult trade-off and, as Stein (2012) emphasizes, there is a need to supplement monetary policy with additional regulatory measures to achieve financial stability in economies with shadow financial markets, such as money market mutual funds. We argue that the drop in the franchise value that results from digitalization narrows the range of interest rate hikes that achieve price stability without compromising financial stability.

References

Acharya, Viral V, Rahul S Chauhan, Raghuram Rajan, and Sascha Steffen, "Liquidity Dependence and the Waxing and Waning of Central Bank Balance Sheets," Technical Report, National Bureau of Economic Research 2023.

Begenau, Juliane, Monika Piazzesi, and Martin Schneider, "Banks' risk exposures," Technical Report, National Bureau of Economic Research 2015.

Berger, Allen N and Timothy H Hannan, "The price-concentration relationship in banking," *The Review of Economics and Statistics*, 1989, pp. 291–299.

Cookson, J. Anthony, Corbin Fox, Javier Gil-Bazo, Juan Felipe Imbet, and Cristoph Schiller, "Social Media as a Bank Run Catalyst," *Available at SSRN*, 2023.

Curi, Claudia, Ana Lozano-Vivas, and Maurizio Murgia, "Does Digital Finance Matter? Evidence from the impact of COVID-19 shock on bank stocks," *Working Paper*, 2023.

Degryse, Hans and Steven Ongena, "Competition and regulation in the banking sector: A review of the empirical evidence on the sources of bank rents," *Handbook of financial intermediation and banking*, 2008, *2008*, 483–554.

Diamond, Douglas W and Philip H Dybvig, "Bank runs, deposit insurance, and liquidity," *Journal of political economy*, 1983, *91* (3), 401–419.

Diebold, Francis X and Steven A Sharpe, "Post-deregulation bank-deposit-rate pricing: The multivariate dynamics," *Journal of Business & Economic Statistics*, 1990, *8* (3), 281–291.

Drechsler, Itamar, Alexi Savov, and Philipp Schnabl, "The deposits channel of monetary policy," *The Quarterly Journal of Economics*, 2017, *132* (4), 1819–1876.

_ , _ , and _ , "Banking on deposits: Maturity transformation without interest rate risk," *The Journal of Finance*, 2021, *76* (3), 1091–1143.

_ , _ , and _ , "How to value the deposit franchise," 2023.

_ , _ , and _ , "Why do banks invest in MBS?," 2023.

_ , _ , _ , and Olivier Wang, "Banking on Uninsured Deposits," Technical Report, National Bureau of Economic Research 2023.

Driscoll, John C and Ruth Judson, "Sticky Deposit Rates," *Federal Reserve Board*, 2013.

Egan, Mark, Ali Hortaçsu, and Gregor Matvos, "Deposit competition and financial fragility: Evidence from the us banking sector," *American Economic Review*, 2017, *107* (1), 169–216.

English, William B, "Interest rate risk and bank net interest margins," *BIS Quarterly Review*, 2002, *10* (1), 67–82.

_ , Skander J Van den Heuvel, and Egon Zakrajšek, "Interest rate risk and bank equity valuations," *Journal of Monetary Economics*, 2018, *98*, 80–97.

Erel, Isil, Jack Liebersohn, Constantine Yannelis, and Samuel Earnest, "Monetary Policy Transmission Through Online Banks," *Fisher College of Business Working Paper*, 2023, (2023-03), 015.

Flannery, Mark J, "Market interest rates and commercial bank profitability: An empirical investigation," *The Journal of Finance*, 1981, *36* (5), 1085–1101.

_ , "Interest rates and bank profitability: Additional evidence," *Journal of Money, Credit and Banking*, 1983, *15* (3), 355–362.

Haendler, Charlotte, "Keeping Up in the Digital Era: How Mobile Technology Is Reshaping the Banking Sector," *Available at SSRN 4287985*, 2022.

Hancock, Diana, "Bank profitability, interest rates, and monetary policy," *Journal of Money, Credit and Banking*, 1985, *17* (2), 189–202.

Hannan, Timothy H and Allen N Berger, "The rigidity of prices: Evidence from the banking industry," *American Economic Review*, 1991, *81* (4), 938–945.

Hanson, Samuel G, Andrei Shleifer, Jeremy C Stein, and Robert W Vishny, "Banks as patient fixed-income investors," *Journal of Financial Economics*, 2015, *117* (3), 449–469.

Harris, Matt, "Under Pressure: deposit betas in 2023," *Article Series, The Baker Group*, 2023.

Hong, Claire Yurong, Xiaomeng Lu, and Jun Pan, "FinTech platforms and mutual fund distribution," Technical Report, National Bureau of Economic Research 2019.

Hutchison, David E and George G Pennacchi, "Measuring rents and interest rate risk in imperfect financial markets: The case of retail bank deposits," *Journal of Financial and Quantitative Analysis*, 1996, *31* (3), 399–417.

Jiang, Erica Xuewei, Gloria Yang Yu, and Jinyuan Zhang, "Bank Competition amid Digital Disruption: Implications for Financial Inclusion," *Available at SSRN 4178420*, 2022.

_ , Gregor Matvos, Tomasz Piskorski, and Amit Seru, "Monetary Tightening and US Bank Fragility in 2023: Mark-to-Market Losses and Uninsured Depositor Runs?," Technical Report, National Bureau of Economic Research 2023.

Kang-Landsberg, Alena and Matthew Plosser, "How Do Deposit Rates Respond to Monetary Policy?," Technical Report, Federal Reserve Bank of New York, Liberty Street Economics 2022.

_ , Stephen Luck, and Matthew Plosser, "Deposit Betas: Up, Up, and Away?," Technical Report, Federal Reserve Bank of New York, Liberty Street Economics 2023.

Kashyap, Anil K, Raghuram Rajan, and Jeremy C Stein, "Banks as liquidity providers: An explanation for the coexistence of lending and deposit-taking," *The Journal of finance*, 2002, *57* (1), 33–73.

Koont, Naz, "The Risks of Digital Banking," *Working Paper*, 2023.

Neumark, David and Steven A Sharpe, "Market structure and the nature of price rigidity: evidence from the market for consumer deposits," *The Quarterly Journal of Economics*, 1992, *107* (2), 657–680.

Samuelson, Paul A, "The effect of interest rate increases on the banking system," *The American Economic Review*, 1945, *35* (1), 16–27.

Stein, Jeremy C, "Monetary policy as financial stability regulation," *The Quarterly Journal of Economics*, 2012, *127* (1), 57–95.

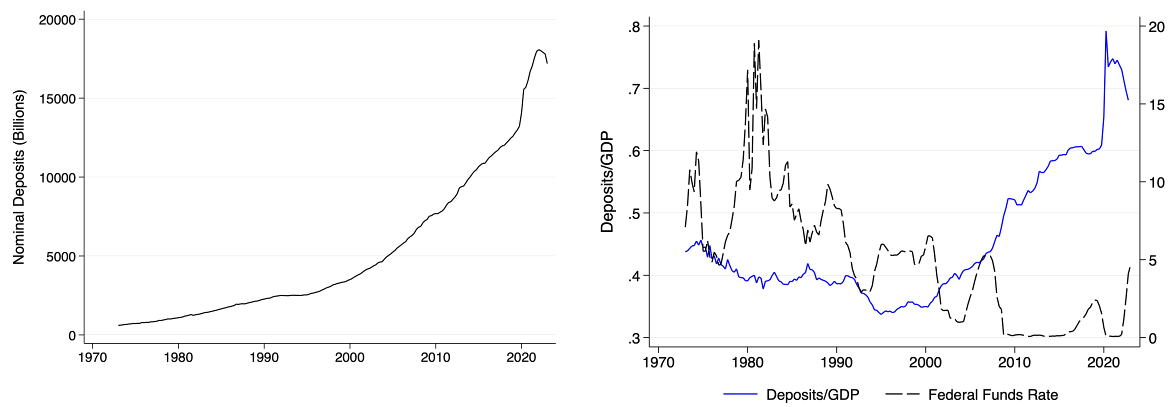
Stulz, René M, "Fintech, bigtech, and the future of banks," *Journal of Applied Corporate Finance*, 2019, *31* (4), 86–97.

Figures

Figure 1: Time-Series Trends

Panel A: Nominal Deposits

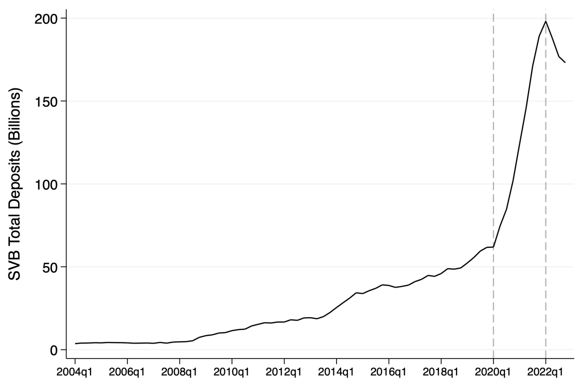
Panel B: Deposit Elasticity



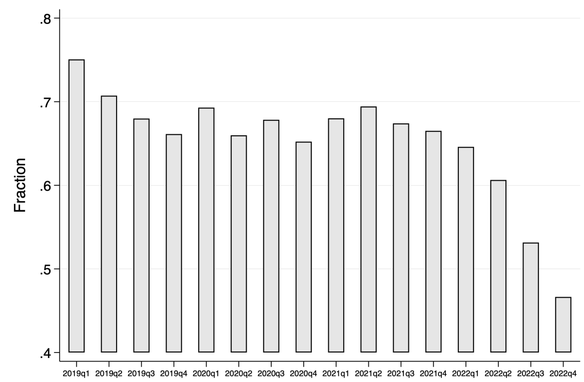
Panel A plots the nominal level of bank deposits, in Billions of dollars, between the first quarter of 1973 and the first quarter of 2023. Panel B plots the ratio of nominal deposits to nominal GDP between the same period, overlayed with the level of the Fed funds rate. All aggregate variables are retrieved from Fred.

Figure 2: Case Study: Silicon Valley Bank

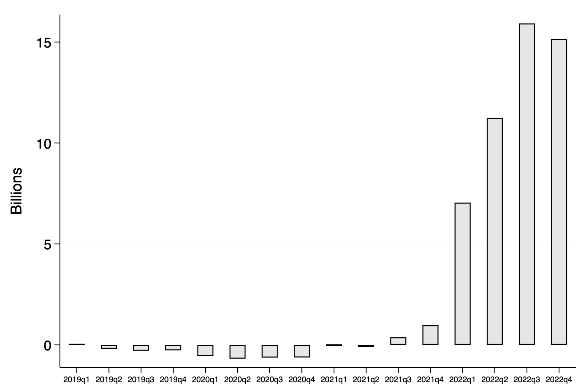
Panel A: Total Deposits



Panel B: Non-Interest Bearing Deposits Ratio

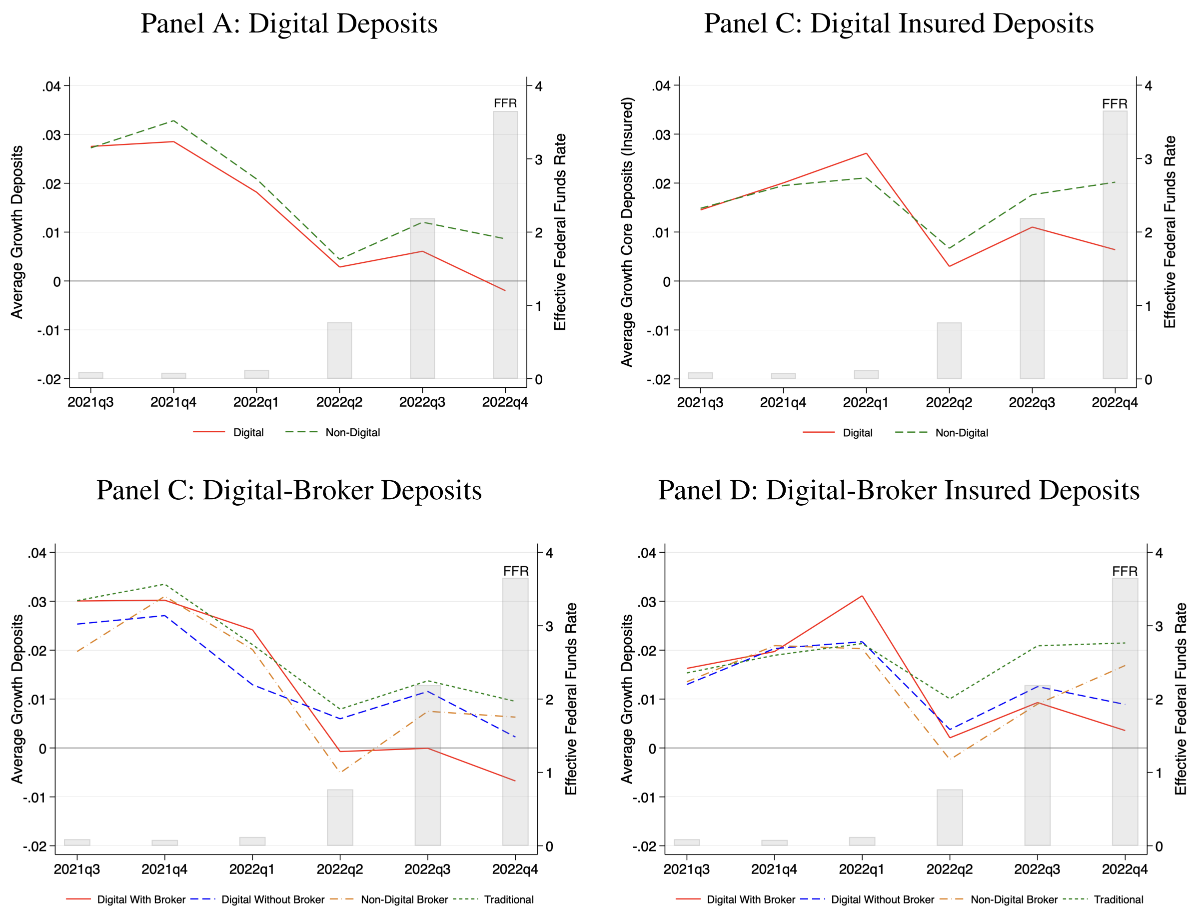


Panel C: Hold to Maturity Losses



Panel A plots SVB's total deposits between the first quarter of 2004 and the last quarter of 2022. Panel B plots SVB's ratio of non-interest bearing deposits to all deposits from the first quarter of 2019 to the last quarter of 2022. Panel C plots SVB's hold-to-maturity losses (or gains) from the first quarter of 2019 to the last quarter of 2022. SVB balance sheet variables come from its consolidated 10-Q filings.

Figure 3: Quarter-Averages: Digital Brokers Experience Sharpest Outflows

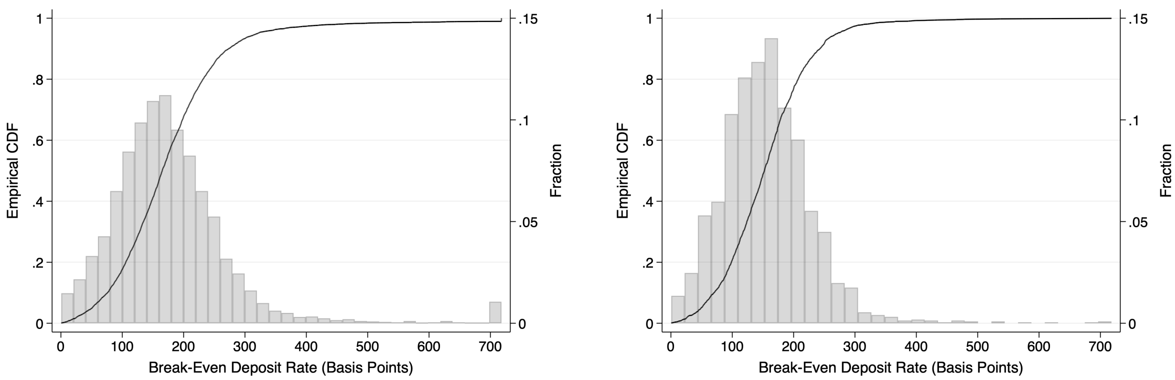


Panel A shows the quarter-averages of percentage growth in deposits, defined as the sum of savings deposits, time deposits, and demand deposits, from 2021Q3 through 2022Q4, separately across digital and non-digital banks that have between \$1 and \$250B in assets. Panel B reproduces the figure using instead banks' estimated insured deposits, as reported to the FDIC and the FDIC SDI. Panel C and D reproduce panel A and B respectively, now showing the decomposition across four groups of banks: digital and non-digital, and banks with brokerage fees versus those don't report these fees, for those banks that have between \$1 and \$250B in assets. Digital banks are those that have a mobile application with at least 300 reviews. The grey bars denote the Fed funds rate. Deposit data are from Call Reports, banks' digital classifications come from Koont (2023), and the effective federal funds rate is retrieved from Fred.

Figure 4: Break-Even Deposit Rates

Panel A: All Banks

Panel B: Insolvent If Zero Deposit Franchise



Panel A plots the distribution and CDF of the cross-section of bank deposit rate break-even points in 2022. For each bank, the break-even point is what increase in deposit rate, expressed in basis points, applied to their deposits, defined as the sum of savings, demand, and time deposits, will annul their 2022 income before taxes. Panel B reproduces the figure including only those banks that have losses in their marked-to-market assets that exceed their book value of equity, as calculated and provided by Jiang et al. (2023). Income and deposit data are from Call Reports, and banks digital classifications come from Koont (2023).

Tables

Table 1: Summary Statistics

Panel A: Digital Platforms in 2022 for All Banks

	Number	% of Total	Mean Assets	Median Assets
Number of banks	4,529		3.42	0.23
Digital Banks	1,096	23%	12.55	0.69
Broker	404	9%	30.75	1.78
Digital Brokers	257	5%	46.82	3.17

Panel B: Digital Platforms in 2022 for Banks With Assets Between $1 Billion and $250 Billion

	Number	% of Total	Mean Assets	Median Assets
Number of banks	647		8.38	2.04
Digital Banks	411	64%	10.66	2.32
Broker	268	41%	13.31	3.48
Digital Brokers	199	31%	16.13	4.43

Panel C: Bank Deposits

		Mean	Std Dev	p25	p50	p75
Deposits	*Growth*	0.067	0.146	-0.011	0.040	0.109
Core Deposits	*Growth*	0.090	0.175	-0.006	0.049	0.138
Non-Time Deposits	*Growth*	0.090	0.175	-0.006	0.049	0.138
Insured Deposits	*Growth*	0.057	0.149	-0.013	0.030	0.090
Interest-Bearing Ratio	*Level*	0.791	0.121	0.731	0.804	0.867
	Growth	-0.012	0.044	-0.029	-0.009	0.006

Panel A tabulates the number of digital banks and brokers in 2022, and panel B repeats the tabulation focusing only on banks with between $1 and $250 billion in asset size. Panel C shows summary statistics for banks' deposit categories, as described in the main text. Assets are reported in billions of dollars. A bank is classified to be *Digital* if it has a mobile application with greater than 300 reviews. A bank is classified to be a *Broker* if it reports non-zero brokerage fees in Call Reports. Digital classifications come from Koont (2023), and bank balance sheet information come from Call Reports.

Table 2: Deposits to GDP

	(1) Change in Deposits/GDP
Δ FFR $\times$ 1970s	-0.000
	(0.001)
Δ FFR $\times$ 1980s	0.001
	(0.000)
Δ FFR $\times$ 1990s	-0.001
	(0.002)
Δ FFR $\times$ 2000s	-0.005***
	(0.001)
Δ FFR $\times$ 2010s+	-0.027**
	(0.012)
Constant	0.002
	(0.001)
Observations	199
R2	0.17

This table reports the slope estimates from the quarterly time-series regression of level differences in nominal deposits normalized by GDP, on level differences in the Fed funds rate interacted with indicator variables for each decade. The sample period spans from 1971Q1 to 2023Q1. The 2010+ decade includes the years through 2023. Heteroskedasticity-robust standard errors are reported in parentheses. One, two, and three stars indicate statistical significance at the 10%, 5%, and 1% level, respectively.

Table 3: Deposit Volumes and Composition

	Deposits				Deposit Composition
	(1)	(2)	(3)	(4)	(5)
	All (Non-brokered)	Core	Excl. Time	Insured	$\frac{\text{Interest Bearing Deposits}}{\text{Deposits}}$
Δ FFR	-0.016***	-0.026***	-0.039***	-0.014***	0.005***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)
Δ FFR $\times$ Digital	-0.006***	-0.005***	-0.004**	-0.003***	0.001**
	(0.001)	(0.001)	(0.002)	(0.001)	(0.000)
Δ FFR $\times$ Broker	-0.007**	-0.008***	-0.012***	0.005	0.005***
	(0.003)	(0.003)	(0.004)	(0.004)	(0.001)
Δ FFR $\times$ Digital $\times$ Broker	0.002	0.000	0.005	-0.003	-0.001
	(0.004)	(0.004)	(0.005)	(0.005)	(0.001)
Bank FE	Yes	Yes	Yes	Yes	Yes
Observations	75889	75692	75624	75954	75711
R2	0.23	0.21	0.21	0.20	0.09

This table reports the slope estimates from an annual bank-level panel regression of proportional changes in various measures of deposits on level changes in the Fed funds rate, Δ FFR, interacted with indicator variables for whether a bank has a digital platform, Digital, and offers brokerage services, Broker. The sample period is from 2010 through 2022. In column (1) Deposits are defined as the sum of savings deposits, time deposits, and demand deposits. Column (2) considers Core Deposits as reported to the FDIC SDI. Column (3) Excl. Time considers the sum of savings and demand deposits. Column (4) considers banks' estimated insured deposits as reported to the FDIC SDI. Column (5) considers the proportional changes in the ratio of interest-bearing deposits to all deposits. A bank is classified to be *Digital* if it has a mobile application with greater than 300 reviews. A bank is classified to be a *Broker* if it reports non-zero brokerage fees in Call Reports. All specifications include a bank fixed effect. Standard errors are clustered by bank and reported in parentheses. One, two, and three stars indicate statistical significance at the 10%, 5%, and 1% level, respectively.

Table 4: Digital Banks Experience Larger Effects in Counties with High Internet Usage

	Deposits		Savings Rate $<$ 100K	
	(1)	(2)	(3)	(4)
Δ FFR $\times$ HH Internet Prop $\times$ Digital	-0.182***	-0.262***	0.538**	0.571*
	(0.064)	(0.067)	(0.240)	(0.301)
Δ FFR $\times$ HH Internet Prop $\times$ Broker		-0.103		0.324
		(0.173)		(0.464)
Δ FFR $\times$ HH Internet Prop $\times$ Digital $\times$ Broker		0.223		-0.196
		(0.180)		(0.472)
Bank-Year FE	Yes	Yes	Yes	Yes
County-Year FE	Yes	Yes	Yes	Yes
Observations	284194	284194	13982	13982
R2	0.35	0.35	0.86	0.86

This table reports the slope estimates from an annual bank-county-level panel regression of proportional changes in deposits and deposit interest rates on level changes in the Fed funds rate, Δ FFR, interacted with the county-level proportion of households that have internet subscriptions, HH Internet Prop, and with indicator variables for whether a bank has a digital platform, Digital, and offers brokerage services, Broker. HH Internet Prop ranges from 0 to 1 and is retrieved from the 2019 Census ACS. The sample period is from 2010 through 2022. In columns (1) and (2) Deposits are a bank's deposits in a given county for a given year, calculated as the sum of all deposits accruing to branches of the bank in that county, retrieved from the FDIC SOD. In columns (3) and (4) Savings Rate $<$ 100K is the average savings rate for deposit volumes below \$100,000 across the branches of a bank in a given county-year. A bank is classified to be *Digital* if it has a mobile application with greater than 300 reviews. A bank is classified to be a *Broker* if it reports non-zero brokerage fees in Call Reports. All specifications include a bank-year and county-year fixed effect. Standard errors are clustered by county and reported in parentheses. One, two, and three stars indicate statistical significance at the 10%, 5%, and 1% level, respectively.

Table 5: Banks' Interest Expense Betas

	Beta (Level Change in Int Exp/Assets)			
	(1)	(2)	(3)	(4)
	1983-2017	2010-2017	Digital 2010-2017	Digital Broker 2010-2017
ΔFFR$_t$	0.093***	0.114***	0.107***	0.111***
	(0.001)	(0.003)	(0.003)	(0.003)
ΔFFR$_{t-1}$	0.180***	0.105***	0.110***	0.107***
	(0.001)	(0.003)	(0.003)	(0.003)
ΔFFR$_{t-2}$	0.016***	0.101***	0.101***	0.101***
	(0.001)	(0.003)	(0.004)	(0.004)
ΔFFR$_{t-3}$	0.074***	0.032***	0.025***	0.029***
	(0.001)	(0.004)	(0.004)	(0.004)
ΔFFR$_t\times$ Bank Type			0.040***	0.046***
			(0.006)	(0.008)
ΔFFR$_{t-1}\times$ Bank Type			-0.031***	-0.026***
			(0.008)	(0.010)
ΔFFR$_{t-2}\times$ Bank Type			-0.004	-0.008
			(0.008)	(0.011)
ΔFFR$_{t-3}\times$ Bank Type			0.045***	0.034***
			(0.008)	(0.010)
Bank FE	Yes	Yes	Yes	Yes
Int Exp Beta	0.363	0.352	0.343	0.348
Int Exp Beta for Bank Type			0.397	0.402
Observations	1227529	203500	203500	203500
R2	0.25	0.10	0.10	0.10

This table reports the slope estimates from an quarterly bank-level panel regression of level changes in interest expenses divided by assets on contemporaneous and lagged level changes in the Fed funds rate, Δ FFR. Column (3) includes interaction terms for digital banks, and column (4) for digital-broker banks. A bank is classified to be *Digital* if it has a mobile application with greater than 300 reviews. A bank is classified to be a *Broker* if it reports non-zero brokerage fees in Call Reports. All specifications include a bank fixed effect. Heteroskedasticity-robust standard errors are reported in parentheses. One, two, and three stars indicate statistical significance at the 10%, 5%, and 1% level, respectively.

Table 6: Banks' Interest Expense Betas

	Beta (Level Change in Int Exp/Assets)		
	(1)	(2)	(3)
	2010-2022	Digital 2010-2022	Digital Broker 2010-2022
ΔFFR_t	0.299***	0.299***	0.301***
	(0.004)	(0.004)	(0.004)
ΔFFR_{t-1}	-0.055***	-0.055***	-0.057***
	(0.005)	(0.006)	(0.005)
ΔFFR_{t-2}	-0.596***	-0.602***	-0.602***
	(0.003)	(0.004)	(0.003)
ΔFFR_{t-3}	0.620***	0.616***	0.623***
	(0.004)	(0.005)	(0.005)
$\Delta\text{FFR}_t \times$ Bank Type		-0.001	-0.027**
		(0.008)	(0.014)
$\Delta\text{FFR}_{t-1} \times$ Bank Type		-0.001	0.041**
		(0.012)	(0.020)
$\Delta\text{FFR}_{t-2} \times$ Bank Type		0.025***	0.111***
		(0.007)	(0.012)
$\Delta\text{FFR}_{t-3} \times$ Bank Type		0.020*	-0.046**
		(0.010)	(0.019)
Bank FE	Yes	Yes	Yes
Int Exp Beta	0.268	0.258	0.265
Int Exp Beta for Bank Type		0.303	0.344
Observations	305531	305531	305531
R2	0.27	0.27	0.27

This table reports the slope estimates from an quarterly bank-level panel regression of level changes in interest expenses divided by assets on contemporaneous and lagged level changes in the Fed funds rate, Δ FFR. Column (3) includes interaction terms for digital banks, and column (4) for digital-broker banks. A bank is classified to be *Digital* if it has a mobile application with greater than 300 reviews. A bank is classified to be a *Broker* if it reports non-zero brokerage fees in Call Reports. All specifications include a bank fixed effect. Heteroskedasticity-robust standard errors are reported in parentheses. One, two, and three stars indicate statistical significance at the 10%, 5%, and 1% level, respectively.