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SOFR FUTURES AND OPTIONS

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FOREWORD BY GALEN BURGHARDT
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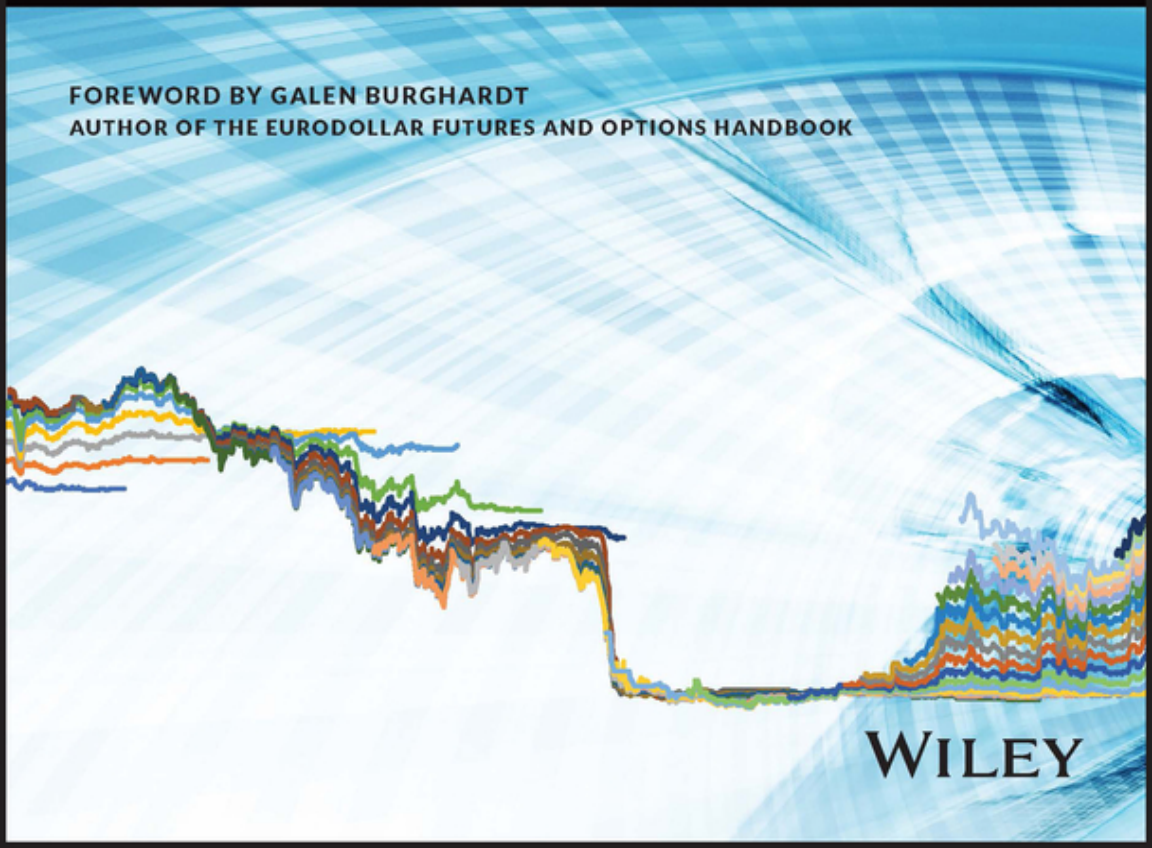

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SOFR Futures and Options

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SOFR Futures and Options

A Practitioner's Guide

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Foreword

by Galen Burghardt
February 2022

Writing this foreword is a little like writing an obituary for a dear friend. LIBOR, and the Eurodollar futures and options contracts that have been tied to it for nearly 40 years, will be put to bed soon. And so ends a remarkable era of financial innovation that transformed the world of interest rate risk management and academic research.

Still, if you're reading this Foreword, chances are that SOFR, and its related futures and options contracts, have made the competitive cut and are serving as replacements for my old friends. So let's spend the next few paragraphs reflecting on what we've learned.

I think I can be most helpful by recounting some of the reasons the Eurodollar futures contract helped to revolutionize the world of banking and finance. And by finance, I mean both applied and academic.

A LITTLE BIT OF HISTORY

First, it's worth remembering that at the time Eurodollar futures were first listed in the 1980s, there had never been a futures contract that cash settled to an abstract concept. In talking with Rick Kilcollin, who was largely responsible for the contract's design, I learned that the LIBOR market in the early 1980s was thin, and that the development of an index that could capture a relevant financing rate and resist attempts at manipulation was still unfinished. With that in mind, what the Chicago Mercantile Exchange (CME) devised was an ingenious survey in which banks of whatever credit rating were not asked what rate they were paying for interbank funds in London. Instead, they were asked to provide the rate at which they perceived funds were offered to prime quality banks. This, combined with the practice of throwing out the high and low responses, produced a survey outcome with an astonishing degree of agreement.

Second, it's worth remembering that when the contracts were first listed, they were the runty cousins of the certificate of deposit contract. A special, and less expensive, membership was created by the CME for trading the

contract, which took place in a small corner of the CD pit. I may have made up this story, but I recall someone saying that Fred Arditti, who was the CME's head of research at the time, would visit the pit each day and come back saying, "I die a little each day when I see how little is going on there."

Then all hell broke loose. Continental Illinois, whose CDs were deliverable into the CD futures contract (and whose motto was "We will find a way") suffered some substantial loan losses and took a hit to its credit rating. It didn't take long for the market to start worrying about credit risk in the deliverable instrument and to look elsewhere.

At the same time, the interest rate swaps market was beginning to take hold and grow, and the Eurodollar futures market was poised perfectly to go along for the ride.

A REVOLUTION IN FINANCE

Eurodollar futures proved to be a financial engineer's dream tool. In the 1980s, the idea of zero-coupon bonds was largely found in textbooks. As was the idea that one could break up the yield curve into three-month (3M) segments and use those segments to study yield curve behavior and the sensitivity of one's financial position to each of those segments.

Now these ideas seem commonplace, but at the time, the world of bonds was almost unbelievably primitive – at least in the world of actual bonds. And the market for forward rates was nearly nonexistent. Try to imagine, for example, what it was like to extract a continuously compounded forward rate curve from the traded bond market. Even if one used data from the Treasury market – possibly the deepest and most liquid bond market in the world – the results could be almost hilariously erratic. In contrast, with Eurodollar futures, one had the next best thing – a quarterly compounded forward rate curve – served on a platter.

Well, almost. It's one thing to know that convexity matters, and another to know just how much. In the late 1980s, Terry Belton and I published a piece for our clients at Discount Corporation of New York Futures called *The Financing Bias in Eurodollar Futures*. The idea was a simple one based on the daily settlement of gains and losses on futures. That is, if one were short Eurodollar futures, one would be able to invest cash coming in at higher rates (i.e., when rates were going up and you were making money on your short position) and borrow the cash you paid out at lower rates when rates were falling. This was an obvious advantage to the shorts, and if you could do it long enough and over big enough swings, the advantage could add up to real money. At the time we published the note, though, the Eurodollar futures curve only went out a year or two, and the

advantage proved not to be worth much for such short-dated contracts. So that research note sank without a trace.

In time, though, the CME extended the Eurodollar futures curve out to 5 years and then to 10 years. And when it did, the interest rate swaps market used these newly available futures rates to price their swaps. The problem, though, as Bill Hoskins and I discovered when we published *The Convexity Bias in Eurodollar Futures* – perhaps one of the most important research notes of our working lives – was that the market had failed to take the value of convexity into account. Swaps were priced as if futures rates were forward rates so that it was possible to receive fixed on a swap and hedge the position by shorting Eurodollar futures and make completely riskless money as rates rose and fell. Not long after we published that note, the market became aware of the mispricing and completely readjusted.

Another lesson that Bill Hoskins taught me, although it took him a while, was that forward rates (or prices) are breakeven values. That is, if you finance a position to any given forward date, you know just how much the price of what you have can rise or fall before you make or lose money as of that forward date. This is a hugely valuable tool.

One example of just how valuable a tool it is came when Gavin Gilbert, a wonderfully voluble friend of mine, rang me one day to announce, more or less at the top of his lungs, "Galen! You won't believe it! I just bought the forward 2-year TED for zero!" For this to make sense, you need to know that we had just published a good piece of work called *Measuring and Trading Term TED Spreads*. This was the basis for much of what you could find on Bloomberg if you visited that particular page. We had not, however, considered the buying and selling of term TEDs forward. But Gavin had. He found that if he bought a two-year note two months forward and sold the appropriate strip of Eurodollar futures, he basically owned the spread at 0. Since the two-year TED spread at the time was trading at roughly 20 basis points, he expected to make 20 basis points on the trade. And he also knew that the spread would have to go negative for him to lose money.

I, of course, checked into it and found that by the time I got there, the spread could be bought forward for 10 basis points. So we published a note (as Gavin knew we would) telling our clients about the trade. What made the trade remarkable, though, was that even with highly sophisticated and integrated markets, the term repo market was not yet in sync with the term LIBOR market. Hence the glaring mispricing.

One of the things you learn in any class on derivatives is that the gains and losses on the derivative look just like the gains and losses you would experience on a trade that you could construct in the cash market. So, for example, a long Eurodollar futures position has the same payoff as a cash position in which you borrow money for a term equal to the contract's

expiration date and lend for a term that is three months longer. As a result, a long Eurodollar futures position is the equivalent of a simple borrow short/lend long yield curve trade.

Once, during one of our classes on Eurodollar futures, a young man from Panagora asked me what the Sharpe ratio of a Eurodollar contract would look like. It was the first time I'd ever heard the question, so I had to beg off. But when we got back to the office, we tackled the question and found that we could analyze the gains and losses combined with their standard deviations and calculate very straightforward Sharpe ratios. When we did this, we learned that the most profitable part of the yield curve carry trade was in the first two or three years of the yield curve. If you're interested, you can find these early results on page 64 of *The Eurodollar Futures and Options Handbook*, at least until it disappears from the face of the earth. Or you can look for one of our yield curve carry notes such as *Yield Curve Carry Rides Again*.

It was neat, too, that these results conformed to what Antti Ilmanen had written in one of his extraordinary monographs at Salomon Brothers. The note was called *Does Duration Extension Enhance Long-Term Expected Returns?* (Ilmanen 1995). He concluded that once you got past the two-year mark, you had more or less exhausted any useful excess returns and that no, you didn't get paid for taking extension risk.

I should add that one of the greatest contributions of Eurodollar futures in the banking industry can be attributed to one of its most prosaic features. That is, they were futures contracts, which meant that one could buy them in the morning and sell them in the afternoon and have the positions offset. For asset/liability managers, this feature was a godsend. The chairman of JPMorgan's asset/liability committee once volunteered in casual conversation that they had revolutionized his life. He was no longer bound to deposit, swap, and forward rate agreement positions that would stay on the books for weeks, months, or years (and that carried with them all kinds of credit risk). Instead, if his bank's risk position changed during the course of a trading day, he could simply add to or offset open futures positions without having to worry about being stuck with them.

ALL THE BEST

To conclude, before I wear out my welcome here, I would like to thank Doug and Christian for inviting me to contribute this Foreword. It gave me a chance to think back over some of the great joys of being in these markets at a time when financial history was being made and to reconnect with some old friends. I would also like to thank my colleagues at the CME for all the

support they have given me over the years. The time I spent there from 1983 to 1986 were great fun and set me up for a career that I could never have imagined. And, of course, the CME's financial support for *The Eurodollar Futures and Options Handbook* made it possible to produce a volume that has been paying dividends for nearly 20 years.

So, with that, thank you all. And let's hope that the next 40 years of trading and innovation are just as thrilling as the past 40 years have been. Or as my old boss and mentor, Morton Lane, liked to say, "May we all have prosperous futures with many options."

Galen Burghardt
Evanston, IL
February, 2022

Introduction

This book is about the SOFR futures and options complex at the Chicago Mercantile Exchange (CME). Before providing an overview of its topics, we take a look at the relevant history. To understand SOFR futures and options, we need to understand SOFR; to understand SOFR, we need to understand LIBOR; and to understand LIBOR, we need to understand Eurodollars.

EURODOLLARS

The most basic definition of a Eurodollar is a US dollar held in a bank outside of the United States. Given that dollars are fungible, it may not be obvious that a dollar held offshore should differ in any respect from a dollar held onshore. But depository institutions in jurisdictions other than the United States are subject to different regulations than those in the United States. For example, the US government is typically unable to confiscate assets held by banks domiciled outside of the United States. And this fact figures prominently in some of the origin stories of the Eurodollar market.

One such story is that the Chinese government, fearing confiscation of its dollar balances after the outbreak of the Korean War in 1950, transferred most of these balances to *Banque Commerciale pour l'Europe du Nord*, a Paris-based bank that had been started by Russian exiles in 1921 and acquired by Gosbank in 1925 (Dormael 1997, pp. 1–9). These offshore dollars, opened in the name of the Hungarian National Bank, became the first Eurodollars. They were later leant to various French banks and to the Paris branch of Bank of America. Over time, other communist countries channeled their dollars through Europe, with the business expanding to another Russian institution, the Moscow Narodny Bank, based in London. These offshore dollars were leant to various Western European governments, and by the late 1950s, American multinationals were using funds obtained in this market to finance their expansion throughout Europe.

Another feature of the Eurodollar market was that these offshore dollars were not subject to the typical exchange rate controls that governed onshore deposits. For example, in 1955, Midland Bank found it profitable

to acquire 30-day offshore dollar deposits at a rate of 1.875% for the purpose of buying sterling in the spot market and selling it 30 days forward at a premium of 2.125%. In this FX swap, Midland paid an effective rate of 4% for pounds sterling at a time when the official rate at the Bank of England was 4.5%. The rate Midland paid for these offshore dollars was well above the maximum rate of 1% for 30-day deposits specified at the time by Regulation Q in the United States. But exchange controls prevented the arbitrage using onshore dollars. By tapping the Eurodollar market, Midland was able to pursue the arbitrage despite exchange rate controls – and despite the interest rate premium paid in the offshore market.

Eurodollars include other benefits as well. For example, they don't attract an FDIC insurance fee, estimated currently to be on the order of 8 to 9 basis points for large banks (Keating and Macchiavelli 2017). And they aren't subject to central bank reserve requirements. So while dollars are fungible in a broad sense, dollars can sometimes be put to a wider variety of uses when they're held overseas.

EURODOLLAR FUTURES

As the market matured, various futures exchanges considered the possibility of introducing futures contracts on Eurodollars. At one point, the Chicago Mercantile Exchange considered a futures contract that required the seller to open an offshore time deposit for the buyer. But this procedure was considered too cumbersome, so the CME designed the contract to be cash-settled. No other futures contract had settled with a simple cash payment at expiration, so the CME was taking a bit of a risk with this contract (Burghardt 2003).

In order for the contract to be settled in cash, the CME needed a way to construct an index to be used in calculating the final settlement price of the contract. To that end, the CME designed an interesting process. Each day, it would randomly select 20 banks from a pool of London banks active in the Eurodollar market and ask each bank for the rate at which it believed prime quality banks could borrow dollars for three months. The highest and lowest quartiles were discarded, and the two middle quartiles were averaged. Then, at some randomly chosen time during the subsequent 90 minutes, the process was repeated with a second set of randomly chosen banks. The CME then averaged the two results (Robb 2012).

It's important to note that the CME did not publish the identities of the banks that participated in either of the two surveys.

This system worked well for quite some time. But in 1996, the reference rate for Eurodollar contracts was no longer the dominant index for the

massive market over-the-counter interest rate swaps, and CME applied for permission to switch from the reference rate it had been calculating since 1981 to LIBOR.

LIBOR

In the early 1980s, the market had a need for standardized reference rates that could be used to settle various forms of interest rate swaps, and members of the British Bankers Association (BBA) asked the BBA to arrange a standardized interest rate for this purpose. In 1984, the BBA introduced the BBAIRS code – the British Bankers Association Interest Rate Swap code. This code suggested terms and conditions to govern interbank transactions with maturities up to two years. And as part of this process, the BBA in 1984 introduced BBA interest settlement rates. The rate-setting process continued to evolve and was standardized by the BBA in 1986 as LIBOR – the *London Interbank Offered Rate*.

The LIBOR rate determination process was similar in spirit to the process the CME had used since 1981 for its Eurodollar futures contract. But there were a few differences. For example, the BBA polled the same 16 banks every day. And since the same banks were polled each day, there was no need to poll them a second time during the day. And, unlike the CME, the BBA publicly displayed the rate submitted by each bank in the panel.

The fact that the rate submitted by each bank was made public mattered even more when, in 1998, the question submitted to each bank was changed. The original question was, "At what rate do you think interbank term deposits will be offered by one prime bank to another prime bank for a reasonable market size today at 11 a.m.?" The new question was changed to read, "At what rate could *you* borrow funds, were *you* to do so by asking for and then accepting interbank offers in a reasonable market size just prior to 11 a.m.?" [Emphasis added.]

And it was *this* new question to which banks were responding when the Great Financial Crisis of 2008 hit.

THE GREAT FINANCIAL CRISIS

The subprime mortgage crisis, which started in 2007, eventually led to a number of bank failures in 2008. The most notorious examples were Bear Stearns in March of that year and Lehman Brothers in September, but the entire banking system was deeply affected, and the Federal Reserve orchestrated a large-scale infusion of capital into the banking system, largely via

the purchase of preferred shares in 42 US banks. Similar assistance was provided in one form or another to banks in many other jurisdictions, including the UK and many other parts of Europe.

One of the consequences of the great financial crisis is that banks largely stopped lending to one another on an unsecured basis, as each bank was unsure about the creditworthiness of the others. Central banks quickly stepped into the breach, providing substantial funding via repo operations and collateralized currency swap lines with other central banks.

With unsecured interbank lending greatly reduced, the LIBOR polling process became somewhat academic. How would a bank know where it could borrow in the interbank market if it wasn't active in the interbank market? And if no banks were active in the interbank market, what was the LIBOR polling process measuring *precisely*?

Perhaps Citigroup's Willem Buiter put it best when he said, "LIBOR is the rate at which banks don't lend to one another." Questioned about this comment in a Parliamentary committee hearing, Bank of England Governor Mervyn King commented:

> *The world has changed totally; people are very worried about lending, and indeed hardly anybody is willing to lend to any bank around the world for three months unsecured; they want to lend secured. . . . I think that in future we will see far less lending to banks on an unsecured basis and far more on a secured basis. The inter-bank market has very often been a market in which overnight or short-term cash holdings can be distributed around the banking system, and banks were willing to do it with each other unsecured at Libor. I just do not think it plays that role now, and I think we are going to see developing over the next few years a much more intensive method in which banks can redistribute cash surpluses and shortages among each other on a more secured basis. At present they are doing it directly with the central bank, and that is true around the world, not just in the UK.*[1]

THE LIBOR RIGGING SCANDAL

If LIBOR's days were numbered as a result of the switch from unsecured to secured interbank lending, the nail in the coffin was evidence that the process had been manipulated by some of the traders at some of the banks in the LIBOR survey panel.

[1] Oral evidence taken before the Treasury Committee on Tuesday 25 November 2008.

As early as April 2008, the *Wall Street Journal* published an article suggesting some banks were submitting LIBOR rates that were unjustifiably low (Mollenkamp 2008). Two reasons were offered for this behavior. First, some of these banks – and their clients – stood to gain if the published LIBOR rates could be suppressed. Second, some of these traders hoped to give the appearance that all was well with their particular bank. For example, it came out in hearings that Paul Tucker, then executive director of markets at the Bank of England, had called Barclay's CEO, Bob Diamond, regarding Barclay's LIBOR submissions. Diamond's notes from that call are quite revealing:

> *Further to our last call, Mr Tucker reiterated that he had received calls from a number of senior figures within Whitehall to question why Barclays was always toward the top end of the Libor pricing. His response was, "You have to pay what you have to pay." I asked if he could relay the reality, that not all banks were providing quotes at the levels that represented real transactions; his response: "Oh, that would be worse."*
>
> *I explained again our market rate driven policy and that it had recently meant that we appeared in the top quartile and on occasion the top decile of the pricing. Equally I noted that we continued to see others in the market posting rates at levels that were not representative of where they would actually undertake business. This latter point has on occasion pushed us higher than would otherwise appear to be the case. In fact, we are not having to "pay up" for money at all.*
>
> *Mr. Tucker stated the level of calls he was receiving from Whitehall were "senior" and that while he was certain we did not need advice, that it did not always need to be the case that we appeared as high as we have recently.* (House of Commons 2012).[2]

In the end, a slew of bankers were convicted for their roles in the LIBOR rigging scandal, and fines totaling more than USD 9 billion were levied against large banks, including Barclays, Citigroup, Deutsche Bank, JP Morgan, Lloyds, RBS, Rabobank, and UBS.

Perhaps most significant for our purposes is that regulators in many jurisdictions concluded that LIBOR was not fit for purpose and that it needed to be retired. In different parts of the world, authorities have suggested

[2]It's worth noting that Bob Diamond, an American, was forced to resign from Barclays by the Bank of England and the UK Financial Services Authority, while Paul Tucker went on to become Deputy Governor of the Bank of England and was later knighted for his services to central banking.

different candidates for replacing LIBOR. But in the US, authorities have settled on SOFR – the *secured overnight financing rate*.

SOFR AND REPO MARKETS

To understand SOFR, one needs first to understand repo – short for repurchase agreement. As the name suggests, a repo transaction is one in which a security – typically a bond – is sold and *simultaneously repurchased* at an agreed price with settlement on an agreed date in the future. In other words, the bond is sold in the spot market and simultaneously bought back on a forward date for a different price. The repurchase price is typically greater than the sale price, and the difference between the two prices reflects the cost of borrowing between the sale date and the subsequent repurchase date, with the bond serving as collateral.

For example, imagine that I could sell USD 100 million par amount of bonds for an invoice price[3] of 101,000,000 in the spot market and that I simultaneously could arrange to repurchase those same bonds tomorrow for an invoice price of USD 101,000,280.56. The difference between the sale price and the purchase price – USD 280.56 in this case – is the interest I pay to borrow USD 101 million overnight. In this example, the overnight repo rate is $(280.56 / 101{,}000{,}000) \times (360/1) = 0.001$ – i.e., 0.1%.

The mechanics of this repo transaction involve me selling a bond today and simultaneously agreeing to repurchase the bond tomorrow at a price we agree on today. But the economic rationale for repo transactions is to borrow money using a bond as collateral for the loan – i.e., to arrange a secured financing – in this case, an overnight secured financing. Not surprisingly, the repo rate associated with this overnight secured financing is called the secured overnight financing rate (SOFR). We describe the mechanics of the repo market and the secured overnight financing rate in much greater detail in Chapter 1.

As it happens, the repo market is a very large, very active market. The Brookings Institution estimated the average daily turnover in the US repo market in 2021 at somewhere between USD 2 trillion and USD 4 trillion *per day*. Repo agreements can be arranged for various terms, but the most common term is one day – i.e., *overnight*. In fact, even when people intend to borrow funds for a longer period, they often simply arrange to leave the repo agreement "open," meaning the repo arrangement will keep rolling over for

[3]The invoice price of the bond is the total price one must pay for the bond, including accrued interest. Bond prices are typically quoted on a "clean" basis – i.e., without accrued interest. But the invoice for the bonds will add the accrued interest to this amount – hence the term *invoice price*. In practice, bond prices are expressed assuming a par amount of USD 100.

a term of one day until otherwise ended by one of the two parties to the transaction.

Many large institutions are required to report repo transactions, with the result that the Federal Reserve has a wealth of daily repo transactions that it can use to monitor the market for overnight secured financing.[4]

With LIBOR viewed as an unreliable benchmark, the Board of Governors of the Federal Reserve and the Federal Reserve Bank of New York in 2014 jointly convened the Alternative Reference Rate Committee (ARRC) for the purpose of identifying a risk-free replacement for USD LIBOR. Over time, the membership of ARRC was expanded to include quite a number of regulators, banks, GSEs, exchanges, and investment managers. By 2017, the ARRC had settled on SOFR – Secured Overnight Financing Rate – as the replacement for LIBOR and had proposed a transition plan for moving the market from LIBOR to SOFR, the key steps of which are summarized in Figure Intro.1.

Lesser-used USD LIBOR values ceased on 31-Dec-21.

Remaining USD LIBOR values will cease on 30-Jun-23.

Supervisory guidance instructed banks to stop using LIBOR for a reference rate on new products by 31-Dec-21. In fact, continued use of LIBOR as a reference rate for new products was to be considered a "safety and soundness risk."

For derivatives, LIBOR-SOFR fallback spreads (to be used in legacy products) were set by currency and by tenor on 5-Mar-21.

Legacy Eurodollar futures contracts will be converted to SOFR futures at a fixed spread of 26.161 bp.

For consumer cash products, the LIBOR-SOFR fallback spread for each tenor will be:

- Before 1-Jul-23: the median difference between USD LIBOR and SOFR compound in arrears during the previous 10 working days
- After 30-Jun-24: the median spread for that tenor during the five years prior to 5-Mar-21
- Between 1-Jul-23 and 30-Jun-24: the linearly interpolated value between the two rates above

For institutional cash products, such as corporate loans and floating rate notes, for each tenor the fallback spread is the median of the historical differences between USD LIBOR and the compounded in arrears SOFR value over a five-year period prior to 5 March 2021.

FIGURE Intro.1 Transition from LIBOR to SOFR
Source: Authors

[4]For example, US bank holding companies with total assets equal to or greater than USD 100 billion are required to report these transactions, as are foreign banking organizations with total assets of at least USD 50 billion.

SOFR FUTURES AND OPTIONS: TOPICS AND STRUCTURE OF THIS BOOK

While the International Swaps and Derivatives Association (ISDA) has been overseeing the practical implementation of the LIBOR-to-SOFR transition for over-the-counter derivatives, and while the ARRC has been overseeing the practical implementation of the transition for cash products, the CME has been working to facilitate the transition for listed derivatives, namely futures and options.

The last step of the historical evolution of money markets summarized thus far leads to the subject of our book, SOFR futures and options, and links it with the transition from an unsecured term-rate to a secured overnight rate, implying two fundamental changes:

1. Term-lending, which used to be based on the term-rate LIBOR, needs to be based on an overnight reference rate.
2. The transition from LIBOR to SOFR involves the basis between unsecured and secured rates.

The main goal of this book is to provide a conceptual framework for these changes in section 1 and practical help for dealing with them in section 2. Like the subject of this book, SOFR futures and options are historically and conceptually linked to these two fundamental changes. It is the structure of the first part: Chapters 1, 2, and 3 address the implications of switching from a term rate to an overnight rate, and Chapter 4 focuses on the basis.

Chapter 1 outlines the construction of SOFR from the repo market. Since liquidity in the repo market is sufficient only for the shortest tenor, the decision to base lending on a secured reference rate implied the decision to base lending on an overnight rate. This fact is the reason behind the need to migrate the cash loan and derivatives markets from a term rate (LIBOR) to an overnight rate (SOFR).

Chapter 2 describes this migration in the futures markets by comparing SOFR with ED (Eurodollar) contracts. It turns out that it can easily be implemented in the futures market; with the exception of the front month contract, the transition from LIBOR to SOFR as the underlying rate is, for practical purposes, little more than a renaming exercise of ED and FF (Fed Funds) futures. Chapter 2 also provides a fair value model for the spread between 1M and 3M SOFR futures:

- The three-month SOFR futures contract settles to a compounded average of SOFR values produced daily by the New York Federal Reserve. This compounded average is quite similar to a geometric average, and it

means the SOFR futures *rate* (100 less the SOFR futures price) is equal to the forward rate between the first and last days of the three-month reference period for that contract.[5]

- In contrast, the one-month SOFR futures contract settles to a *simple* average of SOFR values during the respective calendar month. As a result, the futures rate for a one-month SOFR futures contract is not identical to the forward rate between the first and last days of the relevant reference period. The nature of these differences is highlighted in Chapters 2 and 6.

Chapter 3 discusses the implications of this migration in the cash loan markets. Here, unlike for futures, the transition from the forward-looking term rate LIBOR to the backward-looking overnight rate SOFR met significant resistance. Chapter 3 explains how the tension between the goals of regulators and the needs of borrowers has resulted in the compromise of introducing a term rate for SOFR calculated via a model from the SOFR futures market. As a result of using a model, the cost of hedging the term rate with futures is high, and regulators keep it at a high level by prohibiting a secondary market for the SOFR term rate. This chapter finishes by analyzing two possible scenarios for the further evolution of the tension: It could be resolved either by the high hedging costs for the term rate driving cash loan markets to embrace in-arrears conventions, making the term rate superfluous, or by regulators allowing a secondary market for the term rate, which supports its permanence by reducing the hedging costs – maybe after the frictions caused by the prohibition will have become clear.

Chapter 4 then addresses the implications of switching from an unsecured to a secured reference rate. It provides an economic framework and a statistical model to understand the unsecured–secured basis and applies it to analyze the spread between ED and FF futures on one hand and SOFR futures on the other hand. As the model establishes a link between the unsecured–secured basis driving the ED–SOFR futures spread and the CCBS (cross currency basis swap), it allows replacing the CCBS, which is part of many relative value trades, but involves high capital and transaction costs, in some trades with the much cheaper spread future.

Chapter 5 describes the options on SOFR futures and finds that the transition from the term rate LIBOR to an averaged or compounded overnight rate has major implications for the future options:

[5]There are some circumstances in which the equivalence is approximate rather than exact.

- As soon as the reference period starts, the future option transmogrifies into a path-dependent exotic Asian option. Options on 1M SOFR contracts are then Asian options of the American type with arithmetic averaging, which are a mathematical challenge and for which no pricing formula exists. One consequence of the absence of a way to determine the Greeks – specifically, the delta required for delta hedging – is the relatively late migration of liquidity from ED to SOFR future options; another consequence is an increased difficulty of using SOFR rather than ED future options for hedging caps and floors.
- On the other hand, before the reference period starts, options on SOFR futures are standard options referring to a forward rate, which can be priced and analyzed by well-established methods – though the values are quite sensitive to the statistical process chosen. Here, the conclusion from Chapter 2, that for most practical purposes the conceptual difference between a term rate and an average or compound of overnight rates can be reduced to a renaming exercise of already known analytic concepts with some extra caution for the front-month contract, can be applied again – precisely by excluding the front month from the consideration. Chapter 5 summarizes the realized and implied volatility analysis for the secured yield curve, including the distribution of risk and return, which Galen has mentioned in his Foreword. Expanding the secured versus unsecured theme from Chapter 4, we also highlight the opportunities for trading options on SOFR futures versus options on ED contracts and hope that the attractiveness of these spread positions will support the transition of liquidity.

Chapter 6 considers some of the idiosyncrasies of SOFR futures contracts. We find that, while the Eurodollar futures suffered from a much-discussed convexity bias, the three-month SOFR futures contract suffers from no such bias, as the contract has no convexity. On the other hand, there is a slight bias in the one-month SOFR futures contract, owing to the fact that it settles to a simple, arithmetic average of SOFR rates during its reference period. We also consider the conditions under which market participants need to be concerned about any financing bias affecting the SOFR futures contracts. In Chapter 6, we also discuss the way in which SOFR futures prices, possibly with adjustment, can be used to create a term structure of overnight forward rates along the SOFR yield curve.

Section 2 has the objective to help the market practitioner applying the new products, SOFR futures and options, for concrete tasks, such as hedging. The conceptual discussion of section 1 gave a sense for those parts, where the approaches known from ED contracts can simply be transferred, and for those, where extra caution is required – specifically the term rate and options. Section 2 uses these results and outlines the necessary adjustments of analysis and hedging techniques in the SOFR universe.

Chapter 7 illustrates basic principles using the simplest possible examples – namely, of a corporate treasurer who wishes to convert a portion of his floating-rate balances to fixed rate using SOFR futures contracts. We pay particular attention in this chapter to the pernicious effects of date mismatches. When the reference period of your hedging instruments doesn't precisely coincide with the reference period of the underlying quantity you want to hedge, this date mismatch risk is inevitable. In Chapter 7, we offer a few suggestions for ways in which this date mismatch risk can at least be mitigated.

Chapter 8 considers hedging the Term SOFR rate. The CME adopted its Term SOFR valuation methodology for a number of good reasons, but the simplicity of the calculations wasn't one of them. Their computation methodology creates some unique issues for anyone using or hedging the Term SOFR rate. For example, the methodology allows the possibility that the prices of futures contracts with reference periods well beyond the end date of the Term SOFR reference period can influence the published Term SOFR rate. This is in contrast to methods traditionally used to calculate term rates and forward rates along LIBOR curves built with Eurodollar futures contracts, and market participants at least should be aware of this effect when using or hedging the CME's Term SOFR rate.

Chapter 9 builds on the discussion of the secured–unsecured basis in Chapter 4 and explains how the elimination of that basis in the asset swap spreads of government bonds results in the three key markets, futures, swaps, and bonds, all becoming conceptually similar. Welcome consequences of this convergence in the SOFR universe are a straightforward hedge of swaps and bonds, with futures and the exclusion of the basis risk in hedges of government bonds with futures.

Chapter 10 builds on the discussion of options in Chapter 5 and explains – in sharp contrast to Chapter 9 – how the migration to SOFR has necessarily resulted in major difficulties for hedging caps and floors with options on futures. On top of this, the recommendation of ARRC to apply the floor of some loans on a daily basis has added another layer of challenges.

IMPLICATIONS OF SOFR FOR MARKET ANALYSIS

In addition to the focus on the conceptual and practical aspects of the transition from LIBOR to SOFR, from time to time this book offers insights into the general implications of a secured reference rate for market analysis:

- All analysis tools developed for the unsecured yield curve can now be transferred to the secured yield curve. For example, like Eurodollar futures provide consecutive 3M forward segments of unsecured lending