



Minos Zombanakis, July 16, 1926 - December 22, 2018

LIBOR Inside Out

Transition and Challenges

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"Firms should treat [the discontinuation of LIBOR] as something that will happen and which they must be prepared for. Ensuring that the transition from LIBOR to alternative interest rate benchmarks is orderly will contribute to financial stability." Andrew Bailey, Chief Executive, Financial Conduct Authority, July 12, 2018 [1].

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Executive Summary

On July 12, 2018, Christopher Giancarlo, Chairman of the CFTC stated that “The discontinuation of LIBOR is not a possibility. It is a certainty. We must anticipate it, we must accommodate it and we must adapt to it.” Further on the same day, Andrew Bailey, Chief Executive of the FCA explained that “firms need to end their reliance on LIBOR by end-2021 [, and] overnight risk-free rates (RFRs) are the right foundation for interest rate markets.”

The secular decline in unsecured wholesale funding could become a serious systemic risk: hundreds of trillions of dollars in derivatives gross notional, as well as trillions of dollars of indexed cash interest rate instruments may be imperiled by unreliable IBOR benchmarks. LIBOR, despite major structural improvements by its regulator, the FCA, and its administrator, the IBA, may disappear as soon as 2021.

The financial community regulating, participating and using these benchmarks has gathered in workgroups across major jurisdictions, looking not only for a consensual Alternative Reference Rates (ARRs), but also for a smooth transition plan. The answers and schedules are diverse across currencies, but they are well under way: secured or unsecured rates, overnight only or full forward-looking rate term-structure - each jurisdiction has devised distinct solutions.

The expectation is that the new benchmarks will be based on deep liquid, resilient and sustainable underlying markets, that the existence or the creation of a forward-looking term structure with a derivatives market is a critical success factor, and that ARRs should be practically indistinguishable from a risk-free rate, thereby eliminating the legacy credit risk component of IBORs.

This article describes the evolution to today’s situation, presents alternative possible solutions that can be considered, highlights the transition paths, and explores the major impacts on markets and their participants.

This article is also Available with Wilmott Magazine, Issue 100 at [http://onlinelibrary.wiley.com/journal/10.1002/\(ISSN\)1541-8286](http://onlinelibrary.wiley.com/journal/10.1002/(ISSN)1541-8286)

Point of View

- The secular decline in unsecured wholesale lending is thinning out the LIBOR and other IBORs to the brink of extinction. According to the UK's FCA itself and despite IBA's laudable efforts with the reformed rate administration, LIBOR may cease its publication after 2021. This is a major source of systemic risk, with the potential for material disruptions in money markets and beyond. Various recent official projections estimate the residual derivatives gross notional exposure into 2022 at more than \$57 trillion. All market participants need to focus on a transition out of LIBOR.
- Currency workgroups identified alternatives to IBORs and laid out paced transitions plans towards these Alternative Reference Rates. ARR's are designed to be robust and sustainable over time, and they are calculated on high volumes of transactions from deep and liquid markets. It is reasonable to assume that their adoption will be successful, and that the transition will require major program coordination, within and across market participants.
- Unlike the outgoing IBORs, most ARR's include neither a credit risk component, nor a forward-looking term structure. Therefore, the transition from IBORs to ARR's cannot be like-for-like, and ARR's will change IBORs' market economics with impact on valuation, trading, risk, hedging, margining, operations, data, systems, indentures and contracts. Each market participant needs a custom transition program by currencies, by instruments, asset classes and by industry segments.
- To reduce systemic and operational risk, market participants should consider seek to reduce their IBOR exposure wherever possible (e.g., maturation, compression, closeout). They should strive to transition toward ARR's or other fallback benchmarks as soon as possible, as per existing or amended contract language, and eliminate or minimize their reliance on LIBOR by the end of 2021. Economic, legal, tax and accounting issues still stand in the way, but they are being addressed by work groups, regulators and lawmakers to facilitate the transition, both for derivatives as well as for cash instruments. However, some challenges linger, such as renegotiating contracts - with asymmetric economic advantages or in fragmented high-volume markets - which may be challenging and expensive, and which may have lumped together stubborn systemic risk exposures.

By Currency for each ARR, the transition plan is specific: secured ARR or not, available forward-looking term structure or not, existing derivatives market or not, existing market structure or not (FCM/SEF/CCP). Therefore, transition programs from IBORs to ARR's will have to reconcile the old and the new markets, but also accommodate each currency specific transition schedules. In particular, the new forward-looking term structures for the ARR's that did not have one - along with credit risk or liquidity term

structure premium between ARRs and other rates, such as LIBOR, IBORs, or the likes of EFRR or OIS - are already emerging and they may prime the liquidity essential for the market transition. New cross-currency and basis markets, as well as further liquidity fragmentation, are also creating new risks and opportunities for early agile adopters.

Roadmap for IBOR Market Transition

With today's ubiquitous utilization of IBORs throughout financial operations, the transition roadmap should span across the whole organization including product sales and marketing, modeling, valuation, exposure and risk, operations, clearing and settlement, accounting, treasury, legal, technology, and more. This includes:

- Promptly assess the impact at senior level, and layout the roadmap for the transition, with adoption and sponsorship of program to cope with the scale and complexity of the IBOR reform.
- Set up an IBOR transition program office and work groups to coordinate many IBOR transition related activities across various divisions of the enterprise with appropriate representation of experienced resources from program management, accounting, valuation, risk management, data, and technology.
- Conduct a Qualitative and Quantitative Impact Assessment of IBOR transition across the firm. The impact assessment should cover:
 - Product inventory: inventory of Cash and Derivatives IBOR exposures, with materiality and time lines. The impact assessment should identify and catalog direct or indirect IBOR references in products' definitions, in particular with exposures and contracts that mature after 2021 (or 2019 for EONIA and EURIBOR).
 - Financial exposure: expected and worst-case scenario with the discontinuance of IBORs. Impact such as on hedging, Risk Weighted Assets and capital, costs for renegotiations or close-out of existing contracts, funding costs impact. These exposures should determine appropriate actions and priorities in the transition plan.
 - Systems and Operations: impact on systems, processes, capacities and other in-flight programs. In addition to the wide-ranging impacts on the business, the transition is also set to have a significant impact on positions valuation and accounting.
 - Strategy and risk mitigation: organized and prioritized actions guide the transition plan and condition its success. With the Alternative Rate(s) to IBORs comes new ARR based products, revised customer engagement strategy and updated program governance structure. The transition plan should also mitigate the risk of an ongoing exposure to IBORs into 2022 and beyond, especially by amending the fallback language and enhancing risk disclosures. Importantly,

the transition strategy should lay out tailored plans for cash and derivatives products, firm infrastructure, and contracts repapering.

- Budgeting for the transition: short-term and long-term budgets to shoulder the cost of plan execution.
- Engage and communicate with senior management with strategic and tactical updates, design decisions, internal and external dependencies, roadmap, risk management, budget monitoring, in compliance with policies, procedures and regulations, and with the proper monitoring and controls.
- External communication program with customers, counterparties, and other stakeholders – such as industry, industry forums - to involve them in the understanding about the impact of the IBOR transition with the new ARR and how that transition may impact market structure, vendor and commercial relationships.

Introduction

LIBOR, and other “IBORs”, originated in the 60s with term rates on syndicated loans, then they grew essentially from usage in the Eurocurrency¹ markets. Their main purpose is now three-fold:

1. IBORs are the reference rates for unsecured wholesale funding.
2. IBORs are the benchmarks for most floating rate cash instruments, such as in loans, bonds and structured products.
3. IBORs are the backbone reference rates for a momentous market of listed and bilateral interest rates and hybrid derivatives² – many of which are widely used to hedge interest rate risk.

After 50 years of existence, IBOR’s derivatives’ exposures dwarf the liquidity of the underlying unsecured wholesale forward looking term funding market. The secular decline of IBOR’s underlying market has raised great concerns about the latent systemic risk built into the interest rate derivatives markets. Specifically, the LIBOR panel of twenty remaining publishing banks has shrunk and is at risk of further attrition.

Therefore, the FCA stated [2] on July 27, 2017, that by the end of 2021, it would no longer be necessary to “persuade, or compel banks to submit to LIBOR”. Consequently, the market should prepare itself for a paced transition to other alternative and sustainable interest rate benchmarks – or else brace for impact. Finally, on July 12, 2018, the FCA lucidly stated [3] that “firms need to end their reliance on LIBOR by end-2021, and that overnight risk-free rates (RFRs) are the right foundation for interest rate markets.”

Leading to these milestones and following the great recession and the LIBOR related misconducts, the FCA produced a report [7] in 2012 (Wheatley Review), followed in 2013 by IOSCO’s report on principles for financial benchmarks [8], and then in 2014 by the Financial Stability Board’s paper [21] on reforming major interest rates benchmarks. Regulators and market participants from the major currencies huddled in workgroups around the world in search of successors for IBORs, in the form of a risk-free rates (RFRs).

In response to the objectives of the Financial Stability Board (FSB) in the United States, the Federal Reserve convened the Alternative Reference Rates Committee (ARRC) in 2014, with the representatives of major cash and derivatives market participants and their supervisors.

¹ Unrelated to the EUR as a currency, the term “Euromarkets” describes the non-domestic market of a given currency. It was coined for “Eurobank”, which was an USSR’s bank and which originally sought dollar denominated transaction remote from US supervisory reach. For example, a JPY bond issued in New York – completely unrelated to the EUR – would thereby be called an “Euroyen” Bond.

² The size of USD derivatives’ gross notional in the order of ten times the United States’ GDP, and the global derivatives market is at least twice as large.

The ARRC identified a short list of secured and unsecured Alternative Reference Interest Rates (ARRs) that are firmly based on transactions from a robust underlying market and that comply with emerging standards, such as the “IOSCO’s Principles for Financial Benchmarks”. The ARRC also engaged with the ISDA to consider leading practices for robustness in derivatives contracts including fallbacks and new benchmark rates to prepare for the possible permanent cessation of IBORs. The ARRC also devised an adoption plan with means to facilitate the acceptance and use of the alternative benchmark rates.

In June 2017, the ARRC in the United States selected the Secured Overnight Funding Rate (SOFR) as LIBOR’s Alternative Reference Rate for the USD. Jerome Powell (FRB) and Christopher Giancarlo (CFTC) then noted [22] in August 2017 that the choice of SOFR “resolves the central problem with LIBOR, because it will be based on actual market transactions currently reflecting roughly \$800 billion in daily activity. That will make it far more robust than [panel-based] LIBOR.”

In the US, the FRBNY started to publish SOFR in April 2018, and the CME offered SOFR related futures in May 2018 [10]. Separately, LCH has been clearing SOFR OIS and SOFR Basis Swaps since on or about July 2018.

Again in July 2018 before the CFTC’s Market Risk Advisory Committee, Brian Quintenz restated the endorsement for SOFR - as the future alternative benchmark for USD money markets - and which adoption may be accomplished in a manner that avoids unnecessary confusion, fragmentation, and disruption - in particular with regard to certainty for the new ARRs in trading, hedging, margining and clearing.

Finally, and on the same day, Andrew Bailey (FCA) and Christopher Giancarlo (CFTC) voiced ominous statements on July 12, 2018, about LIBOR. According to them:

1. The underlying weaknesses of LIBOR cannot be remedied,
2. LIBOR discontinuity should be considered as a certainty, and
3. Market participants must prepare for it.

How did we get there?

Libor from Dawn to Dusk

LIBOR origin is sometimes credited to Minos Zombanakis of Manufacturers Hanover Trust, in or about 1969. According to Ridley and Jones [23], he arranged an \$80 million loan for the Shah of Iran with a rate based on a set of reported interbank funding asks. That loan's rate was made of a spread over the said interbank funding rate, hence it could be syndicated as well as readjusted over time based on the interbank lending conditions.

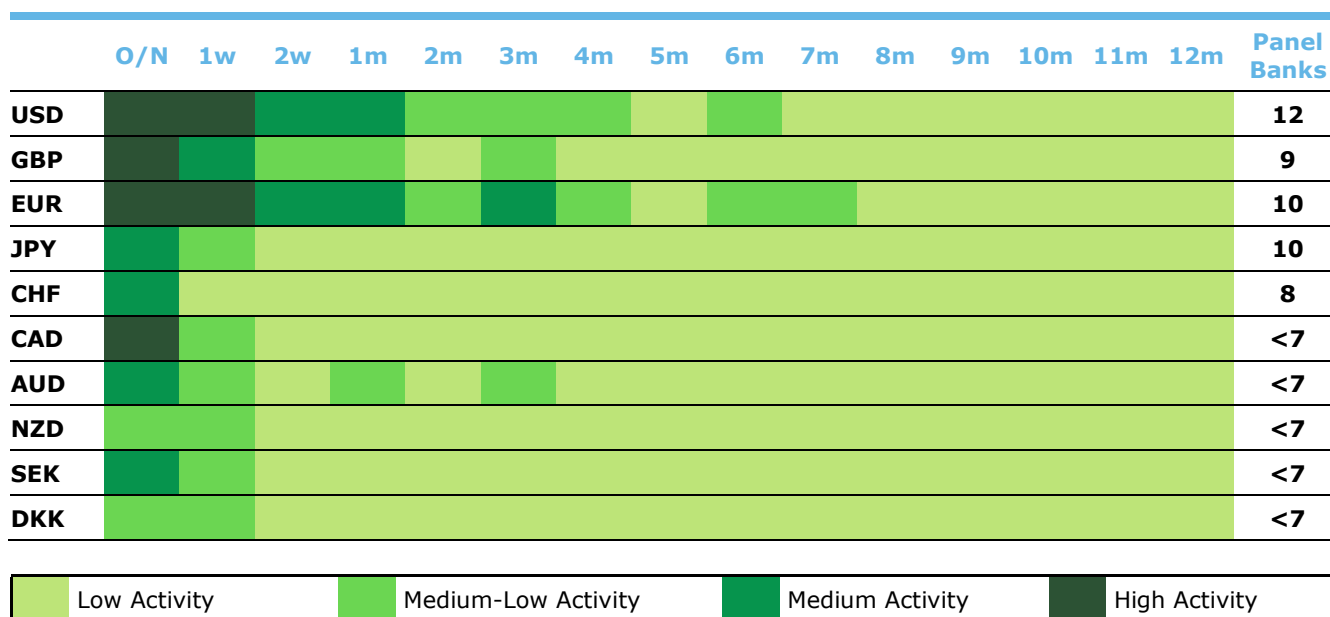
Sadly, Minos Zombanakis passed away on December 22, 2018, shortly before this article went to press. The Wall Street Journal wrote [36] that "Minos Andreas Zombanakis was born on July 16, 1926, in the village of Kalyves on the Greek island of Crete... Though in a house with dirt floors, Mr. Zombanakis earned degrees in economics and public administration at Harvard, where a professorship of international finance was endowed in his name in 2010"

Further, "[Minos Zombanakis] was a pioneer in the Euromarkets, a means of tapping the billions of dollars and other currencies held outside their countries of origin. He and other bankers used those funds to package loans and bond issues for companies and nations. The Euromarkets thrived by bypassing national regulations and recycling expatriated funds held by companies, oil exporters, people with numbered Swiss accounts and others."

As cash and derivatives markets based on LIBOR developed, banks then leaned toward reporting underestimated funding costs, which led to the British Bankers' Association (BBA) taking control of the rate in 1986, and formalizing LIBOR data collection and governance [7]. By 2011, BBA's LIBOR published term rates for ten currencies with fifteen tenors spanning from one day to one year.

Following the LIBOR misconducts and the 2012 "Whitley review", LIBOR's Regulator and Administrator roles were split between the FCA (Financial Conduct Authority) and the IBA (Inter-Continental Exchange Benchmark Administrator) respectively. Now in 2018, IBA publishes 35 term rates: five currencies (USD, GBP, EUR, CHF, JPY), seven tenors (o/sn, 1w, 1m, 2m, 3m 6m, 12m), with 11 to 16 panel-bank contributors per currency.

Exhibit 1: Unsecured Deposit Transactions by LIBOR Contributing Banks, as of 2011 Inter-bank Deposit Transactions

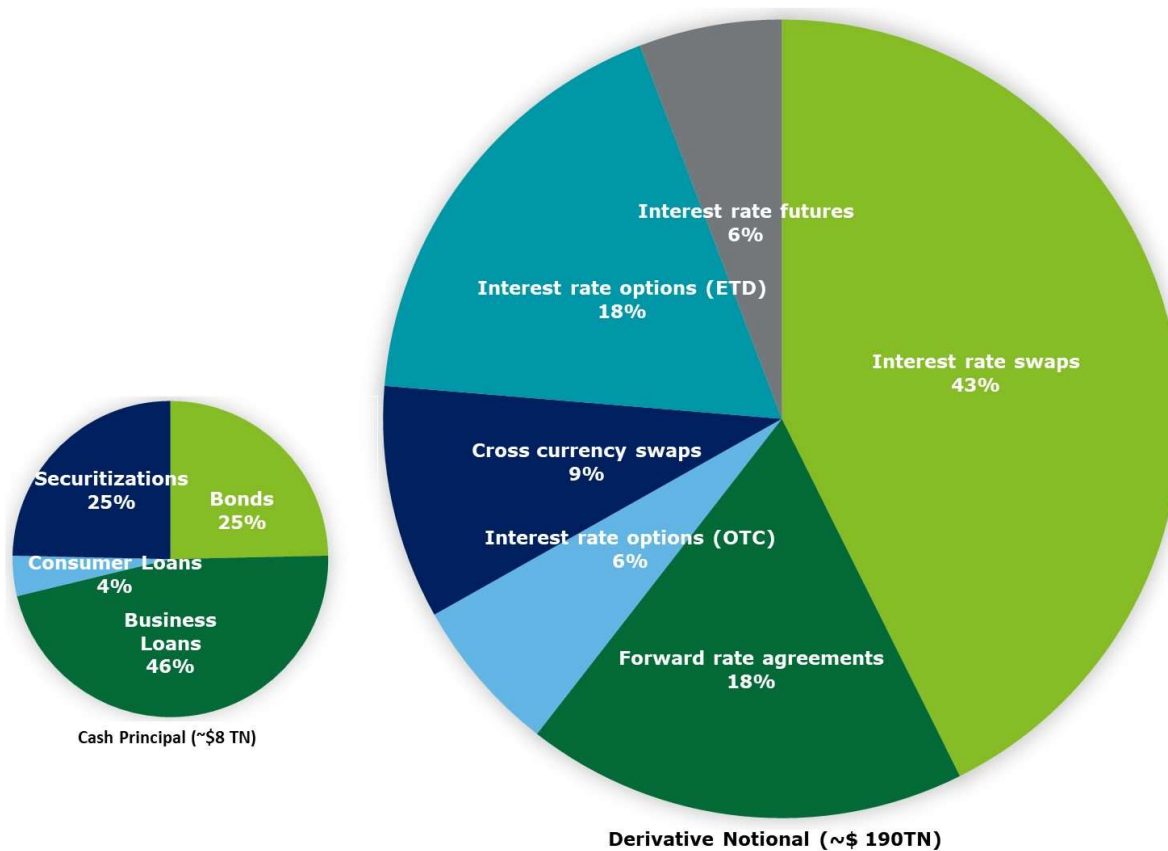


(Source: Wheatley Review calculations [7])

To date, IBORs remain the pillar of global money markets, and enjoy a liquid and wide market of interest rate derivatives, with hundreds of trillions in outstanding gross notional (e.g., interest rate futures, interest rate swaps, currency swaps, forward rate agreements, interest rate swaptions, listed and bilateral options).

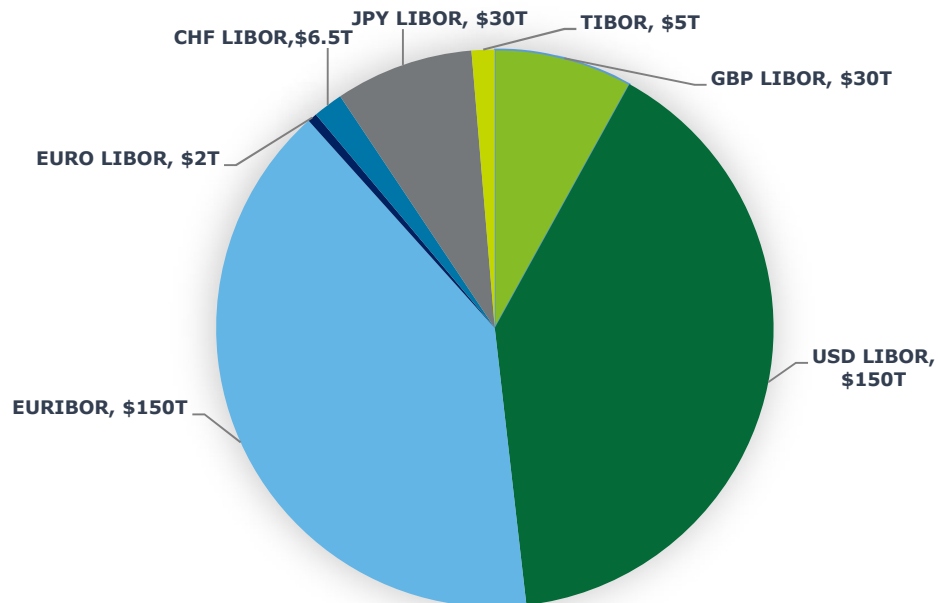
In addition, there are trillions in principal loans and bonds referencing IBORs (e.g., student loans, credit cards, syndicated loans, floating rate notes, commercial paper, municipal contracts, mortgages, structured vehicles). But according to ISDA, IBORs' exposures to outstanding cash principal amounts and to outstanding derivative gross notional footprints are very imbalanced, as shown below:

Exhibit 2: Outstanding Exposures for USD LIBOR in Various Asset Classes as of March 2016 (pie-charts not to comparative scale)



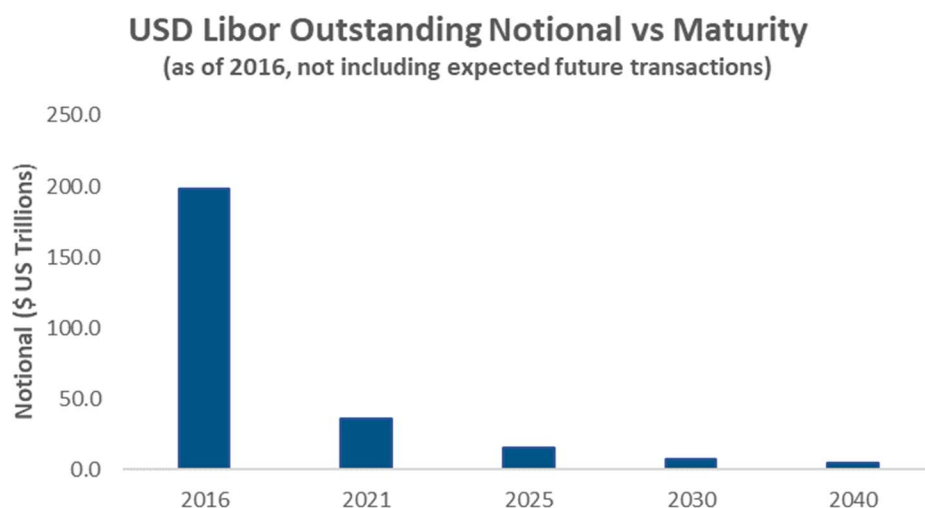
(As of 2016. Source: NYFRB, Second Report of the Alternative Reference Rate Committee, March 2016. [4])

Exhibit 3: Outstanding Notional for IBORs in 6 Currencies as of March 2014 (\$TN, as of March 2014)



(Source: Market Participants Group on Reforming Interest Rate Benchmarks, March 2014 [7])

Exhibit 4: Estimated LIBOR Notional Footprint by Maturity, as of 2016, excluding expected futures transactions



(As of 2016. Source: NYFRB, Second Report of the Alternative Reference Rate Committee, March 2016. [4])

Exhibit 5: IBOR Market liquidity by currency-tenor combination

	USD-LIBOR	GBP-LIBOR	EURIBOR	Euro-LIBOR	JPY-LIBOR	TIBOR	CHF-LIBOR
1m	High	Medium	High	Low	Low	Low	Low
3m	High	High	High	Low	Medium	Low	High
6m	Medium	Medium	High	Low	Medium	Medium	High
12m	Low	Low	Medium	Low	Low	Low	Low

High	> \$1 TN
Medium	\$100 BN <x< \$1 TN
Low	<\$100 BN

(Source: Market Participants Group on Reforming Interest Rate Benchmarks, March 2014 [7])

Exhibit 6: IBOR Market footprint by rate and asset class

	USD-LIBOR	GBP-LIBOR	EURIBOR	Euro-LIBOR	JPY-LIBOR	TIBOR	CHF-LIBOR
Syndicated Loans	High	Medium	Medium	Low	Medium	Medium	Low
Business Loans	High	Medium	High	Low	Medium	Medium	Medium
Retail Loans	Low	Low	Medium	Low	Low	Low	Medium
FRNs	High	Medium	High	Low	Medium	Low	Low
Securitization	High	Medium	Medium	Low	Low	Low	Low
OTC Derivatives	High	High	High	Low	High	Medium	High
ETD	High	High	High	Low	Medium	Medium	Medium
Deposits	Low	Low	Low	Low	Low	Low	Low

High	> \$1 TN
Medium	\$100 BN <x< \$1 TN
Low	<\$100 BN

(Source: Market Participants Group on Reforming Interest Rate Benchmarks, March 2014 [7])

Unfortunately, and according to the Bank of England's Financial Policy Committee [15], LIBOR notional exposure is still creeping up. For example, Andrew Bailey stated on July 12, 2018 [1] that LCH alone

cleared approximately a third of \$170 trillion of LIBOR indexed interest rate swaps which are maturing after the end of 2021.

Since 2012-2014, Regulators and Administrators interventions have significantly strengthened IBORs' governance, controls, standards, processes, data and systems. Yet, the scarcity of the underlying transactions poses a high systemic risk to the market, including but not only in the case of a permanent cessation of IBORs publication.

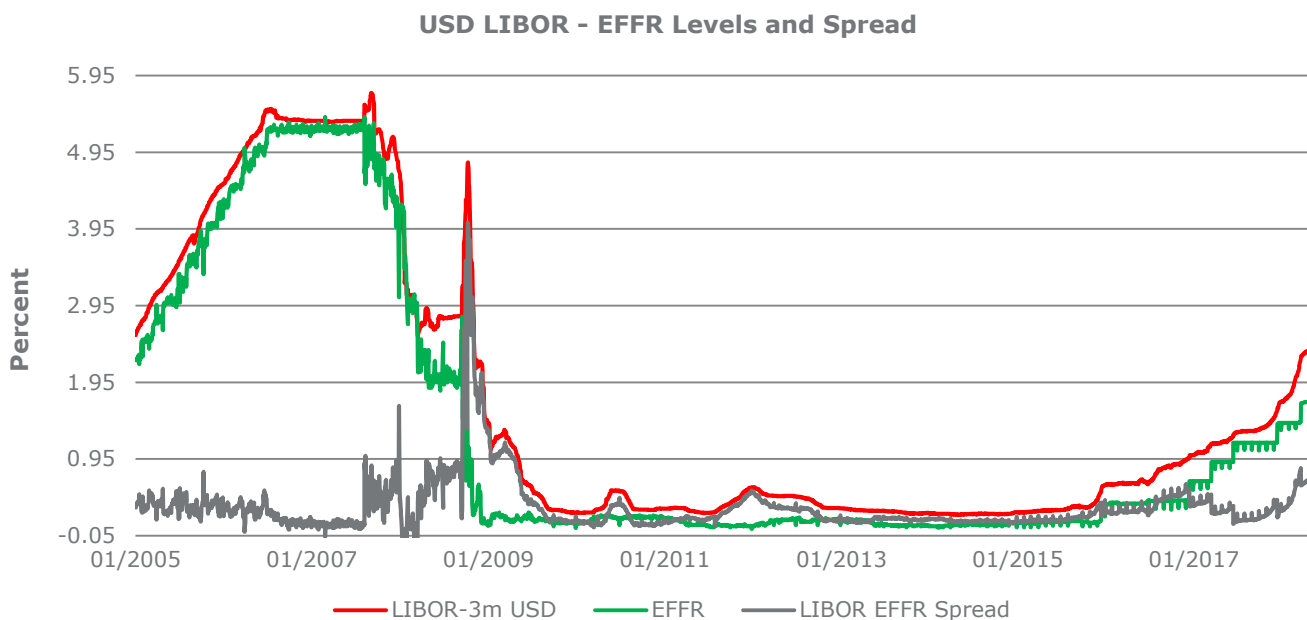
Along with other currency working groups, the ARRC in the United States considered several alternatives to replace USD's LIBOR. Many key interest rates associate with LIBOR, including rates such as the Effective Fed Funds Rate (EFFR) and the Overnight Bank Funding Rate (OBFR), both published by the Federal Reserve, or the Overnight Indexed Swap ("OIS") rate.

The EFFR is reported by the FRB as a volume weighted median of unsecured overnight rate at which about 150 reporting banks lend reserve balances to each other (volume of about \$70B a day). The OBFR is similar to and includes not only EFFR but also Eurodollar transactions (volume of another \$240B a day). However, 90% of overnight Fed Fund transactions are lent by Government Sponsored Entities (GSE) for they cannot earn interest on excess reserves at the Federal Reserve, and that may be a source of idiosyncrasies, stress-sensitivity and uncertainties over time. A standard Overnight Indexed Swap (OIS) is a fixed/floating interest rate swap, where floating equals to the compounded average of EFFR, hence also reflecting the shortcomings of EFFR.

Before the financial crisis, IBOR rates were risk free proxies and they were used both for projecting and for discounting future cash flows. That approximation was conventional because - for example with the USD - EFFR and LIBOR were close enough to each other (spread within a handful of basis points). However, during the 2008 financial crisis these rates diverged significantly, propelled by the increased credit risk of banks and by the decreased liquidity of the interbank market. The LIBOR-EFFR spread, which had hovered around a few basis points for years, skyrocketed close to 4% at the peak of the crisis. However then too, EFFR and OIS remained within a dozen basis points' spread, and from there on, OIS rates replaced LIBOR for risk-neutral present valuation of future cash flows, leading to a dual curve practical framework for the pricing of derivatives: projection with LIBOR, discounting with OIS.

The LIBOR-OIS spread (LOIS) is the combination of both credit and liquidity risk components [14]. Empirical evidences³ show that LOIS was evenly balanced between credit and liquidity up to 2009, but that it has dominantly been explained by liquidity since then. It is worth mentioning that LOIS has widened again since 2017, possibly reflecting scarcity in term versus overnight lending.

³ See Crepey Douady, in references

Exhibit 7: Levels and Spread between USD LIBOR and EFFR

(Source: ICE Benchmark Administration Limited (IBA) - <https://fred.stlouisfed.org/categories/22> [19])

After the 2008 financial crisis, the Basel committee, supervisors, and regulators stepped in to introduce major new liquidity and counterparty risk management standards.

The Basel committee introduced short and long-term liquidity ratios - e.g., the Liquidity Coverage Ratio (LCR) and the Net Stable Funding Ratio (NSFR) - which not only inhibited the supply and demand for expansive inter-bank funding, as banks improved planning and management of their funding, but which also skewed the demand toward secured rather than unsecured funding. Separately, regulators prescribed counterparty value adjustment (CVA) for counterparty credit risk, as well as new market structures for derivatives trading, clearing and settlement, including initial and variation margin (IM/VM) for both centralized (CCP) as well as bilateral clearing and settlement. With improved liquidity planning and reduced counterparty credit risk, the unsecured interbank funding market thinned out further, supplying less transactions from yet fewer market participants.

Despite IBA's efforts to improve LIBOR's practices, the secular decline of unsecured wholesale term funding has led LIBOR panel-banks to become exceedingly reliant on expert judgment rather than on actual transactions quotes. This reliance creates legal risk for the banks in the panel, with no evident corresponding benefits, which led to further attrition in the panel. In 2011, LIBOR was publishing ten currencies with fifteen tenors. Today and despite IBA's welcomed improvements, LIBOR only has five remaining

currencies, each with seven quoted tenors - some of which have little or no transaction volume.

The FCA cited the example [3] of a currency-tenor rate which had a meager fifteen qualifying transactions in 2016. More broadly, one of the most heavily USD LIBOR tenor referenced, the three-month LIBOR, has a median daily volume of funding transactions of less than \$1B. With an outstanding USD derivatives gross notional measured in hundreds of trillions, the dearth of underlying transaction data creates not only a legal risk for the panel banks, but also a systemic risk for the market as a whole. This is a major cause for concern in financial markets.

IBOR Reform

The 2012 Wheatley Review of LIBOR provided an assessment and proposed orientations for reforms. The Financial Stability Board (FSB), and its Official Sector Steering Group (OSSG), later endorsed similar recommendations. That led to short term recommendations for “LIBORs+” enhancements, and to the development and the adoption of long term alternative risk free reference rate benchmarks, or ARRs based on “IOSCO’s Principles for Financial Benchmarks”.

IOSCO’s 2014 publication defined 19 high-level principles to consider for financial benchmarks in general, and interest rates in particular, under two sets of principles [24]. First is the **benchmark appropriateness** based on underlying market size, liquidity and potential evolution. Design, methodology, governance, controls, accountability, administration, supervision and process around changes to the benchmark are part of these key considerations. Second is the **contingency planning** in the event of a permanent discontinuation, by incorporation of robust fall back provisions. IOSCO’s principles were largely endorsed by the financial community, the G20, and later reflected in the EU’s Regulation on Financial Benchmarks.

Separately, ICE Benchmark Administration (IBA) became the administrator of LIBOR in 2014, implementing the FCA’s reforms with Panel Banks and regulators. IBA specifically put in place a committee for the independent challenge of LIBOR’s operations, a code of conduct for the Panel Banks, and a waterfall methodology with governance and controls around the production of LIBORs.

IBA publishes LIBOR midday in London, based on IBA’s trimmed arithmetic mean of submissions from 11 to 16 banks for any given currency. IBA requires the submissions to be based on relevant transaction data, or at least by expert judgment using an approved methodology based on objective criteria and relevant market information. Each panel bank refers to IBA’s three-level waterfall methodology:

1. Volume weighted of sufficient IBA-eligible *transaction data* in the unsecured wholesale funding
2. If not, *transaction derived data* including time-weighted historical and interpolations of IBA-eligible transaction data
3. Finally, if no sufficient transaction or transaction-derived data is available for a particular currency-tenor, each bank submission is based on an *objective methodology* which is bilaterally agreed upon between IBA and each panel bank, and which may include other transactions, instruments, quotes or market observations.

IBA has been strengthening IBORs with maximum use of the transaction data (aka LIBOR+). However, the lack of a liquid market for some currency-tenor pairs creates practical difficulties, and the OSSG

recommended that currency workgroups identify new or existing IOSCO compliant ARR benchmarks to replace IBORs in a range of contracts, in particular derivatives, and that they propose a plan for fallback rates, fallback contract language and a paced transition away from IBORs.

While IBA continues to develop frameworks that would enable the continued publication of LIBOR beyond 2021, market participants develop alternative benchmarks to prevent market disruptions in the event of the permanent cessation of the publication of some or all IBORs - currencies or tenors.

ARRC Criteria for Potential Alternative Reference Rate

In the United States, the ARRC was convened by the FRB to identify a set of best IOSCO compliant ARRs for the USD, a transaction based risk-free rate with a deep underlying market. The ARRC evaluated a set of alternative rates with respect to the following criteria:

- **benchmark quality**, such as liquidity, transaction volume, resilience through period of illiquidity or resilience through changes in the regulatory environment or in the monetary policy framework,
- **methodological quality**, such as standardized data terms, transparency and availability of current and historical data,
- **accountability**, ensuring compliance with IOSCO's principles
- **governance**, promoting the integrity of the benchmark
- **ease of transitioning**, such as relevance for trading and hedging, potential for a term market.

As a result, for the USD, ARRC selected the *Secured Overnight Financing Rate* (SOFR), providing market participants with an IOSCO compliant alternative to USD-LIBOR. Currently however, and unlike LIBOR's forward-looking term structure, SOFR only provides overnight spot rate.

Secured Overnight Financing Rate (SOFR)

SOFR is an overnight, nearly risk-free rate which measures of the cost of overnight Treasury secured collateralized borrowing. SOFR is based on actual transactions within a robust \$700B+ daily underlying market, which is made of three pools:

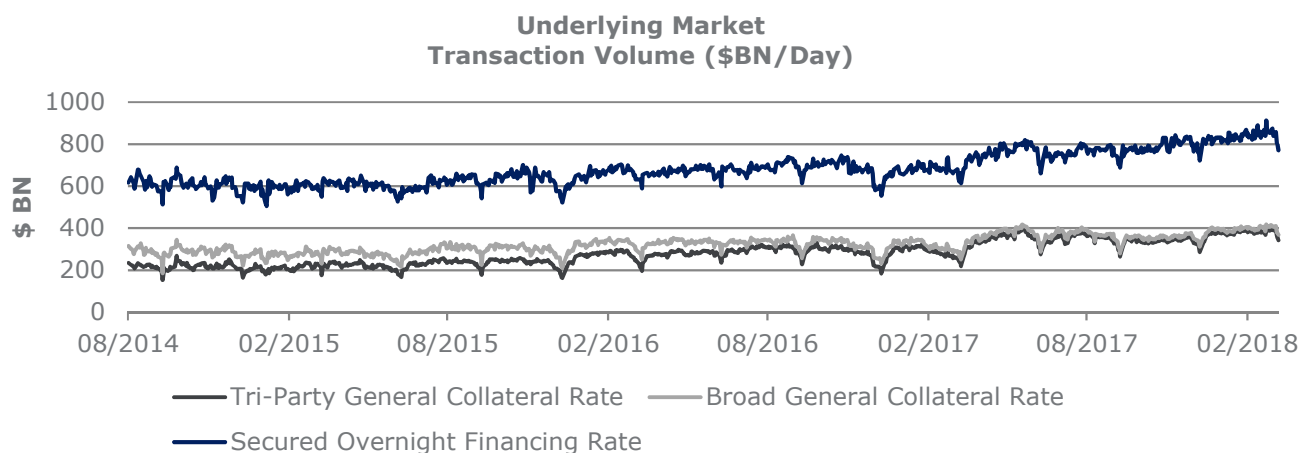
1. the Tri-Party General Collateral Rate (TGCR), on a pool of repo transactions with Treasury collateral which are settled at the Bank of New York Mellon by a large set of diverse market participants
2. the Tri-Party General Collateral Finance Rate (GCFR), on another segment of the Tri-Party repo market which is blind brokered and cleared through the DTCC's GCF repo market
3. the Bilateral Repo Market cleared with FICC's Delivery Versus Payment (DVP) service, where Treasury trades are not necessarily blind brokered, and which is filtered to remove the lower quartile of

transactions considered potentially “specials” (e.g., transaction for specific Treasury issues with scarcity value).

SOFR is then calculated as a volume-weighted median of transaction-level TGCR from the Bank of New York Mellon, GCF Repo transaction data from DTCC, and bilateral Treasury repo transactions cleared through FICC's DVP service. Each business day since April 2018, the New York Fed has been publishing the SOFR overnight spot rate on their website at or about 8:00 a.m. EST.

Further, SOFR derivatives market is emerging, with CME's 1-month and 3-month SOFR futures, launched in May 2018, along with several EFFR, LIBOR and SOFR commodity-spread contracts, priming the new SOFR term structure of interest rates. As of July 2018, the CME had about \$5B in daily notional trading, with up to 12,000 contracts in open interest.

Exhibit 8: Transaction Volumes Underlying SOFR

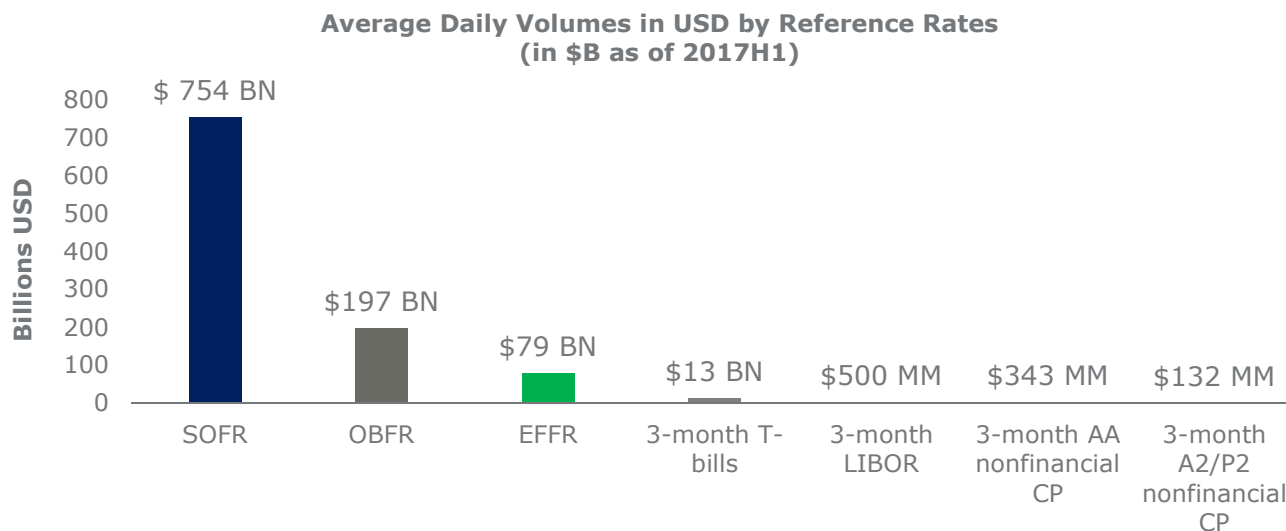


(Source: ICE Benchmark Administration Limited (IBA) - <https://fred.stlouisfed.org/categories/22> [19])

The ARRC considered many alternatives to SOFR, including overnight unsecured rates such as the EFFR, the OBFR, and OIS rates against compounded floating EFFR. SOFR is broad and fully transaction-based, with its robust underlying market at an average of about \$800B/day, and hence it turned out to be ARRC's pick.

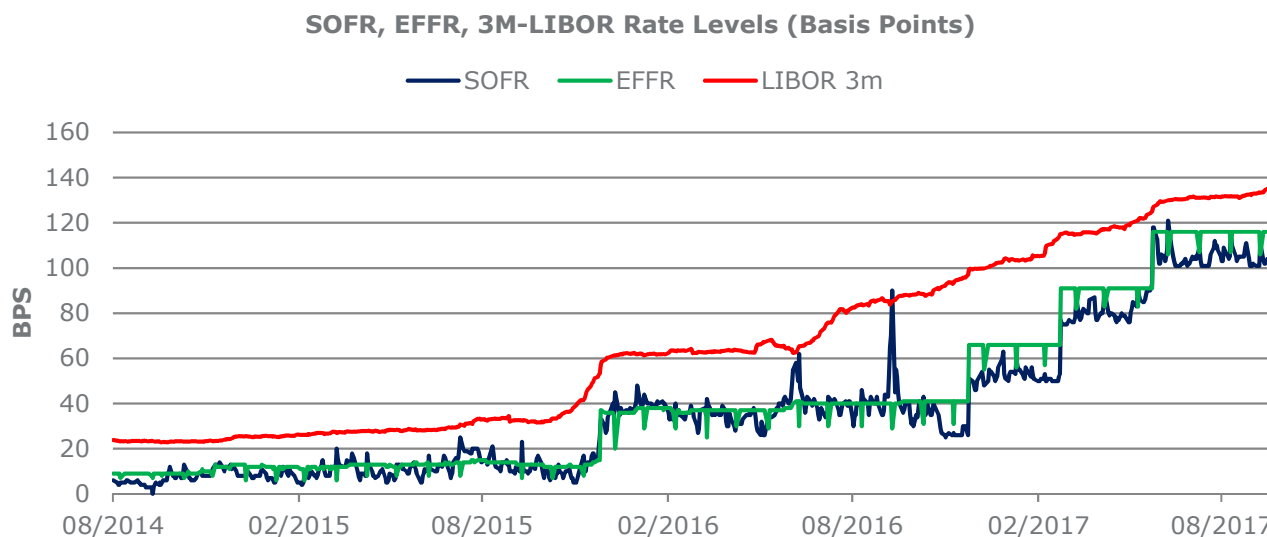
Each transaction underlying SOFR is secured and therefore, SOFR is de facto nearly free of credit risk. SOFR exhibits a high correlation with Eurodollar and EFFR and hence enables the co-existence of Eurodollar, EFFR and SOFR futures, with potential for the development of basis-spread market to support liquidity during the transition period, facilitating not only risk management and hedging, but also forward-looking term liquidity formation in the SOFR futures market itself.

Exhibit 9: Average Daily Volumes in USD Interest Rate Markets for Various Reference Rates



(Source: NYFRB, Second Report of the Alternative Reference Rate Committee, March 2018. [4])

Exhibit 10: Comparing SOFR with EFFR & LIBOR



(Source: NYFRB, Second Report of the Alternative Reference Rate Committee, March 2018. [4])

ARR Benchmarks for other key currencies

Like ARRC, working groups for other major currencies are recommending robust ARR to transition away from existing IBORs:

Exhibit 11: ARR by Currencies

Currency	Alternative RFR	Administrator	Un/Secured	Publication date
GBP	SONIA	BoE	Unsecured	Published since 4/2018
USD	SOFR	FRB of NY	Secured	Published since 4/2018
EUR	ESTER	ECB	Unsecured	Expected 10/2019
CHF	SARON	SIX Swiss Exchange	Secured	Currently being published
JPY	TONAR	BoJ	Unsecured	Currently being published

GBP-SONIA

The United Kingdom Working Group on Sterling Risk-Free Reference Rates selected Reformed Sterling Overnight Index Average (SONIA) as GBP's ARR. SONIA is an unsecured overnight rate, administered by the Bank of England, and reformed to include bilateral and brokers' transactions.

The reformed SONIA was deemed more robust and simpler to transition to than the alternative overnight repo rate otherwise considered by the UK workgroup. The new SONIA is the 50% volume weighted trimmed mean, averaging about 1 basis point lower than the old SONIA, and with a market of underlying transactions 3 to 4 times thicker than that of the previous one.

As of July 2018, the reported average transaction daily volume overs close to 400 per day, compared to 80 per day before the rate's reform. In comparison, average eligible transaction daily count for the six-month Libor was only two per day.

ICE and LSE now offer SONIA futures contracts, and £5.5T of SONIA OTC derivatives were cleared every month in the spring of 2018. As of June 2018, SONIA referenced OIS had an 18% share of the overall cleared Sterling's interest rate swap market [3].

CHF-SARON

The National Working Group on Swiss Franc Reference Rates selected the Swiss Average Rate Overnight (SARON) as CHF's ARR. SARON is a secured overnight repo rate like SOFR, and became the de facto reference interbank overnight repo rate in August 2009, preceding the discontinuance of TOIS in 2017. In autumn 2017, LCH and Eurex started clearing SARON swaps.

JPY-TONAR

The Japanese Study Group on Risk-Free Reference Rates selected the Tokyo Overnight Average Rate (TONAR) as JPY's ARR. TONAR is an unsecured overnight rate like SONIA and administered by the Bank of Japan.

EUR - ESTER

The EUR Workgroup selected ESTER (Euro Short-Term Rate), after much deliberation by the ECB and a panel of 23 European banks, and following the collapse in volume with EONIA and EURIBOR.

ESTER will begin publishing an overnight rate by October 2019 by the ECB and will be based on daily money market statistical reporting (MMSR) data provided by the 52 largest euro area banks. ESTER is based solely on reported and real deal-related transactions of banks (daily basis, unsecured).

In parallel, Euribor is undergoing reform to comply with the recent EU Benchmarks Regulation (BMR) before the BMR regulatory deadline of January 1st, 2020. Despite regulator's efforts, Euribor reform may fail if the transaction volumes prove insufficient. This could leave the industry with the imperative to adopt ESTER for new business as early as January 2020, and that could be challenging for many institutions. To allay industry planning and scheduling concerns, the ECB may start to publish ESTER well before October 2019.

IBOR Transition Planning & Challenges

In July 2018, Andrew Bailey (FCA) [1], and Christopher Giancarlo (CFTC) [26] stressed the ineluctable imperative to plan immediately and execute promptly market participants' transition away from IBORs. They stated that the discontinuation of LIBOR was not a remote 'black swan', that it will happen, and that firms should be prepared for it - for the sake of financial stability. They added that a misplaced confidence in LIBOR's survival delude firms and further discourage the ineluctable transition.

In concomitant statement that same day, the FCA, the CFTC, and the FSB set out clear expectations of what firms need to do in relation to transition. Firms should ensure that they can demonstrate to their supervisors "that they have plans in place to mitigate the risks and to reduce dependencies on LIBOR".

Indeed, the IBORs' succession exposes market participant to major operational disruptions, augmented by the heterogeneity of diverse ARR jurisdictions, standard idiosyncrasies, and transition schedules. Hence, ARRC and other workgroups focus not only on new benchmark rates, but also on comprehensive transition plans. The future success of the alternative rate benchmarks depends on many factors such as:

1. Market adoption of the new proposed overnight ARRs, with liquidity in cash and derivative markets, possibly with ad-hoc credit spreads and liquidity premiums to match LIBOR's legacy of unsecured term wholesale funding.
2. Steering changes in market policies and practices, including market coordination within and across currencies
3. Successful corporate cross-functional programs with collaboration across marketing, sales and trading, middle and back office operations, risk management, portfolio management, legal & compliance, data management, technology, and other critical groups.
4. The substitution of IBORs by ARRs, or fallback rates in cash and derivatives contract, both in using ARRs or fallback rates and in updating contracts' languages.

When on July 27, 2017, the FCA announced that they would no longer persuade or compel panel banks to contribute to LIBOR beyond December 2021, and whether LIBOR continues beyond 2021, market participants were nudged for a major change in business as usual. One year later on July 12, 2018, the FSB, CFTC and FCA urged market participants into action.

Robust programs to organize, execute, and oversee the transition from LIBOR to ARRs should prevent operational risks and disruptions. Sample transition steps summarized below apply broadly across jurisdictions, however each Working Group is devising their own steps and priorities.

Developing Liquidity and Tenor Structure for Market Adoption

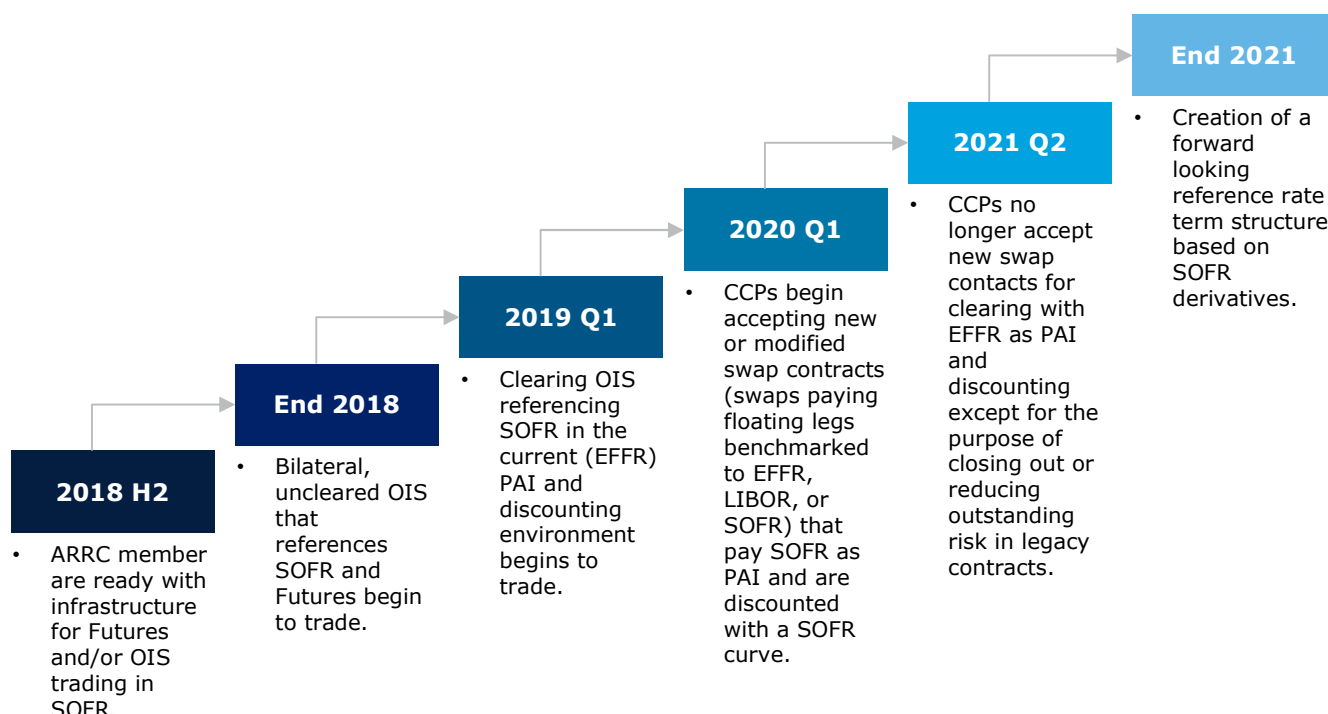
In the United States, a liquid SOFR derivatives market comparable to that of LIBOR derivatives is critical for SOFR adoption. In particular, liquidity requires Exchanges, SEFs and CCPs to list, clear and settle cash and derivatives instruments referencing the new ARRs. The transition plan should prime the liquidity required to support the issuance of, and the transition to, contracts referencing SOFR, as well as create the conditions for a robust forward-looking term structure and credit spread term structure based on SOFR derivatives (as for other ARRs).

For example, in May 2018, the CME launched a one-month SOFR futures strip of seven monthly contracts settling on SOFR arithmetic average in a given calendar month, and a three-month SOFR future strip of 20 quarterly contracts settling on geometric average SOFR in a given reference period between two IMM dates. Notably, while LIBOR's Eurodollar futures is forward looking (e.g., 3M LIBOR, fixed ex-ante), the SOFR's futures are backward looking (e.g., averaged overnight rates, fixed ex-post).

CME also offers inter-commodity spreads futures that reduce leg risk and improve liquidity formation. These one- and three-month instruments include Eurodollar, EFR and SOFR spreads and more such products may be launched over time to create liquidity for the adoption of SOFR. In addition to CME, ICE & Curve Global are already offering 1M and 3M SONIA futures and in March 2018 the Japan Securities Clearing Corporation (JSCC) launched a new set of TONAR swaps with 1M, 3M and 6M coupon payments.

ARRC has also published a timeline for a paced transition as shown below while CME is creating new instruments and liquidity in the new SOFR term market.

Exhibit 12: ARRC Timeline for SOFR Transition

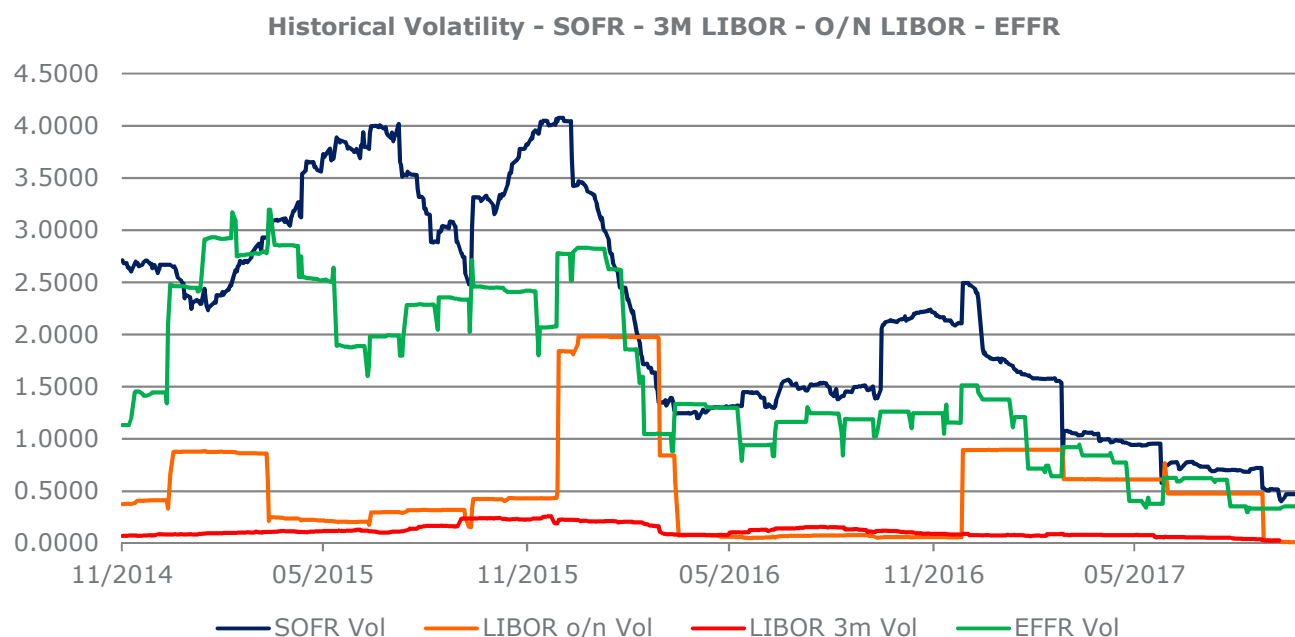


(Source: NYFRB, Second Report of the Alternative Reference Rate Committee, March 2018.)

The NYFRB is the Administrator of the SOFR overnight rate, and it intends to produce SOFR term rates by the end of 2021. The availability of term rates may be necessary for the adoption SOFR as an alternative to LIBOR's term rates, in particular for some cash instruments, as well as for subsets of derivatives utilization.

Since liquidity and adoption are inter-dependent, and since there may not be sufficient liquid SOFR ex-ante tenors by 2022, the current transition plan may require an acceleration of the timeline for developing the tenor structure. Furthermore, the volatilities of panel-based LIBOR and market-based SOFR may be quite different, which could lead to distinct bid-ask spread and transaction costs, the combination of which could influence market adoption for SOFR or other new ARRs.

Exhibit 13: Historical Volatility Comparison between SOFR and LIBOR



(Annualized historical volatility calculated using 60 day rolling window,
Source: ICE Benchmark Administration Limited (IBA) -
<https://fred.stlouisfed.org/categories/22> [19])

New ARR derivatives will be introduced to support a successful transition (e.g., Basis swaps between IBORs and ARRs, or ARR indexed cash instruments.) ARR workgroups have explicitly acknowledged the need for these new instruments as critical success factors for the IBORs' transition.

Basis Risk

Each ARR has specific attributes: secured vs unsecured, available forward-looking term structure of interest rates or not, variable liquidity conditions, cash and derivative markets, adoption schedules by Exchanges, Swap Execution Facilities, Central Clearing Counterparties, Futures Commission Merchants, Banks, and other financial and non-financial institutions.

These nuances fragment market liquidity, but also create basis risks and opportunities between and among ARRs and LIBORs based instruments, particularly hedge basis and cross currency basis risks, by position or in portfolio. Also, different currencies or jurisdictions transition schedules may have a lagging and disruptive effects spanning over months or years, potentially leading to mixed IBORs and ARRs transactions and portfolios.

To reiterate the importance, CFTC's Market Risk Advisory Committee Commissioner Quintenz pointed out on July 12, 2018 [25], that "risk management models must be updated to incorporate RFRs and take into account the basis risk that will exist between LIBOR and the various RFRs across jurisdictions during any transition period".

Term Credit Spread alternative to LIBOR curve

LIBOR-OIS spread (LOIS) comprises both a credit spread and a liquidity premium component, which may be modeled separately – although not necessarily independently. For example, the credit component may be estimated by the skew of the Credit Default Swap (CDS) curve of a representative borrower LIBOR panelist, and the liquidity component by the volatility of the spread between a lender LIBOR panelist rate and the EFFR, as described in the Crepey-Douady model [14].

That model further quantifies the liquidity component as an option premium of the aforementioned volatility, compensating the term loan vis-à-vis the corresponding overnight rolling loan. The option is at the money when the lender's term rate matches the compounded overnight rate.

All ARRs proposed at the moment are overnight transaction based rates, because their primary mandate is to eliminate the subjectivity of the panel bank publication. The (new) benchmarks come with the requirements of a deep and liquid market, which can only be represented at the moment with a spot overnight rate. Building a forward-looking term structure, with or without a credit spread, will take time for market making and market adoption. During the ramp up, liquidity may be scarce, creating the classic chicken and egg liquidity conundrum. The possible work around is a backward-looking term structure.

The development of say a robust LIBOR-SOFR basis swap or forward looking markets, along with relevant futures contract solutions, may

facilitate the transition, especially with some cash instruments, and in the absence of liquid forward looking term interest rate or term credit spread market, the transition to the new ARR's may be challenging for certain products.

While the forward-looking term structure of interest rates and credit spreads is of concern, there is a market consensus that the bulk of the interest rate derivatives markets primarily need risk-free overnight rates based on a deep and liquid pool of transactions. The purpose of those rates, for derivatives instruments, is primarily to hedge short-term interest rate risk, not long-term interest rate risk or bank credit risk.

However, a forward-looking term rates may be preferred economically and operationally by bond, loan and securitization markets, and the lack thereof leaves unanswered questions in transition plans and creates uneasiness with some business models. Therefore, in the cash market, there will be the need for a forward-looking term structure.

Valuation, Hedging, Risk, Collateral Management and Clearing

The transition from IBORs to ARR's will change the economics of money markets, fixed income markets, possibly other asset classes, including for valuations, risk models, optimal hedges, financial products' design sales and marketing, as well as indentures and contracts, or trading and processing systems. Also, one should not underestimate the risk of bloated gross notional exposures with the old benchmark going into the post 2021 period, should the market procrastinate to adopt the new benchmarks during the current transition period.

However, during and in support of the transition period, Futures Commission Merchants (FCM), Swap Execution Facilities (SEF), Central Clearing Counterparties (CCPs) may propose pricing, margining, clearing and settlement solutions with OIS referencing either EFRR or SOFR for Price Alignment Interest⁴ (PAI) and Risk Neutral Present Valuation (RNPV), while the new ARR and legacy IBOR trades will coexist within the same clearing pool. CME and LCH are now offering clearing services for SOFR and SONIA. LCH is clearing SARON swaps, and the Japan Securities Clearing Corporation (JSCC) is also clearing TONAR swaps.

For example, new swaps may reference SOFR PAI and RNPV, while legacy IRS contracts may reference EFRR PAI and RNPV. In this scenario, CCPs may nudge the market with a transition period and cut-off dates, and otherwise legacy contracts may mature or close out, so that the clearing pool may progressively transition to SOFR alignment and discounting.

⁴ CCP's PAI is an overnight interest rate paid by the party in the money (ITM) to the collateral posting party out of the money (OTM), on a derivatives' variation margin (VM), to align the economics of the cleared derivatives with the economics of uncleared derivatives - for which the party ITM pays interest rates to the party OTM, which is posting the cash VM.

Also, hedges may have to be rebalanced when the transition to the ARR is out of sync between the books' positions and their hedges. For example, should a position and its hedge originally reference the same benchmark, but one moves to the ARR while the other stays on IBOR, the unattended hedge effectiveness may be source of unhedged basis risks. For some strategies such as those hedging interest rate risks with long tenor derivatives, the transition may suffer from liquidity gaps at the far end of the curve.

Historically, LIBOR's low volatility and high kurtosis have made LIBOR too leptokurtic for a direct practical use in risk management applications. On the contrary with SOFR, new applications may be possible. Further, since SOFR is a secured rate, it can be applied to risk neutral hedging without any material credit risk considerations.

ISDA's fallback rates

In July 2018, the ISDA issued a consultation [12] to capture the market preferences on the appropriate fallback rates for derivatives contracts, in the eventuality of the cessation of the publication of IBORs for certain currencies.

Concomitantly the same month, UK's Sterling working group also launched a consultation [16] about forward-looking term structure, while that topic was also on the top of the agendas for the SARON and SOFR working groups.

ISDA's consultation goal was to be able to propose workable fallback rates in new derivatives contracts otherwise still referencing IBORs, in order to support operational continuity with minimal financial disruption in the eventuality of the cessation of IBORs. For legacy derivatives contracts, these fall back rates could also be an alternative, but only if all parties a transaction agreed to it and amended their bilateral contracts accordingly.

In their consultation, ISDA proposed nine possible solutions, asking market participants to rank their preferences, challenge the proposals, or possibly object to the solutions. ISDA intended to make a determination "based on the consensus among respondents and what is best for the market overall".

ISDA proposed solutions for GBP, JPY, CHF and AUD (USD and EUR were out of scope) were two-pronged and included ISDA's four *Adjusted Risk Free Rates* and ISDA's three *Spreads Adjustment Methodologies*. Out of the 12 possible combined solution, three were mutually exclusives, which left nine possible solutions per currency. ISDA further asked the market whether the retained solutions should be identical across currencies.

Further, "the fallbacks that ISDA is implementing are to address the systemic disruption that could occur if a key IBOR is permanently discontinued. These fallbacks are not proxies for the relevant IBORs but will provide clarity and certainty to market participants if an IBOR is permanently discontinued."

ISDA's Adjusted Risk Free Rate (IARFR):

1. Spot Overnight Rate:
SONR sets on the date that is one or two business days (depending on the relevant IBOR) prior to the beginning of the relevant IBOR tenor. SONR is easy to understand and to implement, but it is volatile and it ignores the inherent variations in risk-free rates over different tenors.
2. Convexity-Adjusted Overnight Rate:
CAONR makes a first order correction to SONR to adjust for convexity. The modification attempts to account for the difference between flat overnight interest with SONR versus the realized rate of interest that

would be delivered by daily compounding of the RFR over the IBOR's term. CAONR comes closer to the term structure of the interest rates, but the *convexity adjustment* may incompletely match the shape of the term structure, especially in high or volatile short-term rates regimes.

3. Compounded Setting in Arrears Rate:

CSIAR sets in arrears of the relevant IBOR tenor period, as the RFR observed and compounded daily over that tenor period. CSIAR is an *averaged* rate. And therefore is less volatile than SONR or CAONR. However and by definition, CSIAR's only available information required for its calculation at the start of its reference period are expectations, and it cannot be set until after the end of that period.

4. Compound Setting in Advance Rate:

CSUFR sets up-front of the relevant IBOR tenor period, at the RFR observed and compounded daily over the previous tenor period of the last analogous previous IBOR tenor period - therefore introducing a convexity with the time lag between setting and settling. The difference in market conditions between the past compounding period and the current period is biased and may affect hedging.

ISDA's Spread Adjustment Methods (ISAM)

1. Forward Spread:

FAS sets the spread adjustment based on observed market prices for the forward spread between the relevant IBOR and the adjusted RFR in the relevant tenor at the time the fallback is triggered.

2. Historical Mean Median Spread:

HMAS sets the spread adjustment on the mean or median spot spread between the IBOR and the adjusted RFR calculated over a significant, static lookback period (e.g., 5 years, 10 years) prior to the relevant announcement or publication triggering the fallback provisions.

3. Spot Spread:

SSA sets spread adjustment based on the spot spread between the IBOR and the adjusted RFR on the day prior the trigger of the fallback provisions (a variation would be to use the average of the daily spot spread between the IBOR and the adjusted RFR over a specified number of days).

The 'compounded setting in arrears rate' for the adjusted risk-free rate (RFR), and the 'historical mean/median approach' for the spread adjustment was the choice of a significant majority of market participants, based on the summary report published by ISDA on Dec 20, 2018 [12].

Further, the economic valuation impact of the legacy positions with the change in benchmark rate may go beyond rates' levels. For instruments with embedded volatility, it may be difficult to establish a simple conversion mechanism when valuation depends not only on the interest rates levels, but also on their volatility or higher order sensitivities.

	Forward Spread	Historical mean/median Spread	Spot-spread
Spot Overnight Rate	n/a	3. Spot Overnight Rate with Historical Mean/Median Approach	7. Spot Overnight Rate with Spot-Spread Approach
Convexity-adjusted Overnight Rate	n/a	4. Convexity-adjusted Overnight Rate with Historical Mean/Median Approach	8. Convexity-adjusted Overnight Rate with Spot-Spread Approach
Compounded Setting in Arrears Rate	1. Compounded Setting in Arrears Rate with Forward Approach	5. Compounded Setting in Arrears Rate with Historical Mean/Median Approach	n/a
Compound Setting in Advance Rate	2. Compounded Setting in Advance Rate with Forward Approach	6. Compounded Setting in Advance Rate with Historical Mean/Median Approach	9. Compounded Setting in Advance Rate with Spot-Spread Approach

Fallback rates and fallback clauses may be useful, but as per Andrew Bailey's metaphor, one may count on the "seatbelt", but should strive to avoid the crash "when LIBOR reaches the end of the road". He stated plainly that the "smoothest and best means for this transition is to start moving away from LIBOR in new contracts".

LOIS: One Step Beyond.

Credit and Funding Cost

While the market wrestles with *Fallback Rates*, *Adjusted Risk Free Rates* and other *Spread Adjustment Methodologies*, one may take a fresh look at the IBOR–OIS spread (denoted $LOIS=L-R$) to get a deeper understanding of that spread nature and composition.

On August 6, 2007, at the dawn of the great financial crisis, increasing discrepancy appeared between the interbank offered rates (IBORs, L , which are term-loan contracts, from one month to one year, the most common one being 3 months, set in advance, paid in arrears) and overnight indexed swap rates (OIS rates, r or R , which are forward contracts on the accumulation of daily interests over the loan period).

With either rate, the borrower receives a loan lump sum, while the lender receives a scheduled cash flow stream of repayments. With OIS, the loan is effectively overnight and is reconducted daily, unless the lender, who is long an option, exercises its Call to terminate the loan (see Fig. 1). This Call option premium drives the spread between the two rates, and is a function of two distinct variables:

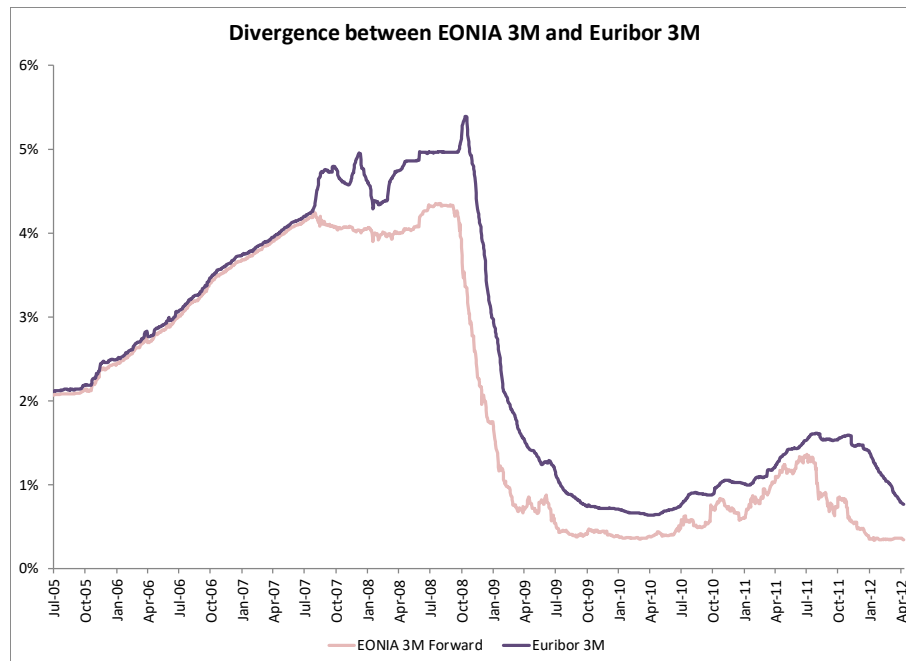
1. The slope of the interbank credit spread - a risk premium
2. The volatility of the cost of capital for the lending bank - an option premium

Empirical data analysis [14] actually suggests that the two sources have either an equivalent impact, or that the second one dominates.

Following the great financial crisis, the OIS rate (R) became the ubiquitous risk free rate in the markets. In an OIS swaps, the floating rate is an overnight compounding of the short-term risk free rate r_t (e.g. EFFR for the USD or EONIA for the EUR). As a result, an OIS rate R can be interpreted as a suitable average of r_t .

$$R = E \left[\frac{1}{T} \int_0^T r_t dt \right]$$

Exhibit 14: Sudden divergence between the 3m Euribor and the 3m EONIA-swap rate that occurred on Aug 6 2007



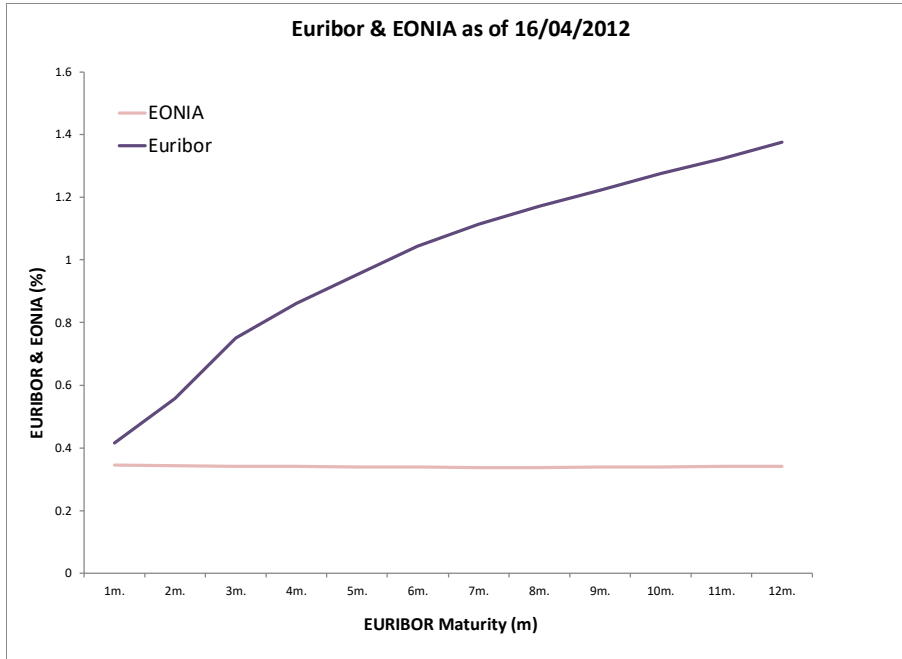
Theoretical arbitrage should imply that $L = R$. But although the momentous interest-rate derivatives market⁵ still references IBORs (L), the bulk of the liquidity in the short-term fixed income market has been shifting towards EFFR/OIS (USD) or EONIA/OIS (EUR) rates (R). While the IBORs bank-panels are shrinking, the IBORs and the OIS rates enduringly decouple (see Fig. 1 and 2), and the actual funding rate becomes that of overnight collateralized secured lending r_t .

Consequently, interest-rate products' valuation frameworks now typically involve (at least) two curves – an IBOR fixing curve and an OIS discounting curve, including a convexity adjustment, which may be a non-negligible contributor to the implied option premium [34].

Separately, this implied Call Option has XVA implications, through the relations between counterparty credit risk and cost of funding [31][35].

⁵ Derivatives such as IRS, FRA, Caps, Floors, Swaptions, Euro-currency Futures.

Exhibit 15: Term structure of Euribor vs EONIA-swap rates on 16 April 2012



LOIS Formula

The IBOR-OIS spread $L - R$, commonly called *LOIS*, is most often explained by a combination of inter-institution credit risk and of liquidity risk [29][30][33].

The Liquidity component is routinely described as the outstanding remainder of the spread, once the LOIS' credit component has been subtracted. However, the vanishing liquidity is rarely precisely defined. On the contrary, a stylized equilibrium model may define a lending tenor-rate compared to an overnight rolling lending rate [32].

Let N be the fixed notional of an IBOR loan at the fixed rate L over a contractual period of length T . Separately, let n_t be the stochastic notional amount at the overnight loan at the stochastic rate r_t during $[t, t + dt]$.

Ex-ante, the IBOR rate L is given by the bank-panel, and the OIS rate R is given above.

Let:

$$U(r_0) = E \left[\frac{1}{T} \int_0^T \max_{n_t} \phi(r_t, n_t) dt \middle| r_0 \right]$$

and:

$$V(L) = \max_N \psi(L, N)$$

where U and V represent the respective maximum lending profit on the OIS market, where $\phi(r, n)$ signifies the lender's daily-profit from lending an amount n at rate r on the overnight OIS market, while $\psi(L, N)$ signifies the lender's term-profit from lending the amount N at rate L on the IBOR tenor market. In both cases, these profits are maximized with respect to their lending amounts and their lending rates.

Beyond a certain threshold, both maximum profits decrease with loan size, given that the lender's marginal funding cost increases with the loan's notional size. In both cases, the lender has one optimal loan size with regards to its cost of funding.

The equilibrium rate between overnight and term loan is reached for a value L^* such that:

$$V(L^*) = U(r_0) \Leftrightarrow \max_N \psi(L^*, N) = E \left[\frac{1}{T} \int_0^T \max_{n_t} \phi(r_t, n_t) dt \middle| r_0 \right] \quad (1)$$

thus determining the LOIS equilibrium value of $L^* - R$. Equation (1) expresses an equilibrium relation between the expected profit of the overnight rolling lending versus the IBOR term lending, for a lender involved in both markets and also indifferent to the optimal amounts values prescribed by the solutions to the corresponding convex optimization problems of U and V .

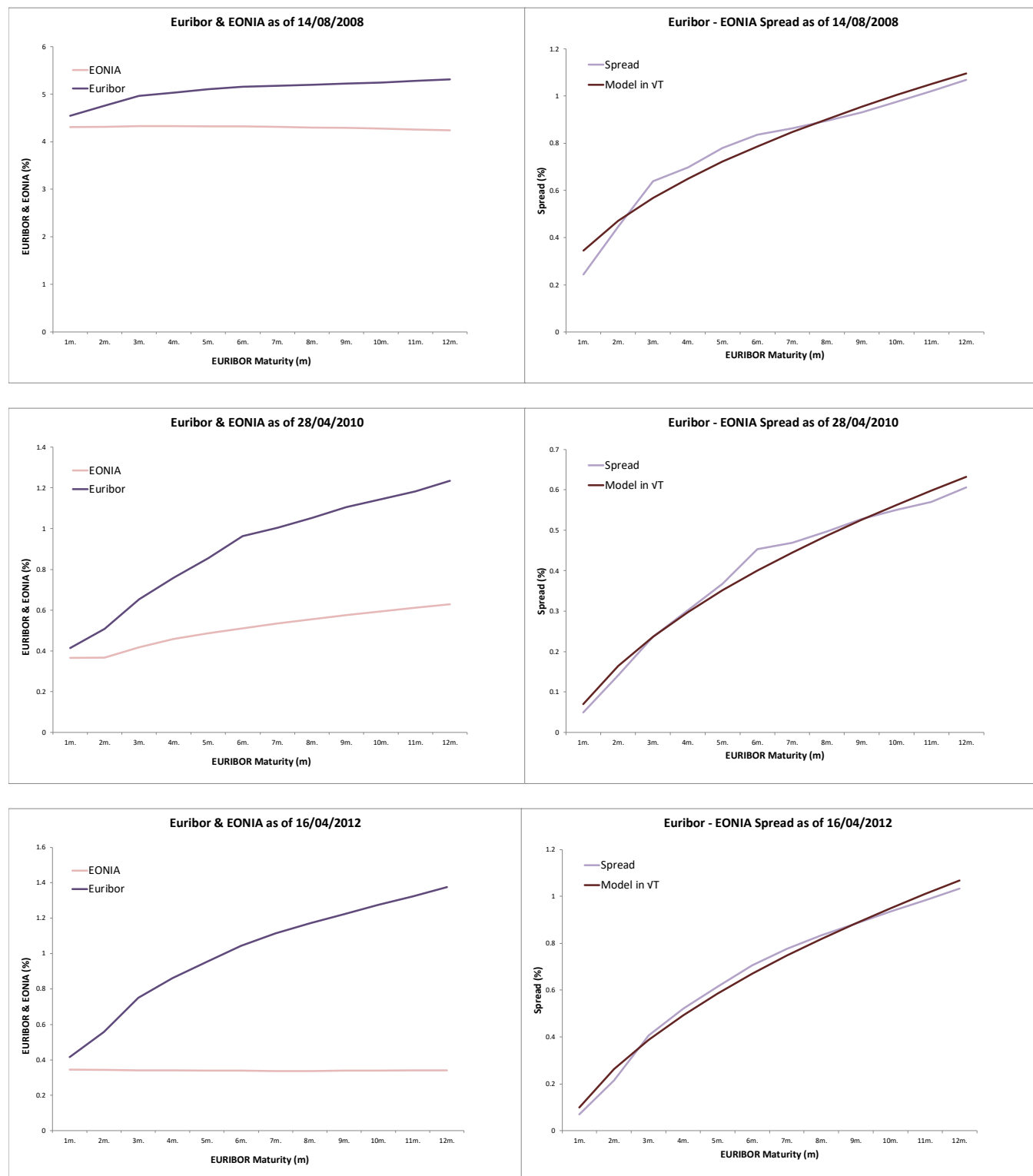
Then, under suitable assumptions on ϕ and ψ , LOIS results from equation (1) as a consequence of the *slope* λ^* of the credit curve of a representative IBOR panelist, as a borrower in an interbank loan, and of the volatility σ^* of the spread $c_t = \alpha_t - r_t$ between the funding cost rate α_t of a representative IBOR panelist, as a lender in the interbank market, and the overnight rate r_t .

More specifically, one can derive the following LOIS formula from (1):

$$L^* - R \approx \lambda^* + \sigma^* \sqrt{\frac{T}{2}}$$

The first term λ^* is a borrower's credit component, which can be seen as the *intrinsic-value* component of the LOIS, while the second term $\sigma^* \sqrt{T/2}$ is a lender's liquidity component, which can be seen as the *time-value* of the LOIS (see Fig 3).

Exhibit 16: Euribor / EONIA-swap rates (left) and square-root fit of the LOIS (right), $T = 1m$ to $12m$. Top to bottom: Aug 14, 2008, Apr 28, 2010 and Apr 16, 2012



Applications

Empirical observations revealed that the square root term structure of the LOIS is consistent with this theoretical analysis [32]. On the EUR market studied there over the period July 2007 to June 2012, LOIS appeared to be balanced between credit and liquidity until the beginning of 2009. From thereon, LOIS has been dominated by liquidity.

The LOIS formula may be used in quantitative trading to imply the value σ^* "priced" by the market from an observed LOIS and from a borrower's CDS slope taken as a proxy for λ^* . Lenders may then find it useful to compare this implied σ^* to their internal estimate of the realized funding spread volatility, so that they may decide whether they should lend upon IBOR or upon OIS.

This is analogous to going long or short an equity option, depending on the relative position of the implied and realized volatilities of the underlying stock.

This implied volatility σ^* may also find applications in the volatility parameter one needs to enter for the funding spread process c_t in a stochastic model used for CVA computations.

Legacy Positions, Contract Amendments

Significant IBOR exposures may exist in long-dated maturities and may carry on beyond the cessation of IBORs. The uncertainty around LIBOR continuity post 2022 requires the effective transition of these outstanding positions. Multiple approaches may be considered each with varying challenges by asset classes, counterparty, currency, and jurisdiction.

For derivatives markets, participants may first reduce notional exposure with multilateral compression and conversion exercises. Second, they may include the generalization of fallback language as proposed by the ISDA's new "IBOR fallbacks for 2006 ISDA Definition". For new contracts, ISDA's new fallback rates language may be triggered in the eventuality of the cessation of the publication of IBORs.

For legacy contracts, the ISDA published the 2018 Benchmarks Supplement Protocol [28], intended to help market participants incorporate the ISDA Benchmarks Supplement into their interest rate, FX, equity and commodity derivatives transactions. The ISDA Benchmarks Supplement was published in September 2018, and was primarily developed in response to requirements under the EU Benchmarks Regulation for certain contracts to reflect the actions parties will take if a referenced benchmark is materially changed or ceases to be provided. By incorporating the ISDA Benchmarks Supplement into the terms of relevant transactions, market participants will be able to ensure these events are taken into account in their contracts and specify the fallback arrangements that would apply. By using the new ISDA 2018 Benchmarks Supplement Protocol, market participants will be able to incorporate the ISDA Benchmarks Supplement into their contracts quickly and efficiently, but they are voluntary the adhering parties.

For cash products, ARRC also published guiding principles in September 2018 for a robust LIBOR fallback contract language [17], primarily aimed toward newly issued cash products such as business loans, securitizations, or floating rate notes previously referencing LIBOR. With these guidelines, ARRC recommends that market participants change the contract language at the earliest, with practicality and consistency across asset classes. Contract fallback language should reduce disruptions, such as valuation changes or litigation risk, and include specific triggers to successor rate(s). The choice of a successor rate, spread adjustment and succession schedule should be straightforward, easy to communicate to borrowers and investors.

Amending contracts with fallback language may lead to increased transition costs or operational risk. On one hand, a transition protocol for swaps may be applied across the board for existing and new swap

contracts, but on the other hand, for securities such as Floating Rate Notes, Syndicated Loans, or Structured Products, changes in the indentures may lead to protracted and costly negotiations between stakeholders with conflicting interests.

In cases where the parties have asymmetric advantages, renegotiating contracts may be a real challenge, and with the sheer number of contracts to be renegotiated, financial, commercial and operational challenges may be quite expensive. Although progress have been slow, the LMA and the AFME proposed documentation for syndicated loans and securitizations respectively [20]. The US Working Group's Bond Market sub-group is reviewing the issues on fallbacks in floating rate bonds.

Tax and Accounting

The adoption of ARR will impact fair value designation and hedge accounting. ARR changes will lead to valuation challenges (e.g., with IFRS 13). Early termination or settlement of asset or liability could also lead to material economic accounting impact. In certain scenarios, hedging measurements with different curves may result in discrepancies and ineffective hedges.

Also, changes in contracts fair values may impact taxation or changes in taxation. If IBORs are not effectively offset by the ARR, financial instruments and their respective hedges may need to be booked separately. Hedges booked separately and recorded at fair value may result in net income volatility and impact balance sheets and earnings.

Technology Infrastructure Readiness

Various institutional infrastructures (e.g., data providers, trade data repositories and middleware, core retail and commercial banking systems, trading and processing systems in the capital markets, and even nonfinancial corporate systems) will require upgrades to support the transition and incorporate new data streams. Robust ARR historical data sets should be available and set up for utilization by trading, valuation, risk and other reference data systems.

One meaningful challenge may be with the concomitant forward looking (e.g. LIBOR) and backward looking (e.g. SOFR) valuation frameworks. In particular, if a deep and liquid forward looking term structure lingers to materialize with the new ARRs, conventional market practices may change altogether.

Market participants will need programs to transition systems with the involvement of all stakeholders, from comprehensive functional specifications to integration testing and user acceptance.

Regulation and Compliance

The transition to ARRs may create difficult modifications with existing regulations, with new operational risk and fallback regulatory changes. For example, a non-margined position can become margined through contract amendments.

Separately, the transition to ARRs may trigger margin calls for existing derivatives which currently require the use of IBORs. The changes may go as far as asset-liability management in pension funds or life insurance companies, where some regulators mandate the use of IBORs in the valuation process, for example with liability-driven investments valuation or with asset-liability funding ratio calculations for regulatory reporting.

Legal, Contracts, Repapering and Operational Risk

The transition to ARR's may require substantial amendments to legacy contracts, or trigger unexpected obligations or create divergent economic interest from the stakeholders (e.g., in hedging exposures, margining derivatives exposure, or valuation of liability driven investments).

Legal risk with legal continuity and contract frustration may arise during the transition to ARR's. The basis between old and new reference rates could lead counterparties to make the case for contract frustration and trigger contract discharge. In particular, in the case of the transition from unsecured IBORs to a secured ARR's, contract frustration may be more likely than in the transition to another unsecured rate.

Impact on other Asset Classes

The current focus is mostly on transitioning interest rate derivatives to the ARR's. But there are other wholesale asset classes, such as collateralized loan obligations, for which trustees are typically loath to amend contractual terms. Further for retail products, such as mortgages, the volume and the heterogeneity of the outstanding contracts pose a significant challenge to planning and executing the transition. The implications of the transition to ARR's ripples far and broadly through multiple asset classes.

List of Abbreviations and Acronyms

Abbreviation	Description
AFME	Association for Financial Markets in Europe
ARR	Alternative Reference Rate
ARRC	Alternative Reference Rates Committee
BMR	Benchmark Regulations
CCP	Central Clearing & Settlement Counterparty
CFTC	Commodity Futures Trading Commission
CHF	Swiss Franc
CME	Chicago Mercantile Exchange
CVA	Credit Valuation Adjustment
DTCC	Depository Trust and Clearing Corporation
DVP	Delivery versus Payment
EFFR	Effective Fed Fund Rate
EONIA	Euro Overnight Index Average
ESTER	Euro Short-Term Rate
EURIBOR	Euro Interbank Offered Rate
EUR	Euro Currency
Eurex	Eurex Exchange
FCA	Financial Conduct Authority, UK
FCM	Futures Commissions Merchant
FICC	Fixed Income Clearing Corporation
FRB	Federal Reserve Board
FRBNY	Federal Reserve Bank of New York
FSB	Financial Stability Board
GBP	Sterling Pound
GCFR	General Collateral Finance Repurchase Agreements
GSE	Government Sponsored Entities
IBA	ICE Benchmark Administration, where ICE stands for Intercontinental Exchange
IBOR	Interbank Offered Rate (Including LIBOR and similar interbank panel based rates)
ICE	Intercontinental Exchange
IM	Initial Margin

IMM	International Monetary Market
IOSCO	International Organization of Securities Commissions
IARFR	ISDA Adjusted Risk Free Rate
IRS	Interest Rate Swap
ISAM	ISDA Spread Adjustment Methodology
ISDA	The International Swaps and Derivatives Association
JPY	Japanese Yen
JSCC	Japan Securities Clearing Corporation
LCH	London Clearing House
LCR	Liquidity Coverage Ratio
LIBOR, L	London Interbank Offered Rate
LMA	Loan Market Association
LSE	London Stock Exchange
MMSR	Money Market Statistical Reporting
NSFR	Net Stable Funding Ratio
OBFR	Overnight Bank Funding Rate
OIS, R	Overnight Indexed Swap (rate)
OSSG	Official Sector Steering Group
OTC	Over the Counter
PAI	Price Alignment Interest
RFR	Risk Free Rate
RNPV	Risk Neutral Present Value (risk neutral measure with fiat currency numeraire)
SARON	Swiss Average Rate Overnight
SEF	Swap Execution Facility
SOFR	Secured Overnight Financing Rate
SONIA	Sterling Overnight Index Average
TOIS	Tomorrow/Next Overnight Index Swap
TONAR	Tokyo Overnight Average Rate
USD	United States Dollar
VM	Variation Margin

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