LIBOR Transition

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Interest rates Modeling
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Abstract

The London Interbank Offered Rate (LIBOR) has long been a key financial benchmark, but manipulation scandals and declining interbank activity have led to its replacement. This project examines LIBOR's role, its limitations, and the reasons for its discontinuation. We analyze the transition to risk-free rates (RFRs) like SOFR, SONIA, and €STR, detailing fallback rate calculations using historical median spreads and compounding methods. A Python-based framework demonstrates the financial impact of these adjustments, particularly for long-term contracts. By improving fallback mechanisms and transparency, the shift to alternative benchmarks enhances financial stability.

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1 Introduction

The *London Interbank Offered Rate* (LIBOR) has served as a key benchmark for global financial markets for decades, underpinning a vast array of financial instruments, including loans, derivatives, and bonds. However, concerns over its reliability, stemming from manipulation scandals and declining interbank lending activity, have led regulators and market participants to transition towards *alternative reference rates* (ARRs).

The shift away from LIBOR marks one of the most significant financial market transformations in recent history, impacting trillions of dollars in financial contracts. The transition is not merely a replacement of one benchmark with another but requires substantial changes in pricing models, risk management strategies, and contractual fallback provisions.

In this project, we examine the **LIBOR transition**, starting with an overview of its role and limitations. We explore the reasons behind its discontinuation, including both the LIBOR scandal and structural issues in the post-crisis interbank market. Next, we discuss the introduction of new risk-free rates (RFRs), such as SOFR, SONIA, and €STR, which have been designated as replacements across different jurisdictions.

A key challenge in the transition is ensuring economic continuity, particularly for legacy contracts referencing LIBOR. To address this, the International Swaps and Derivatives Association (ISDA) developed a standardized fallback methodology, which includes spread adjustments to account for structural differences between LIBOR and RFRs. We delve into the methodology for fallback rate computation, including its implementation using Python.

2 LIBOR: an overview (Fabio Marcaurelio)

Interbank rates (commonly labelled as **IBOR**, short for *Interbank Offered Rates*) represent the cost at which primary financial institutions can borrow money from each other and they serve as widely accepted reference rates for numerous transactions. In financial markets, the most widespread interbank rate is **LIBOR** (short for London Interbank Offered Rate), even if there exist other similar rates, such as **EURIBOR** which is published by the European Money Markets Institute, based on the averaged interest rates at which Eurozone banks offer to lend unsecured funds to other banks in the euro wholesale money market.

The *London Interbank Offered Rate* (LIBOR) came into widespread use in the 1970s as a reference interest rate for transactions in offshore Eurodollar markets. In 1984, it became apparent that an increasing number of banks were trading actively in a variety of relatively new market instruments, notably interest rate swaps, foreign currency options and forward rate agreements [1]. While recognizing that such instruments brought more business and greater depth to the London Inter-bank market, bankers worried that future growth could be inhibited unless a measure of uniformity was introduced.

[1] **Interest rate swaps** are forward contracts where one stream of future interest payments is exchanged for another based on a specified principal amount. **A foreign currency option** is a contract giving the option purchaser (the buyer) the right, but not the obligation, to buy or sell a fixed amount of foreign exchange at a fixed price per unit for a specified time period. **A forward rate agreement (FRA)** is an agreement between two parties who agree on a fixed rate of interest to be paid/received at a fixed date in the future.

In October 1984, the *British Bankers' Association* (BBA) working with other parties, such as the Bank of England, established various working parties, which eventually culminated in the production of the BBA *standard for interest rate swaps*, or "BBAIRS" terms [2]. In January 1986, the British Bankers' Association published LIBOR - initially in US Dollars, Japanese Yen and Sterling (and later in 10 currencies with fifteen maturities calculated for each) – as the average of each submitting bank's estimate of the rate at which panel banks could borrow from each other. the definition of **LIBOR** was published in 1998, which reads

> *The rate at which an individual Contributor Panel bank could borrow funds, were it to do so by asking for and then accepting inter-bank offers in reasonable market size, just prior to 11.00 London time.*

This definition in still in force today. Specifically, every day the BBA asks a panel of AA-rated banks the question

> *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 am?*

The BBA threw out the highest four and lowest four responses, and averaged the remaining middle ten, yielding a 22% trimmed mean. The average was reported at 11:30 am. LIBOR was produced for 5 currencies (USD, EUR, GBP, JPY, CHF) and for 7 maturities, denoted as tenors (1 day, 1 week, 1, 2, 3, 6 and 12 months). In order to correctly price derivatives, it is crucial that the applied interbank interest rate is **risk-free** [3]. In fact, it referred to AA-rated banks, therefore to transactions that were perceived to have credit risk almost equal to zero. This is why, mathematically, LIBOR has been determined as a **forward simply compounded rate** assuming absence of risk, as follows:

Suppose that we are standing at time t, and we fix two points in time S and T, with $t < S < T$. We set up the following construction:

1. At time t we sell one S-bond. This will earn us $P(t, S)$ dollars.
2. We use this income to buy $\frac{P(t,S)}{P(t,T)}$ T-bonds. Therefore, our net investment at time t is worth:
$$P(t, S) - \frac{P(t, S)}{P(t, T)} \cdot P(t, T) = 0.$$
3. At time S, the S-bond matures, so we need to pay one dollar.
4. At time T, the T-bonds mature at one dollar each, so we will receive the amount:
$$\frac{P(t, S)}{P(t, T)}$$
dollars.

[2] **BBA IRS** was the precursor of LIBOR, hence these standards constitute the first form of regulation of the rate.

[3] **Risk-free rate** is the theoretical rate of return received on zero-risk assets, which serves as the minimum return required on riskier investments.

5. Thus, the net effect overall is that, based on a contract at t, an investment of one dollar at time S has brought $\frac{P(t,S)}{P(t,T)}$ dollars at time T.

6. This means that, at time t, we have set up a contract guaranteeing a riskless rate of interest over the future interval $[S, T]$. Such an interest rate is called the **forward rate**, or **LIBOR rate**[1].

Definition 1. Simply-compounded forward interest rate: *The simply-compounded forward interest rate prevailing at time t for the expiry $S > t$ and maturity $T > S$ is denoted by $F(t; S, T)$ and is defined by*

$$F(t; S, T) := \frac{1}{\tau(S, T)} \left(\frac{P(t, S)}{P(t, T)} - 1 \right) \tag{1}$$

It is the solution to the equation

$$1 + \tau(S, T)F = \frac{P(t, S)}{P(t, T)}$$

Nonetheless, after the global financial crisis, it is no longer reasonable to assume that LIBOR is a risk-free rate. To investigate the phenomenon, we compare LIBOR with a commonly accepted proxy for the risk-free rate which is **OIS** *overnight index swap rates* through the **LIBOR-OIS spread** [4]. Following the paper maded by Duffie and Krishnamurthy (2016)[2] during the 2007-2008 crisis the dispersion of credit risk among banks made LIBOR less reliable as a common benchmark, as it no longer reflected banks' average funding costs in a uniform way. In parallel, money market pricing became more fragmented and influenced by specific liquidity and credit factors, causing the greatest dispersion among market rates. Figure 1 shows the spread of three-months USD LIBOR (and other relevant rates) over the three-month USD OIS rate.

[4]The **LIBOR-OIS spread** is the difference between LIBOR – the floating rate at which banks lend to each other – and overnight index swap rates, which are set by central banks. As LIBOR reflects bank credit risk, while OIS is considered risk-free, the LIBOR-OIS spread is widely seen as a gauge of the creditworthiness of the banking system.

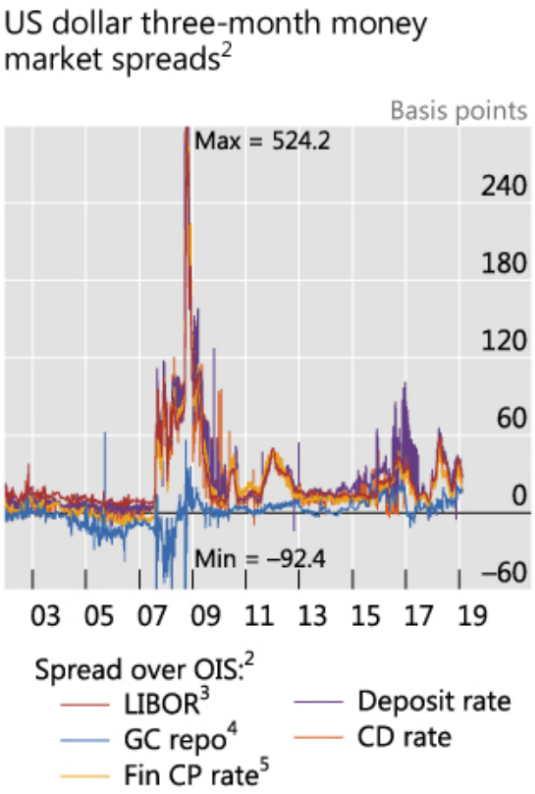

Figure 1: USD three-months LIBOR spread over three-months USD OIS rate[3]

As can be seen the mathematical construction described above based on the no-arbitrage condition can no longer be applied as LIBOR was clearly incorporating credit and liquidity risk after the outbreak of the financial crisis, in addiction the market became segmented, in the sense that different yield curves arose from market instruments that depended on a specific tenor, thus leading to multiple yield curves and one of the most general approaches to model these multiple curves is based on affine processes[5]. For over a decade, swap and derivatives markets have begun to replace LIBOR with OIS for calculating cash flows and valuations. OIS are preferred because they reflect risk-free rates (based on central bank overnight rates) rather than the cost of money between banks, which includes credit risk.

2.1 Reasons behind the replacement

As we anticipated in the previous section, the main factors that allowed the replacement of LIBOR are mainly two, the first of a judicial nature and the second of a market nature. In the first case we are talking about the **LIBOR scandal** that brought to light a structured banking fraud aimed at altering the real value of LIBOR. In the second case, as we anticipated, LIBOR lost interest in the post-crisis period also due to the **loss of representability** of a situation called "no arbitrage" as it was understood that risk factors were incorporated within it. These two events meant that LIBOR was gradually replaced in favor of new rates called "Risk-Free".

[5]**Affine processes** are a class of stochastic processes widely used in financial modeling, especially for interest rates, credit risk, and volatility. They are called "affine" because their characteristics (e.g., mean and variance) depend in an affine way on the state of the process itself.

2.1.1 LIBOR scandal

After the 2008 financial crisis, it became clear that LIBOR could no longer be used as a benchmark rate, as it was not an appropriate proxy for the *risk-free rate*. This paragraph summarises some bank practises and crisis fallbacks which brought to this outcome. Firstly, since LIBOR is constructed from a survey of a small set of banks reporting non-binding quotes rather than actual transactions, said banks could easily manipulate their quotes, by understating the borrowing costs they reported for LIBOR. For example, if among the panel banks' assets is a derivative whose payoff is positively related to LIBOR, it is tempting for them to report a higher quote and encourage the others to do the same. This practise generates the impression that banks could borrow from other banks more cheaply than they can in reality. Moreover, it makes the banking system seem healthier than it actually is.

2008

On 29 May 2008, *The Wall Street Journal* (WSJ) published a study suggesting that banks might have been manipulating their submissions during the 2008 credit crunch [4]. Other authorities contradicted The Wall Street Journal article saying there was no evidence of manipulation. In its March 2008 Quarterly Review, the *Bank for International Settlements* stated that "available data do not support the hypothesis that contributor banks manipulated their quotes to profit from positions based on fixings [5]." Further, in October 2008, the *International Monetary Fund* published its regular Global Financial Stability Review which also found that "Although the integrity of the U.S. dollar LIBOR-fixing process has been questioned by some market participants and the financial press, it appears that U.S. dollar LIBOR remains an accurate measure of a typical creditworthy bank's marginal cost of unsecured U.S. dollar term funding[6]."

2010

in April 2010 a study corroborated the results of the earlier Wall Street Journal study, concluding that the LIBOR submissions by some member banks were being understated [7].

2011

The Wall Street Journal reported in March 2011 that regulators were focusing on Bank of America Corp., Citigroup Inc. and UBS AG in their probe of LIBOR rate manipulation[7]. A year later, it was reported in February 2012 that the *US Department of Justice* was conducting a criminal investigation into LIBOR abuse. Among the abuses being investigated were the possibility that traders were in direct communication with bankers before the rates were set, thus allowing them an unprecedented amount of insider knowledge into global instruments.

2012

By 4 July 2012, the breadth of the scandal was evident and became the topic of analysis on news and financial programs that attempted to explain the importance of the scandal. Two days later, it was announced that the *UK Serious Fraud Office* had also opened a **criminal investigation** into manipulation of interest rates. Also the US Department of Justice initiated a criminal investigation concerning LIBOR abuse and manipulation. Already by mid-2012, the issue started to be discussed by the news and financial programs, and made the front page of several newspapers. The media defined the manipulation-practise as **LIBOR scandal.**

2.1.2 from a market perspective

Apart from manipulation practises, LIBOR faced other important drawbacks as a consequence of the global financial crisis. For starters, post-crisis **interbank trading** dropped, especially in the unsecured segment.

This was driven by the Central Banks doings, which characterised the years after 2008. In particular, Central Banks lowered interest rates, keeping them close or below zero, in order to increase money supply and boost economic activity. However, they kept them low for a long time. Therefore, to manage the resulting decrease of inflation they were forced to use unconventional policies, such as asset purchase programs (APPs)[6]. In the US, the *Federal Reserve* conducted large-scale asset purchases between 2008 and 2014. The *European Central Bank* implemented the "quantitative easing" starting 2015.

The Great Financial Crisis hit banks hard, leading to heavy losses and stricter regulations. With tighter capital requirements and increased supervision, banks became more cautious, hoarding liquidity instead of lending to each other. Trust eroded, and the interbank market dried up, making LIBOR increasingly unreliable as a reference rate. To reduce counterparty risk, banks turned to alternative funding sources and limited interbank transactions to safer instruments like repos. As real lending activity dwindled, LIBOR quotes became more guesswork than reality, ultimately sealing its fate as an outdated benchmark.

3 Risk Free Rates (Davide Messina)

In 1986, LIBOR initially set rates for three currencies: the US dollar, the British pound, and the German mark. Over time, the number of currencies increased to sixteen. After some of these currencies merged into the euro in 2000, ten remained. Following the 2013 reforms, LIBOR rates have been calculated for five currencies : USD, GBP, YEN, CHF, EUR [8].

After the transition across all the jurisdictions, as previously discussed, the publication of USD LIBOR rates for overnight, 1-month, 3-month, 6-month, and 12-month tenors officially ended on December 31, 2023.

The replacement of LIBOR with new risk-free rates (RFRs) was completed rapidly worldwide. The publication of USD LIBOR rates for overnight, 1-month, 3-month, 6-month, and 12-month maturities ceased on June 30, 2023.

Meanwhile, all LIBOR rates in GBP, JPY, CHF, and EUR, as well as USD LIBOR rates for the 1-week and 2-month tenors, had already been discontinued as of December 31, 2021. Additionally, the publication of synthetic LIBOR rates for certain JPY and GBP maturities, which were non-representative, either ceased.

To support the transition to the new benchmark rates, synthetic USD LIBOR rates were published from the end of June 2023 until the end of September 2024 [9].

Below is a detailed table outlining all the steps clearly.

3.1 New RFR

The discontinuation of LIBOR was the result of years of preparation by regulators, central banks, and market participants. This extensive effort led to the development of new risk-

[6] **AAPs** are monetary policy instruments through which CBs purchase certain amounts of government bonds or other financial assets, to inject money into the economy and expand economic activity

	USD	GBP	YEN	CHF	EUR
Overnight / SN	Available until 30/06/23	Ceased after 31/12/2021	Ceased after 31/12/2021	Ceased after 31/12/2021	Ceased after 31/12/2021
1 week	Ceased after 31/12/2021	Ceased after 31/12/2021	Ceased after 31/12/2021	Ceased after 31/12/2021	Ceased after 31/12/2021
1 month	Available until 30/06/23, then synthetic rate until 30/09/24	Ceased after 31/12/2021, then synthetic rate until 31/03/23	Ceased after 31/12/2021, then synthetic rate until 31/12/22	Ceased after 31/12/2021	Ceased after 31/12/2021
2 months	Ceased after 31/12/2021	Ceased after 31/12/2021	Ceased after 31/12/2021	Ceased after 31/12/2021	Ceased after 31/12/2021
3 months	Available until 30/06/23, then synthetic rate until 30/09/24	Ceased after 31/12/2021, then synthetic rate until 31/03/24	Ceased after 31/12/2021, then synthetic rate until 31/12/22	Ceased after 31/12/2021	Ceased after 31/12/2021
6 months	Available until 30/06/23, then synthetic rate until 30/09/24	Ceased after 31/12/2021, then synthetic rate until 31/03/23	Ceased after 31/12/2021, then synthetic rate until 31/12/22	Ceased after 31/12/2021	Ceased after 31/12/2021
12 months	Available until 30/06/23	Ceased after 31/12/2021	Ceased after 31/12/2021	Ceased after 31/12/2021	Ceased after 31/12/2021

Table 1: The timeline for the cessation of LIBOR rates and synthetic LIBOR. Source: [9].

free rates (RFRs), which now serve as the primary benchmarks in the money market, replacing LIBOR in both existing and new contracts. Each jurisdiction has established specific fallback rates for LIBOR, as summarized in the table below.

IBOR	Risk-Free Rate	Administrator	Secured or Unsecured	Transactions
USD LIBOR	**SOFR**	New York Fed	Secured	o/n UST repo
GBP LIBOR	**SONIA**	Bank of England	Unsecured	o/n wholesale deposits
JPY LIBOR	**TONAR**	Bank of Japan	Unsecured	o/n call rate
CHF LIBOR	**SARON**	SIX Swiss Exchange Ltd	Secured	Interbank o/n repo
EUR LIBOR	**€STR**	ECB	Unsecured	o/n wholesale deposits

Table 2: Alternative risk-free rates (RFRs) replacing IBOR benchmarks. Source: [9].

The transition from LIBOR to new risk-free rates (RFRs) was a highly complex, costly, and challenging process. It required the coordination of financial institutions, regulators, and policymakers across multiple jurisdictions, involving extensive financial resources and countless hours of work. The shift not only affected global markets but also demanded legal and operational adjustments to ensure a smooth transition.

Despite its successful completion, the process highlighted significant risks and obstacles, serving as a crucial lesson for future financial benchmarks. However, we will not delve into the detailed phases of this transition, as they fall outside the scope of our research, but in this section we will focus solely on the key characteristics of the five main RFRs. [10].

3.1.1 SOFR - Secured Overnight Financing Rate

As detailed by the Federal Reserve Bank of New York [11], in 2017 the Alternative Reference Rates Committee (ARRC) identified the Secured Overnight Financing Rate (SOFR) as the most suitable replacement for USD LIBOR, selecting it as the preferred benchmark for certain financial instruments and derivatives. This rate measures the cost of overnight borrowing, backed by U.S. Treasury securities in the repurchase agreement (repo) market. It is published each business day at around 8:00 a.m. Eastern Time by the Federal Reserve Bank of New York, in collaboration with the Office of Financial Research.

Unlike LIBOR, which was based on estimates of interbank lending rates, SOFR is calculated directly from actual market transactions, making it a more transparent and manipulation-resistant benchmark. The underlying transaction volume exceeds $1 trillion daily, making SOFR one of the most liquid and reliable reference rates in the U.S. financial system. Additionally, because it is rooted in the U.S. Treasury repo market, it is not subject to the same risks of discontinuation as LIBOR, ensuring its long-term viability.

The SOFR Index and three daily compounded averages provide market participants with tools to compute rates over various periods. However, recognizing that some legacy contracts and business loans may face challenges in transitioning to an overnight rate, the CME Group introduced forward-looking SOFR term rates for limited use in specific financial products.

3.1.2 SONIA - Sterling Overnight Index Average

SONIA (Sterling Overnight Index Average) is a key benchmark for the UK sterling market, reflecting the cost of borrowing overnight, secured by collateral. Unlike GBP LIBOR, which relied on estimates from a panel of banks, SONIA is based on actual transactions in the market. The Bank of England is responsible for its administration, and it is published daily, providing a more transparent and reliable rate [12].

Since its introduction in 1997, SONIA was reformed in 2018 to align with international standards. In 2020, the Bank of England introduced the SONIA Compounded Index, which simplifies the calculation of compounded interest rates, further supporting the transition to risk-free rates.

SONIA is primarily used in financial products like swaps and floating-rate notes, with around £30 trillion in assets linked to it annually. In terms of volume, SONIA is referenced in over £90 trillion of new transactions each year.

When comparing GBP LIBOR with SONIA, key differences stand out. LIBOR was a forward-looking rate, based on panel bank submissions, and covered multiple periods, such as 1-week, 3-month, and 1-year terms. In contrast, SONIA is an overnight rate, based on real market transactions, and is considered nearly risk-free, as it minimizes credit and liquidity premiums. Moreover, LIBOR exposed borrowers to potential bank credit risks, while SONIA provides a more stable and transparent alternative.

3.1.3 TONAR - Tokyo Overnight Average Rate

As part of Japan's transition away from JPY LIBOR, the Study Group on Risk-Free Reference Rates identified the uncollateralized overnight call rate, commonly referred to as TONA rate or TONAR (Tokyo Overnight Average Rate), as the most suitable Japanese yen risk-free rate [13].

TONA is calculated and published by the Bank of Japan based on actual overnight unsecured lending transactions brokered exclusively by money market intermediaries (tanshi companies), explicitly excluding direct bilateral transactions. The rate is determined as a volume-weighted average, ensuring it accurately reflects market activity. It was selected due to its deep underlying market, sufficient transaction volume, and diverse participant base, which contribute to its robustness and resilience against manipulation. Unlike LIBOR, which relied on panel bank submissions and incorporated credit and liquidity risk, TONA is nearly risk-free as it represents overnight lending with minimal credit exposure.

By adopting TONA, Japan aligns with global risk-free rate reforms, ensuring a more transparent and reliable benchmark for JPY-denominated financial contracts.

3.1.4 SARON - Swiss Average Rate Overnight

In Switzerland's transition from CHF LIBOR, the Swiss Average Rate Overnight (SARON) was identified as the preferred risk-free rate. SARON is a secured overnight interest rate derived from actual transactions and quotes in the Swiss repo market, administered by SIX [14].

Unlike LIBOR, which reflected unsecured interbank lending based on panel bank estimates, SARON is grounded in a fully collateralized market where participants, including banks and the Swiss National Bank (SNB), exchange short-term liquidity against securities. This structural difference ensures greater transparency and resistance to manipulation. SARON is calculated using around 110 actual interest rates daily, compared to LIBOR's reliance on a handful of estimated submissions, which contributed to the rate-rigging scandals that undermined its credibility. Moreover, SARON is published every ten minutes, with three daily fixings, offering a more dynamic and responsive benchmark compared to LIBOR's once-daily publication.

By anchoring the CHF risk-free rate to a robust, secured market, Switzerland enhances financial stability and aligns with global benchmark reforms aimed at increasing reliability and market integrity.

3.1.5 €STR - Euro Short-Term Rate

The Euro Short-Term Rate (€STR) was introduced by the European Central Bank (ECB) to reflect the cost of unsecured overnight borrowing in the euro area. On October 2, 2019, €STR officially replaced the Euro Overnight Index Average (EONIA) as the primary reference rate for the euro overnight market. This transition was carefully planned and successfully completed on January 3, 2022, when EONIA was permanently discontinued [15].

The key difference between €STR and EONIA lies in their calculation methodologies and data sources. While EONIA was based on a panel of banks reporting rates for interbank unsecured lending, €STR is derived from actual transactions between banks and other financial counterparties, providing a broader and more accurate representation of the market. To facilitate the transition, from October 2, 2019, EONIA was recalibrated as €STR plus a fixed spread of 8.5 basis points until its cessation.

As for EUR LIBOR, it represented the average interest rate at which major banks operating in euros were willing to lend funds in the unsecured interbank market. However, due to manipulation concerns and declining liquidity in the underlying market, EUR LIBOR was gradually phased out. Unlike USD LIBOR in the United States or GBP LIBOR in the United Kingdom, the discontinuation of EUR LIBOR had a limited impact,

since in Europe it had always played a marginal role, as financial markets already favored EURIBOR for term rates (1M, 3M, 6M, etc.) and EONIA—later replaced by €STR—for overnight rates. Since EUR LIBOR was neither officially supported by European authorities nor widely used in financial contracts, its phase-out had minimal market disruption. Moreover, EUR LIBOR was based on estimates rather than actual transactions, making it less robust compared to EONIA and EURIBOR, which were preferred by European regulators for their stronger transaction-based methodology.

4 Transition Problem (Matteo Lenzi)

What happens to contracts with a notional value of trillions of dollars when they reference a benchmark that ceases to exist? [16] This question has been at the core of the transition from the London Interbank Offered Rate (LIBOR) to alternative reference rates (ARRs) following LIBOR's phase-out at the end of 2021.

The **International Swaps and Derivatives Association** (ISDA) introduced the **Fallback Protocol** and a Supplement to mitigate this issue, ensuring that legacy derivative contracts referencing LIBOR would not become invalid or require immediate renegotiation. The protocol establishes a standardized mechanism for transitioning LIBOR-linked contracts to an alternative reference rate, thereby reducing legal uncertainty and minimizing market disruptions.

To mitigate the risk associated with the discontinuation of one or more IBORs while market participants maintain exposure to those rates, counterparties are encouraged to agree on contractual fallback provisions. These provisions define adjusted versions of risk-free rates (RFRs) as replacements for discontinued benchmarks [17].

4.1 Fallback Rate

The **fallback rate is typically an Alternative Reference Rate (ARR) with a spread adjustment designed to account for the economic differences between LIBOR and the ARR**. While LIBOR included a credit risk premium reflecting bank borrowing costs, ARRs are generally risk-free or nearly so because based on overnight secured lending. The spread adjustment ensures a smoother transition by maintaining economic equivalence between the original and replacement benchmarks.

The ISDA Fallback Protocol provides a broad framework for transitioning derivatives from LIBOR to ARRs, covering most derivative exposure by notional value across currencies. While primarily designed for non-cleared derivatives under an ISDA Master Agreement, cleared derivatives are also expected to follow suit under central counterparty (CCP) rules. However, some discrepancies may arise, as CCP fallback provisions are typically mandatory.

Cash instruments, including floating rate notes, syndicated loans, and securitizations, are not directly covered by the ISDA protocol due to greater contractual variability. Instead, fallback provisions for these products are guided by national working groups, such as the Alternative Reference Rates Committee (ARRC) in the US, which aims to align cash product fallbacks with ISDA's approach. However, differences persist—loan contracts often revert to Daily Simple SOFR, whereas ISDA fallbacks rely on a compounded overnight rate. These distinctions across currencies and financial products introduce additional complexity, requiring firms to carefully manage benchmark mismatches in their portfolios.

4.2 Methodology for Spread Adjustment

The transition from LIBOR to alternative reference rates (ARRs) required a methodology to maintain economic continuity. ISDA addressed this challenge by developing a standardized spread adjustment methodology. The adjustment is calculated as the five-year historical median[16] of the spread between LIBOR and its term-adjusted ARR counterpart. This approach ensures a smooth transition by averaging out short-term market fluctuations and reflecting the typical risk premium embedded in LIBOR over time.

For example, when replacing a three-month USD LIBOR contract, the fallback mechanism involves calculating the compounded SOFR rate over the same three-month period. However, because SOFR is an overnight rate, its value is only known at the end of the period. To maintain consistency with LIBOR's forward-looking nature, the ISDA methodology applies the predefined spread adjustment to account for the structural difference.

Fallback Adjustments When a fallback rate is triggered, certain modifications must be applied to ensure compatibility between the discontinued IBOR and the replacement RFR. These adjustments address two key differences:

1. **Term Structure:** LIBOR has predefined tenors (e.g., 1, 3, or 6 months), whereas RFRs like SOFR are daily rates. To adjust for this, the compounded-in-arrears methodology is used, meaning the ARR is compounded over the relevant period to align with the original IBOR tenor.

2. **Credit and Liquidity Spread:** LIBOR incorporated a premium reflecting interbank lending risks, while RFRs are nearly risk-free. To account for this, the fallback adjustment adds a spread based on the five-year median of the historical difference between IBOR and the compounded RFR.

These adjustments were established through extensive market consultations and regulatory guidance to minimize disruptions and ensure a fair transition.

The finalized calculation methodology is detailed in the IBOR Fallbacks Rate Adjustment Rule Book[18].

4.2.1 Calculation of Fallback Rate

The Fallback Rate (FR) for a given IBOR, Tenor f, and Rate Record Day t is determined as:

$$FR_{f,t} = ARR_{f,t} + SA_{f,t}$$

where:

- $FR_{f,t}$: Fallback Rate for Tenor f on Rate Record Day t.
- $ARR_{f,t}$: Adjusted Reference Rate for Tenor f on Rate Record Day t.
- $SA_{f,t}$: Spread Adjustment for Tenor f on Rate Record Day t.

The result is rounded to the nearest Rounding Precision, with ties rounded half away from zero.

4.2.2 Calculation of Adjusted Reference Rate

The Adjusted Reference Rate (ARR) is computed as:

$$ARR_{f,t} = \frac{DayCount_I}{DayCount_{BR}} \times \frac{1}{\delta_{S_{f,t},E_{f,t}}} \times \prod_{u \in AP_{f,t}} [(1 + \delta_{u,u+1} \times RFR_u) - 1]$$

where:

- $DayCount_I, DayCount_{BR}$: Day count conventions for IBOR and the Reference Rate.
- $S_{f,t}, E_{f,t}$: Accrual start and end dates for Tenor f.
- $AP_{f,t}$: Set of all days in the accrual period.
- RFR_u: Risk-Free Rate on day u.
- $\delta_{S_{f,t},E_{f,t}}$: Accrual factor for the accrual period.
- $\delta_{u,u+1}$: Time fraction between consecutive days u and $u+1$.

This ensures ARR reflects the compounded risk-free rate over the IBOR tenor.

4.2.3 Calculation of Spread Adjustment

The Spread Adjustment (SA) for an IBOR, Tenor f, and Rate Record Day t is:

$$SA_{f,t} = \begin{cases} \text{Median}\left(\{L_{f,u} - ARR_{f,u} \mid u \in MP_{f,t}\}\right), & t \leq \text{Fixing Date} \\ SA_{f,t-1}, & \text{otherwise} \end{cases}$$

where:

- $MP_{f,t}$: Median Period for Tenor f.
- $L_{f,u}$: IBOR value on day u, or if post-cessation, interpolated as:

$$L_{f,u} = \frac{L_{f_0,u} \times \text{Days}(IM_{f,u}, IM_{f_1,u}) + L_{f_1,u} \times \text{Days}(IM_{f_0,u}, IM_{f,u})}{\text{Days}(IM_{f_0,u}, IM_{f_1,u})}$$

where f_0 and f_1 are the lower and upper interpolation tenors.

The Spread Adjustment remains fixed after the Fixing Date and is rounded to the nearest Rounding Precision.

4.2.4 Python Implementation for Fallback Rate Calculation

To compute the fallback rate, we implemented a Python script that follows the ISDA methodology[19]. The script takes as input the historical risk-free rate (RFR) data, calculates the spread adjustment using the five-year median difference, and then applies it to the ARR to derive the fallback rate. The formula used is:

$$FR_{f,t} = ARR_{f,t} + SA_{f,t}$$

where $FR_{f,t}$ is the fallback rate, $ARR_{f,t}$ is the adjusted reference rate, and $SA_{f,t}$ is the spread adjustment. Our implementation iterates through different tenors, ensuring correct compounding of the overnight rate where applicable.

For this analysis, we focused on the Secured Overnight Financing Rate (SOFR) as the underlying risk-free rate. However, the same methodology can be applied to other alternative reference rates (ARRs), such as €STR, SONIA, or TONA, by adjusting the historical data inputs and recalibrating the spread adjustment accordingly. The results obtained from the Python computation for SOFR are summarized in the following table:

Tenor	**Spread Adjustment**	**ARR**	**Fallback Rate**
ON	0.000064	0.000000	0.000064
1W	0.000384	0.000000	0.000384
1M	0.001145	0.000000	0.001145
2M	0.001846	0.000103	0.001949
3M	0.002616	0.000069	0.002685
6M	0.004283	0.000085	0.004368
12M	0.007151	0.000336	0.007488

Table 3: Fallback rate computation results for SOFR.

The results illustrate that for shorter tenors, the adjusted reference rate (ARR) remains negligible, while the spread adjustment dominates the fallback rate calculation. For longer tenors such as 12M, ARR contributes more significantly.

5 Conclusion

The transition from LIBOR to alternative reference rates (ARRs) marks a fundamental shift in financial markets, driven by both regulatory pressures and structural inefficiencies in the interbank lending system. The phase-out of LIBOR was necessitated by its vulnerability to manipulation and its diminishing representativeness due to declining interbank transactions. While the introduction of risk-free rates (RFRs) like SOFR, SONIA, and €STR has addressed these concerns, the transition process has been far from seamless.

One of the most significant challenges has been ensuring economic continuity for legacy contracts. The adoption of fallback mechanisms, particularly the spread adjustment methodologies developed by ISDA, has been crucial in mitigating valuation disruptions. Our analysis, supported by a Python-based computational framework, has shown how these fallback rates are derived and their potential financial implications, especially for long-dated contracts.

Despite the progress made, operational challenges remain. The coexistence of multiple RFRs across jurisdictions has introduced basis risks, and differences in fallback methodologies between derivatives and cash markets may create hedging inefficiencies. Moreover, the transition has required extensive updates to financial models, risk management frameworks, and contractual agreements, imposing significant costs on market participants.

Looking ahead, the full adoption of RFRs will depend on further market adaptation and regulatory oversight. While LIBOR's demise has reinforced the need for transparent

and transaction-based benchmarks, ongoing refinements in rate-setting mechanisms and liquidity development in RFR-linked markets will be essential. The transition ultimately represents a move toward a more resilient financial system, though continuous monitoring will be necessary to address residual risks and ensure long-term stability.

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