INTERNET APPENDIX

VALUING STICKY DEPOSITS

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IA.1. THE DATA

This section provides details about the datasets used in the analyses. Table IA.1 provides a description of all the data and variables used in the study along with their definitions and corresponding sources.

IA.1.1. Federal Funds Futures and Interest Rate Swaption Data

We collect daily prices of federal funds futures with six months to expiration for the period from December 6, 1988, to June 30, 2025, from the Bloomberg system. Federal funds futures are quoted as 100 minus the average daily effective federal funds rate over the delivery month. For instance, on January 3, 2000, the market price of the federal funds futures contract expiring in June 2000 was 93.82. This means that the market is pricing in an average daily federal funds rate of $100 - 93.82 = 6.18\%$ over the month of June 2000.[1]

We also collect daily data on one-year into one-year at-the-money swaption volatilities for the period from January 24, 1997 to June 30, 2025 from the Bloomberg system.[2] Prior to June 30, 2023, swaptions reference interest rate swaps where the cash flows on the floating leg are based on the 3-month LIBOR rate. Following LIBOR's official discontinuation in the U.S. on June 30, 2023, we use swaptions where the floating rate of the underlying swap is the Secured Overnight Financing Rate (SOFR) for the period from July 1, 2023 onward.

IA.1.2. Call Reports and Federal Funds Rate

We use quarterly bank-level data from the Consolidated Reports of Condition and Income (Call Reports) provided by the Federal Financial Institutions Examination Council (FFIEC). From the Call Reports, we construct key variables including total domestic deposits and interest expense on domestic deposits. We supplement this with data on the federal funds rate from the Federal Reserve Bank of St. Louis FRED database (FRED).

IA.1.3. Core Deposit Intangibles

The primary measure of deposit value is derived from the core deposit intangibles recorded in typical bank merger/acquisition transactions. These values represent

[1] For detailed specifications of federal funds futures contracts, see www.cmegroup.com/markets/interest-rates/stirs/30-day-federal-fund.contractSpecs.html.

[2] Swaptions data first become available in the Bloomberg system on January 24, 1997.

the premium that an acquiring bank pays for the deposits of a target institution as part of an actual market transaction.

When a bank acquires another bank in a merger or acquisition, current generally accepted accounting principles (GAAP) in the U.S. require the acquiring bank to use the fair value method in recording the business combination in its financial statements. The specific requirements are detailed in two pronouncements by the Financial Accounting Standards Board (FASB) designated as ASC 805 *Business Combinations* and ASC 820 *Fair Value Measurements and Disclosures*.

As part of this process, the acquiring bank records the fair value of the intangibles acquired in the transaction, the most common of which is designated as the core deposit intangible (CDI). The CDI represents the difference between the acquiring bank's estimate of the economic value of the acquired deposits and the book value of those deposits. Since a core deposit intangible is recorded only when an actual merger/acquisition transaction occurs, the core deposit intangible can be interpreted as the deposit premium paid in a successful merger or acquisition to acquire the target bank's deposits. In this sense, the core deposit intangible can be viewed as the market-clearing price for the target bank's deposits.

Formally, under ASC 805, goodwill and identified intangibles are created on the buyer's consolidated financial statements as a result of the transaction. For bank and thrift deals, the CDI is separated from goodwill and other identified intangibles, and represents specifically the premium paid to acquire the deposit base. This premium is amortized over the expected life of the acquired deposits, typically 5 to 10 years.

We collect data on CDI from 2,134 merger/acquisition transactions that occurred from 1988 to 2025 from S&P Capital IQ Pro.[3] This database aggregates information from multiple sources including regulatory filings (Call Reports, FR Y-9C reports), company press releases and deal documents, advisor websites, and stock exchanges. We calculate the CDI premium as follows:[4]

$$\text{CDI Premium } \% = \frac{\text{Core Deposit Intangible}}{\text{Total Core Deposits Excl. Gov. Assisted Deals}} \times 100. \quad (1)$$

CDI premia in our sample range from 0.13% to 11.80%, with a mean of 1.95% and standard deviation of 1.36%. Figures IA.1 and IA.2 present the frequency distribution and time series of CDI premia.

[3]We exclude one observation for which the reported CDI is more than 13 standard deviations above the sample average.

[4]When the denominator in Equation (1) is not available, we use total core deposits.

IA.1.4. FDIC Failed Bank Auction Data

IA.1.4.1 FDIC Bidding Process

The FDIC's resolution process follows a structured timeline mandated by the Federal Deposit Insurance Corporation Improvement Act of 1991 (FDICIA). When a bank becomes critically undercapitalized, the Prompt Corrective Action provision generally requires closure within 90 days. During this period, the FDIC prepares to resolve the bank by marketing it to potential acquirers through a competitive auction process.

The FDIC solicits bids for failing institutions from qualified, financially sound FDIC-insured banks that meet established regulatory requirements. Potential bidders access confidential information about the failing institution through secure virtual data rooms (VDRs), which contain financial data, loan files, and details about the resolution transaction structure. The compressed timeframe, often just a few weeks between when detailed information becomes available and when bids are due, can create an environment of significant information asymmetry and time pressure for potential acquirers.

Bidders submit sealed bids specifying which assets they will purchase, which liabilities (particularly deposits) they will assume, and what cash payment they require from (or will pay to) the FDIC. Each bidder essentially states the amount of additional cash needed to cover any shortfall between the value of assumed liabilities and purchased assets. If liabilities exceed assets, the acquirer typically requests cash from the FDIC. Conversely, if assets exceed liabilities, the acquirer pays the FDIC. The FDIC is required by statute to select the bid that imposes the least cost on the Deposit Insurance Fund. This involves comparing each bid to the estimated cost of a "payout" scenario, where the FDIC would pay insured depositors directly and liquidate all assets through the receivership. The winning bid is the one that minimizes expected losses to the Deposit Insurance Fund while meeting regulatory requirements.

IA.1.4.2 Data Collection Process

We obtain deposit premium data from failed bank auctions conducted by the Federal Deposit Insurance Corporation (FDIC) during the 2000–2025 period. The FDIC provides summary information for banks resolved through purchase and assumption agreements on its failed bank list website.[5] We hand-collect data by downloading and examining the purchase and assumption agreements and bid summaries for each failed bank auction.

[5]See https://www.fdic.gov/bank-failures/failed-bank-list.

For each failed bank in our sample, we extract information directly from the FDIC's bid summaries and publicly available purchase and assumption agreements. These legal documents contain detailed terms of the transactions, including the deposit premiums offered by winning bidders. When bid summaries are not available (primarily in the earlier part of the sample period), we examine the FDIC press releases, which often contain information about the deposit premium paid by the winning bidder. This process yields a sample of 503 failed banks for which we have observable market pricing data for deposit accounts.[6] Figure IA.3 presents the incidence of bank failures by year.

IA.1.4.3 FDIC Auction Premia

The deposit premium emerges directly from this bidding structure. When an acquirer assumes deposits (liabilities) and purchases assets worth less than those deposits, the difference represents the capital shortfall. The deposit premium is the amount the acquirer is willing to pay (or requests in subsidy) per dollar of deposits assumed, reflecting the acquirer's valuation of those deposit balances. The FDIC auction premium is given by

$$\text{FDIC Auction Premium \%} = \frac{\text{(Assets Purchased - Deposits Assumed)}}{\text{Deposits Assumed}} \times 100\,. \quad (2)$$

A positive premium indicates that the acquirer values the target's deposits above their book value, while a negative premium (or required payment from the FDIC) indicates that the target's deposits are worth less than their book value when considering the associated assets and franchise value.

These FDIC auction premia are particularly well-suited for testing our model for several reasons. First, they represent actual market-clearing prices determined through competitive bidding among qualified financial institutions. Second, the auctions provide a relatively clean setting where banks evaluate deposits in isolation from other strategic considerations that might complicate merger/acquisition transactions. Third, the compressed timeframe of acquisitions (auctions typically conducted over a few days) ensures that deposit premia reflect contemporaneous market conditions and interest rate environments, allowing us to examine how deposit values vary with the riskless rate as predicted by our model.

Typical FDIC auction premia range from -1.50% to 9.28%. The average bid is

[6] There are 504 failed bank transactions with associated premia. We exclude one transaction since its press release is ambiguous about whether the reported premium refers to assumed assets and/or deposits.

0.53% with a standard deviation of 1.21%. Overall, the distribution is more skewed than that of the CDI premia, reflecting the fact that these transactions often involve distressed institutions, unlike voluntary bank merger/acquisition transactions, which typically include healthier banks. Figure IA.4 presents a scatterplot of the deposit premia by year.

Additional variables extracted from the purchase and assumption agreements and bid summaries include bank name, geographic location of the failed bank's headquarters, FDIC certificate ID, approximate total assets and deposits of the failed bank, name of the institution acquiring the failed bank, date the bank is closed by regulators, classification of bid (winning, cover, or other), premium or discount on assets acquired, nature of transaction (e.g., whole-bank purchase and assumption, insured deposit transfer), whether all deposits or only insured deposits are assumed, whether the transaction involves whole bank or partial bank assets, and whether the transaction includes a loss-sharing agreement with the FDIC.

We match each failed bank auction to the average federal funds rate for the month prior to the date of the purchase and assumption agreement announcement. This captures the prevailing interest rate environment immediately surrounding the bid submission and bank closure dates, given the compressed timeline of FDIC auctions.

IA.2. THE VALUATION MODEL

In this section, we derive a closed-form expression for the value of a bank deposit account, denoted by $V(r)$, as viewed from the bank's perspective. As shown in Equation (4) in the paper, the valuation model leads to a nonhomogeneous ordinary differential equation (ODE) for $V(r)$ given by

$$\tfrac{1}{2}\,\sigma^2\,r^2\,V_{rr} + \theta\,r\,V_r - \Big(r + \lambda + \alpha\,(1-\beta)^2\,r^2\Big)\;V = -(1-\beta)\,r, \tag{3}$$

where $V_{rr} = \frac{d^2V}{dr^2}$ and $V_r = \frac{dV}{dr}$. The deposit beta satisfies $0 \le \beta < 1$, and $\sigma, \theta, \lambda, \alpha$ are constants. The function to be solved for is $V(r)$.

The solution is required to satisfy the boundary conditions

$$\lim_{r\to\infty} V(r) = 0\,, \tag{4}$$

$$\lim_{r\to 0} V(r) = 0\,. \tag{5}$$

We will first transform this equation into the nonhomogeneous Whittaker equation (Babister (1967), Equation (5.26)) given by

$$y_{zz} + \left(-\frac{1}{4} + \frac{\kappa}{z} + \frac{\frac{1}{4} - \mu^2}{z^2} \right) y = z^{\nu - 1/2} \,, \tag{6}$$

where y_{zz} denotes the derivative $\frac{d^2y}{dz^2}$. As the first step, we express the ODE in its normal form, which lacks a first-derivative term. To do this, we normalize the leading coefficient and transform the dependent variable. We begin by dividing Equation (3) by the coefficient of the second-derivative term, $\frac{\sigma^2}{2}r^2$, resulting in

$$V_{rr} + \frac{2\theta}{\sigma^2 r} V_r - \left(\frac{2(r+\lambda)}{\sigma^2 r^2} + \frac{2\alpha(1-\beta)^2}{\sigma^2} \right) V = -\frac{2(1-\beta)}{\sigma^2 r} \,. \tag{7}$$

This equation is of the form $V_{rr} + P(r)V_r + Q(r)V = F(r)$, with

$$P(r) = \frac{2\theta}{\sigma^2 r} \,, \tag{8}$$

$$Q(r) = -\frac{2}{\sigma^2 r} - \frac{2\lambda}{\sigma^2 r^2} - \frac{2\alpha(1-\beta)^2}{\sigma^2} \,, \tag{9}$$

$$F(r) = -\frac{2(1-\beta)}{\sigma^2 r} \,. \tag{10}$$

Next, we introduce a transformation of the dependent variable of the form $V(r) = r^p\, y(r)$, where p is a constant to be determined. The derivatives of $V(r)$ are

$$V_r = p\, r^{p-1}\, y + r^p\, y_r \,, \tag{11}$$

$$V_{rr} = p\,(p-1)\, r^{p-2}\, y + 2\,p\, r^{p-1}\, y_r + r^p\, y_{rr} \,. \tag{12}$$

Substituting these into the normalized ODE in Equation (7) and dividing the entire equation by the common factor r^p yields

$$\begin{aligned} y_{rr} &+ \left(\frac{2p}{r} + \frac{2\theta}{\sigma^2 r} \right) y_r \\ &+ \left(\frac{p(p-1)}{r^2} + \frac{2\theta p}{\sigma^2 r^2} - \frac{2}{\sigma^2 r} - \frac{2\lambda}{\sigma^2 r^2} - \frac{2\alpha(1-\beta)^2}{\sigma^2} \right) y = -\frac{2(1-\beta)}{\sigma^2 r^{p+1}} \,. \end{aligned} \tag{13}$$

To eliminate the first-derivative term y_r in Equation (13), we set its coefficient to zero, resulting in $p = -\frac{\theta}{\sigma^2}$. With this value for p, Equation (13) simplifies to the normal form

$$y_{rr} + I(r)\, y = G(r)\,, \tag{14}$$

where the coefficient $I(r)$ is given by

$$I(r) = \frac{p(p-1)}{r^2} + \frac{2\theta p}{\sigma^2 r^2} - \frac{2}{\sigma^2 r} - \frac{2\lambda}{\sigma^2 r^2} - \frac{2\alpha(1-\beta)^2}{\sigma^2}. \tag{15}$$

Using $p = -\frac{\theta}{\sigma^2}$ and after some rearranging and canceling terms, this expression simplifies to

$$I(r) = \left(\frac{\theta}{\sigma^2} - \frac{\theta^2}{\sigma^4} - \frac{2\lambda}{\sigma^2}\right)\frac{1}{r^2} - \frac{2}{\sigma^2 r} - \frac{2\alpha(1-\beta)^2}{\sigma^2}\,. \tag{16}$$

The nonhomogeneous term in Equation (14) is

$$G(r) = -\tfrac{2(1-\beta)}{\sigma^2 r^{p+1}}. \tag{17}$$

Lastly, the transformed equation for $y(r)$ is given by

$$y_{rr} + \left[-\frac{2\alpha(1-\beta)^2}{\sigma^2} - \frac{2}{\sigma^2 r} + \left(\frac{\theta}{\sigma^2} - \frac{\theta^2}{\sigma^4} - \frac{2\lambda}{\sigma^2}\right)\frac{1}{r^2}\right] y = -\frac{2(1-\beta)}{\sigma^2} r^{-p-1}. \tag{18}$$

The next step is to perform a linear transformation of the independent variable, $z = c\,r$, where c is a constant to be determined. This scaling is chosen to match the coefficients of the normal-form equation (Equation (18)) with those of the Whittaker equation (Equation (6)). Using the chain rule, we transform the derivatives with respect to r into derivatives with respect to z. First, note that the chain rule implies $y_r = c\, y_z$ and $y_{rr} = c^2\, y_{zz}$. Next, we substitute these expressions into Equation (18) and replace r with z/c. After dividing by c^2, we obtain the transformed equation for y given by

$$y_{zz} + \left[-\frac{2\alpha(1-\beta)^2}{c^2\sigma^2} - \frac{2}{c\sigma^2 z} + \left(\frac{\theta}{\sigma^2} - \frac{\theta^2}{\sigma^4} - \frac{2\lambda}{\sigma^2}\right)\frac{1}{z^2}\right] y = -\frac{2(1-\beta)}{c^2\sigma^2}\left(\frac{c}{z}\right)^{p+1}. \tag{19}$$

We now compare Equation (19) term-by-term with the nonhomogeneous Whittaker equation in Equation (6). Note that the target form has a coefficient of unity on the right-hand side. The transformation will yield a constant pre-factor, k, which carries through the derivation. We begin by matching the constant term

$$-\frac{2\alpha(1-\beta)^2}{c^2\sigma^2} = -\frac{1}{4}\,. \tag{20}$$

Solving for the constant c yields

$$c = \frac{2\sqrt{2\alpha}(1-\beta)}{\sigma}\,. \tag{21}$$

Next, matching the $1/z$ term gives us

$$\kappa = -\frac{2}{c\sigma^2} = -\frac{2}{\sigma^2}\left(\frac{\sigma}{2\sqrt{2\alpha}(1-\beta)}\right) = \frac{1}{\sigma\sqrt{2\alpha}(\beta-1)}\,, \tag{22}$$

where we have substituted Equation (21) for c.

Turning next to the $1/z^2$ term, results in

$$\frac{\frac{1}{4}-\mu^2}{z^2} = \left(\frac{\theta}{\sigma^2} - \frac{\theta^2}{\sigma^4} - \frac{2\lambda}{\sigma^2}\right)\frac{1}{z^2}\,. \tag{23}$$

After rearranging, we obtain

$$\mu^2 = \frac{1}{4} - \left(\frac{\theta}{\sigma^2} - \frac{\theta^2}{\sigma^4} - \frac{2\lambda}{\sigma^2}\right) = \frac{1}{4} - \frac{\theta}{\sigma^2} + \frac{\theta^2}{\sigma^4} + \frac{2\lambda}{\sigma^2}\,. \tag{24}$$

This can be rewritten by completing the square as

$$\mu^2 = \left(\frac{1}{2} - \frac{\theta}{\sigma^2}\right)^2 + \frac{2\lambda}{\sigma^2}\,. \tag{25}$$

We define μ as the positive root without loss of generality, as only μ^2 appears in the differential equation, which results in

$$\mu = \sqrt{\left(\frac{1}{2} - \frac{\theta}{\sigma^2}\right)^2 + \frac{2\lambda}{\sigma^2}}\,. \tag{26}$$

Finally, we match the nonhomogeneous term. The right-hand side of the transformed equation is $-\frac{2\,(1-\beta)}{c^2\,\sigma^2}\,c^{p+1}\,z^{-p-1}$. Comparing exponents with the target form $z^{\nu-1/2}$ implies

$$\nu - \frac{1}{2} = -p - 1\,, \tag{27}$$

which can be solved for ν after substituting in $p = -\frac{\theta}{\sigma^2}$, resulting in

$$\nu = -p - \frac{1}{2} = \frac{\theta}{\sigma^2} - \frac{1}{2}\,. \tag{28}$$

The constant k is thus given by

$$k = -\frac{2(1-\beta)}{c^2\sigma^2} c^{p+1}\,, \tag{29}$$

which, using $c^2\sigma^2 = 8\alpha(1-\beta)^2$ and substituting in the expressions for c and p, simplifies to

$$k = -\frac{1}{4\alpha(1-\beta)} \left(\frac{2\sqrt{2\alpha}(1-\beta)}{\sigma}\right)^{1-\theta/\sigma^2}\,. \tag{30}$$

Thus, the transformed equation is given by

$$y_{zz} + \left(-\frac{1}{4} + \frac{\kappa}{z} + \frac{\frac{1}{4} - \mu^2}{z^2}\right) y = k\, z^{\nu-1/2}. \tag{31}$$

Lastly, to match Equation (6), we define a rescaled function $w(z) = y(z)/k$. The equation for $w(z)$ is then given by

$$w_{zz} + \left(-\frac{1}{4} + \frac{\kappa}{z} + \frac{\frac{1}{4} - \mu^2}{z^2}\right) w = z^{\nu-1/2}\,, \tag{32}$$

and the full transformation for $V(r)$ is

$$V(r) = k\, r^p\, w(c\, r)\,. \tag{33}$$

Homogeneous Solution. Next, we analyze the solution to the homogeneous Whittaker equation, which is given by Equation (6) with the right-hand side set to zero,

$$w^h_{zz} + \left(-\frac{1}{4} + \frac{\kappa}{z} + \frac{\frac{1}{4} - \mu^2}{z^2} \right) w^h = 0\,. \tag{34}$$

Equation (34) is a second-order linear ODE, and its solution is a linear combination of two linearly independent solutions. These are given by the Whittaker functions $M_{\kappa,\mu}(z)$ and $W_{\kappa,\mu}(z)$ (see Abramowitz and Stegun (1965)). These functions are themselves defined in terms of the confluent hypergeometric (Kummer) functions of the first and second kind, $M(a, b, z)$ and $U(a, b, z)$, respectively, and are given by

$$M_{\kappa,\mu}(z) = e^{-z/2}\, z^{\mu+1/2}\, M\left(\mu - \kappa + \tfrac{1}{2}, 2\mu + 1, z\right)\,, \tag{35}$$

$$W_{\kappa,\mu}(z) = e^{-z/2}\, z^{\mu+1/2}\, U\left(\mu - \kappa + \tfrac{1}{2}, 2\mu + 1, z\right)\,. \tag{36}$$

The solution to Equation (34) is therefore

$$w^h(z) = m\, M_{\kappa,\mu}(z) + w\, W_{\kappa,\mu}(z), \tag{37}$$

where m and w are arbitrary constants. The corresponding homogeneous solution for the original variable $V(r)$, denoted $V^h(r)$, is

$$V^h(r) = k\, r^p\, w^h(c\, r) = k\, m\, r^p\, M_{\kappa,\mu}(c\, r) + k\, w\, r^p\, W_{\kappa,\mu}(c\, r)\,. \tag{38}$$

Next, we consider the boundary conditions given in Equations (4) and (5). To do this, we examine the asymptotic behavior of the homogeneous solutions as $r \to \infty$ and as $r \to 0$. First, recall from Equation (21) that $c = \frac{2\sqrt{2\alpha}(1-\beta)}{\sigma} > 0$. The asymptotic expansions for the Whittaker functions for large $c\, r$ are

$$\begin{aligned} M_{\kappa,\mu}(c\, r) &\sim \frac{\Gamma(2\mu + 1)}{\Gamma(\mu - \kappa + 1/2)} e^{\pi i(\mu-\kappa+1/2)} e^{-c\, r/2} (c\, r)^{-\kappa} \\ &\quad + \frac{\Gamma(2\mu + 1)}{\Gamma(\mu + \kappa + 1/2)} e^{c\, r/2} (c\, r)^{\kappa}\,, \end{aligned} \tag{39}$$

$$W_{\kappa,\mu}(c\, r) \sim e^{-c\, r/2} (c\, r)^{\kappa}\,. \tag{40}$$

The solution based on $M_{\kappa,\mu}(c\, r)$ contains a term that grows exponentially as $r \to \infty$. The polynomial factor r^p cannot suppress this exponential growth. Consequently, for the solution to vanish at infinity, the coefficient of the $M_{\kappa,\mu}(c\, r)$ term in Equation (38) must be zero, resulting in

$$m = 0\,. \tag{41}$$

In contrast, the solution based on $W_{\kappa,\mu}(c\,r)$ decays exponentially as $e^{-c\,r/2}$. This term satisfies the boundary condition at infinity. Therefore, any valid homogeneous component of the solution satisfying the boundary condition in Equation (4) must be of the form

$$V^h(r) = w\,k\,r^p\,W_{\kappa,\mu}(z(r)) = w\,k\,r^p\,W_{\kappa,\mu}(c\,r)\,. \tag{42}$$

Next, we examine the behavior of the remaining homogeneous solution near the origin. As $r \to 0$, the behavior of $W_{\kappa,\mu}(c\,r)$ for small $c\,r$ is generally a linear combination of a regular and an irregular solution, unless 2μ is an integer, which would introduce logarithmic terms. Assuming 2μ is not a nonnegative integer, the behavior is given by

$$W_{\kappa,\mu}(c\,r) = \frac{\Gamma(-2\mu)}{\Gamma(1/2-\mu-\kappa)}M_{\kappa,\mu}(c\,r) + \frac{\Gamma(2\mu)}{\Gamma(1/2+\mu-\kappa)}M_{\kappa,-\mu}(c\,r)\,. \tag{43}$$

For small $c\,r$, $M_{\kappa,\pm\mu}(c\,r) \sim (c\,r)^{\pm\mu+1/2}$. Since we have defined μ to be positive, the dominant ("most singular") term for small $c\,r$ comes from $M_{\kappa,-\mu}(c\,r)$ which behaves as $(c\,r)^{-\mu+1/2}$. Thus, the leading-order behavior of $V^h(r)$ as $r \to 0$ is

$$V^h(r) \sim k\,w\,r^p(c\,r)^{-\mu+1/2} \sim k\,w\,r^p(c\,r)^{-\mu+1/2} \propto r^{p-\mu+1/2}\,. \tag{44}$$

The exponent of r in Equation (44) is

$$p - \mu + \frac{1}{2} = -\frac{\theta}{\sigma^2} - \sqrt{\left(\tfrac{1}{2} - \tfrac{\theta}{\sigma^2}\right)^2 + \tfrac{2\lambda}{\sigma^2}} + \frac{1}{2}\,. \tag{45}$$

It is straightforward to show that the exponent of r in Equation (45) is strictly negative. This means that $V^h(r)$ diverges as $r \to 0$, implying that $V^h(0) = 0$ requires

$$w\ = 0, \tag{46}$$

leading to the trivial solution $V^h(r) = 0$. This may seem puzzling at first. However, consider the case $\beta = 1$. The right-hand side in Equation (3) is identically zero. In this case, the deposit earns the prevailing market rate, and therefore confers no economic benefit to the bank. Accordingly, the underlying economics require that the value of $V(r)$ is zero for all values of r. This situation corresponds precisely to the case in which the homogeneous ordinary differential equation determines $V(r)$, and it is thus consistent with the solution to the homogeneous equation being identically zero.

Particular Solution. We next derive a particular solution to the ODE for the deposit account in Equation (3) using the results from Section 5.4 in Babister (1967). First, a particular solution $w^p(z)$ for the normalized ODE in Equation (32) is given by

$$w^p(z) = N^{\nu}_{\kappa,\mu}(z)\,. \tag{47}$$

This function, referred to as the nonhomogeneous Whittaker function, has the series representation

$$N^{\nu}_{\kappa,\mu}(z) = z^{\nu+3/2} \sum_{n=0}^{\infty} a_n z^n\,. \tag{48}$$

The first two coefficients of the series are

$$a_0 = [(\nu+1)^2 - \mu^2]^{-1}\,, \tag{49}$$

$$\begin{aligned} a_1 &= -\kappa \left[\left((\nu+1)^2 - \mu^2\right) \left((\nu+2)^2 - \mu^2\right) \right]^{-1} \\ &= -\kappa\, a_0 \left[(\nu+2)^2 - \mu^2 \right]^{-1}\,, \end{aligned} \tag{50}$$

and for $n \geq 2$, the coefficients satisfy the recurrence relation

$$\left[(\nu+n+1)^2 - \mu^2 \right] a_n \;=\; -\kappa\, a_{n-1} + \tfrac{1}{4}\, a_{n-2}\,. \tag{51}$$

This series solution is valid provided that $\nu \pm \mu$ is not a negative integer, which would result in one of the denominators in the recurrence relation to become zero, leading to infinite coefficients. However, since λ and σ are positive constants, it is straightforward to show that this condition is satisfied for typical parameter values in the empirical settings we consider in the analyses.

Lastly, a particular solution to the ODE for the deposit account in Equation

(3) is given by

$$V^p(r) = k\, r^p\, N^{\nu}_{\kappa,\mu}(c\, r)\,. \tag{52}$$

Next, we consider the boundary conditions given in Equations (4) and (5) by examining the asymptotic behavior of $V^p(r)$ as $r \to 0$ and $r \to \infty$. First recall from Equation (21) that $c = \frac{2\sqrt{2\alpha}(1-\beta)}{\sigma} > 0$. Next, for small r, the series for $N^{\nu}_{\kappa,\mu}(c\, r)$ is dominated by its first term

$$N^{\nu}_{\kappa,\mu}(c\, r) \sim a_0 (c\, r)^{\nu+3/2}\,. \tag{53}$$

Therefore, the behavior of $V^p(r)$ near the origin is given by

$$V^p(r) \sim k\, r^p\, a_0 (c\, r)^{\nu+3/2} = (k\, a_0\, c^{\nu+3/2})\, r^{p+\nu+3/2}\,. \tag{54}$$

The exponent of r is

$$p + \nu + \frac{3}{2} = \left(-\frac{\theta}{\sigma^2}\right) + \left(\frac{\theta}{\sigma^2} - \frac{1}{2}\right) + \frac{3}{2} = 1\,. \tag{55}$$

Thus, $V^p(r) \propto r^1$ as $r \to 0$. This implies that the particular solution satisfies the boundary condition at the origin, $\lim_{r\to 0} V^p(r) = 0$.

Turning next to the asymptotics for $r \to \infty$, we first note that the function $N^{\nu}_{\kappa,\mu}(c\, r)$ is defined by a power series in $c\, r$. Moreover, as $r \to \infty$, it decays exponentially (see Equations (5.30)–(5.33) in Babister (1967)). Since $c > 0$,

$$\lim_{r\to\infty} V^p(r) = \lim_{r\to\infty} \left(k\, r^p\, N^{\nu}_{\kappa,\mu}(c\, r)\right) = \lim_{r\to\infty} \left(k\, r^{-\frac{\theta}{\sigma^2}}\, N^{\nu}_{\kappa,\mu}(c\, r))\right) = 0\,. \tag{56}$$

General Solution. The general solution $V(r)$ to the nonhomogeneous ODE in Equation (3) is the sum of the homogeneous solution $V^h(r)$ and the particular solution $V^p(r)$. Recall that $V^h(r)$ is the solution to the associated homogeneous equation. To satisfy specific boundary conditions, it is possible for $V^h(r)$ to be identically zero. We have shown that the boundary conditions $\lim_{r\to\infty} V(r) = 0$ and $\lim_{r\to 0} V(r) = 0$, require the constants w and m to be zero, leading to $V^h(r)$ being identically zero. Thus, the general solution is identical to the particular solution

$$V(r) = V^p(r) = k\, r^p\, N^{\nu}_{\kappa,\mu}(c\, r)\,. \tag{57}$$

After substituting the parameters into Equation (57), this expression becomes

$$V(r) = \frac{1}{4\alpha(\beta-1)} \left(\frac{2\sqrt{2\alpha}(1-\beta)}{\sigma}\right)^{1-\theta/\sigma^2} r^{-\theta/\sigma^2} N^{\nu}_{\kappa,\mu}\left(\frac{2\sqrt{2\alpha}(1-\beta)}{\sigma} r\right)\,. \tag{58}$$

Lastly, we rewrite Equation (58) more compactly. To do this, first recall the parameters

$$\nu = \theta/\sigma^2 \;-\; 1/2\,, \tag{59}$$

$$\kappa = 1/\left(\sqrt{2\alpha}\,\sigma\,(\beta-1)\right)\,, \tag{60}$$

$$\mu = \sqrt{\nu^2 + 2\lambda/\sigma^2}\,. \tag{61}$$

Letting

$$\phi = \sqrt{8\alpha}\,(1-\beta)/\sigma\,, \tag{62}$$

the closed-form solution for the value of a deposit account to the bank is

$$V(r) \;=\; \kappa\;(1-\beta)\,(\phi\, r)^{-\theta/\sigma^2}\; N^{\nu}_{\kappa,\mu}\,(\phi\, r)\;, \tag{63}$$

which matches Equation (5) in the paper.

IA.2.1. Expected Maturity

In this section, we derive the expected life of a deposit account. To begin, recall that the dynamics of the short-term riskless rate under the risk-neutral pricing measure are

$$dr = \theta\, r\, dt + \sigma\, r\, dZ, \tag{64}$$

where θ and σ are constants and Z is a standard Brownian motion. The instantaneous cash flow on the deposit account is $\beta\, r\, dt$ and the depositor withdraws with intensity $\lambda + \alpha\,(1-\beta)^2\, r^2$ over the next instant. For notational convenience, we set

$$\Lambda(r) = \lambda + \alpha\,(1-\beta)^2\, r^2\,. \tag{65}$$

Let τ denote the random withdrawal time. The expected life is the expected time to withdrawal under the risk-neutral pricing measure, conditional on the current short-term riskless rate r,

$$L(r) = E\left[\tau \,|\, r\right]. \tag{66}$$

We will provide an intuitive derivation of the ODE for $L(r)$.[7] Consider the expected life $L(r)$ at time t. Over the next instant, the probability of withdrawal is $\Lambda(r)dt$ and the probability of survival is $1 - \Lambda(r)dt$. This implies that

$$L(r) = (\Lambda(r)dt)\,dt + (1 - \Lambda(r)\,dt)\,(dt + E[L(r + dr)]). \tag{67}$$

Next, we apply Itô's Lemma to $L(r)$, giving

$$dL(r) = L_r(r)\,dr + \tfrac{1}{2}L_{rr}(r)\,(dr)^2. \tag{68}$$

Substituting the dynamics of r and taking expectations under the risk-neutral measure gives

$$E\left[dL(r)\right] = \Big(\theta\, r\, L_r(r) + \tfrac{1}{2}\,\sigma^2\, r^2\, L_{rr}(r)\Big)\,dt. \tag{69}$$

Substituting the expectation back into Equation (67) gives us

$$L(r) = (\Lambda(r)\,dt)\,dt + (1 - \Lambda(r)\,dt)\,\Big(dt + L(r) + \Big(\theta\, r\, L_r(r) + \tfrac{1}{2}\,\sigma^2\, r^2\, L_{rr}(r)\Big)dt\Big). \tag{70}$$

Expanding the terms and ignoring terms of order $(dt)^2$ results in

$$\Big(\theta\, r\, L_r(r) + \tfrac{1}{2}\,\sigma^2\, r^2\, L_{rr}(r)\Big) - \Lambda(r)L(r) + 1 = 0. \tag{71}$$

Lastly, using (65) and re-arranging, gives us the resulting ODE for the expected life of the deposit account $L(r)$,

$$\tfrac{1}{2}\,\sigma^2\, r^2\, L_{rr}(r) + \theta\, r\, L_r(r) - \Big(\lambda + \alpha\,(1-\beta)^2\, r^2\Big)\, L(r) = -1\,. \tag{72}$$

We next consider the boundary conditions for this ODE. First, as $r \to \infty$, the rate-

[7] A more formal treatment of stopping times can be found in Karatzas and Shreve (1998).

driven component of the withdrawal intensity, $\alpha\,(1-\beta)^2\,r^2$, grows without bound and dominates the constant term λ. The instantaneous probability of withdrawal becomes infinitely high. In such a high-rate environment, any rational depositor would immediately withdraw their funds to reinvest at the much higher market rate. Therefore, the expected time until withdrawal should approach zero, resulting in the first boundary condition,

$$\lim_{r\to\infty} L(r) = 0\,. \tag{73}$$

Second, as $r \to 0$, the rate-driven incentive to withdraw vanishes. The term $\alpha\,(1-\beta)^2\,r^2$ approaches zero and thus the total withdrawal intensity approaches the constant baseline intensity λ. In this limiting case, the withdrawal process simplifies to a standard Poisson process with a constant rate λ. The waiting time for the first event in such a process is known to be exponentially distributed with a mean of $1/\lambda$. Thus, the average life of the deposit must converge to this value as rates approach zero, giving us the second boundary condition,

$$\lim_{r\to 0} L(r) = \tfrac{1}{\lambda}\,. \tag{74}$$

The ODE in Equation (72) can be solved using the same techniques as those used to derive the closed-form solution for $V(r)$ in Section IA.2. Instead of presenting the full solution here, we solve Equation (72) directly using standard numerical techniques.

IA.2.2. Special Case of Constant Interest Rates

In the case of constant interest rates, Equation (3) simplifies significantly, since V_r and V_{rr} are zero. Specifically, we obtain

$$-\left(r+\lambda+\alpha(1-\beta)^2 r^2\right)V = -(1-\beta)r, \tag{75}$$

which can be solved directly for $V(r)$, giving

$$V(r) = \frac{(1-\beta)\,r}{r+\lambda+\alpha(1-\beta)^2 r^2}. \tag{76}$$

An important advantage of this special case is that it allows us to endogenize the deposit pricing strategies of banks. Specifically, we can solve for the optimal deposit beta that maximizes the value of the deposit premium to a bank.

To derive the optimal deposit beta, we first take the derivative of Equation (76) with respect to β. Using the quotient rule results in

$$V_\beta = \frac{-r(\lambda + r) + \alpha(1-\beta)^2 r^3}{\left[\lambda + r + \alpha(1-\beta)^2 r^2\right]^2}. \tag{77}$$

Next, we set the derivative to zero and solve for the deposit beta, denoted by $\beta^\star$. Using $\alpha > 0$ and $r \geq 0$, we get

$$\beta = 1 - \sqrt{\frac{\lambda + r}{\alpha r^2}}. \tag{78}$$

We assume that the deposit betas must be nonnegative, which implies

$$\sqrt{\frac{\lambda + r}{\alpha r^2}} \leq 1 \iff \alpha r^2 - r - \lambda \geq 0. \tag{79}$$

Let $\bar{r}$ denote the positive root of the equation $\alpha r^2 - r - \lambda = 0$. Standard results imply

$$\bar{r} \;=\; \frac{1 + \sqrt{1 + 4\alpha\lambda}}{2\alpha}\,. \tag{80}$$

We thus have two cases.

Case 1: $0 < r < \bar{r}$. In this case, the optimal deposit beta is zero:

$$\beta^\star \;=\; 0\,. \tag{81}$$

The corresponding value for the deposit premium is

$$V(r) = \frac{r}{\lambda + r + \alpha r^2}\,. \tag{82}$$

Case 2: $r \geq \bar{r}$. In this case, the optimal deposit beta is given by

$$\beta^\star \;=\; 1 - \sqrt{\frac{\lambda + r}{\alpha r^2}}\,. \tag{83}$$

The corresponding value for the deposit premium is

$$V(r) = \frac{(1-\beta^{\star})r}{\lambda + r + \alpha(1-\beta^{\star})^2 r^2} = \frac{1}{2\sqrt{\alpha(\lambda + r)}}\,. \tag{84}$$

IA.3. CALIBRATION

In this section, we describe how we estimate the model parameters. Our empirical work combines quarterly bank-level financial data from Call Reports, market-based deposit premia from FDIC failed bank auctions and merger/acquisition transactions, and macroeconomic indicators from FRED. The construction of bank-specific parameters, including deposit betas and Poisson intensity estimates, relies on these foundational data sources along with our theoretical framework described in Section 4.

IA.3.1. Estimating the Parameters of the Interest Rate Process

We estimate the drift and volatility parameters of the interest rate process using federal funds futures and interest rate swaptions data, respectively.To begin, recall that the interest rate follows the lognormal process given by

$$dr = \theta\, r\, dt + \sigma\, r\, dZ, \tag{85}$$

where θ and σ are the constant parameters to be estimated, and Z is a standard Brownian motion. Note that this model implies that the riskless rate is conditionally lognormally distributed. This also implies that the expected level of the riskless rate at time T conditional on the current short-rate r is given by

$$E\left[r_T\right] = r\, e^{\theta T}\,. \tag{86}$$

We use the following simple approach to estimate θ. On each date t, we first set r equal to the current level of the federal funds rate and $E\left[r_T\right]$ equal to the federal funds futures rate for the futures expiring in six months ($T = 0.5$), denoted by F. We then solve Equation (86) for θ on each day during the December 6, 1988–June 30, 2025 period:

$$\theta = \tfrac{1}{0.5}\Big(\log(F) - \log(r)\Big)\,. \tag{87}$$

As the point estimate for θ we use the median value of the daily estimates, giving us a value of $\theta = 0.1041$.

Next, we turn to estimating σ. Recall that swaption volatilities are quoted relative to the Black (1976) model. Thus, the swaption volatility observed in the market at date t can be used directly in the model as the estimate of σ for that date. As the point estimate for σ we again use the median value of the daily estimates over the January 24, 1997 to June 30, 2025 period, giving us a value of $\sigma = 0.3736$.

IA.3.2. Estimating the Parameters of the Intensity Process

To estimate the parameters of the intensity process (λ and α), we use each bank's deposit beta (β) following a tiered approach. First, we use deposit betas from Drechsler, Savov, and Schnabl (2021) where available. Second, for banks not in their sample, we estimate deposit betas following their methodology using either quarterly Call Reports data from 1984 through 2024 or by matching to bank holding company data from the CDI dataset. Third, for banks where estimation is not feasible, we assign the sample average deposit beta.

Event definition. Next, we define "wake-up" or "run" events and use them to estimate the Poisson parameters λ and α. Specifically, we define a wake-up (or run) event as a cumulative decline in a bank's total deposits of at least 3% over the preceding four quarters. More specifically, we define an indicator variable $I_{i,t}$ that equals one if bank i's deposits fall by at least 3% over the prior year, and zero otherwise. This cutoff corresponds roughly to the 95th percentile of the distribution of annual deposit changes across our sample, capturing economically significant outflows rather than normal seasonal fluctuations. Alternative thresholds yield similar parameter estimates and model-implied valuations, and results remain stable when allowing bank-specific or quarter-specific cutoffs that adjust for heterogeneity in deposit growth volatility.

Modified Poisson specification. In a standard Poisson model, the dependent variable represents a count variable—in our context, the expected number of depositor wake-ups for a given bank i in quarter t. Empirically, we do not observe multiple wake-ups per bank–quarter. Instead, we observe whether any wake-up occurred, i.e., whether deposit growth falls below a threshold. Accordingly, we estimate the conditional expectation of a binary indicator rather than a count outcome.

We use a modified Poisson regression with an identity link to estimate the mean function. This approach follows Gouriéroux et al. (1984) and Cameron and Trivedi (2013), who show that Poisson quasi-maximum likelihood consistently estimates parameters of the conditional mean as long as the conditional expectation is correctly specified, even when the dependent variable is binary. This approach is also widely used for binary and fractional outcomes (see Santos Silva and Tenreyro (2006) and Papke and Wooldridge (1996)).

Intuitively, the Poisson specification remains appropriate because the model's structure is continuous-time—it governs the intensity of rare depositor wake-up events, not the realized number of counts. When events are infrequent, as in our data, the Poisson and Bernoulli likelihoods coincide to a first-order approximation, so the modified Poisson regression estimates recover the parameters of the intensity process directly. In contrast, using a logit or linear probability model would consistently estimate the probability of a wake-up but would not preserve the structural mapping between the regression coefficients and the Poisson hazard parameters λ and α implied by the model.

We estimate the following specification from 2017 through 2025.[8]

$$I_{i,t} = \lambda + \alpha(1 - \beta_i)^2 r_t^2 + \varepsilon_{i,t}, \tag{88}$$

where r_t denotes the federal funds rate and β_i denotes bank i's deposit beta.

IA.3.3. Mapping of the Valuation Framework

Both the CDI premia (Section IA.1.3) recorded in bank merger/acquisition transactions and the FDIC auction premia (Section IA.1.4) provide direct empirical counterparts to the theoretical deposit value $V(r)$ in our model. In the valuation framework presented in Section 4 of the paper, we define $V(r)$ as the value of a deposit account to the bank. Specifically, $V(r)$ is the difference between the par value of the deposit and the present value of cash flows paid to depositors. The deposit premia paid by acquiring institutions represent their willingness to pay above book value for the right to assume deposit liabilities, reflecting their assessment of the economic value of these sticky deposits.

CDI and FDIC auction premia are two measures that complement each other in important ways. FDIC auction premia reflect valuations under distressed conditions with compressed due diligence periods, potentially leading to higher information asymmetry and risk premias (Granja (2013) and Granja, Matvos, and Seru (2017)). In contrast, bank merger/acquisition transactions involve voluntary deals between typically healthy institutions with more extensive due diligence periods. FDIC premia may thus represent lower bounds on deposit values, while CDI premia from

[8]Restricting the estimation to this window ensures comparability with the environment of positive nominal rates and meaningful variation in the federal funds rate. Earlier periods with near-zero short-term rates are excluded, as deposit rate adjustments were largely constrained by the effective lower bound, leading to biased or truncated beta estimates.

bank merger/acquisition transactions may better reflect equilibrium valuations in normal market conditions.

Our empirical strategy compares the observed deposit premiums from FDIC auctions to the model-implied values $V(r)$ calculated using the calibrated valuation framework. This comparison allows us to test the key predictions of our model, particularly the nonlinear relationship between deposit values and interest rates, and to validate whether the economic forces captured in our theoretical framework, i.e., deposit beta, stickiness parameters, and interest rate dynamics, can explain real-world deposit pricing.

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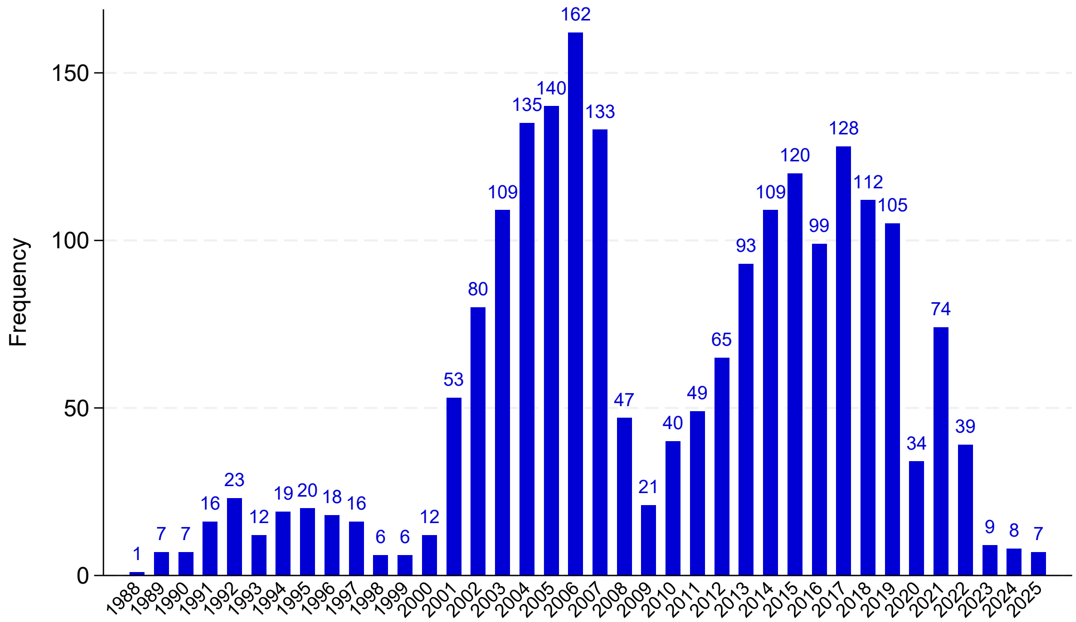

Figure IA.1. Distribution of CDI Premia

This figure shows the frequency distribution of core deposit intangibles (CDI) premia by year from 1988 to 2025. CDI premia are recorded in merger/acquisition transactions and represent the premium paid by acquiring banks for the target institution's deposit base. The sample includes 2,134 bank merger/acquisition transactions from S&P Capital IQ Pro.

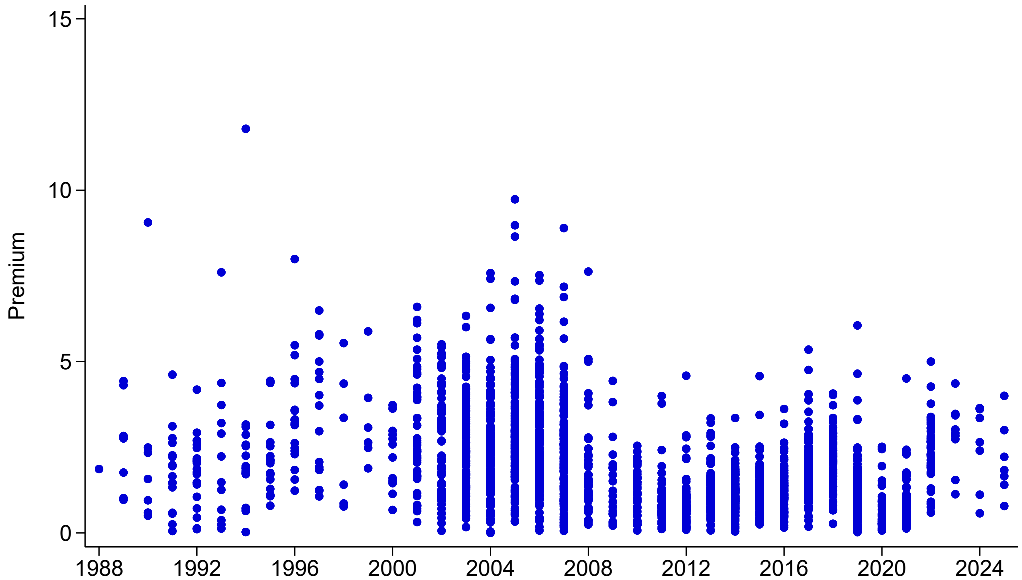

Figure IA.2. CDI Premia

This figure presents a scatterplot of core deposit intangibles (CDI) premia over time from 1988 to 2025. Each point represents the CDI premium (as a percentage) recorded in a bank merger/acquisition transaction. CDI premia range between 0% and 11.80%, with a mean of 1.95% and standard deviation of 1.36%.

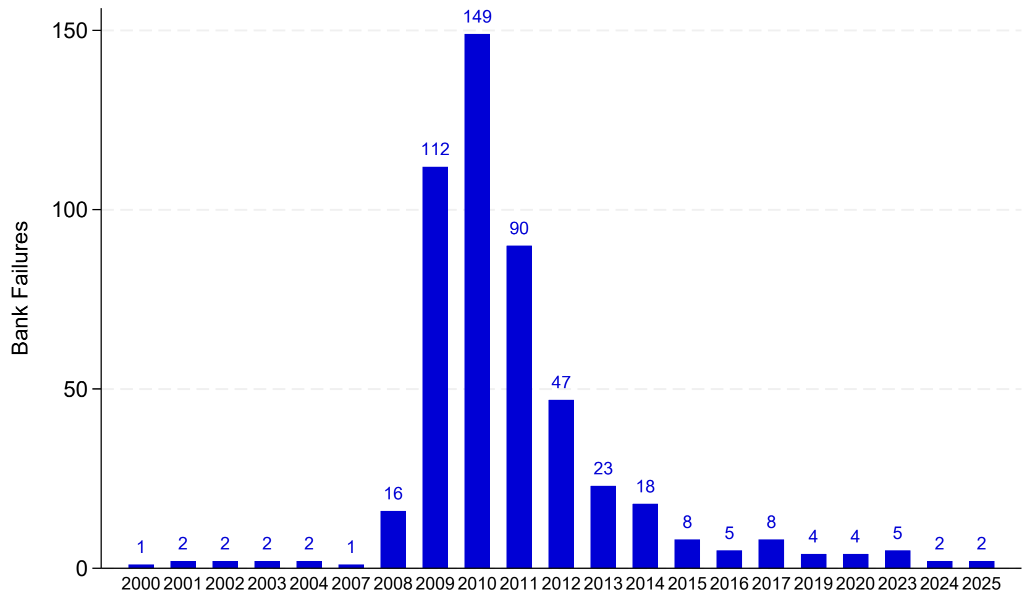

Figure IA.3. Bank Failures

This figure shows the frequency of bank failures by year from 2000 to 2025. The sample includes 503 failed banks resolved through FDIC purchase and assumption agreements with observable deposit premium data. Bank failures peaked during the 2008–2012 financial crisis period.

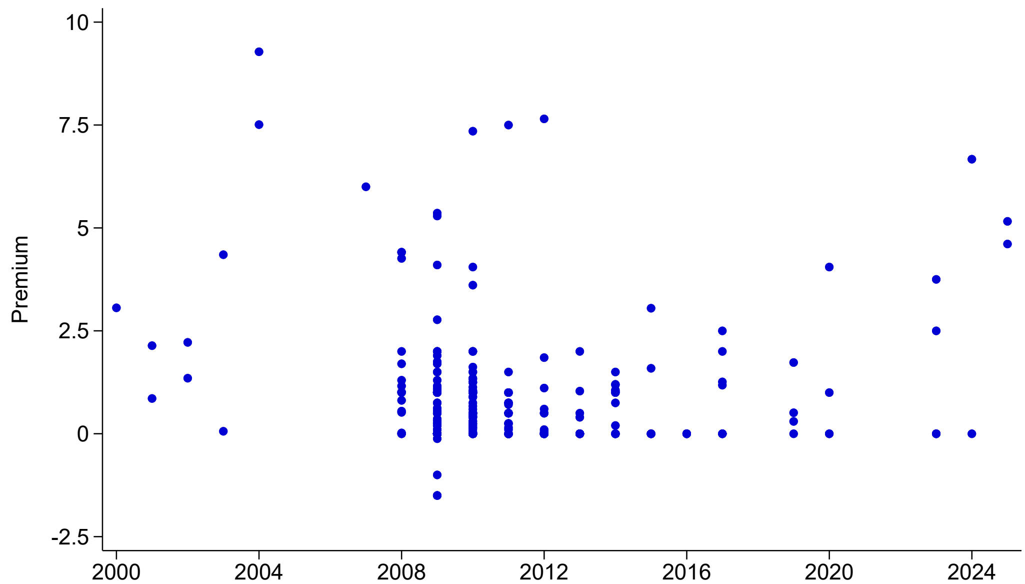

Figure IA.4. FDIC Auction Premia

This figure presents a scatterplot of deposit premia from FDIC failed bank auctions over time from 2000 to 2025. Each point represents the deposit premium (as a percentage of the book value of the deposit accounts) paid by the winning bidder in a purchase and assumption agreement. FDIC auction premia range from -1.50% to 9.28%, with a mean of 0.53% and standard deviation of 1.21%.

Table IA.1. Variables and Estimated Parameters

This table summarizes the variables and estimated parameters used in the structural model. Panel A describes the parameters for the interest rate process. Panel B describes bank-level variables constructed from FFIEC Call Reports, for the period from 1984Q1 through 2024Q4. Panel C lists the parameters associated with the withdrawal intensity process. Panel D describes market-based measures of deposit premia from bank merger/acquisition transactions and FDIC failed bank auctions.

Variable	**Description**	**Frequency**	**Source**
Panel A: Interest Rate Process			
Riskless rate (r_t)	Short-term riskless rate (see Equation (85)).	Daily	Effective federal funds rate for the period from from December 6, 1988, to June 30, 2025. Data obtained from the Federal Reserve Economic Data (FRED), St. Louis Fed.
Drift (θ)	Drift parameter of the interest rate process (see Equation (85)).	Daily	Federal funds futures contracts with six months to expiration for the period from December 6, 1988, to June 30, 2025. Data obtained from the Bloomberg Terminal.
Volatility (σ)	Volatility parameter of the interest rate process (see Equation (85)).	Daily	Implied volatilities of one-year into one-year interest rate swaptions for the period from January 24, 1997 to June 30, 2025. Data obtained from the Bloomberg Terminal.
Panel B: Bank-Level Variables			
Total Domestic Deposits	Total deposits held in domestic offices (Schedule RC-E).	Quarterly	FFIEC Call Reports (RCON2200) for the period from 1984Q1 through 2024Q4.
Interest Expense on Deposits	Total interest expense paid on domestic deposits during the quarter.	Quarterly	FFIEC Call Reports (RIAD4170) for the period from 1984Q1 through 2024Q4.
Deposit Rate	Interest expense on deposits divided by average total deposits, annualized by multiplying by 4.	Quarterly	Constructed from FFIEC Call Reports for the period from 1984Q1 through 2024Q4.
Deposit Growth	Percentage change in total domestic deposits over four quarters: $(\text{Deposits}_t - \text{Deposits}_{t-4})/\text{Deposits}_{t-4} \times 100$.	Quarterly	Constructed from FFIEC Call Reports for the period from 1984Q1 through 2024Q4.
Wake-Up Event Indicator ($I_{i,t}$)	Binary indicator that equals 1 if bank i experienced deposit decline $\geq 3\%$ over the preceding four quarters, and equals 0 otherwise.	Quarterly	Constructed from FFIEC Call Reports.
Panel C: Withdrawal Intensity Process			
Deposit Beta (β_i)	Sensitivity of bank deposit rates to federal funds rate changes, estimated over the 1984–2024 period.	Bank-level	Estimated following Drechsler, Savov, and Schnabl (2021) using FFIEC Call Reports and St. Louis FRED
Baseline Intensity (λ)	Baseline Poisson wake-up intensity parameter.	Constant	Estimated via modified Poisson regression on Call Reports data.
Rate-Sensitivity (α)	Sensitivity of wake-up intensity to interest rate spreads.	Constant	Estimated via modified Poisson regression on Call Reports data.
Panel D: Market-Based Deposit Premia			
Core Deposit Intangible (CDI) Premia	Core deposit intangible asset as percentage of acquired core deposits in voluntary bank merger/acquisition transactions.	Transaction-level	Data are from S&P Capital IQ Pro for the period from January 1988 to June 2025.
FDIC Auction Premia	Premium paid per dollar of acquired deposits in FDIC-assisted Purchase and Assumption (P&A) agreements for failed bank resolutions.	Transaction-level	Data are hand-collected from FDIC P&A agreements for the period from January 2000 to June 2025.