Artificial Intelligence and Financial Risk Management: An Application to Silicon Valley Bank

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Executive Summary

- Silicon Valley Bank (SVB)'s collapse in early March 2023 represents one of the largest bank failures in U.S. history and is a textbook case study of interest rate risk mismanagement.
- An exploration of SVB's balance sheet prior to the crisis reveals a heavy weighting toward longer-maturity securities on the asset side, coupled with generous deposit rate policies on its liability side.
- When U.S. interest rates rose rapidly over the course of 2021-23, SVB's mark-to-market losses on its securities portfolio more than offset its gains from higher net interest income, with its disclosure sparking a bank run that ended in collapse.
- A full simulation of potential interest rate risk scenarios shows that SVB was exposed not just to a general increase in rates but also to a steepening of the yield curve with longer-maturity interest rates rising even as shorter-maturity rates remain low.
- As of Q1 2021, Delfi's AI algorithms would have recommended to SVB a "spreading" strategy of calibrated long positions in short-maturity Federal Funds futures contracts complementing short positions in longer-maturity U.S. Treasury futures contracts.
- Adopting this hedging strategy would have reduced the ex-ante volatility of SVB's financial performance by **95%**.
- Ex-post, such strategy would have resulted in a **+$3.5bn** gain in SVB's performance instead of a **-$2bn** loss, likely precluding the panic that led to its ultimate demise.

1. Introduction

Silicon Valley Bank (SVB) was the 16th largest bank in the United States with $211bn in total assets under management as of December 2022. Almost half of all U.S. venture-funded startups banked with it. During just a few days, from March 8 to March 10, 2023, SVB collapsed, taking many by surprise. It became the second largest bank failure in U.S. history (until it was supplanted less than a month later by First Republic bank). It's now widely understood that SVB mismanaged interest rate risk.

Meanwhile, the world has been amazed with advances in artificial intelligence (AI) coming out of the same Silicon Valley, from the humanlike responses of Large Language Models (LLMs) such as ChatGPT to the generative art capabilities of Stable Diffusion and the world-beating game strategies of AlphaGo.

In the context of recent developments in AI capabilities, what possibilities do such algorithms bring to banks to help avoid SVB-like failures in the future?

We at **Delfi** have been driving at this very question, developing algorithmic AI solutions to manage interest rate risk. In this special report, we apply our capabilities on SVB's balance sheet to answer the following questions: What interest rate risk did SVB's balance sheet feature? What, if any, mistakes did SVB's management team make in their risk management? And what can AI-enabled hedging strategies do to help banks manage interest rate risk in their books?

2. How sensitive was SVB to interest rate risk?

To begin with, it's useful to distinguish the interest rate risk on a bank's balance sheet between risk that originates from its assets vs. risk from its liabilities.

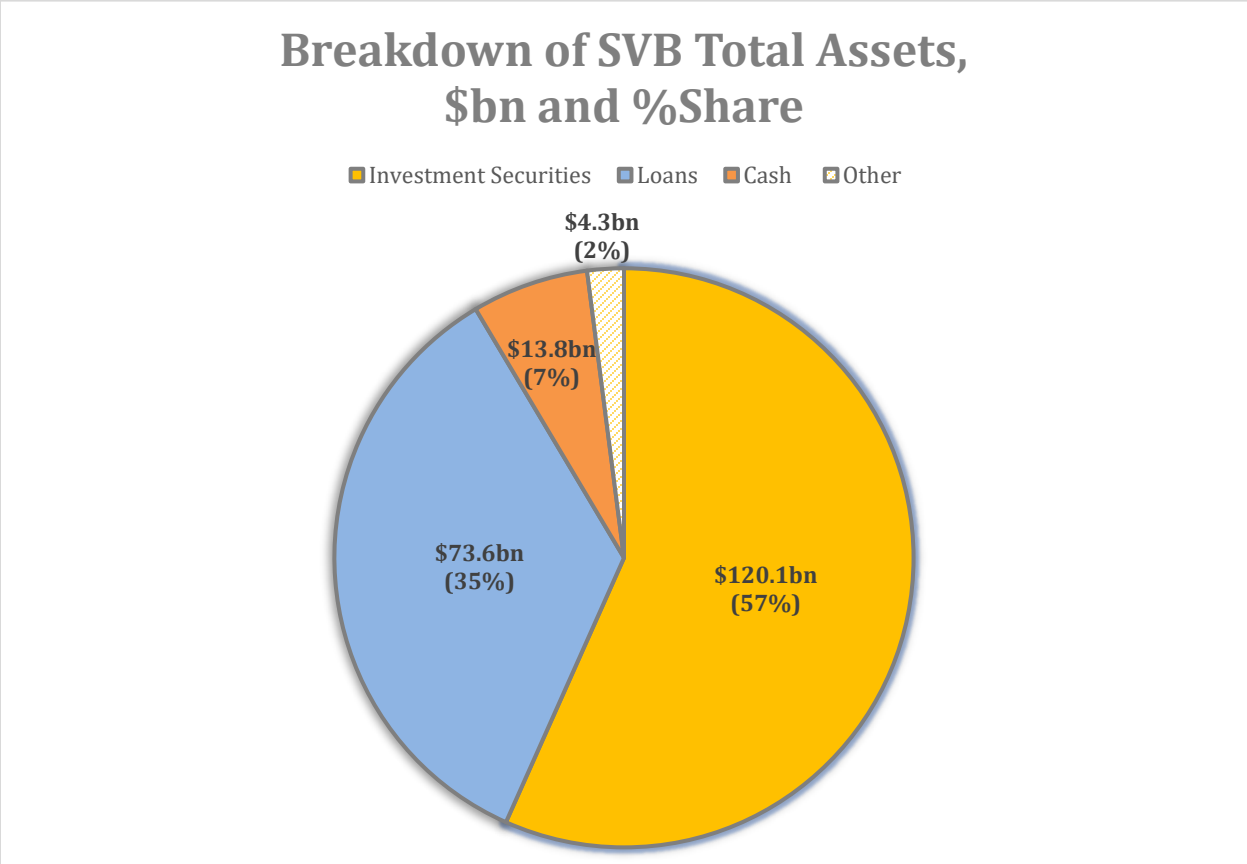
Assets

On the asset side, banks typically hold a portfolio of loans (e.g., mortgages, construction loans, small business loans, or consumer loans) and a portfolio of tradable financial securities (e.g., U.S. Treasuries, agency securities, mortgage-backed securities). Both loans and financial securities can be sensitive to interest rates.

In the case of SVB, its assets were unusually heavily concentrated in securities. As Chart 1 shows, SVB held 35% of its total assets in loans vs. 57% in securities and other assets. This compares with the average 24% share of securities in the entire banking sector's assets as a

whole.[1] This high concentration of securities holdings formed the first element of the chain reaction that led to SVB's demise.

Chart 1: Breakdown of 2022 SVB Total Assets, $bn and % share

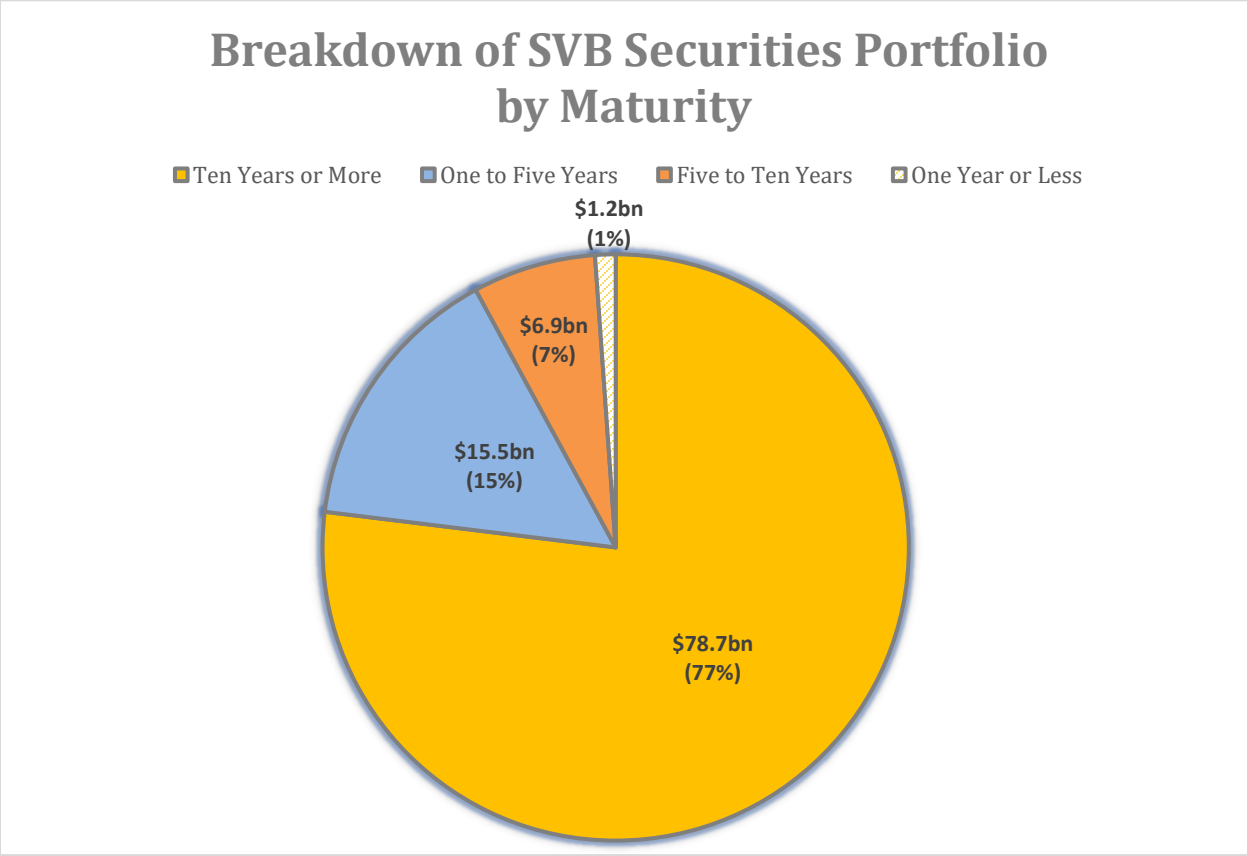


Source: 2022 SVB Annual Report

To be sure, SVB's holdings were in large part composed of U.S. Treasuries and agency bonds with fixed coupons. These securities are considered among the safest and most liquid of financial assets. Nevertheless, this portfolio is still exposed to interest rate risk and the fair market prices of these securities fell as rates rose. Furthermore, the securities that SVB did hold were generally in longer-maturity bonds that were particularly sensitive to interest rates due to their high duration, as shown in Chart 2.

[1] It is plausible that SVB struggled to originate loans sufficiently quickly to offset rapid deposit growth from 2020 to early 2022. Many of its depositors were also VC-funded startups that already had cash and did not need to borrow.

Chart 2: Breakdown of 2022 SVB Securities Portfolio by Maturity

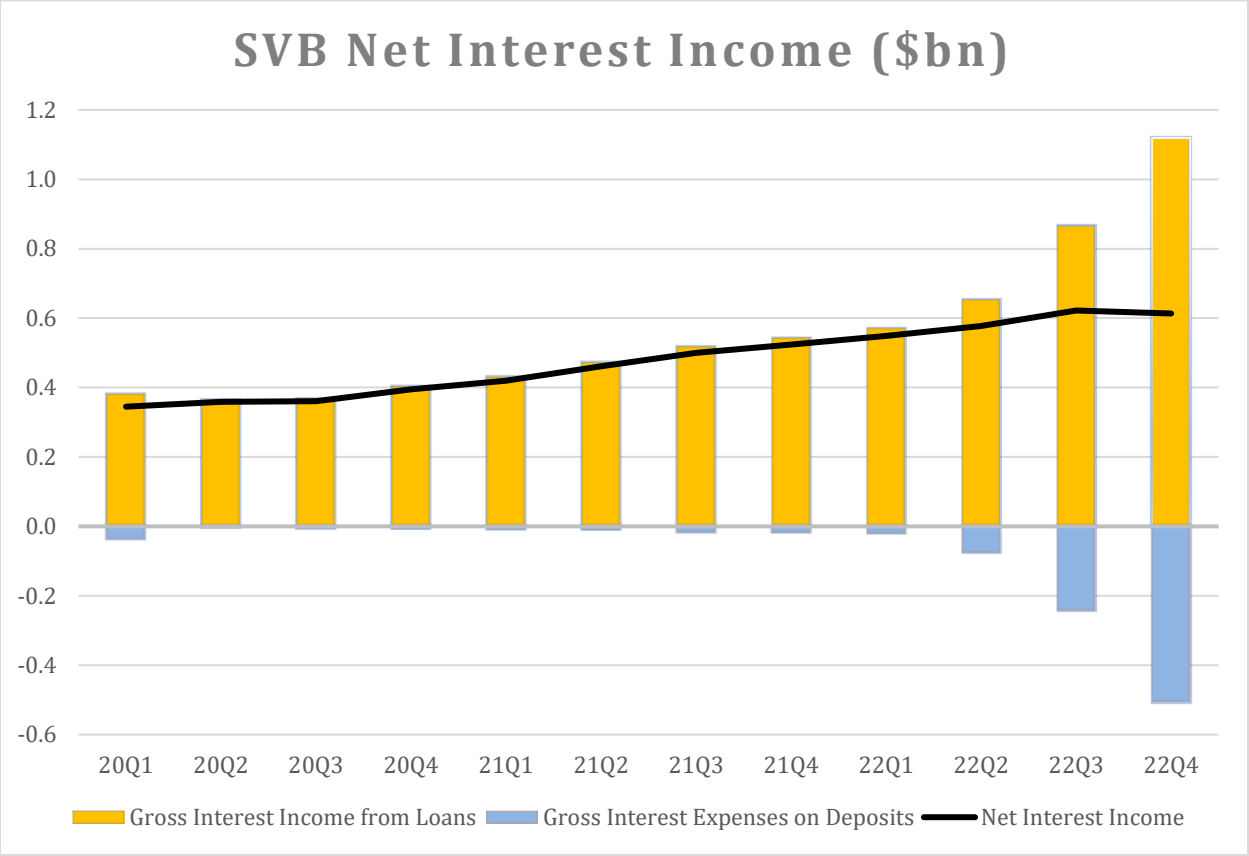


Source: 2022 SVB Annual Report

It is important to recognize that SVB also had a substantial loan book on the asset side of its balance sheet. Some of these loans likely had floating-rate terms and thus would have generated higher interest income as interest rates rose. New loans, even those with fixed-rate terms, would also have been originated at higher rates, further boosting expected future income.

As we see in Chart 3, SVB's interest income from its loan book did in fact rise from about $400mn per quarter in Q1 2020 to over $1.1bn by Q4 2022, thanks in part to higher interest rates.

Chart 3: SVB Gross and Net Interest Income and Expenses ($bn)



Source: SVB Call Reports

Lastly, it is worth mentioning that SVB may have been indirectly exposed to higher interest rates through broader macroeconomic and credit conditions. All else equal, higher interest rates cool economic activity, increasing the risk of defaults. But in SVB's case, its failure came too soon for any latent credit issues to materialize.

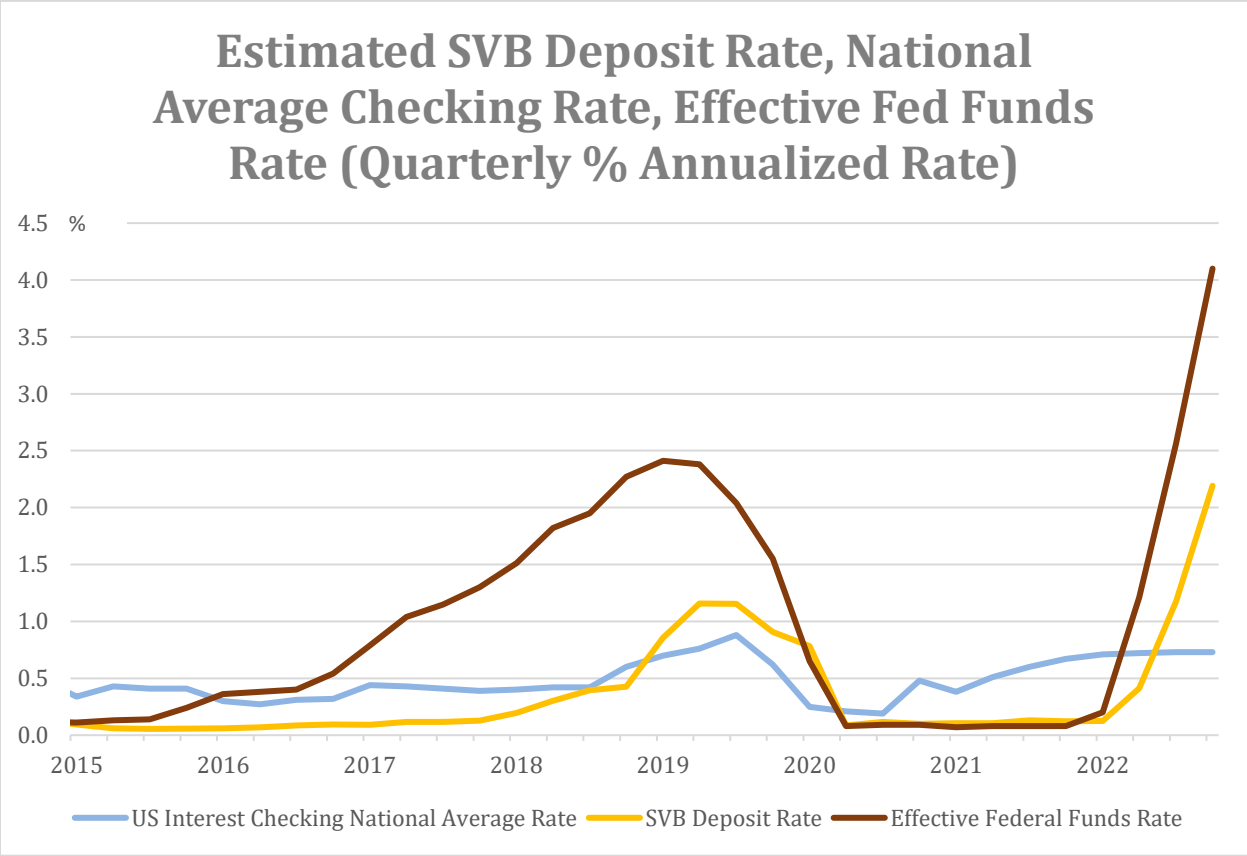
Liabilities

Meanwhile, SVB's liabilities primarily were against its depositors who chose to park their cash at the bank. As of the end of 2022, SVB had $80.8bn in non-interest-bearing accounts and $92.3bn in interest-bearing accounts. The remaining $22.3bn was in other liabilities (e.g., short-term borrowing).

Higher interest rates would have directly lessened SVB's income by increasing the amount of interest payments it had to pay to its depositors in interest-bearing accounts, such as savings accounts or money market accounts. However, banks often make the interest they pay their depositors lower and less sensitive to market fluctuations than the interest they receive from their borrowers, earning a spread between loan and deposit rates. The sensitivity of a bank's deposit

interest rate to market rates is sometimes called "beta," with beta = 1 meaning 100% passthrough of changes in market interest rates to deposit rates.

Chart 4: Estimated SVB Deposit Rate, U.S. National Average Checking Rate, and Effective Federal Funds Rate



Source: Bankrate, St. Louis Federal Reserve Bank, SVB Call Reports

As Chart 4 shows, when the Fed funds rate rose, the average rates paid by U.S. banks on their checking accounts remained depressed, consistent with a beta far less than one. This is in part because banks have market power and can count on their depositors to be "sticky" and maintain deposits at the bank despite the bank paying below market interest rates.[2]

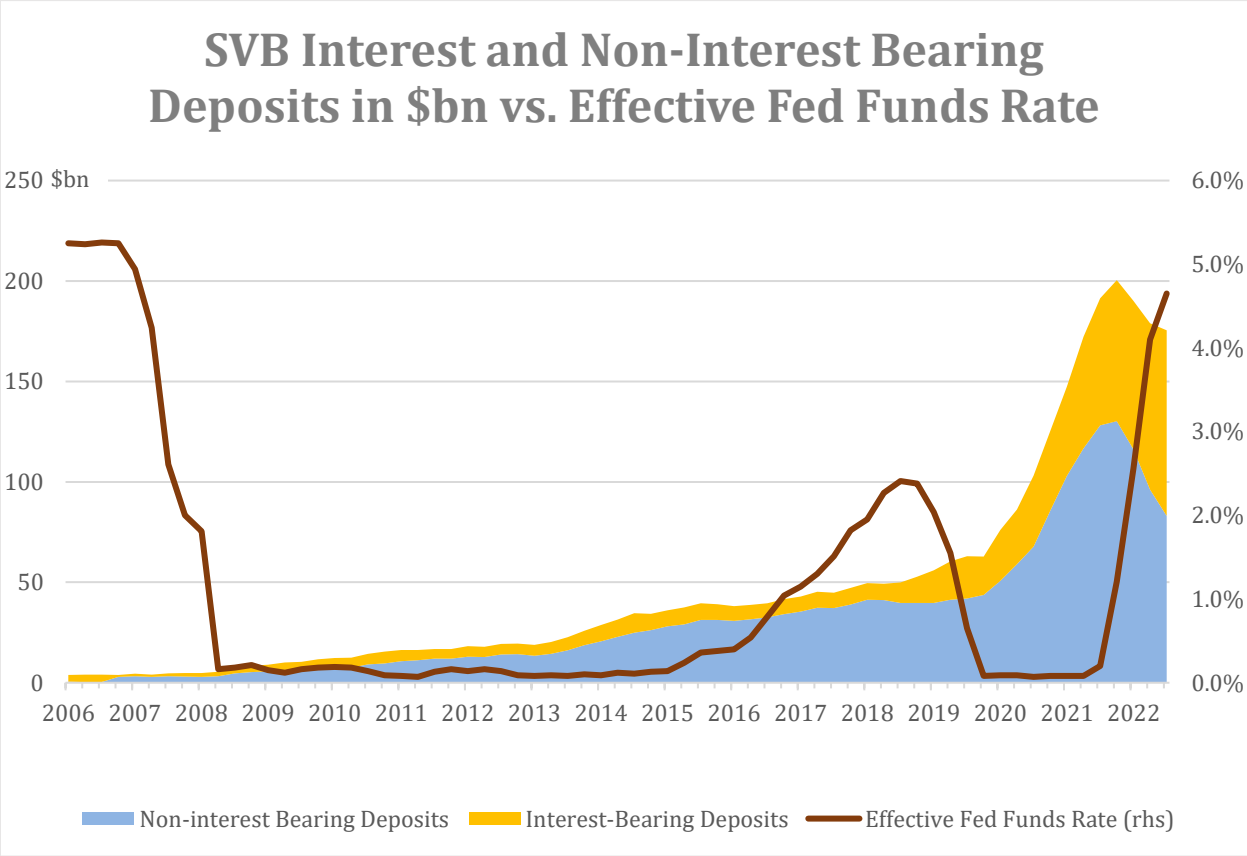
In the case of SVB, we cannot directly observe its beta but as mentioned above, its total interest expenses on deposits were $862mn in 2022, significantly below its interest income. And we can roughly estimate its beta by regressing its deposit interest expense on the Fed funds rate. Chart 4

[2] A recent paper by Drechsler, Savov, and Schnabl (2021) titled "Banking on Deposits: Maturity Transformation without Interest Rate Risk" published in *The Journal of Finance* formalizes and empirically verifies this point about bank market power and the "stickiness" of depositors.

shows how SVB's deposit rate policy was somewhat more generous than the national average, with an estimated beta of 0.5 compared to the national beta of 0.1.

Lastly, SVB was also *indirectly* exposed to interest rates through its depositor base that was concentrated in the technology sector. The technology sector is notoriously rates-sensitive, given the heavy weighting of company valuations toward long-term cash flows. This sector's valuations and access to credit came under strain from higher interest rates. Chart 5 shows how as interest rates began rising in 2021, SVB's previously meteoric growth in non-interest-bearing deposits reversed and started shrinking (even before the rapid deposit flight in its last few weeks). Interestingly interest-bearing deposits remained stable, possibly due to SVB's generous interest rates compared to the national average.

Chart 5: SVB Interest and Non-Interest Bearing Deposits vs. Effective Fed Funds



Source: SVB Call Reports

Furthermore, SVB's depositor base proved to be savvy with digital technology to frictionlessly move money; supercharged by social media and fast communication with VC investors and

influencers, they withdrew (or attempted to withdraw) billions of dollars of deposits in a very short period of time.[3]

3. A "stress" test of SVB's balance sheet

Having reviewed the broad strokes of SVB's balance sheet and its sources of exposure to interest rate risk above, let us examine more closely how vulnerable SVB was to the historic volatility in interest rates observed in 2021-22. While **Delfi** does not have access to any private or proprietary information about SVB, we can try to simulate the challenges SVB faced by extrapolating a version of its balance sheet using publicly available information.[4]

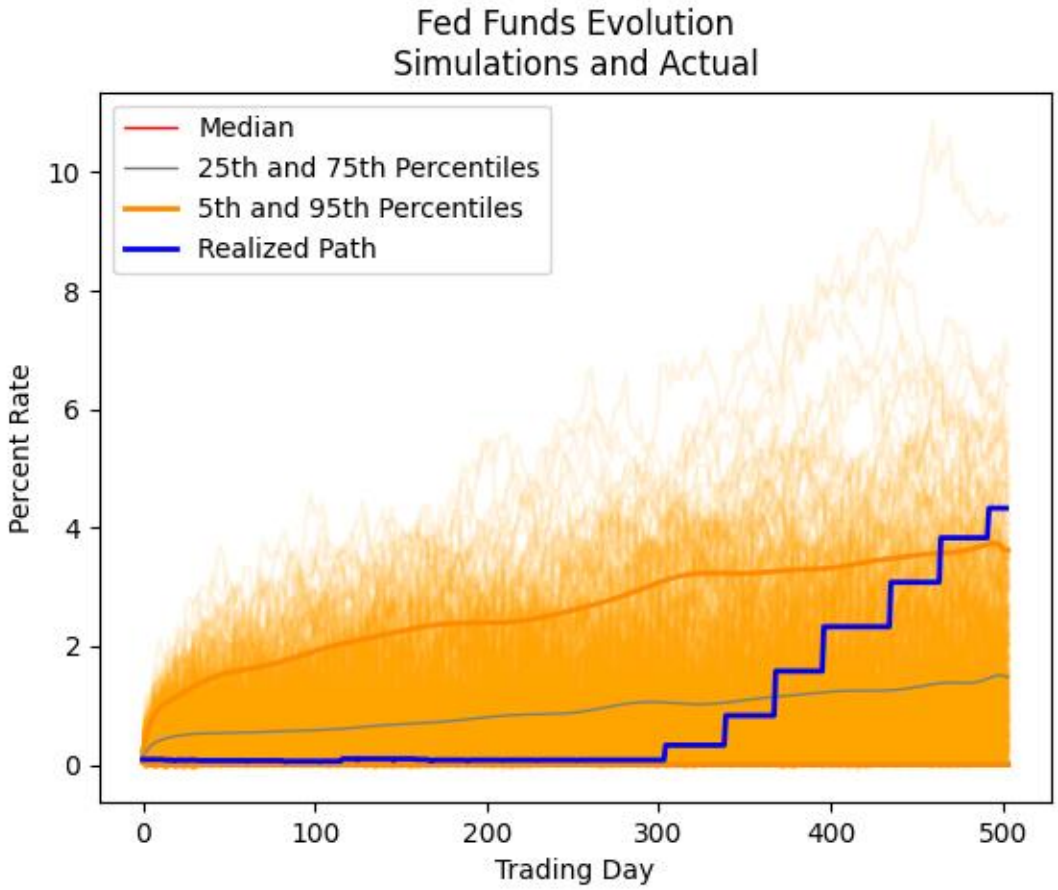
We start with **Delfi's** stochastic simulation of potential interest rate scenarios from 2021 to 2022. With the benefit of hindsight, we know that the Fed embarked upon the fastest pace of rate hikes since the 1970s in an effort to constrain above-target inflation. At the beginning of January 2021, however, there was only a 1.2% probability that the Fed funds rate would rise to at least 4.75% over the next two years, according to our models.[5]

[3] Much reporting has focused on this, including one of a series of excellent articles on SVB's demise by Matt Levine of Bloomberg, available here: https://www.bloomberg.com/opinion/articles/2023-03-10/startup-bank-had-a-startup-bank-run

[4] For this analysis, we rely upon SVB's publicly available Call Reports, which provide a snapshot on SVB's allocations of assets and liabilities across categories and maturity buckets. In particular, from its Q4 2020 Call Report, we extrapolate a hypothetical balance sheet, which, while not accurate in all details, would at least be consistent with their Call Report's aggregates. We then analyze the evolution of this extrapolated balance sheet over 2 years to December 31, 2022. Because this balance sheet is only an approximation of what truly was on SVB's balance sheet over time, our simulation only generally tracks the actual performance of SVB. Even considering this, the purpose of this exercise is not to exactly recreate what actually happened to SVB, but to demonstrate the mechanics of both interest rate-driven impacts and the effectiveness of AI-enabled hedging.

[5] This figure was derived from the cumulative probability of rates reaching a level above 4.75% at the end of the time period as estimated from the empirical distribution of Delfi's Fed funds simulations. A diagram of these projected evolutions is displayed in Chart 6.

Chart 6: Simulations and Actual Realization of the Federal Funds Rate

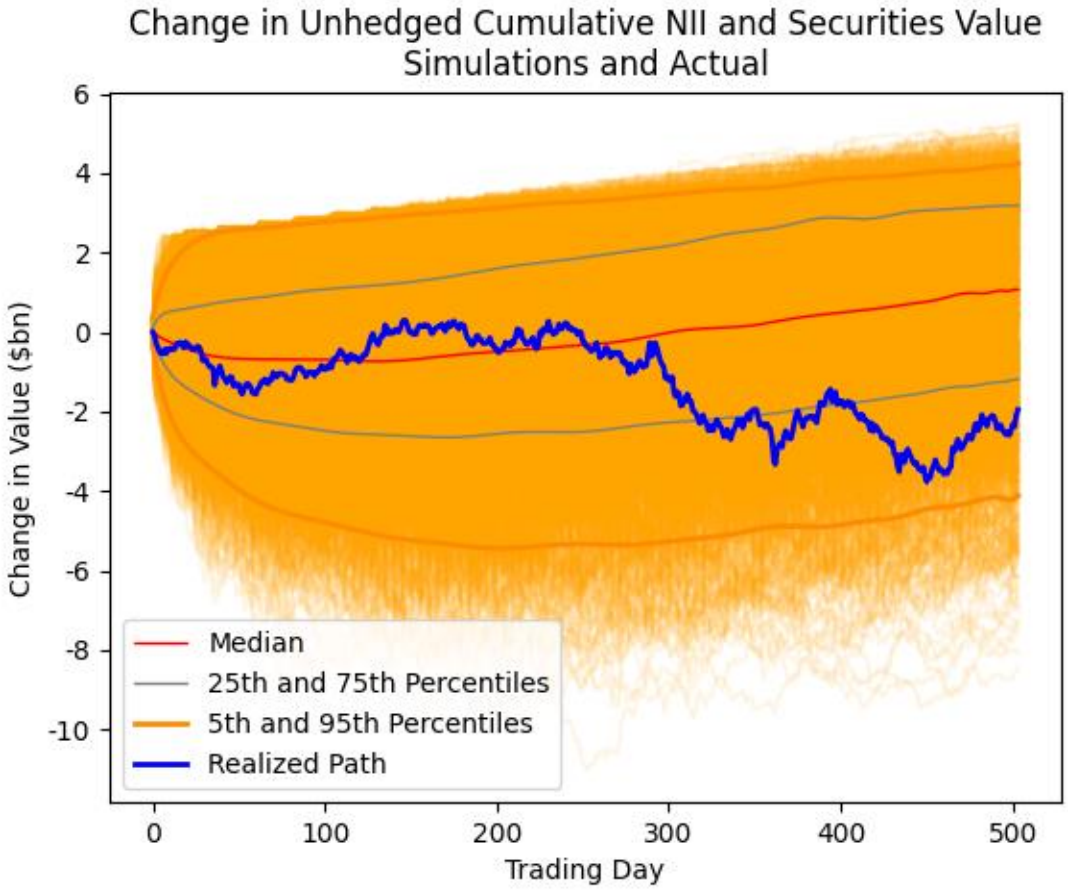


Source: Federal Reserve Board, Delfi

We then pass these scenarios through SVB's extrapolated balance sheet to realize different outcomes for key performance indicators such as cumulative net interest income over the next 24 months and changes in the fair market value of its securities portfolio.[6]

[6] For simplicity, in this white paper, we assume that SVB's balance sheet remains largely static and the beta of its interest rates on deposits to market interest rates is 0.5. Our algorithm is also able to handle dynamic interest rate-sensitive balance sheet compositions, which we shall show in future reports.

Chart 7: Simulations and Realization of Unhedged SVB Balance Sheet Performance



Source: Federal Reserve Board, SVB Call Reports Reports, Delfi

As Chart 7 shows, under most scenarios, SVB would have suffered because larger losses on its security holdings would have more than offset gains in interest income resulting from higher interest rates. Considering the actual path of the Fed funds rate, our simulations suggest that SVB balance sheet would lose approximately $2bn by the end of 2022 when considering both its cumulative net interest income over 24 months and the losses on its securities portfolio.

The steep rise in interest rates manifested itself in the form of $17bn in losses on the modeled security holdings, consistent with SVB's own public reports. To be sure, SVB could choose not to show mark-to-market losses directly on its income statement by categorizing its loss-bearing securities as "hold-to-maturity." But sharp-eyed investors could still see the losses in footnotes in its public filings. These losses eroded SVB's tier 1 equity base of $15.5bn, forcing it to raise additional capital. But the "shock" news announcements of its realized mark-to-market losses as

SVB began selling its securities to raise liquidity disrupted its attempts for a further capital raise and triggered a negative spiral of panic.[7]

In retrospect, given the fair value of their remaining securities, SVB might in theory have been able to access sufficient liquidity to meet depositor withdrawal requirements and allow it to continue to hold its loss-bearing securities to maturity. But due to administrative difficulties and the last-minute nature of the request, SVB failed to secure a loan from the San Francisco Federal Home Loan Bank or tap into the discount window from the Federal Reserve in time.[8] Ultimately, SVB's regulators decided to shut down the bank on Friday, March 10, 2023.

We also tested whether SVB's balance sheet could have been protected if SVB had been able to exercise more market power over its depositors and had a lower beta. The answer we get from our simulations is unfortunately no. Even if we make an extreme hypothetical assumption that SVB paid no interest to its depositors at all, this would have saved SVB only $700mn from 2021-23, likely insufficient to offset the large losses from its securities portfolio.

While SVB's losses in its securities portfolio proved a critical trigger for the bank's failure, it is important not to draw the wrong lessons on this front. In general, mark-to-market losses in the value of securities by themselves should not be construed as a signal of bank weakness or poor risk management. If the bank has other assets or revenue streams that gain from higher interest rates (or liabilities that diminish), then a fall in the market value of securities can be naturally offset by gains elsewhere. And indeed, our simulated SVB's $17bn in securities losses were partially offset by $15bn in simulated cumulative net interest income.[9] This also highlights SVB's liquidity mismatch, with the fall in securities valuation immediately crystalizing upon liquidation while the net interest income accumulates over time. But even so, SVB's performance could have been improved further, if it pursued an optimal risk management strategy, as shown in the next section.

4. How could AI-driven hedging have helped SVB?

In this section, we demonstrate how **Delfi**'s artificial intelligence and machine learning capabilities could help banks construct a balance sheet protection strategy using liquid interest rate futures contracts and how this solution might have aided SVB's position in retrospect. While

[7] SVB was far from the only bank to see mark-to-market losses on its securities portfolio completely wipe out its equity. Jiang, Matvos, Piskorski, and Seru (2023) detail the distribution of banks in their working paper "Monetary Tightening and U.S. Bank Fragility in 2023: Mark-to-Market Losses and Uninsured Depositor Runs?"

[8] The Wall Street Journal reports on the last-ditch efforts by SVB to tap the Fed discount window in an article published on March 22, 2023, available here: https://www.wsj.com/articles/how-the-last-ditch-effort-to-save-silicon-valley-bank-failed-89619cb2

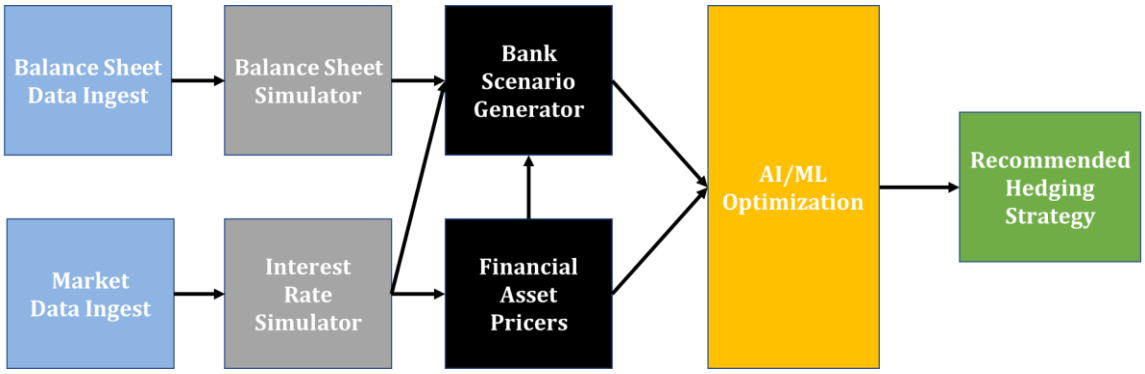
[9] SVB's actual reported cumulative net interest income from 2021-22 was approximately $8bn instead of $15bn, with the discrepancy arising from the fact that we cannot observe SVB's balance sheet directly and therefore, our simulated SVB uses an extrapolated balance sheet based on limited data from its public call reports. But the broader point still stands.

many banks do have tools to hedge their exposure to interest rate risk (e.g., interest rate swaps), these tools can be both inefficient and expensive.[10] **Delfi** uses AI to rapidly and cost-effectively tailor an appropriate risk management strategy to continuously protect its clients from interest rate risk.[11]

Delfi's framework for algorithmic risk management

As Chart 8 shows, **Delfi** first develops a joint simulation of both the entire interest rate yield curve and other key driver rates as well as a dynamic evolution of the bank's balance sheet. As discussed above, by running thousands of simulations, **Delfi** can assess the sensitivity of a bank's balance sheet to potential interest rate volatility.

Chart 8: Diagram of workflow for Delfi's risk management



But perhaps more importantly, **Delfi** uses pricing models to value not just the securities portfolio on a bank's balance sheet but also various financial instruments that can be used to hedge said balance sheet, such as Treasury futures contracts and interest rates swaps.

The universe of possible financial strategies that use these instruments to construct potential hedging strategies is virtually infinite, and this curse of dimensionality had previously stymied attempts to fully automate financial optimization. But recent advances in AI combined with domain expertise make searching this action space for the ideal hedging strategy computationally feasible.

In particular, **Delfi** uses an ensemble approach that combines financial domain knowledge from our team of experienced economists with off-policy deep reinforcement learning, deep learning-based "proxy models" that can substitute for computationally expensive economic accounting,

[10] Jiang et al. (2023) document how sparsely banks use hedging instruments like interest rate swaps to protect themselves, with what hedging strategies that are being used more concentrated among banks larger than $250bn in size.
[11] For more information on our machine learning algorithms, please visit www.delfi.co or contact info@delfi.co for more details.

and genetic algorithms that fine-tune the solution. Thanks to this, **Delfi**'s AI can generate a recommended hedging strategy on even complex balance sheets within minutes instead of days.

Applying Delfi's AI to Silicon Valley Bank

Rewinding back to the beginning of 2021, we simulate the implementation of a hedging strategy for SVB. In this simulation, using **Delfi**'s proprietary algorithms, we reduce volatility of SVB's balance sheet performance (given a preferred risk tolerance) from the beginning of 2021 to the end of 2022, as measured by the cumulative net interest income over those 24 months plus any mark-to-market changes in the fair market value of its securities portfolio.

Table 1: Delfi's recommended hedging strategy for SVB at the beginning of 2021

Instrument	**Notional Position ($mn)**
Federal Funds Futures	18,299.2
2y T-Note Futures	(10,183.6)
5y T-note Futures	(142.4)
10y T-note Futures	(13,600.0)
T-bond Futures	(3,106.2)

Source: Delfi

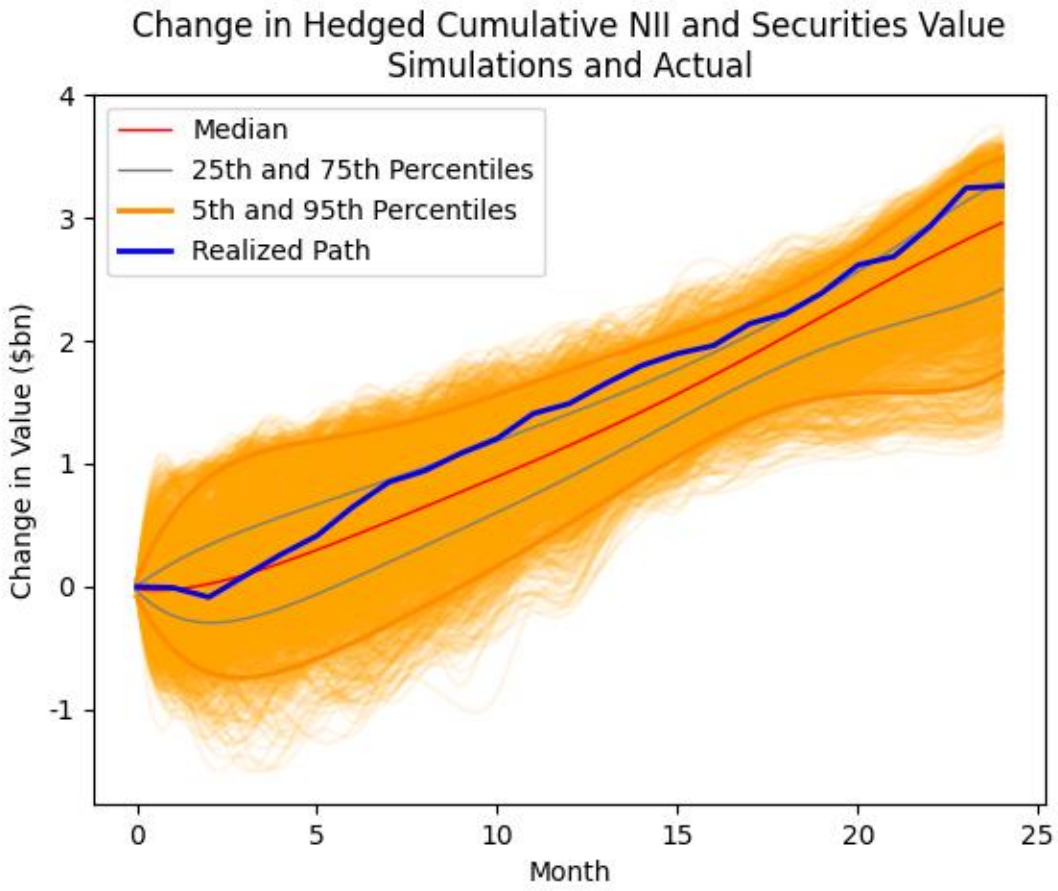
As Table 1 shows, the hedging strategy comprises a $18bn notional long position in the Fed Funds futures with offsetting short positions in the 2y, 5y, 10y, and T-bond futures contracts. The largest short position is a notional $13.6bn short in the 10y Treasury note futures, the most liquid of all Treasury futures contracts (which we instructed the AI to calibrate to by construction).[12]

The differential positions in the Treasury futures reflect how AI had identified that SVB's balance sheet featured risk exposure not just to parallel shifts in the yield curve but also changes in its steepness. This makes sense because SVB's net interest income is largely linked to short-term interest rates like the Fed funds rate while its securities portfolio featured a significant amount of long duration assets. Therefore, yield curve dynamics that feature the front-end of the curve remaining low but long-term yields rising (i.e., a steepening of the curve) would be particularly painful for SVB. **Delfi**'s AI correctly identified this and determined that the most

[12] To the untrained eye, these notional amounts might appear large. But compare this to e.g., the amount of notional interest rate derivative contracts reported by e.g., HSBC USA at the end of 2022 (which was smaller than SVB in total asset size at $162.4bn), which was $162.9bn, of which $30.8bn was in futures/forwards contracts alone.

effective hedge against it would be largely a "spread" position coupling a long position in short-term Fed Funds futures with offsetting short positions in longer-maturity Treasury futures.

Chart 9: Simulations and Realization of AI-Hedged SVB Balance Sheet Performance



Source: Federal Reserve Board, SVB Call Reports, Delfi

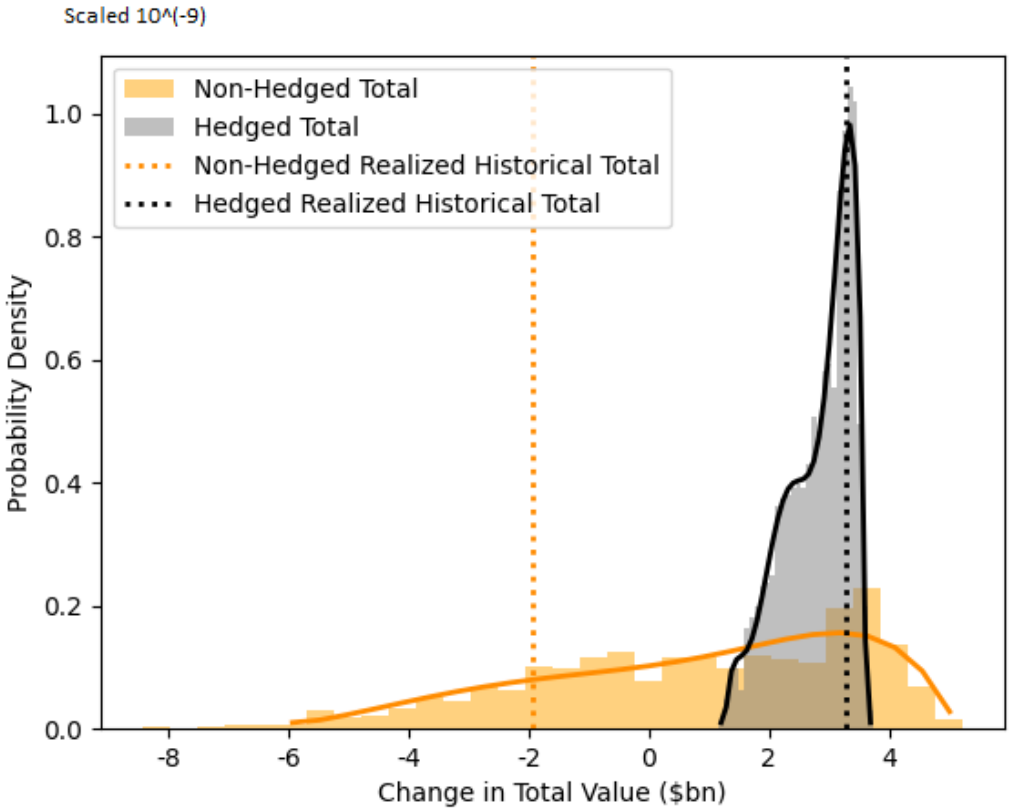
Our simulations suggest that SVB's performance would have been a gain of +$3.3bn instead of losses of -$2.0bn, and the volatility of its performance would have been reduced by 95%![13] The hypothetical effective cost of this hedging program was calculated to be about $30 million relatively small, given the high liquidity of the futures contracts **Delfi** uses to construct its risk management strategies.[14] Given this strategy, SVB's hedge accounting would have matched the dramatic mark-to-market losses on its securities portfolio with offsetting gains. This in turn

[13] The performance improvement would be even more impressive if we had not restricted the AI to trade effectively only once a month so as to minimize transactions costs.

[14] Delfi's algorithms can also be used to suggest hedging strategies using interest rate swaps instead of futures contracts, which provide overall similar performance though with higher transaction costs. However, futures contracts have advantages in lower costs of execution, greater margin leverage, and better regulatory capital efficiency, so in this special report, we focus on a futures-based hedging strategy.

would have likely precluded the need for an emergency capital raise and the panic-driven bank run that triggered its demise and costly rescue.

Chart 10: Histograms Comparing Unhedged vs. Hedged SVB Balance Sheet Performance



Source: Federal Reserve Board, SVB Call Reports, Delfi

While it is generally true that some sacrifice in upside is necessary for this hedge (in a similar manner to paying a premium for insurance against a bad event that one hopes never materializes), in SVB's case this sacrifice was not particularly high. We estimate that the positive 95 percentile upside scenario would have been a gain of approximately $3.5bn when hedged vs. $4bn when remaining unhedged. Meanwhile, on the downside 5th percentile, using AI-based hedging moves the bank's performance from a potential loss of -$4bn to a gain of +$1.5bn. This tradeoff seems well worth the expense.

Incidentally, reporting suggests that SVB's asset-liability committee (ALCO) was alerted about the bank's risk management failures, including by federal regulators. Federal Reserve Vice Chair for Regulation and Supervision Michael Barr details in Congressional testimony a litany of

warnings and reports of deficiencies to SVB's management from its supervisors, a theme further reinforced in the Federal Reserve's more comprehensive review of the situation.[15]

But as Mr. Barr testified, "the bank did not effectively manage the interest rate risk of those securities or develop effective interest rate risk measurement tools, models, and metrics." According to the Fed's review, SVB's risk management process had "fundamental weaknesses" such as a lack of modeling of plausible scenarios, inability to do back-testing, and a focus on short-term Net Interest Income (NII) instead of looking at other metrics such as Economic Value of Equity (EVE), which would reflect changes to securities valuations.

Perhaps even worse, in 2022, even as interest rates started to rise, SVB's management became overly fixated on the possibility that interest rates would fall back down and removed what hedges it had in place, with fatal consequences. These process shortcomings had prompted regulators to issue a Matters Requiring Attention (MRA) notice to SVB, and subsequently an intention to downgrade SVB's rating from "satisfactory" to "less-than-satisfactory" but the bank failed before such a letter could be sent.[16]

5. Conclusion

We first provided an overview of SVB's balance sheet, its assets and liabilities, as well as the sources of its interest rate exposure. We showed how SVB's assets were unusually heavily weighted in securities, and in longer-maturity securities at that. When interest rates rose rapidly over the course of 2021-23, mark-to-market losses on its securities portfolio more than offset gains to net interest income. Coupled with a flight-prone depositor base from an industry already pressured by macroeconomic conditions, the reported losses drove a bank run that resulted in SVB's ultimate collapse.

Then we showed how careful modeling of interest rate risk at the beginning of 2021 together with **Delfi**'s AI-enabled algorithmic optimization could have shielded SVB from its heavy losses by steering its ALCO toward effective futures-based derivative hedging strategies. This would have offset the mark-to-market losses faced by SVB, precluding the kind of bank run that led to its historic failure.

The AI revolution has already greatly impacted the consumer and retail sectors through such solutions as item recommendation engines or generative media content. With this special report,

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[15] Vice Chair Barr's testimony can be found at https://www.federalreserve.gov/newsevents/testimony/barr20230328a.htm
The Federal Reserve's review of its practices in regards to Silicon Valley Bank can be found at https://www.federalreserve.gov/publications/review-of-the-federal-reserves-supervision-and-regulation-of-silicon-valley-bank.htm

[16] The Wall Street Journal reports on the lack of a Chief Risk Officer in an article published on March 23, 2023. The article may be accessed here: https://www.wsj.com/articles/svb-silicon-valley-bank-collapse-chief-risk-officer-f6e1fcfd

we show that, with careful design and analysis, recent AI advances can also provide demonstrable benefits to bank risk management as well in an accessible manner.

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