How Do Government Guarantees Affect Deposit Supply?

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Abstract

The market value of deposit insurance changes over time and across banks as the value of the underlying put option changes, but the premium they pay for the insurance does not adjust to completely capture this variation. As a result, the effective subsidy that banks enjoy from deposit insurance changes over time and across banks, affecting their incentive to supply deposits. Factors that change the market value of insurance, such as asset risk and interest rates, move the supply curve. Consistent with this idea, we show that the deposit supply curve shifts outward during periods of high risk and for riskier banks. The effect is more pronounced for insured deposits. Our findings uncover a novel channel of deposit supply, with immediate implications for the transmission of monetary policies and existing research on "deposit channel of monetary policy" and "reaching-for-yield" literature.

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1 Introduction

Bank deposits are central to economic growth and liquidity creation. It is not surprising that a large literature in banking and economics studies forces that shape the demand and supply of deposits, and consequently their impact on economic outcomes. Economic shocks, policy choices, consumer preference, and banking market structure have all been shown to affect the demand and supply of deposits in the prior literature.[1] In this paper, we uncover a new channel that shifts the supply curve of bank deposits: variation in the effective subsidy that banks enjoy from deposit insurance. Our results have important implications for the interpretations for some of the key findings in the banking literature, including the effect of interest rates on deposit supply and the managerial incentives to reach for yield in low interest rate environment.

Bank deposits are insured by regulators in almost all major economies. In the United States, the Federal Deposit Insurance Corporation (FDIC) guarantees deposits up to a certain amount in the event of a bank's failure. Banks pay a premium to the FDIC, called the Deposit Insurance Premium (DIP), to avail of this guarantee. FDIC's guarantee gives the insured bank a put option that can be exercised by them in the event of default. Therefore, the market value of deposit insurance varies with factors that change the value of a put option, such as the riskiness of the underlying assets. However, the premium paid by banks to the FDIC does not adjust fully to reflect changes in its market value for four key, not mutually exclusive, reasons: (a) banks are classified into coarse risk categories for the assessment of FDIC insurance premium, (b) they are often subsidized, (c) premiums change infrequently, and (d) premiums typically depend on the actuarial value of insurance and not on the risk-neutral distribution of losses.[2] Therefore, the market value of insurance changes over time and across banks but the fees paid by banks do not change by the same amount. Consequently, the government guarantee in the form of deposit insurance creates variation in the effective subsidy across time and across banks.

[1] Black (1975) and Fama (1985) focus on the effect of reserve requirements. Gorton and Pennacchi (1990) highlight the role of bank deposits in alleviating information frictions faced by savers. Stein (1998) teases out the role of adverse selection on the demand and supply of deposits. Kashyap and Stein (2000) focuses on the effect of policy shocks on banks' ability to raise outside funding and its impact on loan supply. Stein (2012) discusses the goals and methods of financial stability policy in an economy with privately-created money such as bank deposits. Gilje et al. (2016) relate exogenous supply shocks to bank deposits to lending markets. Drechsler et al. (2017) document the importance of bank's market power on the supply of deposits. There are numerous other valuable contributions in this field as summarized in survey articles such as Gorton and Winton (2003) and Bhattacharya and Thakor (1993).

[2] While there has been a move towards risk-based pricing of deposit insurance in the recent past, it still is not fully risk-sensitive due to the above mentioned reasons. See Duffie et al. (2003); Ronn and Verma (1986); Marcus and Shaked (1984) for studies on the pricing of deposit insurance premium.

The incentive of banks to supply deposits changes as the subsidy changes. When the risk of a bank increases, the value of the subsidy becomes higher because it is still paying low fees. Therefore, they expand the supply curve. They are now more likely to issue insured deposits and pay a higher rate for them. A contraction occurs when banks enjoy a lower subsidy, as in periods of low risk. Therefore, factors that influence the riskiness of banks over time and in the cross section influence the supply of deposits. We formalize these intuitions in a standard model of insurance pricing, i.e. Merton (1977), where deposit insurance is priced as a put option owned by insured banks. Banks face a convex cost function in raising deposits and the subsidy obtained through the underpriced insurance premium influences their decision to supply deposits. The model shows that the deposit supply curve shifts outwards when a bank's asset risk increases. In addition, the supply curve shifts outward in the low-interest rate regime for two reasons. Since policy rates are often lowered in bad economic times, the Fed interest rates are negatively correlated with bank risk, a fact that we confirm in the data. The negative correlation between interest rate and volatility leads to an outward shift in the supply curve when interest rates are low. Independently, lower interest rates move the supply curve outward in an economy where consumers are willing to pay more for liquidity benefits of deposits in periods with lower liquidity in the system.

We test these implications using detailed data on the quantity and pricing of deposits for all the U.S. banks covered in the Call Reports from 1986 to 2023. Our goal is to empirically establish a link between deposit insurance subsidy that a riskier bank enjoys and its deposit supply. In our main tests, we use the non-performing loans to asset ratio of a bank in a given quarter as our key measure of asset risk. Since asset risk is an unobserved quantity, using the NPL ratio as a proxy for asset risk has several benefits. The measure is an indicator of the performance of the bank's asset, mapping directly to the model primitive. It captures the riskiness of a bank's asset through the deterioration in its lending portfolio, allowing us to measure the time-varying nature of a bank's asset risk (Nagel and Purnanandam, 2020). It is available for the entire sample of banks, unlike some market-based risk measures that are only available for publicly traded banks. Finally, we are able to obtain this measure for the entire sample period, i.e., for almost four decades, providing us with substantial variation in monetary policy shocks and bank risk.

Our main empirical specification uses a panel data regression, using bank-quarter observations over a period of almost four decades, to establish a link between asset risk and deposit supply. We show that banks with one standard deviation higher NPL ratio have 1.7% higher deposits. We include bank fixed effects to soak away the effect of factors such as the bank's management style, franchise value, and geographical presence on deposit supply. We include time-fixed effects to soak away aggregate risk factors. In later analyses, we present time-series evidence to shed light on the aggregate dynamics of bank risk and deposit supply.

A key identification challenge for establishing a link between changes in subsidy and deposit supply is reverse causality: if banks with higher deposit insurance subsidy make riskier investments, then we are likely to find a positive correlation between measures of bank risk and deposits. It is well known that subsidized insurance can increase a bank's incentive to make riskier loans. Note that if a bank increases its asset risk in a given quarter, it will take several quarters for the loans to turn into an NPL. Hence, the use of NPL as a measure of asset risk ameliorates this concern because higher levels of NPL in a given quarter are a reflection of riskier portfolio choices made by the banks in the past.

We directly address this endogeneity concern with an instrumental variable strategy using a Bartik instrument. For each bank-quarter in the sample, we obtain the bank's loan portfolio composition across five different asset classes, namely, real estate loans, C&I loans, household & consumer loans, agricultural loans, and loans to other financial firms, three years ago. Fixing their portfolio weight at this point, we obtain the predicted value of their non-performing loans ratio based on the aggregate default rate of each category over time. Thus, we obtain an instrument that depends on the cross-sectional differences in a bank's initial portfolio decision and the subsequent economy-wide shocks to the respective asset categories. Since the portfolio allocation is set three years prior to the deposit supply decisions we analyze, it is not influenced by reverse causality concerns. Further, the allocation of asset portfolio three years ago is unlikely to be influenced by the knowledge of future default rates of these categories, which occur years later in the sample. These arguments form the basis of our identifying assumption.

The instrument varies by bank based on their lagged asset allocation and over quarters based on the economy-wide shocks to each of the asset classes. In the first stage regression, we find a statistically strong coefficient on the portfolio weight instrument. The instrument is strong: even with bank and quarter-year fixed effects, it explains almost 10% of the variation in the realized NPL ratio of banks in the entire sample. The F-statistic of the instrument is over 100. Using the predicted value of NPL ratios, we find a positive and strong coefficient on the amount of deposits of the bank. One standard deviation higher NPL ratio causes an increase of 16.1% in the quantity of deposits.

We present two additional results on the quantity of deposits before turning to our results on deposit pricing. We show that as the NPL ratio increases, the fraction of insured deposits at a bank also increases. This finding is consistent with our channel that banks supply higher amounts of deposits when the value of government subsidy goes up, and that insured deposits directly benefit the most from this government subsidy. In our second test, we estimate the model using branch-level data on deposit quantities. A key advantage of this specification is that we include both the branch fixed effects, as well as county $\times$ quarter-year fixed effects, to separate out the impact of local economic conditions, demand for deposits, and banking market competition from the effect we capture from the subsidy effect. The branch-level regression model rules out the possibility that distressed banks are located in areas with different compositions of depositor base since we are able to include county fixed effects in these models to account for local depositor base and economic conditions. Our results remain strong in these specifications.

Does the increase in the quantity of deposits represent a supply shift instead of a demand shift? To establish the supply side effects, in our next test, we analyze the pricing of deposits in response to an increased value of the insurance subsidy that the banks enjoy. If banks increase the supply of insured deposits in response to an increase in subsidy, then we expect interest rates offered by them to increase. A demand side effect produces just the opposite prediction. Banks provide interest rates on deposits of different denominations. We focus on two denominations for our analysis: the wholesale insured rates, defined as rates offered on deposits that exploit the insured limit to the maximum, i.e., on deposits of $100,000 until 2010 and $250,000 after that. We find that banks with a one standard deviation higher NPL ratio offer interest rates on these products that are 1% higher relative to the mean. The results are similar for the 2SLS regression model with a larger economic magnitude, with an 11% increase. In addition, we also analyze interest rates on denominations just below the maximum insured limit: $50,000 before 2010 and $200,000 after that point. Our results remain similar.

In sum, banks with higher NPL ratios have higher amounts of deposits, and they pay higher rates on them: the combined effect of an increase in quantity and a decrease in price is consistent with our hypothesis that banks shift the supply curve outward when the value of deposit insurance subsidy goes up. Our results so far exploit variation across banks over time. We now present some aggregate effects using time-series analysis.

Figures 2 plots the aggregate changes in deposits in the banking sector during a quarter, along with changes in NPL over a long time series from 1986 to 2021. The positive correlation between the two time series is striking. The bottom panel presents the plot for only the insured deposits: the pattern is even more striking. We estimate a time-series regression using the growth rate of aggregate deposits as the dependent variable and the growth rate in NPL ratio as the explanatory variable. One standard deviation increase in NPL growth is associated with a 1.1% higher deposit growth rate. Consistent with our channel, the NPL growth rate is associated with an increase in the fraction of insured deposits in the system. Finally, the deposit spread, defined as the difference between the Federal Funds rate and the rates offered by banks, decreases with the increase in the NPL ratio. Together these results show that as the banking sector enjoys higher government subsidy, it increases the supply of deposits.

The value of deposit insurance subsidy can change not only with the volatility of the asset but also with the interest rate in the economy. We find a strong negative correlation between the NPL ratios and the Fed Funds rates. As interest rates fall, the value of the deposit insurance subsidy goes up, and the banking sector's willingness to increase the supply of deposits goes up. Our insight, therefore, has implications for the relation between interest rates and deposit supply as documented by the deposit channel of monetary policy (Drechsler et al., 2017). In Drechsler et al. (2017) the mechanism driving the connection between interest rates and deposit supply is the market power that the banks enjoy. In our channel, it is the value of the deposit insurance subsidy that affects the supply of deposits. These channels are not mutually exclusive; instead they can reinforce each other. In our next test, we replicate the key findings of the deposit channel literature, and then add NPL ratio as an additional explanatory variable in the regression model. Specifically, we estimate our branch level regression model for deposit quantity with the inclusion of changes in Fed Funds rate and the HHI of the local deposit market as in the deposit channel literature, and then include our measure of bank risk as an additional explanatory variable. The impact of NPL ratio on deposit quantity remains strong, suggesting that the effect we document is not simply a reflection of bank market power. In addition, we show that the inclusion of the NPL ratio in the model explains about 30% of the effect of changes in Fed Funds rate on deposit quantity estimated by the earlier literature. In sum, the subsidy channel provides an independent explanation of movement in the deposit supply curve in response to interest rate changes.

Our study also has implications for the literature on reaching-for-yield in financial intermediation (Rajan, 2006; Acharya and Naqvi, 2019). This behavior has been generally described as the propensity to invest in riskier assets in low interest rate environment to achieve higher yields. Managerial incentive to target a desired nominal return, regardless of risk, is a common friction that can explain this behavior. Our channel that subsidy increases during low interest rate environment provides an independent explanation of this behavior. Said differently, banks are willing to invest in riskier securities as a result of increased government subsidy, rather than managerial agency frictions.

Our paper is related to Billett et al. (1998) who show that deposit insurance shields banks from market discipline. They find that banks substitute towards insured deposits, away from uninsured ones, as they get downgraded by Moody's, making market discipline less effective. One of our findings that the fraction of insured deposits go up in response to the increase in asset risk is consistent with this finding. However, the economic mechanism behind of our study is not rooted in market discipline that they focus on. More importantly, we tease out the expansion in supply curve, not merely a substitution across insured and uninsured deposits. Further, our study traces out the supply curve using both the quantity and pricing data, unlike their study that predominantly focuses on equity market returns of banks.

2 History of Deposit Insurance Premiums

The Banking Act of 1933 led to the creation of the FDIC as the guarantor of bank deposits in the United States. Since then, bank deposits have been fully insured up to a certain limit, most recently up to $250,000 per depositor per bank. In the early years of the formation of the FDIC, the deposit insurance premium that the banks paid was a flat amount, i.e., every bank paid the same amount to the FDIC every year for obtaining deposit insurance. After the Savings & Loans Crisis of 1980s, Congress passed a legislation in 1989 requiring the FDIC to maintain reserves of at least 1.25% of insured deposits in its Deposit Insurance Fund.[3] A flat-rate schedule was approved to achieve the target level of reserves.[4] The FDIC's Deposit Insurance Fund is maintained by quarterly premiums (called assessments) that are calculated as each bank's assessment base multiplied by an assessment rate.

A later regulation in 1991 required the FDIC to charge the insurance premium based on the riskiness of the bank. The first risk-based assessment went into effect on a transitional basis in 1993, and became permanent in 1994. Banks were categorized into three groups based on their capitalization ratio and further divided into three groups based on their supervisory ratings, providing a total of nine groups of banks for deposit fee assessment. However, there was little

[3]See https://www.minneapolisfed.org/article/1998/a-brief-history-of-reserves-and-premiums#1

[4]See https://www.fdic.gov/analysis/cfr/staff-studies/2020-01.pdf for a detailed history of deposit insurance premium in the United States.

variation in premiums paid by banks in practice: the premium varied between 23 basis points to 31 basis points from the least risky to the most risky group.

By 1996, when the deposit insurance fund had reached its target of 1.25%, 95% banks paid no insurance premium at all, providing no variation in their fees.[5] This system continued between 1996 and 2006, where most banks paid no assessment fees for accessing deposit insurance. FDIC continued to categorize banks into 9 categories, in a 3x3 matrix based on capitalization and supervisory rating, but banks in the top-most category, i.e., those assessed as well capitalized and with healthy supervisory rating paid zero assessment fees. In terms of the amount (number) of deposits more than 96% (92%) of banks fell under this safest category, effectively making the system risk-insensitive (Duffie et al., 2003).

FDIC undertook a serious attempt to move towards risk-based pricing in 2007. Banks were now categorized into four categories based on their capital ratio and supervisory rating. The assessment rate varied from 5 basis points to 43 basis points across banks based on this method. However, a majority of banks were still under the safest category and there was little variation across banks in a category. In 2009, in the immediate aftermath of the global financial crisis, the assessment method was significantly revised, taking into consideration not only the bank's overall capital and supervisory rating, but also on the composition of their debt (e.g., the extent of unsecured debt or brokered deposits). Some distinctions were made based on whether a bank falls under the large or small bank category as well, as determined by a $10 billion asset threshold. As a result, the assessment fees varied considerably across the four risk categories and it also varied within a risk-category depending on the liability composition of the bank. The net result of this modified system was a variation in deposit insurance premium between 7 to 77.5 basis points across banks. Finally, in 2016, the assessment base was further changed, providing a range of 1.5 to 40 basis points across banks.

How large is the magnitude of deposit insurance subsidy? A quantitative assessment is beyond the scope of this paper. The prior literature, however, provides some estimates based on historical data. Duffie et al. (2003) use a reduced form credit risk model to estimate the fair value of market price of deposit insurance premium. In an approximate sense, they show that the fair market price equals the bank's short-maturity credit spread multiplied by the ratio of expected losses to the insurer in the even of failure to expected fractional loss on bank debt. They provide

[5]See Federal Deposit Insurance Corporation. Press Release 87-96: "Under the existing rate schedule in effect since January of 1996, institutions in the lowest risk category will continue to pay no premiums during the first half of 1997. A total of 9,538, or 94.4 percent of all BIF-insured institutions, are in the lowest risk category."

estimates on the CDS spreads of banks and their corresponding insurance premium in 2002. Based on reasonable assumption on loss given default, the fair market premium can be as high as 64 basis points compared to 0 to 3 basis points that most banks paid at the time.

Overall, the history of deposit insurance premium suggests a flat, risk-insensitive premium for most of the history of the U.S. banking. The premiums have become more risk-sensitive after 2007, though not yet fully risk-sensitive since banks are still categorized in coarse rating buckets, and the premium does not adjust with the state price, as a market-based insurer would require.

3 Model

We formalize our intuition in a model similar to Merton (1977) in this section. We consider a bank that issues D dollars of insured deposit and funds a loan of value D+E where E is the equity value. Banks fund a fraction of their loans with equity such that $L = \frac{D}{w}$ so that $E = \frac{D}{w} - D$. w is the leverage ratio. We assume that there are no uninsured deposits in the bank's liability mix. In the baseline specification, deposits provide no liquidity or convenience service and therefore they simply earn the risk-free rate because they are insured: $r_d = r$, where r is the risk-free rate. We assume a maturity date of T for both loans and deposits to keep our analysis focused on our channel.

The loan market is assumed to be perfectly competitive, so banks simply maximize the value of the put option of deposit insurance net of any deposit insurance premium and the convex cost of raising deposits. Raising deposits incurs costs such as branch network operations, ATM network, maintenance cost, and staff cost; together, they are convex in the amount of deposits raised. Deposit insurance premium is paid today at a flat rate of $\bar{p}$ per unit of deposit. Although the deposit insurance premium is flat and constant over time, factors that move its market value such the volatility of bank assets, σ, or r are not. They change with macroeconomic conditions, policy choices, as well as bank-specific factors.

Banks' optimization problem is the following:

$$\max_{\{D\}} P[L, K, \sigma, r, T] - \frac{1}{2}cD^2 - \bar{p}D \quad (1)$$

where, $P[L, K, \sigma, r, T]$ denotes the value of a European put option on the underlying asset L with strike price K, the face value of deposits. Therefore,

$$
\begin{aligned}
P[L,K,\sigma,r,T] &= Ke^{-rT}\Phi(-d_2) - L\Phi(-d_1) \\
d_1 &= \frac{ln(\frac{L}{K}) + (r+\frac{\sigma^2}{2})T}{\sigma\sqrt{T}}; \\
d_2 &= d_1 - \sigma\sqrt{T}; \\
K &= D\cdot e^{rT}; \\
\frac{L}{K} &= \frac{D}{wD\cdot e^{rT}} = \frac{1}{w\cdot e^{rT}}.
\end{aligned} \tag{2}
$$

Simplification of the above expressions lead to the following:

$$
\begin{aligned}
P[L,K,\sigma,r,T] &= D\Phi(-d_2) - \frac{D}{w}\Phi(-d_1); \\
d_1 &= \frac{-ln(w)}{\sigma\sqrt{T}} + \frac{\sigma\sqrt{T}}{2}; \\
d_2 &= d_1 - \sigma\sqrt{T}
\end{aligned} \tag{3}
$$

The first order condition of the bank's optimization problem in Equation 1 can be written as follows:

$$
\frac{\partial P[L,K,\sigma,r,T]}{\partial D} = cD + \bar{p} \tag{4}
$$

Simplifying further:

$$
\begin{aligned}
\frac{\partial P[L,K,\sigma,r,T]}{\partial D} &= \Phi(-d_2) + D.\frac{\partial\Phi(-d_2)}{\partial D} - \frac{\Phi(-d_1)}{w} - \frac{D}{w}\frac{\partial\Phi(-d_1)}{\partial D} \\
&= \Phi(-d_2) - D\phi(-d_2)\frac{\partial d_2}{\partial D} - \frac{\Phi(-d_1)}{w} + \frac{D}{w}\phi(-d_1)\frac{\partial d_1}{\partial D} \\
&= \Phi(-d_2) - \frac{\Phi(-d_1)}{w}
\end{aligned}
$$

Therefore, the optimal quantity of deposits is given by the following equation:

$$
\Phi(-d_2) - \frac{\Phi(-d_1)}{w} = cD + \bar{p}
$$

$$
D^* = \frac{1}{c}\{\Phi(-d_2) - \frac{\Phi(-d_1)}{w} - \bar{p}\} \tag{5}
$$

Optimal supply of deposits decreases when marginal cost c is higher; and when deposit insurance premium paid, $\bar{p}$ is higher. It increases when the default option has a higher value.

Optimal supply as volatility changes: Now, using the envelope theorem, we find the sensitivity of optimal quantity of deposits with respect to asset volatility σ:

$$\begin{aligned}\frac{\partial D^*}{\partial \sigma} &= \frac{1}{c}\frac{\partial}{\partial \sigma}\{\Phi(-d_2) - \frac{\Phi(-d_1)}{w}\} \\ &= \frac{1}{c}\{-\phi(-d_2).\frac{\partial d_2}{\partial \sigma} + \frac{1}{w}\phi(-d_1).\frac{\partial d_1}{\partial \sigma}\}\end{aligned}$$

Note:

$$\phi(-d_2) = \frac{1}{w}\phi(d_1) \tag{6}$$

Therefore,

$$\begin{aligned}\frac{\partial D^*}{\partial \sigma} &= \frac{1}{c}\{-\frac{1}{w}\phi(d_1).\frac{\partial d_2}{\partial \sigma} + \frac{1}{w}\phi(-d_1).\frac{\partial d_1}{\partial \sigma}\} \\ &= \frac{\phi(d_1)}{cw}\{-\frac{\partial d_2}{\partial \sigma} + \frac{\partial d_1}{\partial \sigma}\} \\ &= \frac{\phi(d_1)}{cw}\sqrt{T} > 0 \end{aligned} \tag{7}$$

Therefore, banks supply more deposits when volatility goes up. Periods with higher macroeconomic volatility or bank-specific losses are likely to be associated with a higher supply of deposits.

3.1 Optimal supply as r changes:

Interest rates can affect deposit insurance value through two potential channels. First, policy rates are often lowered in bad economic times, producing a negative correlation between r and σ. Second, interest rates can affect the price of liquidity and therefore the premium depositors are willing to pay for liquidity benefits of deposits. We first present a model where r and σ are negatively correlated. Then we generalize the model to a setting with liquidity benefits.

3.1.1 Policy Rates

Interest rates in the economy follow a negative relation with the observed volatility of the banking sector. This is consistent with the idea that policy interventions often happen during bad economic times, when rates are lowered. We capture that intuition with a simple linear relationship between volatility and interest rate as follows:

$$\sigma = \hat{b} - \hat{a} * r \tag{8}$$

It follows that (Proof in the Appendix):

$$\begin{aligned} \frac{\partial D^*}{\partial r} &= \frac{1}{c}\frac{\partial}{\partial r}\{\Phi(-d_2) - \frac{\Phi(-d_1)}{w}\} \\ &= -\phi(d_1)\{\frac{\hat{a}\sqrt{T}}{cw}\} < 0 \end{aligned} \tag{9}$$

Therefore, when interest rates go up, optimal deposit financing comes down. The sensitivity of optimal deposit supply to interest rate is high when a is high, i.e., when asset volatility is more sensitive to r. If we set this parameter to zero, we obtain Merton (1977) that the value of deposit insurance put option is insensitive to interest rates.

3.1.2 Liquidity Benefits of Deposits

So far, in our model, deposits are priced at the risk-free rate. We now extend our model to include the liquidity benefits of deposits that the consumers enjoy. On average, deposits pay lower interest rates than the risk-free rate because they come with liquidity benefits. In periods of scarce liquidity in the aggregate financial system, the value of liquidity provided by the deposit contracts is likely to be relatively higher compared to periods with abundant liquidity. Periods of low liquidity are characterized in our model as periods of high interest rates. Therefore, we now assume that the interest rate on deposits (r_d) is given by the following schedule that accounts for higher liquidity premium in high interest rate regime:

$$r_d = r(1-\alpha) - \beta, \tag{10}$$

where $0 < \alpha < 1$ and β are positive numbers. As shown in Appendix 7.3:

$$\frac{\partial P[.]}{\partial r} = -\alpha D T e^{-(\alpha r+\beta)T} \Phi(-d_2) < 0 \tag{11}$$

Therefore, the value of the put option decreases when interest rates are high. Consequently, the supply of deposits decreases in a high interest rate regime. As shown in Appendix 7.3, we get the following relationship between optimal deposit quantity supplied by the banks and interest rates:

$$c\frac{\partial D^*}{\partial r} = -\alpha T e^{-(\alpha r+\beta)T} \Phi(-d_2) < 0. \tag{12}$$

Therefore, the optimal quantity of deposits decreases when interest rates go up. The effect is stronger when parameter c is smaller, i.e., for banks that are likely to face a lower marginal cost of raising deposits. Similarly, the effects are stronger for banks that have depositors who value liquidity more (the α parameter).

4 Data and Descriptive Statistics

We collect comprehensive data on bank balance sheet items from the quarterly Call Reports from the FFIEC. Our main outcome variables of interest are total deposits, the ratio of estimated insured deposits to total deposits, and deposit rates. We incorporate information on bank size (total assets) and leverage (total equity capital) as control variables. Additionally, we study branch-level deposit quantities using the FDIC summary of deposits dataset.

To examine how changes in the government subsidy affects deposit supply, we measure the value of deposit insurance as the volatility of bank assets (Merton, 1977). Our main measure of bank risk is the quarterly non-performing loan ratio, which is computed using Call Reports data and defined as nonaccruing loans and accruing loans that are 90 days or more past due divided by total assets.[6]

For our instrumental variables analysis, we use each bank's historical asset holdings across the following five categories: real estate loans, C&I loans, household & consumer loans, agricultural loans, and loans to other financial firms. Specifically, we compute a measure of estimated

[6] In the Call Reports, these measures are RCFD1403 and RCFD1407. When these variables are missing from the Call Reports, we construct it by adding up the NPL from their subcomponents as defined in the Call Reports.

NPL ratio weighted by historical asset composition (portfolio weight for each bank in each asset class from three years ago.

To study the deposit insurance subsidy over time, we augment our baseline dataset with quarterly information on FDIC assessment fees available in the Call Reports. Additionally, we use branch-level deposit rate data from the S&P Global's RateWatch database to measure interest rates, specifically for new insured wholesale deposits (accounts with minimim size at or above the FDIC deposit insurance limit) and submarginal deposits (accounts just below the limit). The RateWatch panel is available from January 2001 to December 2020.

The sample period for our baseline analysis spans 1986 to 2023. Table 1 reports the descriptive statistics of key variables for the full sample period. We winsorize all variables at the 1% level to remove the effect of extreme outliers.

5 Empirical Results

We begin our analysis by using a panel data model to empirically establish a causal link between the deposit insurance subsidy and deposit supply. Additionally, we provide time-series evidence demonstrating how deposit supply fluctuations correspond with changes in monetary policy and macroeconomic conditions. Finally, we conduct a comparative analysis between the subsidy channel and the "deposits channel" to evaluate their relative impact on deposit supply dynamics. Our findings confirm that the subsidy channel plays a distinct and independent role in influencing deposit supply responses.

5.1 Cross-Sectional Effects

We now present empirical evidence linking bank risk, deposit supply, and monetary policy shocks. Our primary goal is to establish a causal relationship between deposit insurance subsidy and deposit supply, while accounting for the role of Federal Funds (Fed funds) rate shocks.

5.1.1 Deposit Quantity

Our empirical analysis begins by examining the relationship between bank risk and deposit supply. We estimate the following panel regression using bank-quarter data:

$$d_{b,t} = \alpha_b + \mu_t + \beta\sigma_{b,t} + \Sigma X_{b,t} + \epsilon_{b,t}. \tag{13}$$

where $d_{b,t}$ represents deposit quantities for bank b in quarter t. We consider two primary measures: the log of total deposit quantity and the fraction of insured to total deposits of a bank. Bank and quarter-year fixed effects (α_b and μ_t, respectively) control for bank-specific and macroeconomic factors, while $X_{b,t}$ includes control variables such as the capitalization ratio (equity-to-assets). The key independent variable, $\sigma_{b,t}$, measures bank risk, proxied by the non-performing loans (NPL) ratio of a bank scaled by total assets.

Column (1) of Table 2 presents the OLS regression results. We find a positive and significant coefficient on the NPL ratio: a one standard deviation increase in the NPL ratio is associated with a 1.7% increase in deposits. This result supports our hypothesis that banks expand deposit supply in response to an increase in the effective subsidy from deposit insurance, which grows as bank risk rises. The inclusion of bank and quarter-year fixed effects ensures that our findings are not confounded by unobserved macroeconomic conditions or bank-specific factors such as management skill or market power.

To address potential endogeneity concerns, we employ an instrumental variable (IV) strategy based on a Bartik-style instrument. This instrument leverages variation in lagged portfolio weights and aggregate NPL shocks to isolate changes in bank risk driven by macroeconomic factors rather than individual bank characteristics.

Our instrument is constructed as follows: for every bank in quarter t, we retrieve its loan portfolio composition from three years prior ($t - 12$ quarters) across five major asset classes: real estate loans, C&I loans, household & consumer loans, agricultural loans, and loans to other financial firms.[7] We then compute an instrumented NPL ratio by multiplying each asset class's lagged portfolio weight ($w_{b,i,t-12}$) by its corresponding NPL rate ($s_{i,t}$) at time t.

$$\text{Portfolio-Weight-IV}_{b,t} = \sum_i w_{b,i,t-12} * s_{i,t}. \tag{14}$$

This instrument estimates the NPL a bank would have experienced if its loan composition had remained unchanged while macroeconomic conditions evolved. By construction, this approach mitigates reverse causality concerns that we are trying to overcome, because the shares cannot be manipulated ex-post; portfolio shares from three years prior cannot be influenced by present-day deposit supply decisions. To further isolate the effect of deposit insurance subsidy, we control for bank capitalization, ensuring that our results are not driven by changes in leverage.

[7] Since the data on agriculture loans became available after 1991, the regression model with the IV design is estimated on a slightly smaller time period from 1994 till 2023.

Column (2) presents the first-stage regression result. The instrument strongly predicts a bank's NPL ratio three years later, with a one standard deviation increase in *Portfolio-Weight-IV* associated with a 0.612 standard deviation increase in the realized NPL ratio. The instrument is highly significant (t-statistic > 50), and the first-stage F-statistic exceeds 100, confirming its strength. The reduced-form estimate in Column (3) shows that a one standard deviation increase in *Portfolio-Weight-IV* is associated with a 9.8% increase in deposits. The second-stage IV regression in Column (4) confirms that a one standard deviation increase in NPL results in a 16.1% increase in deposits.

We also examine how changes in bank risk affect the composition of deposits, particularly the fraction of insured deposits. When a bank becomes riskier, it can increase the value of its deposit insurance subsidy by increasing specifically insured deposits. Therefore, we expect banks to increase the share of insured deposits to total deposits in response to an increase in the NPL ratio.

Table 3 tests this hypothesis, using the fraction of insured deposit as the dependent variable. We additionally control for the bank's size, measured as the log of asset value, in this model to soak away the differential reliance on insured deposits across banks of different sizes. We find that a one standard deviation increase in the NPL ratio is associated with a 1.1 percentage points increase in the insured deposit fraction, using the OLS model in Column (1). The 2SLS regression coefficient, using *Portfolio-Weight-IV* as the instrument, suggests a stronger effect: a one standard deviation increase in the NPL ratio leads to a 3 percentage points increase in the insured deposit fraction. These findings support the view that banks maximize the value of the deposit insurance subsidy by expanding insured deposits, which directly benefit from the government guarantee.

Branch-level regression: Thus far, our results establish a relationship between banks' aggregate deposits and their NPL ratios. However, deposit data is also available at the branch level starting in 1994, coinciding with the availability of our instrumental variable. To further validate our findings and rule out alternative explanations, we estimate the following model, similar to equation 14.

$$d_{i,b,c,t} = \alpha_i + \mu_{c,t} + \beta\sigma_{b,t} + \Sigma X_{b,t} + \epsilon_{i,b,c,t}. \tag{15}$$

where $d_{i,c,b,t}$ represents the log of total branch deposits of branch i of bank b, operating in county c in quarter-year t. Branch and *County* $\times$ *Qtr-Year* fixed effects (α_i and $\mu_{c,t}$, respectively) control for branch-specific and time-varying county-specific factors, while $X_{b,t}$ includes control variables such as the capitalization ratio, number of branches, and bank size. The key independent variable, $\sigma_{b,t}$, measures bank risk, proxied by the non-performing loans (NPL) ratio of a bank scaled by total assets.

To isolate the effect of the deposit insurance subsidy from local demand shocks or banking competition, our branch-level regression model includes branch fixed effects and *County* $\times$ *Qtr-Year* fixed effects. Specifically, branch fixed effects control for time-invariant branch-specific characteristics, while *State* $\times$ *Qtr-Year* or *County* $\times$ *Qtr-Year* fixed effects account for time-varying local economic conditions, including employment opportunities and demand for deposits. These controls ensure that our results are not driven by regional macroeconomic fluctuations but rather by the subsidy effect.

Table 4 presents the estimation results. Columns (1) and (2) show that branches affiliated with banks with higher NPL ratios experience a 2.2% to 2.6% increase in deposits. The 2SLS estimates in columns (3) and (4) reveal an even stronger effect: a one standard deviation increase in the NPL ratio leads to an 18.5-20.6% increase in branch-level deposits. These findings confirm that the outward shift in the deposit supply curve is driven by the value of the deposit insurance subsidy rather than by local economic conditions.

The branch-level results also highlight the spatial heterogeneity in monetary policy transmission. Banks operating in regions with higher NPL ratios (and thus, higher subsidy values) are more likely to experience a pronounced expansion in deposit supply following a Fed funds rate cut. This regional heterogeneity has important implications for the distributional effects of monetary policy, particularly in areas concentrated with non-performing loans.

5.1.2 Pricing

A key distinction between supply- and demand-driven changes in deposits lies in the deposit rate response. If the observed increase in deposits reflects a supply shift due to increased subsidy value, banks should offer higher deposit rates to attract depositors. To examine this, we analyze how deposit pricing responds to changes in bank risk, as specified in equation 15, where the deposit rate serves as the outcome variable.

Table 5 presents the results. The model is estimated at the branch level using data from 2001 to 2020. We use the deposit rate offered on 12-month CDs of denomination $100,000 until 2010 and $250,000, thereafter, referred to as the *Wholesale Insured Rate*, as these represent large-denomination insured CDs. As before, we include branch and *County* $\times$ *Qtr-Year* fixed effects to isolate the effect of factors such as the bank's ATM network or local demand conditions from the effect of NPL ratio.

Consistent with our predictions, banks with higher NPL ratios offer higher deposit rates on wholesale insured deposits. A one standard deviation increase in NPL is associated with a 0.6 basis points increase in deposit rates. Column (2) presents the second-stage IV estimate, showing that the effect is economically larger and precisely estimated: banks with a one standard deviation higher NPL ratio offer 7.4 basis points higher deposit rates on their insured deposits.

We also present the analyses with rates on CDs that are slightly smaller than the wholesale insured rate. For periods before 2010, we use CDs of denomination $50,000 and after 2010, we use CDs of denomination $200,000 for this analysis. Banks with higher NPL ratios offer higher deposit rates on these CDs as well, consistent with a shift in the supply curve.

5.2 Aggregate Effects and Time-Series Evidence

We have so far exploited variations across banks and over time. Our insights have implications for the aggregate evolution of deposit supply as well. Factors that change the value of subsidy are likely to affect the supply of deposits in the aggregate. Specifically, aggregate default risk of the banking sector and the level of interest rates in the economy are predicted to affect deposit supply through the subsidy channel.

Figure 2 plots the time series of quarterly year-over-year changes in total banking sector deposits alongside changes in total NPLs from 1986 to 2021. We compute the aggregate NPLs of the banking sector by simply adding the non-performing loans of every bank during the quarter. We then subtract the log change in this measure compared to the corresponding number a year ago to get the measure of NPL growth during the quarter. We do so to ensure that our measure of NPL growth is not affected by seasonal variation in bank's accounting practices. Thus our captures the growth rate in the non-performing loans in the banking sector net of any seasonality in booking losses, providing us with a meaningful construct of the time-series variation in bank health. The NPL growth rate shows substantial variation over time, ranging from almost 0% during economically prosperous times to as high as 1.5% during the global financial crisis of 2008-09. In the context of our model, the value of deposit insurance subsidy, therefore, is likely to change substantially over time.

Figure 2 shows a strong positive correlation between these measures, with deposit growth increasing when NPL growth is high (correlation $\sim$ 0.3). Further, the correlation is not specific to the period of financial crisis alone: it is a widespread pattern we observe throughout the sample period of 1985 to 2021.

The bottom panel separately plots insured deposit growth, i.e., for the deposit product that directly benefits from insurance subsidy. The relation between the NPL growth rate and deposit growth rate is driven primarily by insured deposit growth during this period. Figure 3 further illustrates how deposit spreads evolve with NPL growth. The negative correlation is striking: when NPL growth is high, deposit spreads (the difference between the Fed funds rate and deposit rates) decline. Overall, these figures provide a strong support for our claim that banks change deposit supply when the value of insurance subsidy changes due to variation in bank risk.

Table 6 quantifies this relationship in a regression model. Column (1) of the Table shows that, aggregate deposits grow when banking sector's NPL increases. One standard deviation increase in the sector's NPL growth is associated with a 1.1% increase in overall deposits. Column (2) shows that the fraction of insured deposits increase with NPL growth rate, as predicted by our subsidy channel. Finally, in Column (3) we show that a one standard deviation increase in NPL growth is associated with a 0.3% decrease in deposit spreads. Together, these results indicate that periods of higher asset risk drive an increase in deposit supply, operating not only at the individual bank level but also at the aggregate level.

5.2.1 Bank Risk and Interest Rate Environment

Our results have implications for the relationship between interest rates and deposit supply. Since policy rates are often lowered in bad economic times, lower Fed Funds rates are associated with higher risk-neutral probability of bank default. In turn, the value of the deposit insurance subsidy increases in low interest rate regime, incentivizing banks to expand deposit supply. As discussed earlier, if depositors are willing to pay higher premium for obtaining liquidity in tighter monetary policy regime, then the deposit insurance subsidy goes up with interest rate, independently of the risk channel.

The bottom panel of Figure 3 plots changes in the Fed funds rate against changes in aggregate banking sector NPLs, revealing a strong negative correlation ($\sim$ -0.5). This relationship confirms the intuition that rates are lowered in bad economic times, and therefore monetary policy affect the value of the deposit insurance subsidy banks receive.

To formally test this, we re-estimate our baseline panel model and present the results in

Table 7, using quarterly changes in the Fed funds rate as the key explanatory variable. We drop the quarter-year fixed effects from this regression because interest rates are quarter-year specific. All standard errors are not clustered both at the bank and the quarter-year level.

The estimates confirm that an increase in the Fed funds rate leads to a contraction in deposit supply and insured deposits, consistent with the model's predictions from Section 3.1.1. Column (1) shows that one standard deviation increase in the Federal Funds Rate is associated with 7.21% standard deviation decrease in deposit quantity; banks lower their deposits in high interest rate regime as already shown by Drechsler et al. (2017). Interestingly, the insured deposits decrease by a higher amount: 8.52% compared to 6.15% for the uninsured deposits. Consistent with that, as the interest rates increase, the fraction of insured deposits increase in the economy. Overall, these results show that banks respond strongly to changes in Fed Funds rate by increasing insured deposits, as our subsidy channel predicts.

Moreover, we replicate key findings from the deposit channel literature (Drechsler et al. (2017)) and demonstrate that incorporating the NPL ratio explains approximately half of the effect of Fed funds rate changes on deposit quantity in Table 8. Specifically, we estimate a branch-level deposit quantity regression, including changes in the Fed funds rate and the Herfindahl-Hirschman Index (HHI) of the local deposit market as in the deposit channel literature, then introduce the NPL ratio as an additional explanatory variable. The strong and significant coefficient on the NPL ratio suggests that the effect we document is not merely a reflection of bank market power. Moreover, including the NPL ratio explains about 30% of the Fed funds rate effect on deposit supply found in prior research.

This result highlights the importance of the subsidy channel as a distinct and independent mechanism for transmitting monetary policy shocks to deposit supply. However, the subsidy channel and the deposit channel are not mutually exclusive; rather, they reinforce one another. For example, during periods of monetary easing, banks with greater market power (as measured by HHI) may experience an even larger expansion in deposit supply due to the combined effects of increased subsidy values and reduced competition.

Together, these findings show that the subsidy channel provides an independent explanation of movement in the deposit supply curve in response to interest rate changes.

6 Robustness Tests

We present a few robustness tests in this section.

6.1 Alternative Measures of Bank Risk

Our key measure of the bank risk comes from an accounting number: the NPL ratio of the bank. As discussed earlier, the use of NPL as a measure of risk matches well with the theoretical construct of our model. It provides us with variation in a bank's asset risk over time, and across banks. The measure is available for all banks in the economy, providing us with a comprehensive sample. We now present our results based on an alternative measure that is derived from market prices: the option-implied volatility of the bank's equity. An immediate advantage of such a market-based measure of risk is that it incorporates the state price in it, and it is fast moving as information about risk becomes available. However, there are two key limitations of the measure: (a) it is available only for a small subset of banks that are publicly traded, and (b) the implied volatility incorporates the effect of bank leverage as well. The second concern can mechanically explain the aggregate results on deposits, since higher deposit financing increases leverage. However, the leverage effect cannot explain the variation in the fraction of insured deposits that our study also focuses on.

Table 10 presents the results. We compute the implied volatility from the option prices of one-year maturity options, and use it's one quarter lagged values in the regression model. Column (1) shows that as a bank's equity volatility goes up, the quantity of deposits go up as well. In economic terms, one standard deviation higher volatility is associated with 1.7% higher deposits. More important, Column (2) shows that the increase is mainly from insured deposits: the fraction of insured deposits go up by 0.5% when the bank's implied volatility goes up by one standard deviation. Table 11 studies the effect of volatility on deposit rates. Our results confirm that the increased quantity of deposits are driven by the supply side effect: banks increase the interest rate they pay on deposits when their implied volatility is higher.

In addition, we use two other market-based measures of bank risk, namely the spread on its Credit Default Swap(CDS) and the spread on bonds issued by the bank. These measures, again, come with the same advantages and limitations as the option-implied measure discussed earlier. For brevity, we only present the corresponding figures linking these measures of risk and deposit quantity in Figures 4. Our results remains the same. Across these measures of risk, we find an increase in deposits during periods of high risk, i.e., when the insurance subsidy is high.

7 Conclusion

This paper identifies a novel mechanism through which government guarantees influence deposit supply: the deposit insurance subsidy. By modeling deposit insurance as a put option, we demonstrate that the value of the subsidy varies with bank risk and macroeconomic conditions, particularly changes in the Fed funds rate and aggregate risk of the banking sector. Since FDIC insurance premiums do not fully adjust to reflect shifts in the market value of deposit insurance, the effective subsidy that a bank enjoys changes with parameters that change the market value of the FDIC insurance guarantee. Using detailed data on U.S. banks from 1986 to 2023, we provide robust empirical evidence that banks expand deposit supply in response to increases in subsidy value, particularly during periods of heightened risk and low interest rates.

Our findings have significant implications for the transmission of monetary policy. We show that the subsidy channel operates alongside the deposit channel documented by Drechsler et al. (2017), explaining approximately 30% of the effect of Fed funds rate changes on deposit quantity. The subsidy channel is particularly relevant during periods of monetary easing, when lower interest rates increase the value of the deposit insurance subsidy and incentivize banks to expand insured deposits. This behavior is evident in the narrowing of deposit spreads and the disproportionate growth in insured deposits during periods of high NPL growth.

The subsidy channel also has implications for financial stability. By incentivizing banks to expand deposit supply in high-risk periods, the deposit insurance subsidy may heighten moral hazard and contribute to systemic fragility. These findings suggest that policymakers should carefully consider the implications of deposit insurance design, particularly in setting risk-sensitive insurance premiums that mitigate excessive risk-taking incentives.

Additionally, our results highlight spatial heterogeneity in the transmission of monetary policy. Banks in regions with higher NPL ratios – and thus greater subsidy values – experience more pronounced expansions in deposit supply following Fed funds rate cuts. This regional divergence has critical implications for the distributional effects of monetary policy, particularly in areas with concentrated banking markets. Future research could further explore how these effects interact with regulatory constraints and broader financial stability considerations.

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Figures

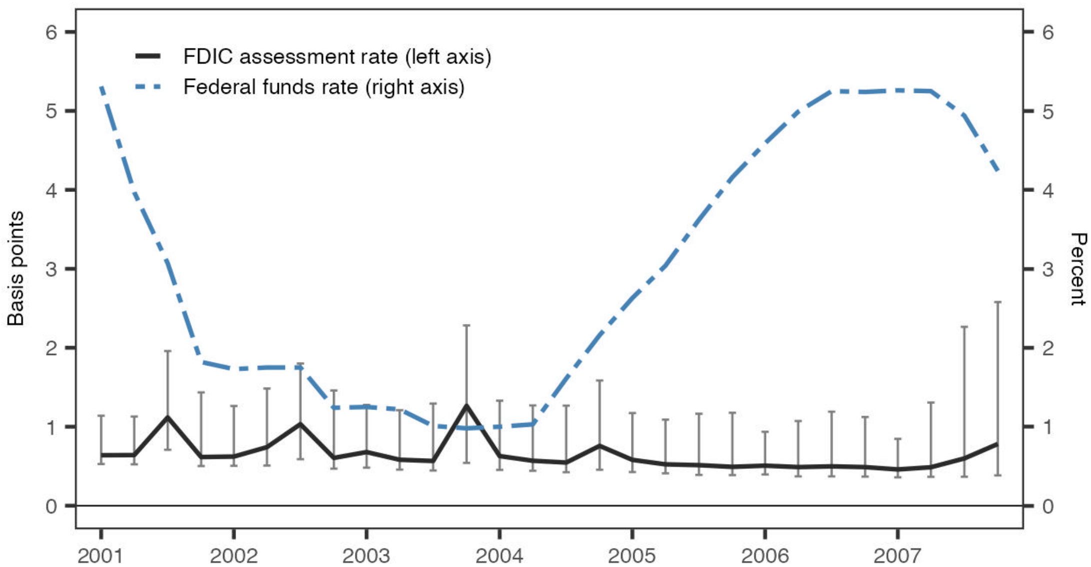

Figure 1: FDIC Assessment Fees Across Time

Notes: This figure plots the relationship between FDIC deposit insurance assessment rates and the effective federal funds rate between 2001Q1 and 2007Q4. The solid line plots the median quarterly assessment rate among commercial banks. Grey bars indicate 25th and 75th percentiles.
Source: Call Reports.

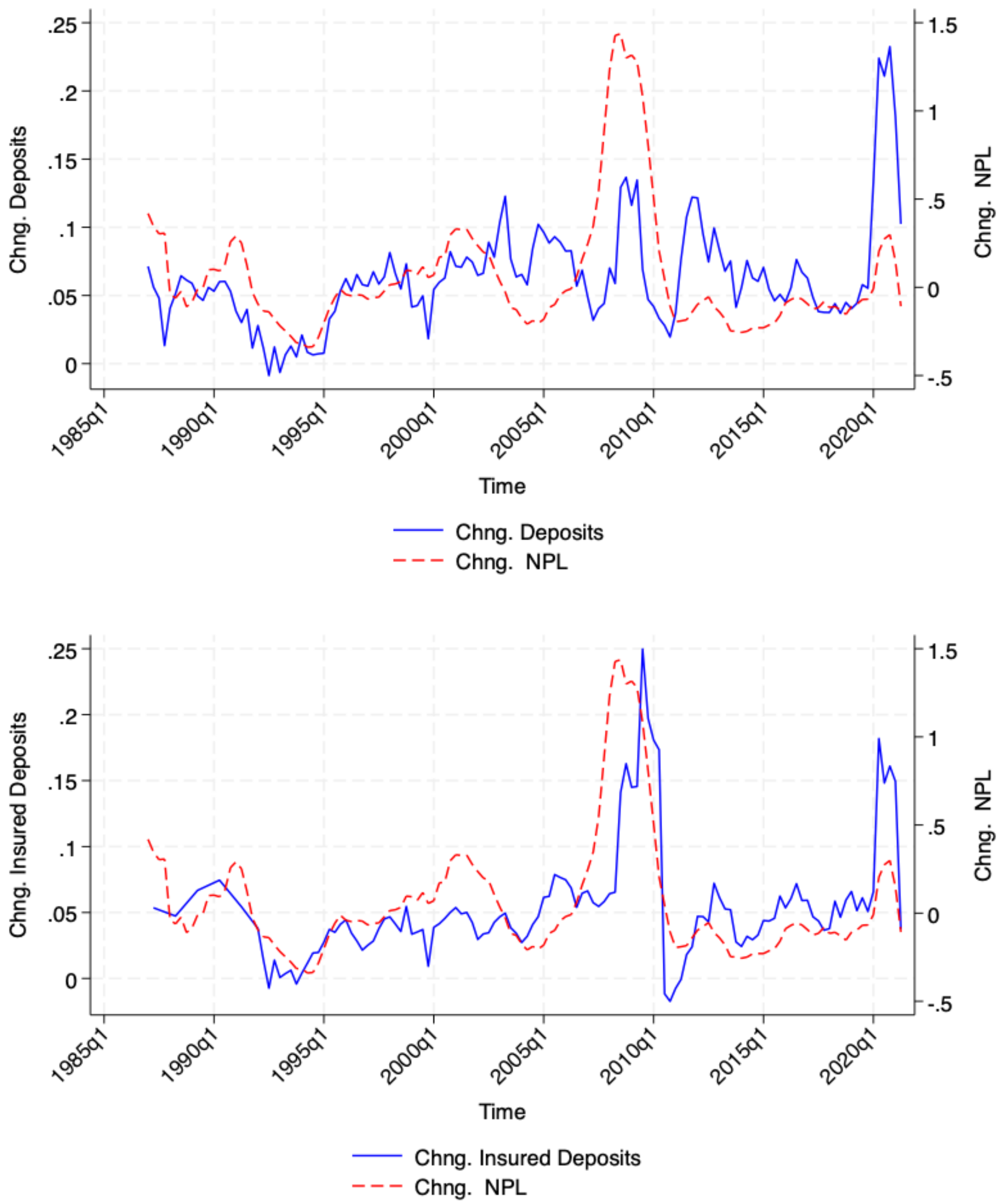

Figure 2: Deposits and NPL Growth

Notes: This figure plots the relationship between quarterly deposit growth rates and the aggregate change in the NPL. The top panel plots the growth of total deposits and the bottom panel plots the growth of insured deposits.
Source: Call Reports.

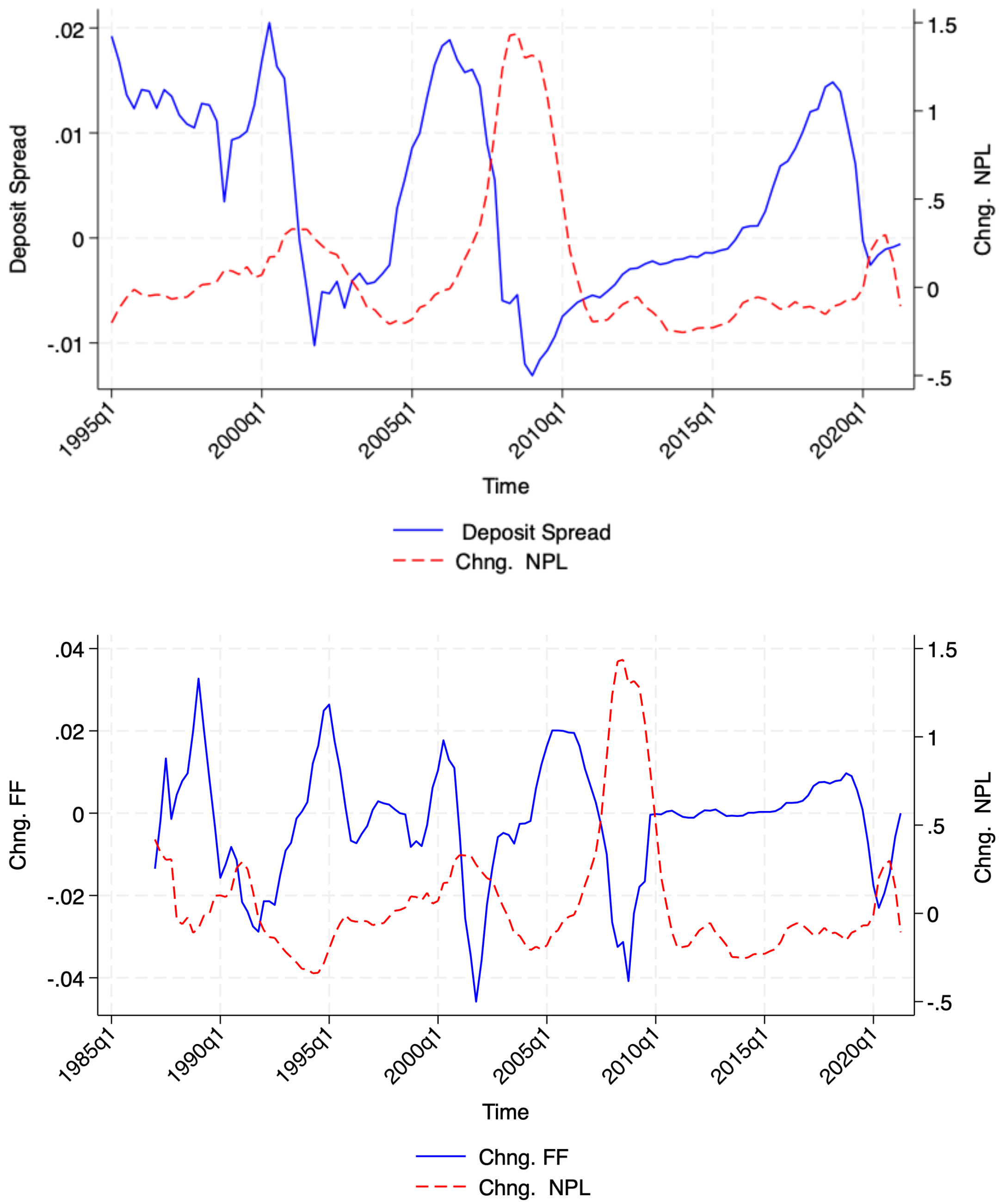

Figure 3: Deposit Spreads, Interest Rates, and NPL Growth

Notes: This figure plots the relationship between interest rates and the change in the NPL ratio. The top panel plots the deposit rate spread and the bottom panel plots the effective federal funds rate, in relation to the change in the NPL ratio.
Source: Call Reports.

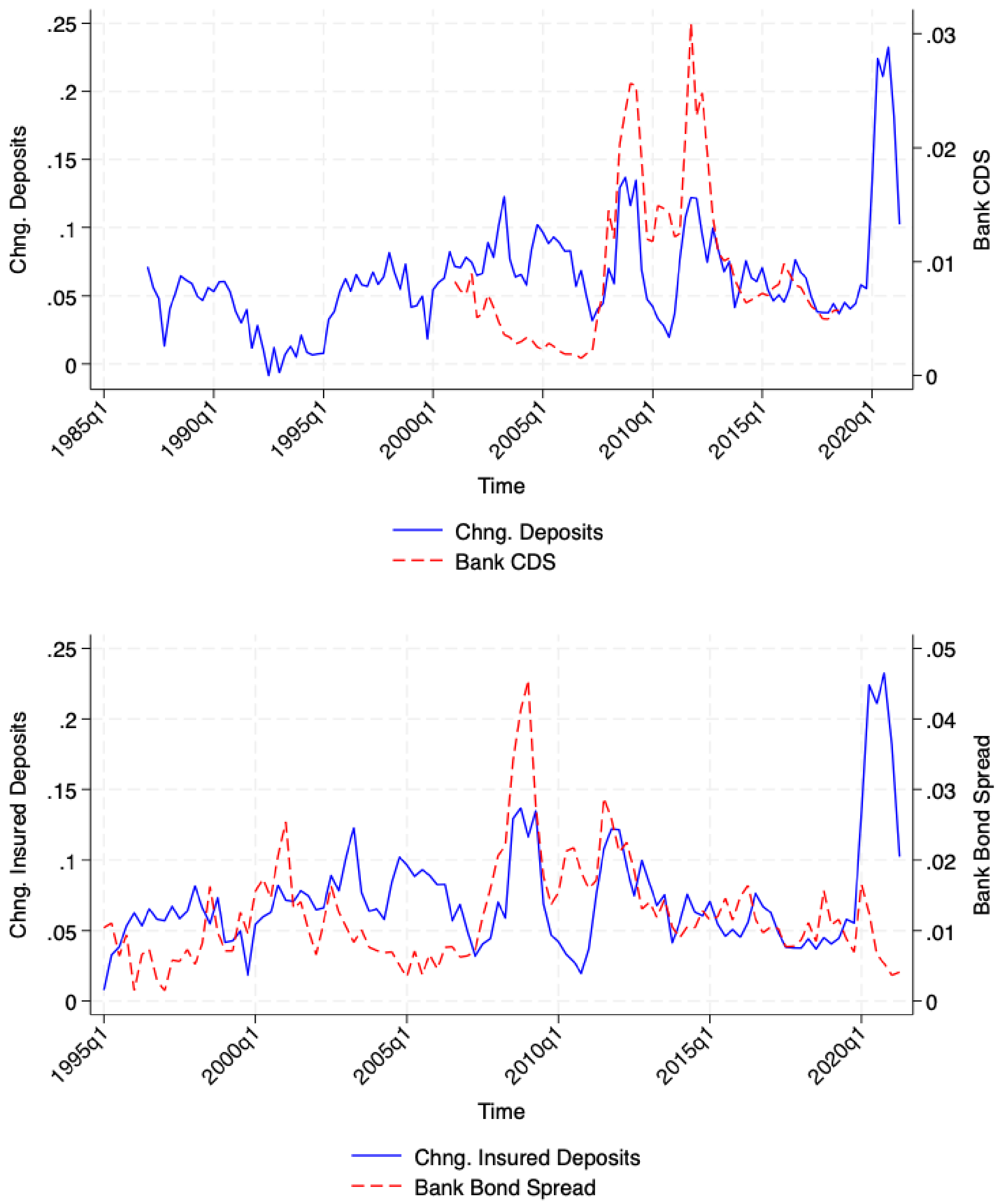

Figure 4: Deposits and Bank Bond Spread

Notes: This figure plots the relationship between quarterly deposit growth rates and CDS spread/Bank bond spread.
Source: Call Reports.

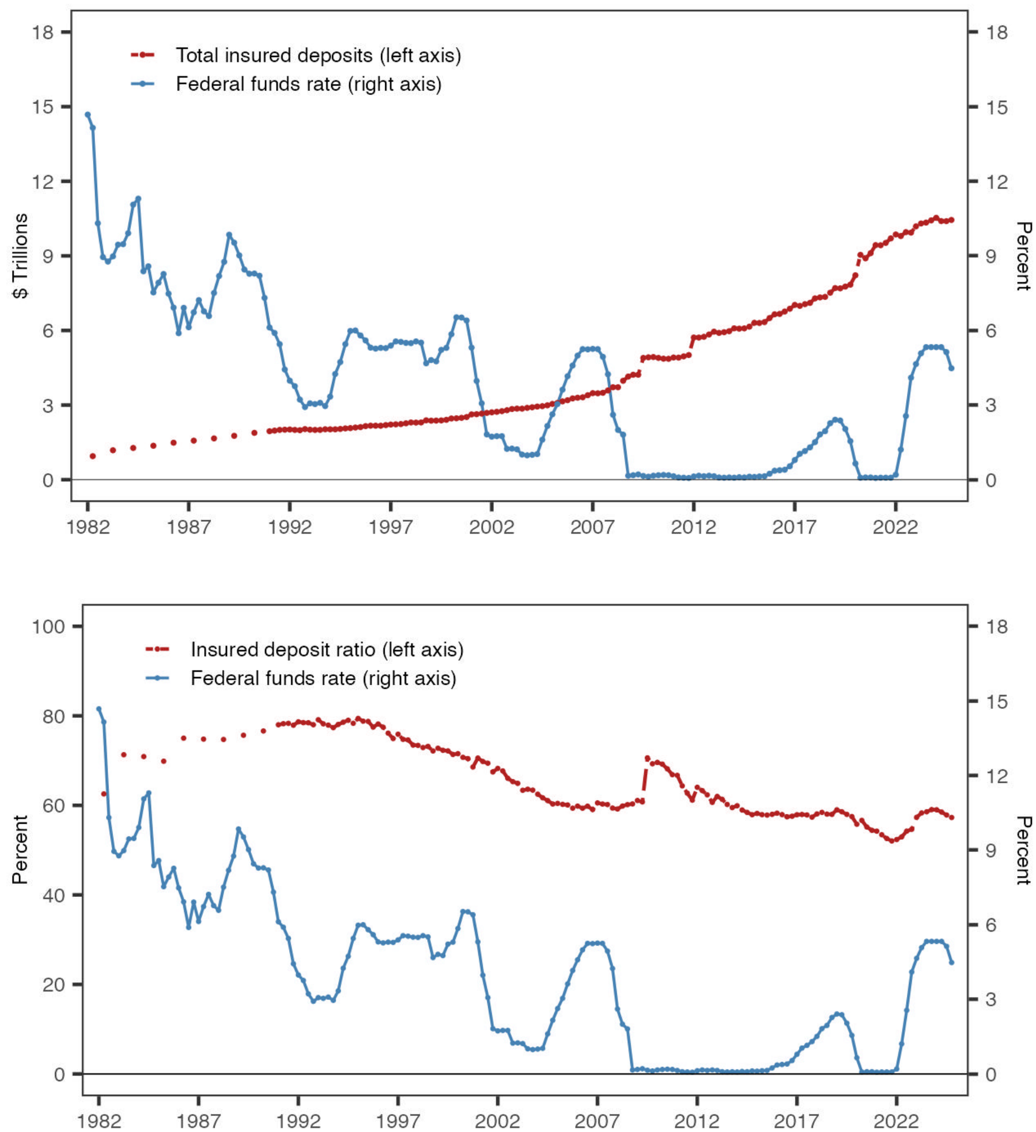

Figure 5: Evolution of Insured Deposits

Notes: This figure plots the total amount of insured deposits (top panel) and the ratio of insured to total deposits (bottom panel) from 1982Q1 to 2024Q4. Both series are plotted against the federal funds rate.
Source: Call Reports, Federal Reserve Board (H.15 Release).

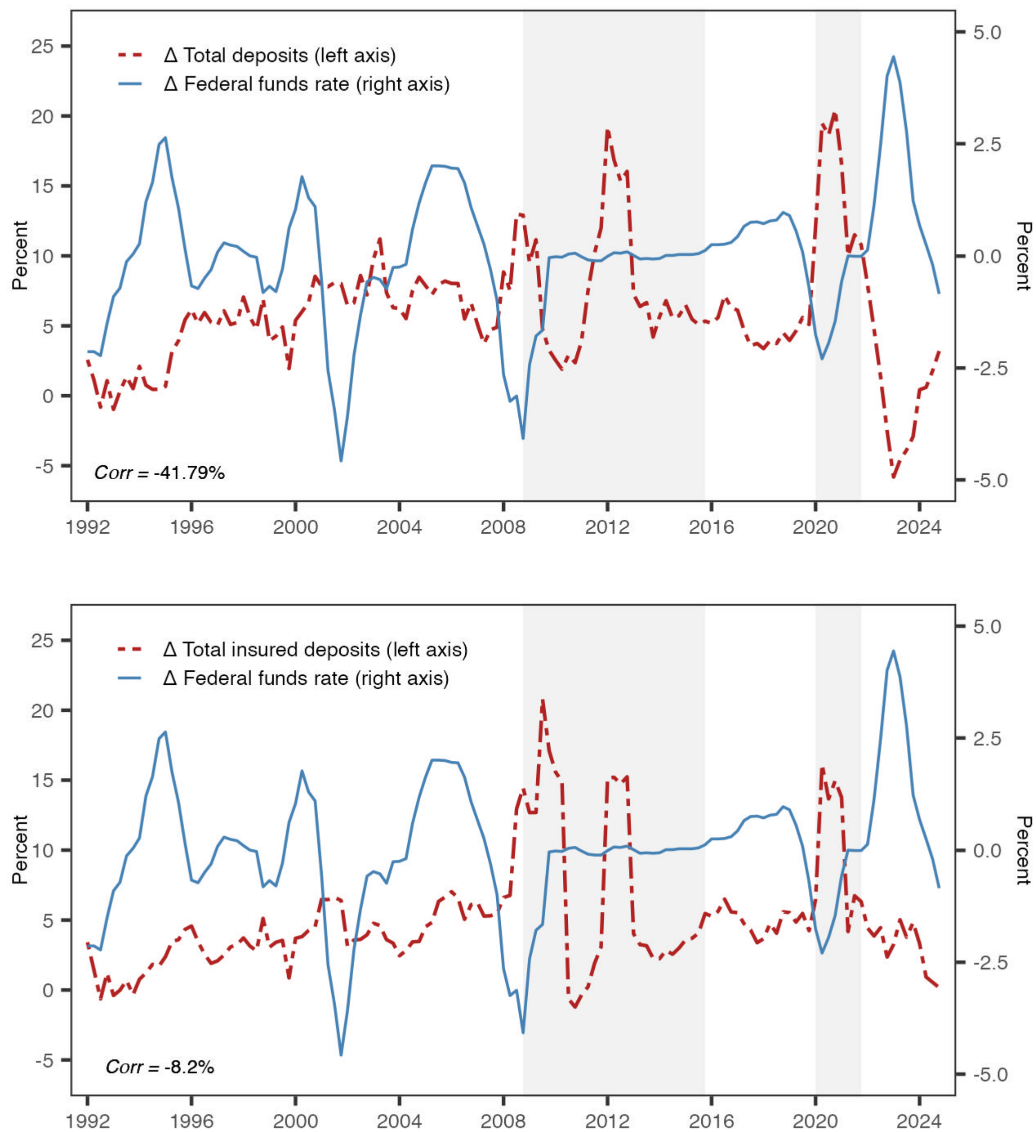

Figure 6: Insured Deposits Channel of Monetary Policy

Notes: This figure plots year-over-year changes in total deposits (Panel A) and insured deposits (Panel B) against year-over-year changes in the federal funds rate. For each panel, we report the correlation between the two series, excluding the recession periods denoted in grey bars. The sample is from 1992Q1 to 2024Q4.
Source: Call Reports, Federal Reserve Board (H.15 Release).

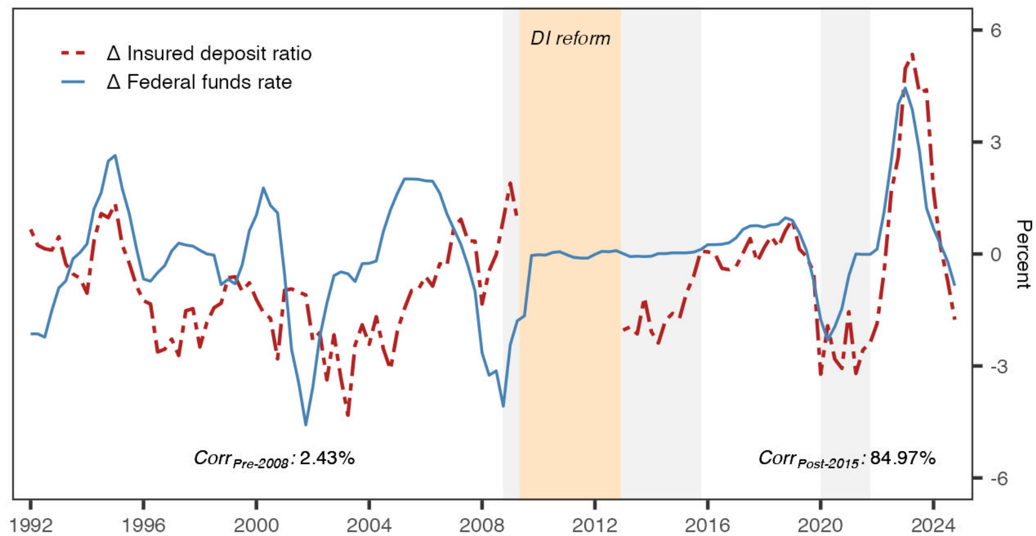

Figure 7: Government Subsidy and Deposit Supply

Notes: This figure plots year-over-year changes in the ratio of insured deposits to total deposits against year-over-year changes in the federal funds rate. The grey bars denote recession periods. The "DI reform" period encompasses the gradual increase of the FDIC deposit insurance limit to $250,000. We report the correlations between the two series in non-recession periods before 2008 and after 2015. The sample is from 1992Q1 to 2024Q4.
Source: Call Reports, Federal Reserve Board (H.15 Release).

Tables

Table 1: Summary Statistics

	Mean	SD	Min	P25	P50	P75	Max	N
Implied σ	0.337	0.24	0.029	0.232	0.280	0.365	8.486	25756
$PortfolioWeightIV$	0.012	0.01	0.000	0.005	0.007	0.015	0.079	732677
$NPLRatio$	0.009	0.01	0.000	0.002	0.005	0.012	0.073	1173296

Notes: Implied σ is rolling one-year implied volatility of sample banks' equity returns using Optionsmetric. NPL ratio is defined as the sum of nonaccrual loans and accruing loans that are past due by more than 90 days. PortfolioWeightIV is the Bartik instrument constructed by multiplying a bank's 3-year lagged portfolio weights across five asset classes by the aggregate NPL levels in those asset classes.
Source: OptionMetrics, Call Reports

Table 2: Deposit Put Channel: Deposit Quantities

	Log(Deposits)	NPL Ratio	Log(Deposits)	
	(1)	(2)	(3)	(4)
NPL Ratio	0.017***			
	(7.11)			
$\widehat{NPLRatio}$				0.161***
				(12.80)
$PortfolioWeightIV$		0.612***	0.098***	
		(50.34)	(13.20)	
Book Equity to Book Assets	-0.254***	-0.086***	-0.131***	-0.117***
	(-48.92)	(-12.56)	(-15.29)	(-13.72)
Observations	1172151	732120	732120	732120
Time FE	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes
First-stage F-stat		2533.94		
R^2	0.9138	0.4791	0.9365	-0.0471

t statistics in parentheses

* $p < .10$, ** $p < .05$, *** $p < .01$

Notes: This table documents the relationship between a bank's NPL Ratio and deposit quantities. Log(Deposits) is the log of total deposits. $\widehat{\text{NPL Ratio}}$ is the NPL Ratio instrumented by the lagged portfolio weights Bartik instrument. T-statistics calculated using standard errors clustered at the bank holding company level are shown in parentheses. *, **, and *** represent statistical significance at the 10%, 5%, and 1% levels, respectively.
Source: Call Reports.

Table 3: Deposit Put Channel: Insured Fraction

	Insured Fraction		
	(1)	(2)	(3)
NPL Ratio	0.011***		
	(28.80)		
$\widehat{\text{NPL Ratio}}$			0.030***
			(18.19)
Portfolio-Weight-IV		0.018***	
		(17.28)	
Book Equity to Book Assets	-0.005***	0.002**	0.004***
	(-8.00)	(2.18)	(5.01)
Bank Size	-0.049***	-0.058***	-0.058***
	(-23.88)	(-19.12)	(-19.55)
Qtr-Year FE	✓	✓	✓
Bank FE	✓	✓	✓
Observations	973,702	732,115	732,112
R^2	0.7706	0.7987	0.0104

Notes: This table documents the relationship between the NPL Ratio of a bank and the fraction of insured deposits. "Insured Fraction" is the fraction of deposits at the bank that are insured. $\widehat{NPLRatio}$ is the NPL Ratio instrumented by the lagged portfolio weights Bartik instrument.
Source: Call Reports.

Table 4: Deposit Put Channel: Branch Deposit Quantities

	Log(Branch Deposits)			
	(1)	(2)	(3)	(4)
NPL Ratio	0.022***	0.026***		
	(5.42)	(4.99)		
$\widehat{NPLRatio}$			0.185**	0.206**
			(2.33)	(2.09)
Book Equity to Book Assets	-0.061***	-0.063***	-0.040***	-0.041***
	(-5.97)	(-6.13)	(-5.54)	(-5.39)
No. Branches	-0.061***	-0.073***	-0.126***	-0.139***
	(-3.13)	(-3.85)	(-5.24)	(-5.57)
Bank Size	0.019**	0.012	0.002	-0.001
	(1.97)	(1.38)	(0.27)	(-0.16)
Observations	1917159	1911341	1342116	1337414
Time FE	No	No	No	No
Branch FE	Yes	Yes	Yes	Yes
State × Time FE	Yes	No	Yes	No
County × Time FE	No	Yes	No	Yes

t statistics in parentheses

* $p < .10$, ** $p < .05$, *** $p < .01$

Notes: This table documents the relationship between a bank's NPL Ratio and branch-level deposit quantities, measured as log total deposits. $\widehat{\text{NPL Ratio}}$ is the NPL Ratio instrumented by the lagged portfolio weights Bartik instrument. *Source:* Call Reports, Summary of Deposits.

Table 5: Deposit Put Channel: Rates Branch level

	Wholesale Insured Rate		Submarginal Insured Rate	
	(1)	(2)	(3)	(4)
NPL Ratio	0.006**		0.011***	
	(2.26)		(2.65)	
$\widehat{\text{NPL Ratio}}$		0.074***		0.066**
		(3.65)		(2.24)
Bank Size	-0.007	0.008	-0.002	-0.002
	(-1.08)	(1.02)	(-0.21)	(-0.18)
Book Equity to Book Assets	-0.008	0.008	-0.003	0.003
	(-1.13)	(0.73)	(-0.34)	(0.25)
No. Branches	-0.014*	-0.025	0.006	0.051**
	(-1.77)	(-1.27)	(0.30)	(2.49)
County $\times$ Qtr-Year FE	✓	✓	✓	✓
Branch FE	✓	✓	✓	✓
Observations	250,298	133,231	198,297	76,305

Notes: This table documents the relationship between a bank's NPL Ratio and the interest rate on insured deposits. $\widehat{\text{NPL Ratio}}$ is the NPL Ratio instrumented by the lagged portfolio weights Bartik instrument. "Wholesale Insured Rate" is the 12M CD rate on 100K deposits from 2001 to 2010 and the 12M CD rate on 250K deposits from 2010 onwards. "Submarginal Insured Rate" is the 12M CD rate on 50K deposits from 2001 to 2010 and the 12M CD rate on 200K deposits from 2010 onwards.
Source: Call Reports, RateWatch.

Table 6: Deposit Put Channel: Time Series NPL Ratio

	Deposit Growth	Chng Insured Fraction	Deposit Spread
	(1)	(2)	(3)
NPL Growth	0.011***	0.008***	-0.003***
	(3.81)	(3.02)	(-4.91)
Observations	138	118	106
R^2	0.0866	0.1412	0.1139

Notes: This table documents the time series correlation between a bank's NPL Ratio and its deposit growth, quarterly change in the fraction of insured deposits, and the deposit spread computed as the federal funds rate minus the average deposit rate.
Source: Call Reports, RateWatch.

Table 7: Deposits and Fed Funds Rate: 1991Q1-2021Q4

	Δln(Dep)	Δln(Ins. Dep)	Δln(Unins. Dep)	ΔIns. Share
	(1)	(2)	(3)	(4)
Δ FF Rate	-0.0907***	-0.0770***	-0.0885***	-0.0071*
	(-4.9299)	(-4.3267)	(-4.4584)	(-1.7377)
ln(Assets)	-0.1059***	-0.1278***	-0.0663***	0.0694***
	(-5.2602)	(-5.9800)	(-3.2870)	(4.9550)
Equity/Assets	2.1135***	2.8408***	0.6124***	0.0479
	(6.3980)	(8.2290)	(5.0158)	(1.2263)
Bank FE	✓	✓	✓	✓
Observations	1,003,642	990,356	984,351	990,941
R^2	0.0783	0.0855	0.0120	0.0757

Notes: This table documents the relationship between the quarterly total deposit growth, quarterly insured deposit growth, the quarterly fraction of insured deposits, and quarterly changes in the Federal Funds Effective Rate. Control variables include size and leverage. **All variables are standardized for ease of interpretation.**
Source: Call Reports.

Table 8: Deposit Put Channel: Deposit Growth

	Deposit Growth						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Δ FF	-0.403***	-0.278***	-0.297***	-0.194*	0.000	0.000	0.000
	(-4.44)	(-2.76)	(-3.08)	(-1.86)	(.)	(.)	(.)
Δ NPL Ratio		0.010***		0.008***	0.005**	0.006***	0.006***
		(3.71)		(3.01)	(2.49)	(3.13)	(3.01)
Bank Size			-0.025***	-0.025***	-0.010***	-0.009***	-0.009**
			(-8.62)	(-8.54)	(-3.16)	(-2.85)	(-2.43)
Book Equity to Book Assets			-0.022***	-0.022***	-0.010***	-0.010***	-0.009***
			(-8.13)	(-8.13)	(-3.20)	(-3.50)	(-2.89)
HHI			0.060***	0.061***	0.048**	0.034**	0.000
			(3.04)	(3.06)	(2.36)	(2.06)	(.)
Δ FF × HHI			-1.295***	-1.420***	-1.113***	-1.262***	0.000
			(-3.42)	(-3.60)	(-3.06)	(-4.56)	(.)
Observations	1701731	1691307	1701730	1691307	1691307	1691281	1686338
Time FE	No	No	No	No	Yes	No	No
Branch FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State × Time FE	No	No	No	No	No	Yes	No
County × Time FE	No	No	No	No	No	No	Yes
R^2	0.1375	0.1379	0.1445	0.1447	0.1532	0.1612	0.1940

t statistics in parentheses

* $p < .10$, ** $p < .05$, *** $p < .01$

Notes: This table replicates the DSS effect on interest rates and documents the relationship between the change in NPL ratio of a bank and deposit growth. Δ NPL Ratio is the one-year change in a bank's NPL Ratio. Δ FF is the one-year change in the federal funds rate. "HHI" is the county-level Herfindahl–Hirschman index of bank branch deposits.
Source: Summary of Deposits, Call Reports.

Table 9: Deposit Put Channel: Rates Bank level

	Deposit Rate		(Banks w/ over 90% Insured)	
	(1)	(2)	(3)	(4)
NPL Ratio	0.044***		0.042***	
	(23.02)		(19.64)	
$\widehat{NPLRatio}$		0.061***		0.072***
		(5.40)		(4.62)
Book Equity to Book Assets	-0.090***	-0.072***	-0.118***	-0.092***
	(-21.09)	(-13.03)	(-16.69)	(-9.91)
Bank Size	0.311***	0.380***	0.389***	0.392***
	(26.09)	(21.11)	(22.04)	(17.07)
Observations	1169507	732112	543454	270291
Time FE	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes
R^2	0.9341	0.0406	0.9334	0.0353

t statistics in parentheses

* $p < .10$, ** $p < .05$, *** $p < .01$

Notes: This table documents the relationship between a bank's NPL Ratio and deposit quantities across different time samples. Log(Deposits) is the log of total deposits. $\widehat{\text{NPL Ratio}}$ is the NPL Ratio instrumented by the lagged portfolio weights Bartik instrument. T-statistics calculated using standard errors clustered at the bank holding company level are shown in parentheses.. *, **, and *** represent statistical significance at the 10%, 5%, and 1% levels, respectively.
Source: Call Reports.

Table 10: Alternative Measure: Volatility – Quantities

	Log(Deposits)	Insured Fraction
	(1)	(2)
L. Implied σ	0.017*	0.005**
	(1.92)	(2.41)
Book Equity to Book Assets	-0.041	-0.000
	(-1.08)	(-0.04)
Bank Size	1.396***	0.018
	(16.84)	(0.88)
Observations	23929	23924
Year-Quarter FE	Yes	Yes
Bank FE	Yes	Yes
R^2	0.9566	0.8010

t statistics in parentheses

* $p < .10$, ** $p < .05$, *** $p < .01$

Notes: Table 10 documents the relationship between the option-implied volatility of a bank's equity and a banks' deposit quantities and the fraction of insured deposits. 'L.Implied σ' is the one quarter lagged one year implied option on a banks' call and put options from OptionMetrics. 'Log(Deposits)' is the log of the total deposits at the bank. Insured Fraction is the fraction of deposits at the bank that are insured. Sources: OptionMetrics, Call Reports

Table 11: Alternative Measure: Volatility – Prices

	Wholesale Insured Rate	Submarginal Insured Rate
	(1)	(2)
L. Implied σ	0.055***	0.042**
	(2.65)	(2.38)
Bank Size	0.036	0.076
	(0.76)	(1.32)
Book Equity to Book Assets	-0.050*	-0.052*
	(-1.71)	(-1.67)
Observations	33522	30400
County × Year-Quarter FE	Yes	Yes
Branch FE	Yes	Yes

t statistics in parentheses

* $p < .10$, ** $p < .05$, *** $p < .01$

Notes: Table 11 documents the relationship between the option-implied volatility of a bank's equity and the interest rate on banks' insured deposits. 'L.Implied σ' is the one quarter lagged one year implied option on a banks' call and put options from OptionMetrics. 'Wholesale Insured Rate' is the 12M CD rate on 100K deposits from 2001-2010 and the 12M CD rate on 250K deposits from 2010 onwards. 'Submarginal Insured Rate' is the 12M CD rate on 50K deposits from 2001-2010 and the 12M CD rate on 200K deposits from 2010 onwards. Sources: OptionMetrics, Call Reports, Ratewatch

Appendix

7.1 Sensitivity of Market Value of Deposit Insurance to 'r'

$$
\begin{aligned}
P[L,K,\sigma,r,T] &= Ke^{-rT}\Phi(-d_2) - L\Phi(-d_1) \qquad (16)\\
d_1 &= \frac{ln(\frac{L}{K}) + (r + \frac{\sigma^2}{2})T}{\sigma\sqrt{T}};\\
d_2 &= d_1 - \sigma\sqrt{T};\\
K &= D \cdot e^{rT};\\
\frac{L}{K} &= \frac{D}{wD \cdot e^{rT}} = \frac{1}{w \cdot e^{rT}}.\\
\sigma &= \hat{b} - \hat{a} * r
\end{aligned}
$$

$$
\begin{aligned}
P[L,K,\sigma,r,T] &= D\Phi(-d_2) - \frac{D}{w}\Phi(-d_1)\\
d_1 &= \frac{-ln(w \cdot e^{rT}) + (r + \frac{(\hat{b}-\hat{a}*r)^2}{2})T}{(\hat{b} - \hat{a} * r)\sqrt{T}}\\
d_1 &= \frac{-ln(w) - rT + (r + \frac{(\hat{b}-\hat{a}*r)^2}{2})T}{(\hat{b} - \hat{a} * r)\sqrt{T}}\\
d_1 &= \frac{-ln(w) + (\frac{(\hat{b}-\hat{a}*r)^2}{2})T}{(\hat{b} - \hat{a} * r)\sqrt{T}}\\
d_1 &= \frac{-ln(w)}{(\hat{b} - \hat{a} * r)\sqrt{T}} + \frac{(\hat{b} - \hat{a} * r)\sqrt{T}}{2}\\
d_2 &= d_1 - (\hat{b} - \hat{a} * r)\sqrt{T} \qquad (17)
\end{aligned}
$$

It follows that:

$$
\frac{1}{D}\frac{\partial P[L,K,\sigma,r,T]}{\partial r} = \frac{\partial \Phi(-d_2)}{\partial r} - \frac{1}{w}\frac{\partial \Phi(-d_1)}{\partial r} \qquad (18)
$$

$$
\begin{aligned}
\frac{\partial \Phi(-d_1)}{\partial r} &= \frac{\partial \Phi(-d_1)}{\partial d_1}\frac{\partial d_1}{\partial r}\\
&= -\phi(-d_1).\frac{\partial}{\partial r}\{\frac{-ln(w)}{(\hat{b} - \hat{a} * r)\sqrt{T}} + \frac{(\hat{b} - \hat{a} * r)\sqrt{T}}{2}\}\\
&= -\phi(-d_1)\{\frac{-\hat{a}.ln(w)}{(\hat{b} - \hat{a} * r)^2\sqrt{T}} - \frac{\hat{a}\sqrt{T}}{2}\}\\
&= \phi(-d_1)\{\frac{\hat{a}.ln(w)}{(\hat{b} - \hat{a} * r)^2\sqrt{T}} + \frac{\hat{a}\sqrt{T}}{2}\} \qquad (19)
\end{aligned}
$$

Now,

$$\begin{aligned}
\phi(-d_2) &= \phi(d_2) = \frac{1}{\sqrt{2\pi}}e^{-\frac{d_2^2}{2}} = \frac{1}{\sqrt{2\pi}}e^{-\frac{(d_1-\sigma\sqrt{T})^2}{2}} = \frac{1}{\sqrt{2\pi}}e^{-\frac{(d_1^2-2d_1\sigma\sqrt{T}+\sigma^2 T)}{2}} \\
&= \phi(d_1)e^{-\frac{(-2d_1\sigma\sqrt{T}+\sigma^2 T)}{2}} = \phi(d_1)e^{-\frac{(-2(ln\frac{L}{K}+(r+\frac{\sigma^2}{2})T)+\sigma^2 T)}{2}} \\
&= \phi(d_1)e^{ln(\frac{L}{K})+rT} = \phi(d_1)e^{ln(\frac{1}{w.e^{rT}})+rT} \\
&= \phi(d_1)e^{-ln(w)} = \frac{1}{w}\phi(d_1) \qquad (20)
\end{aligned}$$

Therefore,

$$\begin{aligned}
\frac{\partial\Phi(-d_2)}{\partial r} &= -\phi(-d_2)\frac{\partial d_2}{\partial r} \\
&= -\phi(-d_2)\{\frac{\partial d_1}{\partial r} + \hat{a}\sqrt{T}\} \\
&= -\frac{1}{w}\phi(d_1)\{\frac{-\hat{a}.ln(w)}{(\hat{b}-\hat{a}*r)^2\sqrt{T}} + \frac{\hat{a}\sqrt{T}}{2}\} \qquad (21)
\end{aligned}$$

Combining with equation 14 above:

$$\begin{aligned}
\frac{1}{D}\frac{\partial P[L,K,\sigma,r,T]}{\partial r} &= \frac{\partial\Phi(-d_2)}{\partial r} - \frac{1}{w}\frac{\partial\Phi(-d_1)}{\partial r} \\
&= -\frac{1}{w}\phi(d_1)\{\frac{-\hat{a}.ln(w)}{(\hat{b}-\hat{a}*r)^2\sqrt{T}} + \frac{\hat{a}\sqrt{T}}{2}\} - \frac{1}{w}\phi(-d_1)\{\frac{\hat{a}.ln(w)}{(\hat{b}-\hat{a}*r)^2\sqrt{T}} + \frac{\hat{a}\sqrt{T}}{2}\} \\
&= (\frac{1}{w} - \frac{1}{w})\phi(d_1)\{\frac{\hat{a}.ln(w)}{(\hat{b}-\hat{a}*r)^2\sqrt{T}}\} + \phi(d_1)(-\frac{1}{w} - \frac{1}{w})\{\frac{\hat{a}\sqrt{T}}{2}\} \\
&= \phi(d_1)(-\frac{2}{w})\{\frac{\hat{a}\sqrt{T}}{2}\} = -\phi(d_1)\{\frac{\hat{a}\sqrt{T}}{w}\} \qquad (22)
\end{aligned}$$

Since $w > 0$, the above value is negative for all parameter values.

7.2 Bank's Optimization Problem

$$\max_{\{D\}} \; P[L,K,\sigma,r,T] - \frac{1}{2}cD^2 - \bar{p}D$$

FOC:

$$\frac{\partial P[L,K,\sigma,r,T]}{\partial D} = cD + \bar{p}$$

Note:

$$P[L,K,\sigma,r,T] = D\Phi(-d_2) - \frac{D}{w}\Phi(-d_1) \tag{23}$$
$$d_1 = \frac{-ln(w)}{(\hat{b}-\hat{a}*r)\sqrt{T}} + \frac{(\hat{b}-\hat{a}*r)\sqrt{T}}{2}$$
$$d_2 = d_1 - (\hat{b}-\hat{a}*r)\sqrt{T}$$

$$\begin{aligned}\frac{\partial P[L,K,\sigma,r,T]}{\partial D} &= \Phi(-d_2) + D.\frac{\Phi(-d_2)}{\partial D} - \frac{\Phi(-d_1)}{w} - \frac{D}{w}\frac{\partial\Phi(-d_1)}{\partial D} \\ &= \Phi(-d_2) - D\phi(-d_2)\frac{\partial d_2}{\partial D} - \frac{\Phi(-d_1)}{w} + \frac{D}{w}\phi(-d_1)\frac{\partial d_1}{\partial D} \\ &= \Phi(-d_2) - \frac{\Phi(-d_1)}{w}\end{aligned} \tag{24}$$

Therefore, optimal quantity of deposits is given by the following equation:

$$\Phi(-d_2) - \frac{\Phi(-d_1)}{w} = cD + \bar{p}$$
$$D^* = \frac{1}{c}\{\Phi(-d_2) - \frac{\Phi(-d_1)}{w} - \bar{p}\} \tag{25}$$

Optimal supply of deposits decreases when marginal cost c is higher; and when deposit insurance premium paid, $\bar{p}$ is higher. It increases when the default option has higher value.

Now using the envelope theorem, let's find the sensitivity of optimal D w.r.t. 'r'

$$\begin{aligned}\frac{\partial D^*}{\partial r} &= \frac{1}{c}\frac{\partial}{\partial r}\{\Phi(-d_2) - \frac{\Phi(-d_1)}{w}\} \\ &= -\phi(d_1)\{\frac{\hat{a}\sqrt{T}}{cw}\}\end{aligned} \tag{26}$$

Therefore, when interest rate goes up, optimal deposit financing comes down.

7.3 Model with Liquidity Benefits of Deposits

Suppose a bank makes a loan of value L with a maturity of T_L at an interest rate r_L. Risk-free rate is r and $r_L > r$. Loan is funded with insured deposit D and equity capital of E. For simplicity assume that the deposits are issued as zero coupon bond with maturity T and a promised rate of return of r_D. Therefore, deposit has a face value of $D.e^{r_d T} \equiv K$. Rate of return on deposits is below the market rate of return r, specifically, $r_d = r.(1-\alpha) - \beta$, where $0 < \alpha < 1$, and $\beta > 0$. This is a flexible parametrization that captures both a fixed amount and a variable amount of liquidity premium a depositor is willing to pay.

Deposits are insured by the FDIC at a fixed rate of c per unit of the market value of a deposit. The market value of the deposit insurance, P, can be obtained by a standard put option formula on the asset value of the bank with the face value of a deposit as the strike price.

$$
\begin{aligned}
P[L,K,\sigma,r,T] &= Ke^{-rT}\Phi(-d_2) - L\Phi(-d_1) \\
d_1 &= \frac{ln(\frac{L}{K}) + (r + \frac{\sigma^2}{2})T}{\sigma\sqrt{T}} \\
d_2 &= d_1 - \sigma\sqrt{T}
\end{aligned}
\tag{27}
$$

The amount of subsidy that a bank enjoys on its insured deposit is the difference between the market value of deposit insurance and the premium paid. The subsidy changes as interest rates change because the fair market valuation of deposit insurance changes with interest rate. When interest rates are high, market value comes down and therefore the subsidy enjoyed by banks comes down. Proof below:

$$
\begin{aligned}
\frac{\partial P[L,K,\sigma,r,T]}{\partial r} &= \frac{\partial K e^{-rT}\Phi(-d_2)}{\partial r} - \frac{\partial L\Phi(-d_1)}{\partial r} && (28) \\
&= \frac{\partial D e^{r_d T} e^{-rT}\Phi(-d_2)}{\partial r} - \frac{\partial L\Phi(-d_1)}{\partial r} \\
&= \frac{\partial D e^{(-\alpha r - \beta)T}\Phi(-d_2)}{\partial r} - \frac{\partial L\Phi(-d_1)}{\partial r} \\
&= \{-\alpha T D e^{-(\alpha r + \beta)T}\Phi(-d2)\} + \frac{D e^{-(\alpha r+\beta)T}\partial\Phi(-d_2)}{\partial r} - \frac{\partial L\Phi(-d_1)}{\partial r} && (29)
\end{aligned}
$$

$$
\begin{aligned}
\frac{\partial\Phi(-d_1)}{\partial r} &= \frac{\partial\Phi(-d_1)}{\partial d_1}\frac{\partial d_1}{\partial r} \\
&= -\phi(-d_1).\frac{\partial}{\partial r}\frac{ln(\frac{L}{K}) + (r + \frac{\sigma^2}{2})T}{\sigma\sqrt{T}} \\
&= -\phi(-d_1).\frac{1}{\sigma\sqrt{T}}\{\frac{\partial}{\partial r}(-lnK) + T\} \\
&= -\phi(-d_1).\frac{1}{\sigma\sqrt{T}}\{\frac{\partial}{\partial r}(-ln(De^{r_d T})) + T\} \\
&= -\phi(-d_1).\frac{1}{\sigma\sqrt{T}}\{\frac{\partial}{\partial r}(-r_d T) + T\} \\
&= -\phi(-d_1).\frac{1}{\sigma\sqrt{T}}\{(-(1-\alpha)T) + T\}
\end{aligned}
\tag{30}
$$

$$
\begin{aligned}
&= -\phi(-d_1).\frac{1}{\sigma\sqrt{T}}\alpha T \\
\frac{\partial\Phi(-d_2)}{\partial r} &= -\phi(-d_2)\frac{\partial d_2}{\partial r} = -\phi(-d_2)\frac{\partial d_1}{\partial r} = -\phi(-d_2)\frac{1}{\sigma\sqrt{T}}\alpha T \\
\frac{\partial P[.]}{\partial r} &= \{-\alpha T D e^{(-\alpha r-\beta)T}\Phi(-d2)\} \\
&\quad -De^{-\alpha r T}\phi(-d_2).\frac{1}{\sigma\sqrt{T}}\alpha T + L\phi(-d_1).\frac{1}{\sigma\sqrt{T}}\alpha T
\end{aligned} \tag{31}
$$

$$
\begin{aligned}
\phi(-d_2) &= \phi(d_2) = \frac{1}{\sqrt{2\pi}}e^{-\frac{d_2^2}{2}} = \frac{1}{\sqrt{2\pi}}e^{-\frac{(d_1-\sigma\sqrt{T})^2}{2}} = \frac{1}{\sqrt{2\pi}}e^{-\frac{(d_1^2-2d_1\sigma\sqrt{T}+\sigma^2 T)}{2}} \\
&= \phi(d_1)\frac{1}{\sqrt{2\pi}}e^{-\frac{(-2d_1\sigma\sqrt{T}+\sigma^2 T)}{2}} \\
&= \phi(d_1)e^{ln(\frac{L}{K})+rT} = \phi(d_1)e^{ln(\frac{L}{D.e^{r_d T}})+rT} \\
&= \phi(d_1)e^{rT}\frac{L}{D.e^{r_d T}} = \phi(d_1)e^{(\alpha r+\beta)T}\frac{L}{D}
\end{aligned}
$$

$$
\frac{\partial P[.]}{\partial r} = \{-\alpha T D e^{-(\alpha r+\beta)T}\Phi(-d2)\} \tag{32}
$$

$$
-De^{-(\alpha r+\beta)T}\phi(d_2).\frac{1}{\sigma\sqrt{T}}\alpha T + L\phi(d_1).\frac{1}{\sigma\sqrt{T}}\alpha T
$$

$$
= \{-\alpha T D e^{-(\alpha r+\beta)T}\Phi(-d2)\} \tag{33}
$$

$$
-De^{-(\alpha r+\beta)T}\phi(d_1)e^{(\alpha r+\beta)T}\frac{L}{D}.\frac{1}{\sigma\sqrt{T}}\alpha T + L\phi(d_1).\frac{1}{\sigma\sqrt{T}}\alpha T
$$

$$
= -\alpha D T e^{-(\alpha r+\beta)T}\Phi(-d2) < 0 \tag{34}
$$

Note from the first order condition:

$$
\frac{\partial P[L,K,\sigma,r,T]}{\partial D} = cD + \bar{p} \tag{35}
$$

$$
\frac{\partial P[L,K,\sigma,r,T]}{\partial D} = \frac{\partial K e^{-rT}\Phi(-d_2)}{\partial D} - \frac{\partial L\Phi(-d_1)}{\partial D} \tag{36}
$$

$$
\begin{aligned}
&= \frac{\partial D e^{r_d T}e^{-rT}\Phi(-d_2)}{\partial D} - \frac{\partial D\Phi(-d_1)}{w\partial D} \\
&= \frac{\partial D e^{(-\alpha r-\beta)T}\Phi(-d_2)}{\partial D} - \frac{\partial D\Phi(-d_1)}{w\partial D} \\
&= e^{-(\alpha r+\beta)T}\Phi(-d2) + \frac{De^{-(\alpha r+\beta)T}\partial\Phi(-d_2)}{\partial D} - \frac{\Phi(-d_1)}{w} - \frac{D\partial\Phi(-d_1)}{w\partial D} \\
&= e^{-(\alpha r+\beta)T}\Phi(-d2) - De^{-(\alpha r+\beta)T}\phi(-d_2)\frac{\partial d_2}{\partial D} - \frac{\Phi(-d_1)}{w} + \frac{D}{w}\phi(-d_1)\frac{\partial d_1}{\partial D}
\end{aligned}
$$

$$
= e^{-(\alpha r+\beta)T}\Phi(-d_2) - \frac{\Phi(-d_1)}{w} \tag{37}
$$

Optimal deposit quantity is given by:

$$\begin{aligned} e^{-(\alpha r+\beta)T}\Phi(-d_2) - \frac{\Phi(-d_1)}{w} &= cD^* + \bar{p} \\ D^* &= \frac{1}{c}\{e^{-(\alpha r+\beta)T}\Phi(-d_2) - \frac{\Phi(-d_1)}{w} - \bar{p}\} \end{aligned}$$

There, the sensitivity of deposit supply to interest rate is given by the following:

$$\begin{aligned} c\frac{\partial D^*}{\partial r} &= -\alpha T e^{-(\alpha r+\beta)T}\Phi(-d_2) + e^{-(\alpha r+\beta)T}\frac{\partial\Phi(-d_2)}{\partial r} - \frac{1}{w}\frac{\partial\Phi(-d_1)}{\partial r} \\ &= -\alpha T e^{-(\alpha r+\beta)T}\Phi(-d_2) - e^{-(\alpha r+\beta)T}\phi(-d_2)\frac{\partial d_2}{\partial r} + \frac{1}{w}\phi(-d_1)\frac{\partial d_1}{\partial r} \\ &= -\alpha T e^{-(\alpha r+\beta)T}\Phi(-d_2) - e^{-(\alpha r+\beta)T}\phi(-d_2)\frac{\alpha T}{\sigma\sqrt{T}} + \frac{1}{w}\phi(-d_1)\frac{\alpha T}{\sigma\sqrt{T}} \\ &= -\alpha T e^{-(\alpha r+\beta)T}\Phi(-d_2) - e^{-(\alpha r+\beta)T}.e^{(\alpha r+\beta)T}\frac{1}{w}\phi(d_1)\frac{\alpha T}{\sigma\sqrt{T}} + \frac{1}{w}\phi(d_1)\frac{\alpha T}{\sigma\sqrt{T}} \\ &= -\alpha T e^{-(\alpha r+\beta)T}\Phi(-d_2) < 0. \end{aligned} \tag{38}$$