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LIBOR TRANSITION ANALYSIS AND CALCULATIONS

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ABSTRACT

The proposed ISDA calculation, compounded setting in arrears with a historical mean or median approach, for 1-month and 3-month Libor to SOFR transitions is not yet equitable for outstanding derivatives contracts maturing after Libor cessation at year end 2021. It is critical to continue both progress on this transition plan and analysis of market needs for a new benchmark rate.

Market participants have long called for an alternative reference rate to replace the flawed benchmark rate. Progress towards SOFR yields a rate more appropriate for future transactions but creates barriers for its adoption into legacy Libor contracts.

A compounded setting in arrears methodology creates an inherently backward-looking transaction-based SOFR that cannot equally substitute into contracts priced off of a forward-looking expectation-based Libor. Systematically, modern derivative payment conventions must be updated to continue operating under the proposed calculation, creating yet another barrier for the adoption of SOFR into outstanding contracts.

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Chapter 1

Introduction

At yearend 2021, banks will no longer be required to submit Libor. SOFR is the named replacement rate, but a transition away from an interest rate that is the foundation of debt markets necessitates a robust plan. Libor is ingrained into financial markets and removing it may result in far-reaching implications.

Market participants demand an alternative benchmark rate because Libor no longer fulfills the requirements of a market benchmark rate. Problems with Libor include the manipulation scandals during the financial crisis and the low volume of underlying market transactions. The Alternative Reference Rate Committee chose SOFR to replace Libor to correct these market concerns.

However, the transition itself creates new qualms. SOFR must be adjusted to include a term component and a bank credit risk premium in order to replace Libor in outstanding derivatives contracts that will not mature before the cessation of Libor. The proposed calculation by ISDA for the adoption of SOFR into Libor contracts needs adjustments before it is sufficient to be implemented.

Chapter 2

Literature Review

Overview of Libor

What is Libor?

Libor is the abbreviation ubiquitously used for the London interbank offered rate. This interest rate is reported every market day at 11:00 am in Great Britain as the rate at which 18 large banks could borrow a “reasonable” amount of money from others in the designated "London interbank market" (Kiff). The formal question posed to each of these banks every market morning is:

> *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 11am?* (Hou)

Libor includes a collection of different bank-reported rates. Libor reports in 7 maturities ranging from overnight to 1 year. These rates include maturities of: overnight, one week, one month, two months, three months, six months, and one year. These term lengths apply to 5 different currencies including the: Euro, US Dollar, Japanese Yen, Great Britain Pound, and the Swiss Franc (LIBOR).

In 2013, the jurisdiction of Libor reporting was turned over to the Intercontinental Exchange, ICE, from the British Bankers Association, BBA. ICE then discontinued Libor reporting for the: New Zealand Kiwi, Swedish Krona, Danish Krone, Australian Dollar, and the Canadian Dollar. ICE also inactivated eight different maturities including two weeks, four months, five months, six months, seven months, eight months, nine months, ten months, and eleven months (Hou).

Each Libor rate is calculated by removing the four highest reported rates and the four lowest, then simply averaging the rest. Most of the debate surrounding integrity of the rates include the inherent fact that the reported rates are merely what the banks *could* transact at, nearly always with few, or no, underlying transactions. Libor has become an educated guess rather than a transaction-established borrowing rate. Libor is more useful as a benchmark for deriving other rates at which business transactions, most often bonds, are conducted (Kiff).

Rate Structure

Using the question posed to the banks for Libor reporting, the rates can be broken down into five components. While banks do not necessarily use a formula to calculate the rate reported to Thomson Reuters, the reported rate inherently represents:

> *Libor = overnight risk free rate over the term + term premium + bank term credit risk + term liquidity risk + term risk premium* (Hou)

Overnight risk free rate represents the rate a perfectly riskless institution would be able to borrow at overnight. The risk free component builds the base for Libor, and the following terms are specialized depending on the specific rate and then hypothetically layered on to come up with the final reported rate.

Term premium refers to the percentage that must add on to the rate for extending the term of the proposed borrowing from an overnight rate. The longer maturities of Libor would, of course, have

a higher term premium added on the overnight risk free rate. The premium is due to the intertemporal rate of substitution for delaying cash flows to the lender further into the future.

Bank term credit risk is the credit riskiness of the bank added onto the base of the risk-free rate. Although these reporting banks are large and stable institutions, they are still not considered entirely risk free. The risk comes from the probability of default during the term of the borrowing. Bank credit risk premium is an essential factor to consider when discussing rates to replace Libor.

Term liquidity risk must also be added on to include the risk for the lender of illiquidity in the interbank markets during the term of the loan. The longer maturities will inherently have higher term liquidity risk as more extended periods expose the lender to more market events. If illiquidity in the market were to occur, the lender could experience increased refinancing costs to roll over the loan.

Finally, the term risk premium is added to fully complete the rate reported by asking at what rate a bank could borrow a reasonable amount of money. The term risk premium is the risk that the prediction of any of the rates used as part of this calculation is different from the rates that are realized. Often expectations are not realized, making this a crucial factor in the calculation.

History of Libor

The man credited with the creation of Libor is Minos Zombanakis, otherwise known as the "Greek Banker." While running the London office for Manufacturers Hanover, now JP Morgan,

Zombanakis created a floating interest rate in order to complete an $80 million transaction for the Shah of Iran in 1969 (Ridley). This rate evolved into the Libor used today.

Zombanakis calculated this floating interest rate by reporting the average of reference rates reported by banks of their costs of borrowing before a set rollover date. This weighted average was rounded to the nearest one-eighth of a percentage and then added to a transaction spread (Ridley). This calculation created the interest rate for the period of any debt tied to Libor. Libor is still calculated almost precisely the same today, but the highest and lowest values are now removed before averaging.

He realized the risk to the integrity of Libor if banks manipulated their reported rate. Banks were kept honest by threats of being removed from the group for falsely inflating rates as well as risks of damaging client relationships if they were to report untruthful rates (Ridley).

Libor became increasingly important in the following decades because of two market trends: the growing demand for Eurodollars in the 1960s-1970s and the introduction of futures contracts as a way to hedge against interest rate risk in the 1980s.

Eurodollars were gaining popularity as foreign companies realized they could conduct their transactions, entirely in US Dollars, without having to deal with US regulations. The significant demand for Eurodollars naturally led to an increased demand for Eurodollar loans. Bankers in London all began to share these risks across multiple banks to meet market demands. Banks syndicated this risk by requiring short term deposits, determined by a floating rate, to fund the

large Eurodollar loans. The loans were renegotiated every 3 to 6 months to adapt to the markets and thus required a floating rate for which Libor was used (Ridley).

Companys' exposure to interest rate risk grew as they took out more loans. Derivatives developed to hedge against this risk. In the 1980s, derivatives popularized for their ability to hedge against interest rate risks (Kiff). Libor, created initially to individually price loans, was no longer sufficient to benchmark large syndicated Eurodollar loans and the derivatives created to hedge them.

Markets demanded a rate at which to transact interest rate futures from the Bank of England and the banking industry trade group. In 1986, the British Bankers' Association launched Libor which quickly became the benchmark not only for derivatives but also for corporate floating rate debt issuance (Kiff). The Bank of England backed the BBA in this endeavor to formalize the process for reporting the rate in order to satisfy market demand for both a consistent and transparent rate (Ridley).

Thomson Reuters collected and distributed the rates on behalf of the BBA starting in 2005 (Ridley). However, with the financial crisis and Libor scandals following, the New York Stock Exchange, with the Intercontinental Exchange, won the bid to produce Libor. The BBA transferred Libor reporting responsibilities over in 2014 (Hou).

Market Significance

While the average person probably has not heard of Libor, its impact is far-reaching. At year-end 2016, the Federal Reserve Bank of New York estimated total exposure to Libor to be $200 trillion.

To put that in perspective, at the time, that was over ten times the US annual GDP. 95% of that exposure is within the derivatives market. However, other categories of financial instruments tied to Libor include institutional loans, floating rate mortgages, floating rate notes, and securitized products. The users of these products are not limited to large financial institutions but also include retail customers, corporations, issuers, investors, asset managers, and any service providers of financial products (Frequently).

While Libor overwhelmingly underscores debt markets used exclusively by financial institutions and large corporations, it financially affects many companies and individuals. The wide-spread application is why the manipulation and the crisis, as it pertained to Libor, were highly scrutinized and created a widespread call to action for Libor reform.

Problems with Libor

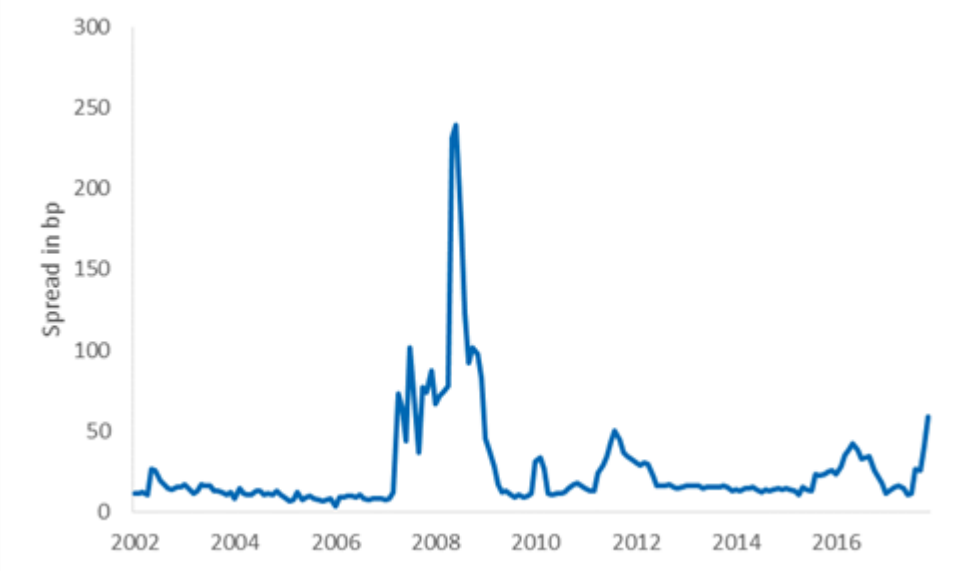
The Financial Crisis and Libor

Before the crisis, Libor closely tracked the Overnight Indexed Swap Rate, OIS, as well as Treasury rates. The Libor-OIS spread contains three elements: bank credit spread, term liquidity spread, and term risk premia. This spread was often used to measure the health of the banking system and averaged ten basis points from 2005 until early 2007 (Hou).

However, during the financial crisis, interbank borrowing rates were driven upwards by counterparty risk as well as the liquidity concerns that accompanied the crisis. There is debate as to which factor contributed most to the rate increases. The Libor-OIS spread rose to well over 200

basis points after the bankruptcy of Lehman Brothers and remained heightened through 2009 (Hou).

[1]Figure 1 Libor-OIS Spread



These elevated interbank borrowing rates compounded and drove Libor continually higher. As banks were not able to access these markets, market concern for the credibility of banks escalated as the liquidity crunch worries dominated. Market concerns drove credit risk premia even higher, thus making it harder for the banks to borrow money.

Libor Manipulation

Towards the beginning of the financial crisis, regulators took notice that Libor was not following expectations based on Credit Default Swap rates. CDS rates show market observations on the

[1] Menezes, Ian. "What's up with the Libor/OIS Spread Lately?" *Aegon AM*, 7 May 2018.

creditworthiness of a company. The market was pricing in the observation that banks were becoming riskier, inferring that the bank credit risk was growing. CDS on banks were expensive during the financial crisis and reported Libor should have increased as well. However, Libor was not increasing as much as CDS rates implied it should be (Hou).

The importance of tracking Libor with market rates, such as CDS rates, is that it was impossible to tamper with the market observations on the riskiness of banks. However, in a financial crisis such as the one in 2007, a bank may be motivated to underreport borrowing costs. In 2008, when speculation of rate manipulation began, a report offered two possible motives for fixing rates: to project financial soundness and to benefit the bank's derivative positions entered into before the financial crisis (Hou).

Official investigations into the matter confirmed rate fixing throughout many large banks. Regulatory agencies fined Barclays, UBS, RBS, and Rabobank a combined total of over $3.5 billion (Hou). Estimates show nearly all of the banks were submitting rates that were averaging 30-40 basis points below true borrowing costs. The market illiquidity made it easier for traders to manipulate rates than it would have been in a typical liquid market (Rotten).

Barclays Rate Fixing

Barclays fought against accusations of underreporting rates by showing that their rate submissions were consistently in the top quartile reported and thus discarded from the rate calculations. However, it is still possible that a bank's intentionally lowered borrowing rates would still be

higher than its peers. It is required for banks to truthfully report what it would cost them to borrow (Hou).

Even today, it is difficult, if not impossible, to prove which rates were fixed by the banks solely by market rates and statistics. It took an official investigation into Barclays to find management directives explicitly instructing employees to "keep Libor submissions low to protect Barclays' reputation" (Hou). Barclays claimed that they believed they had implicit support from the Bank of England to manage rates in this way (Rotten).

Libor Recommendations Mid-Crisis

The issue of rate-fixing by the banks had come to the attention of the Federal Reserve Bank of New York at the inception of the financial crisis. However, at that time they did not have authority over Libor reporting. In 2008, the Federal Reserve Bank of New York sent a report to the bank of England with a set of recommendations on how to improve the authenticity of the reported Libor rates (Hou).

The first recommendation was to expand the reporting pool to a more extensive and more diverse set of banks. Statistically, including a broader set of data increases the confidence in the accuracy of the rate reported. Another suggestion was to report a second USD Libor during market hours to adjust for the time difference between London and New York City. The NY Fed also proposed reducing the number of maturities reported to focus on the reliability of the more prominent rate maturities. More broadly, the report also mentioned the elimination of the incentives to manipulate. Finally, the question posed to the banks was too general and that it should specify the monetary

size of transactions for which the reported rate is to be applied rather than a “reasonable amount” (Hou).

Additional Libor Recommendations

As well as specifying the size of the transaction, the question could improve by changing "at what rate could you borrow funds…" to "at what rate would you lend funds…". During the crisis, Libor and Euribor ceased to parallel one another. The crucial difference between these two rates is that Libor is a "borrowing" rate while Euribor is a "lending rate." A lending rate has an inherent benefit of eliminating an "overconfidence" factor (Hou).

Another issue with Libor highlighted recently, is the low volume of transactions underlying the reported rates used to calculate Libor. These concerns have created skepticism around the sustainability of the rate and led to the creation of the Financial Stability Board reform in 2014. This board has led efforts to improve the number of transactions Libor derives from rather than solely from banks' conjectures. There is a widespread concern for the absence of the real price of term funding in rate reported rates.

For one currency/tenor pair in 2016, there were only 15 underlying transactions that were within the parameters. Assuming none of the transactions were on the same day at the same bank, only 0.33% of the rates published in that currency/tenor pair for the year reported on actual contracts[2]. There are no longer enough interbank unsecured financing transactions to underscore Libor

[2] 252 trading days x 18 banks = 4,536 rates reported (per currency tenor)
(15 transactions / 4,536 rates reported) x 100% = 0.33% rates reported based on transactions

appropriately. Unfortunately, there is no indication of the volume of these transactions improving in the future either (Bailey).

Other concerns include the mismatch between the rate represented by Libor and the rate necessary for contracts involving Libor. For example, an overwhelming amount of transactions connected to Libor stem from the derivatives market. Generally, parties that want to hedge against general interest rate movements including policy rate implications enter into derivative positions calculated on Libor. The term premium and credit premium components are not necessarily needed for these transactions but are included through Libor (Bailey).

Misalignment between the consumer need and what Libor represents can create compounding problems. Often consumer mortgages are tied to Libor, generating a direct correlation between bank credit premium and the cost of the mortgage. However, there is no reason that a consumer should have higher mortgage payments when bank credit weakens. Many calls for reform hope to realign Libor with the parties' purpose for entering into the contract (Bailey).

Despite the aforementioned flaws, there are many reasons for continuing to use Libor. Most prominently, the use of Libor is so ubiquitous that it is convenient to use in contracts. Additionally, alternative reference rates are not established. Because of this, they have not achieved the liquidity required for market-wide adoption into contracts in place of Libor (Bailey).

Transition Scenario and Hurdles

Transition Details

Markets have recognized the problems with Libor as well as other international "Ibors," particularly the lack of underlying transactions. The low volume of transactions has prompted efforts to replace these rates with various alternative reference rates. Subsequently, Banks are not required to report Libor past year-end 2021. Although this does not mean that banks cannot or will not continue to report rates to calculate Libor, many assume that the fines associated with fraudulent Libor submissions will deter banks from unnecessarily reporting borrowing rates.

Specifically, in the United States, the Alternative Reference Rates Committee, ARRC, has been designated by the New York Federal Reserve to take charge of the transition away from Libor. The Secured Overnight Financing Rate, SOFR, is designated as the rate to replace Libor in the transition (IBOR Report).

Contract Equity

Despite the flaws associated with it, Libor is a good representation of Federal Fund Rates and a foundation of debt markets. Most financial instruments involving floating rates are priced off of Libor and will be affected by the transition to SOFR. While many market participants are happy with the efforts to make the benchmark rate more transparent and sustainable, they are wary of the issues inherent with the upcoming transition. Eric Bernstein, president of asset management solutions at Broadridge Financial Solutions Inc. notes that "People may not be happy with the construct of LIBOR, which is fine. But many don't grasp what it will take to replace it" (Baert).

ICE consistently reports Libor, which some market participants note as the most critical attribute of a benchmark rate. According to Rick Baert, traders first and foremost want to be able to assume the credibility and materiality of the benchmark and not have to worry about its reliability. This assumption keeps the market functional and sustainable (Baert).

There must also be contract equity in transitioning from Libor to SOFR to keep the market functioning without significant disruption. Equity ensures that the rate transition does not violate contract law. Willa Cohen Bruckner is a partner in financial services at the New York-based law firm Alston & Bird LLP and best explains the importance of transitioning to an equal rate.

> *If they replace it [Libor], the expectation is that there will be 'winners' and 'losers' -- my quotes. If they have a contract with Libor and replace it with something else, even if it's close to Libor, it won't match. Libor is based on a certain methodology. If it's replaced by SOFR or another rate, if you compare the two over time, it won't be the same. If the contract says Libor and you substitute SOFR, the economics of that is that some will end up ahead and some behind. They'll either get more or pay more. (Baert)*

Fallback Language

One major issue for transitioning away from Libor to an equal alternative reference rate is the lack of clear fallback language on outstanding contracts involving Libor. The Financial Stability Board's new group, the Official Sector Steering Group, comprises of officials from central banks and regulatory agencies and is tasked with coordinating international efforts on interest rate benchmark transitions. OSSG warns market participants to fully understand what the contract

language specifies upon the permanent discontinuation of the relevant interest rate benchmark (IBOR Report).

The FSB also notes that if these provisions are not substantial enough, they must be negotiated and updated in order to prevent market disruption. Many contracts contain specific language detailing the payment calculation if the rate did not report by a particular time one day, but many do not have calculations or transitions set for a permanent cessation. Furthermore, the FSB OSSG has asked the International Swaps and Derivatives Association, ISDA, to amend their agreement language to include specific fallbacks for future contracts. While this will provide future guidance and perhaps an encouraged market-wide adoption for transition, outstanding derivatives contracts will still require a bilateral negotiation between parties. Negotiation will be a challenge for banks and participants due to the high number of outstanding contracts (IBOR Report).

Other categories of financial instruments that will be affected by the transition away from Libor include bonds, floating rate notes, loans, securitizations, consumer loans, and residential mortgages. Most contractual fallback language on bonds and floating notes specifies that if the rate does not report, the payment will fix at the last available reported rate. The major issue with this is that floating rate debt effectively becomes fixed debt and will leave parties open to double exposure on outstanding derivatives (IBOR Report).

The majority of loans will switch to the Effective Federal Funds Rate plus a to-be-determined spread. Securitizations' language allows Fannie Mae and Freddie Mac to name the successor rate. Consumer loans and residential mortgages do not have any overwhelming uniformity on fallback

procedures. Unfortunately, no category of financial instruments tied to Libor has sufficient fallback language in contracts for the transition away from Libor (IBOR Report).

Basis Risk

Not only do all of the categories of financial instruments tied to Libor need sufficient fallback language for the upcoming transition, but these categories must also coordinate to avoid creating basis risk for market participants. As mentioned before, the uniformity of Libor is one of the significant benefits of continuing the rate. Bonds, collateral, and derivatives are all tied to Libor and thus are accessible to hedge and trade. If all of these financial instruments do not transition at the same time to the same alternative reference rate, the participants encounter basis risk. This risk, not initially foreseen or calculated when entering into these contractual positions, could create market disruption.

Need for New Infrastructure

The transition away from Libor compares to two major systemic technological transitions. First, the US equity market decimalization of systems in 2001 to replace fractions. The decimalization created a huge operational challenge to switching systems and transitioning from Libor is inherently more complicated than that. However, a second comparison was made to the transition of the millennial change which caused major market panic but ended up being "much ado about nothing" (Baert).

A major problem arising from the infrastructure change would be rebalancing and the inability to settle trades on time because of the transition of the settlement systems. Along with that, the cost

of transitioning the systems alone could have a costly impact on the market. Eric Bernstein, president of asset management solutions for Broadridge Financial Solutions Inc., notes that:

> *There's huge operational overhead. The cost of processing the trades might be more than what the trade gets. That will bring the value of a portfolio down -- if I can't access the market quick enough to execute and settle, what is the market impact of that? It won't just affect the counterparties involved; it could impact the entire market.* (Baert)

Libor Replacement Rate and Candidate

Ideal Characteristics of Replacement Rate

Returning to the earlier definition of Libor,

> *LIBOR = overnight risk free rate over the term + term premium + bank term credit risk + term liquidity risk + term risk premium*

This formula derives from the question posed to the banks every morning, "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 11am?" (Hou). At the highest level of description, the ideal rate would be the characteristics of Libor, underscored by actual market transactions and ensured credibility.

The Alternative Reference Rate Committee, tasked by the Federal Reserve to name a replacement for Libor, listed a handful of characteristics they looked for in assessing candidate rates. The first quality in determining rates for candidacy is the ability to serve as a benchmark with integrity and

continuity; both traits arguably absent from Libor. Next, the International Organization of Securities Commissions, IOSCO, requires a precise methodology and robustness in calculating the rate in order to comply with its principles. IOSCO Principles contain strict requirements regarding the integrity of the process for compliance. Another concern when selecting a rate is governance to ensure the virtuousness of the rate. Finally, they took into account the ease of transition and implementation to this new rate (IBOR Roadmap).

These qualities led the ARRC to several finalist rates considered. The rates considered were: overnight unsecured lending rates, overnight secured repo rates, policy rates such as the Federal Funds rate, term unsecured lending rates, term overnight indexed swap rates, and treasury bill and bond rates. The final rate considered and ultimately chosen by the ARRC in June 2017 to be the successor of Libor is SOFR, otherwise known as the Secured Overnight Financing Rate (IBOR Roadmap).

SOFR Characteristics

The Secured Overnight Financing Rate, SOFR, is calculated from market transactions of borrowing or lending Treasury securities overnight. There are large volumes of applicable transactions used daily in an objective calculation of the rate; this fills the primary market requirement for a benchmark based on underlying transactions. SOFR also inherently fulfills the need integrity and reliability in the new benchmark as an objective calculation is not subject to "educated guesses" or manipulation.

There are three specific categories of trades designated for inclusion in the calculation of SOFR and companies named responsible for the reporting of each category. First, BNY Mellon collects transaction level tri-party data. Secondly, DTCC solutions report general collateral financing repo trades. Finally, the Fixed Income Clearing Corporation's Delivery-versus-Payment clears and incorporates repo service transactions. The bottom quartile of reported rates are determined to be trading "special" and will be removed from the data daily. A contract is considered to be trading "special" when a cash provider is willing to lend at a lower rate to acquire a particular security. The final SOFR is a volume-weighted median of the transactional data after removing the bottom quartile (Additional).

Problems with SOFR

SOFR will not be able to be directly substituted in for Libor in outstanding contracts as it is missing the bank term credit risk and term premiums. This absence of credit and term premiums makes adoption of SOFR as a replacement more onerous. The overnight rate does not currently have the various terms built out that Libor does; market participation is crucial to building out longer terms of SOFR futures for use in financial instruments that currently price off of Libor futures. However, building out longer terms for SOFR may lessen the liquidity in the overnight term and damage market trust in the rate (IBOR Report).

The most pressing issues for the adoption of SOFR into outstanding Libor derivative contracts are twofold. First, is determining how to substitute an overnight rate, SOFR, for a one-month or three-month term rate Libor. Second, is finding the best way to calculate the bank credit risk premium

to add to the risk-free SOFR to reflect the interbank borrowing rates reported by Libor. ISDA has conducted some recent preliminary surveys on market preference for these calculations.

Chapter 3

Data and Methodology

ISDA Consultation Report

In 2018, ISDA tasked a consulting body, The Brattle Group, to determine market preference for how to adopt risk-free rates, RFR, into IBOR contracts, specifically derivatives. They presented the *Anonymized Narrative Summary of Responses to the ISDA Consultation on Term Fixings and Spread Adjustment Methodologies* in December of 2018. The Brattle Group offered the survey to 137 entities from 19 countries in the Americas, Europe, and the Asia Pacific regions. The broad group of market participants engaged included but were not limited to: banks, corporations, clearinghouses, industry and trade associations, and government entities (Anonymized).

Survey participants were offered four options for their term preference and three options for their spread preference. Term-calculation preferences included: the spot overnight rate, a convexity-adjusted overnight rate, compounded setting in arrears rate, and compounded setting in advance rate. Options for the spread preference included: a forward approach, historical mean/median approach, and a spot-spread approach. Found below is a summary of the fallback preferences reported by the survey group (Anonymized).

[3] Figure 2 Summary of Top Fallback Preferences

	Forward Approach	Historical Mean/Median Approach	Spot-Spread Approach	Total
Spot Overnight Rate	Not Compatible	(Combination 3) 1 respondent ranking	(Combination 7) 1 respondent ranking	**2**
Convexity-adjusted Overnight Rate	Not Compatible	(Combination 4) 1 respondent ranking	(Combination 8) 1 respondent ranking	**2**
Compounded Setting in Arrears Rate	(Combination 1) 41 respondent rankings	(Combination 5) 86 respondent rankings	Not Compatible	**127**
Compounded Setting in Advance Rate	(Combination 2) 2 respondent rankings	(Combination 6) 7 respondent rankings	(Combination 9) 2 respondent rankings	**11**
Total	**43**	**95**	**4**	**142**

ISDA has found these results to be significant and is currently developing fallbacks for derivative contract agreement language with a compounded setting in arrears and the historical mean/median approach for all benchmarks covered by ISDA contracts. They also noted that the mean/median calculation parameters are not yet determined (Anonymized).

Scope of Thesis and Data

The hurdles facing the transition from IBORs to RFRs are many and great. Thus, it is necessary to refine the scope of this thesis with some parameters. First, there are several currencies in which IBORs report. This analysis narrows to USD Libor for the most widespread application. USD Libor determines the value of many different categories of financial instruments; however,

[3] "Anonymized Narrative Summary of Responses to the ISDA Consultation on Term Fixings and Spread Adjustment Methodologies." *ISDA Consultation Report*, The Brattle Group, 20 Dec. 2018.

derivative contracts make up an overwhelming proportion of the market and will, therefore, be the focus of this paper.

Like the USD Libor derivatives market, this thesis will deal primarily in the 1-month and 3-month tenors. Finally, when markets reach the realization that Libor will no longer continue, instruments will begin to be priced exclusively off of SOFR. Since markets will then price the spread for these new contracts, there is no calculation needed for the future contracts that will price through contract negotiations.

However, there is no market spread to convert Libor to SOFR for outstanding contracts that will not reach maturity before the termination of Libor. Consequently, a pressing issue for the markets is: Will the proposed ISDA calculation, compounded setting in arrears with a historical mean or median approach, for 1-month and 3-month Libor to SOFR transition be equitable for derivatives contracts that will mature before year end 2021? It is also imperative to include an assessment of the flaws accompanying the proposed calculation.

There is minimal historical data available for SOFR; as a result, the calculations include all reported rates. Since SOFR is transaction based, there should be no need to remove the initial rates to let it "settle." Bloomberg first reported SOFR on 4/2/18. All rates used in calculations include data from 4/2/18 to 1/31/19. [4]

[4] All data collected from Bloomberg Terminal for the dates 4/2/18-1/31/19. Tickers are as follows: SOFRRATE (SOFR), USGG1M (1-month Treasury), USGG3M (3-month Treasury), US0001M (1-month Libor), US0003M (3-month Libor).

The 1-month calculation and comparison use SOFR, 1-month Libor, and the 1-month Treasury Bill as a similar risk-free rate with a matching term. The Alternative Reference Rate Committee considered the Treasury Bill rates as a candidate for Libor replacement. Theoretically, all that should be missing from the Treasury Bill rate when comparing to Libor would be the bank credit risk premium, while SOFR is missing the term component and bank credit risk premium. The 3-month calculation uses SOFR, 3-month Libor, and the 3-month Treasury Bill.

Calculations

The calculations are similar for the 1-month SOFR and the 3-month SOFR using the respective data. To first build out the term component of the 1-month and 3-month SOFR, a geometric mean was used to compound the overnight rates. An assumption was made using an average of 21 trading days per month and 46 trading days for three months. The geometric mean formula is as follows where N is the number of days in this case.

$$(1 + geometric\ mean)^N = 1 + cumulative\ return$$

$$geometric\ mean = \sqrt[N]{(1 + cumulative\ return)} - 1$$

Since setting in arrears is the overwhelming market preference for term calculation, the settlement date of the calculated rate is the earliest date of the 1-month or 3-month subset of data used. The last date of the subset data used would be the date of payment. An adjustment was then made to align the term SOFR with the Libor on matching settlement dates to account for the backward-looking nature of SOFR and the forward-looking nature of Libor. Since the data is until1/31/2019,

the first settlement date used for comparison was 1/2/2019. The Treasury Bill rate is forward-looking and therefore needs no date adjustment.

This date adjustment highlights an essential difference in the calculation of these rates: compounded setting in arrears yields a backward-looking rate based on transactions for term SOFR, while the comparative Libor is forward-looking and based on expectations. This difference not only creates a basis risk but also generates an absence of predetermined payment with procedural implications. Execution Implications includes a discussion of the proposed transition difficulties.

Using the settlement date-aligned 1-month SOFR, 1-month Libor, and 1-month Treasury Bill, a Libor-SOFR spread was created as well as a Libor-Treasury Bill spread. These calculations are all repeated for the respective 3-month term rates. The statistics calculated on the data sets of the four spreads are median, average, and standard deviation of the samples.

The average and median of the spreads then add to the respective term SOFR and Treasury Bill rates. Next, Libor was subtracted from the mean/median spread-adjusted SOFR and Treasury Bills to create a spread of the differences in the proposed calculations compared to the reported Libor. This final subtraction shows the difference of what the Libor rate was versus what the rate would have been reported as for the day with the proposed ISDA calculation. The average of these differences was taken for each category to see if the historical mean or median approach was a better fit of the past data as proposed by market participants through the ISDA consultation.

Chapter 4

Results

Table 1 One Month Term Calculations

	Libor-Term SOFR Spread	Libor-T Bill Spread
Median	.4050	.4624
Average	.4114	.4824
Standard Deviation	.1205	.1334

Table 2 Average Difference between One Month Adjusted Rates and Libor

	SOFR	T Bill
Mean Approach	3.2887×10^{-16}	-2.4005×10^{-17}
Median Approach	-.0064	-.0120

Table 3 Three Month Term Calculations

	Libor-Term SOFR Spread	Libor-T Bill Spread
Median	.0874	.0717
Average	.0649	.0739
Standard Deviation	.0658	.0624

Table 4 Average Difference between Three Month Adjusted Rates and Libor

	SOFR	T Bill
Mean Approach	-3.8549×10^{-17}	-1.8504×10^{-17}
Median Approach	.0225	-.0022

Result Interpretations

The market preference for building out the term portion of SOFR was almost decisively for the compounded setting in arrears method and was largely for adding the spread based on historical mean or median data. ISDA is moving forward with implementing these into new contract language. However, there has been no further guidance on if the preference is for median or mean and what the parameters on setting these spreads will be. Unfortunately, SOFR has not yet reported for a full year, and without more data, it is not reliable to determine the best approach to these calculations. A larger data set is needed to analyze how these calculations will perform in the future and different interest rate environments.

In the one month calculations, 1-month SOFR fit the historical 1-month Libor more closely than an alternatively proposed 1-month Treasury Bill shown by a narrower standard deviation of the spread. In the three month calculations, the standard deviations of the spread from SOFR and the Treasury Bill are more similar with the Treasury Bill producing a smaller standard deviation.

Using the approaches suggested on the data available, it is clear that a mean of the historical spreads fits the data significantly better than a median. Regardless of the term length or SOFR or

Treasury Bill, the spread after the rates had been fully adjusted compared to Libor was approximately zero using the mean approach. The median approach was also a good fit for the historical data, but not as accurate as the mean approach.

Proposed Calculation Biases

The process proposed by market participants and ISDA raises concern for potential statistical biases. The first issue is a time-period bias. All of these calculations are only applicable to a short period of time that is measured by the data collection. The calculated spreads may not be reflective of a more extended time. A longer period of data is needed for the spreads to be effective in contract substitution. Since there is no further data available, it is unable to determine how the spread will perform. If the spread performs poorly in the future, then the new data will have to be added into the data set, and the effectiveness of the new spread would still be undetermined. Libor will be phased out by year end 2021 allowing the collection of more data before implementation, but changing rate environments in the near future could over-complicate this calculation.

The second bias arising from the calculation stems from retrofitting the statistics to the historical data. An average spread fits historical data well because the data used in the calculation is the same data it is then applied. This calculation does not provide any clarity on the future effectiveness of the resulting spread.

Chapter 5

Execution Implications and Recommendations

Evaluation of the Proposed Calculation

While the majority of this section discusses many issues with the ISDA calculation, it is pertinent to note that this is the first official proposal for the substitution of SOFR into Libor derivative contracts. This progress in itself is a crucial step towards developing a plan to transition outstanding Libor contracts by the year-end 2021. It is essential to address issues with the recommendation; however, it does not negate the substantial progress made.

It is most probable that the final solution will not be a perfect substitution for Libor. The market will have to continue to negotiate and make concessions to find the ideal arrangement. In continuing the progress towards this optimal strategy for SOFR transition into outstanding Libor contracts, it is essential to evaluate concerns raised by the proposed ISDA calculation both inherently and in implementation.

Inherent Issues

A few issues stem from the data and methodology in the proposed calculation. First, the biases of the time-series and retrofitting the statistics to past data create concern for the future effectiveness

of the results. These biases may correct with more data, but as mentioned before, there is no indication of the predictive ability of the historical mean or median spread calculation.

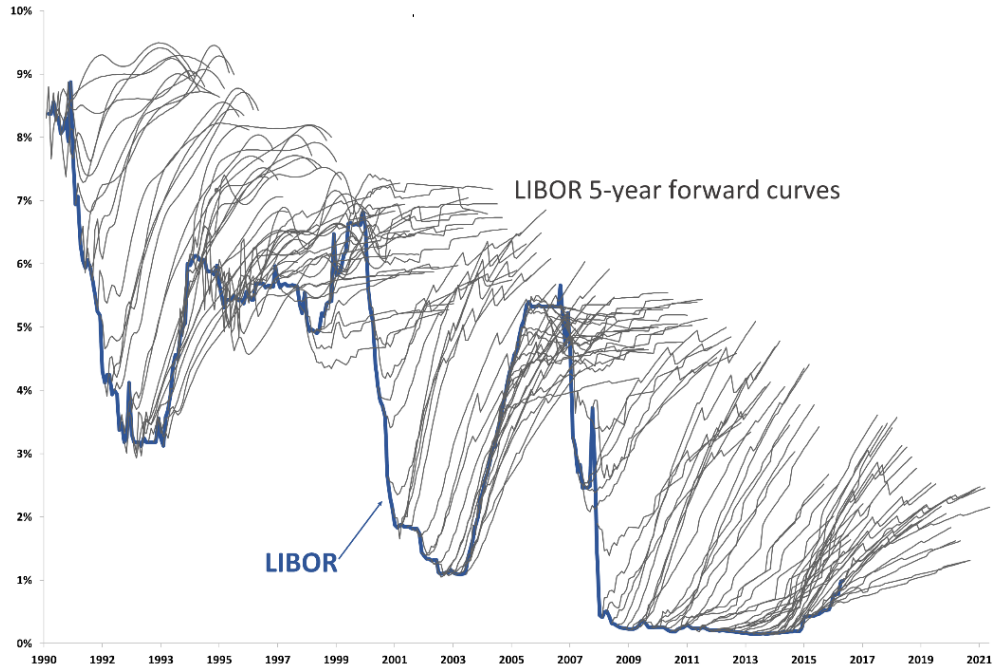
Another complication arising from the methodology is the undecided parameters. There will be some contractual parties that would benefit from a historical mean calculation over a specific time frame where another contract participant would receive a more accurate Libor substitution from a historical median calculation over a different period. The parameters are not yet determined, but there may be many strong opinions motivated by a difference in the criterion. While it may be most accurate to collect all possible data before setting the parameters, some time for deliberation will be required to satiate concerns from different parties.

A third concern with the calculation, and perhaps most alarming, is the difference in what the adjusted rates are measuring. The proposed calculation has the intent of correcting the two absolute differences between SOFR and Libor. First, SOFR is an overnight rate so it must convert to a term rate before substituting for Libor. Second, SOFR is a risk-free rate so it must account for the credit risk premium in a spread. However, the market preference calculation creates two borrowing rates that measure decidedly different terms.

On the settlement date of Libor derivative contracts, usually two business days after the contract is signed (T+2), the market rate is found and applied to the contract over the term. Libor is representative of forward-looking expectations of interbank borrowing rates for the respective term length. By calculating a term SOFR with a compounded setting in arrears of the overnight rates, the term SOFR is a backward-looking transaction rate for the respective term. While the historical spread may attempt to correct the market's poor predictive power, there is not a consistent amount of error between the Libor forward curve and the actual rates. In different rate environments, the

market will over predict or under predict by different amounts. Poor market prediction is another issue with the limited amount of data from a steady rate environment being used to calculate the spread.

[5]Figure 3 Libor Forward Curves vs Realized Libor



This chart demonstrates the difference between the Libor forward curve, or market expectations, and realized Libor. In rising or falling rate interest rate environments the market will under predict and over predict respectively. It is also pertinent to note that there is no consistent spread between market expectations and realizations. Thus, it is important to take into account the effect of different rate settings on the calculation and data set used.

[5] "Quantifying Fixed vs Float | Industry News." Pensford White Paper, Pensford Financial Group, 22 July 2017, www.pensford.com/white-paper-fixed-vs-float/.

Implementation Issues

Many issues arise from the implementation of the proposed calculation. Although this collection is not exhaustive, these barriers must be addressed for a successful transition. To begin, the ISDA computation would necessitate a difference in payment schedules. By calculating the compounded SOFR and setting it in arrears, the payment amount is not known at the settlement date as the convention of Libor contracts currently allows. The payment amount will not be known until it is calculated on the payment date.

Many companies use Libor derivatives to hedge their interest rate risk on outstanding debt. The predictability of payments provided by the contracts is one primary reason for entering into many derivative agreements. The proposed calculation removes this benefit and requires payment instantaneously. Payment procedures will need to be modified internally by companies to accommodate for the quick turnover.

Companies entered into derivative contracts to hedge outstanding debt will also face basis risk if the bond market does not make an identical transition. The loan and derivative transition will need to be indistinguishable in calculation and timing to eliminate basis risk. Timing will require cooperation between regulatory bodies and a significant coordinated effort far beyond the reach of ISDA. Hedges are designed to reduce interest rate risk, but without a seamless transition, the risk could heighten. All problems with the transition simplify to contract equity issues. The initial contract priced off of Libor, so the discontinuation of Libor creates a need for an equal alternative rate. It was initially thought by Wall Street participants that there might be a calculated continuation of Libor to ease the transition away, but the progress made on SOFR has dissuaded those efforts.

Chapter 6

Conclusion and Recommendations

The calculation being adopted by ISDA for SOFR adoption into legacy Libor derivative contracts maturing before year end 2021 is not yet sufficient for market needs. It is critical to continue progress on this transitional plan and proposed calculation while analyzing barriers in implementation.

Future studies will be of the utmost importance for determining the accuracy of the calculated term SOFR rates to replace Libor in outstanding derivative contracts. The ISDA calculations fit the spreads to past data but do not provide any suggestion for future competency. Fortunately, there is time before the Libor expiration at year end 2021 to continue to collect data from both rates and test more parameters for the spread calculation. Future studies may seek to use a moving average for spreads allowed by a more extensive data pool. Changing rate environments may also allow studies to calculate applicable spreads to most accurately replicate Libor.

Other studies could seek proposals for a coordinated effort between regulatory bodies to address the timing issues for transitioning outstanding contracts. The contracts needing a coordinated effort include bond market transitions or other financial instruments such as cross-currency swaps. Ultimately, Wall Street is looking for instructions and direction for this transition. Incongruously, the transition from Libor to SOFR has created a quantitative problem most desperately in need of a qualitative solution.

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EDUCATION

The Pennsylvania State University | *Smeal College of Business* **University Park, PA**
Schreyer Honors College *Aug 2015 - May 2019*
Bachelor of Science in Finance, Minor in International Business
Study Abroad Semester | *Institute for the International Education of Students* **Siena, Italy**
Studied business and economics through local culinary businesses *Jan 2017- Apr 2017*

ANALYST EXPERIENCE

Credit Suisse **New York, NY**
Capital Markets Full Time Analyst Program *Jul 2019*

- Accepted position with Corporate Debt Derivatives team for employment after graduation

Credit Suisse **New York, NY**
Capital Markets Summer Analyst Program- Corporate Debt Derivatives *Jun 2018- Aug 2018*

- Learned the team's products such as fixed and floating swaps, cross currency swaps, caps and floors in order to produce and tailor decks to be distributed to clients through presentations to improve sales
- Created daily interest rate market email for internal and external clients outlining market events and data resulting in more informed and in sync clientele and colleagues
- Presented a mock client pitch with interns to senior employees and won best presentation

Bank of New York Mellon **Pittsburgh, PA**
IS CSD Global Operations Control Management- Summer Analyst Program *Jun 2017 - Aug 2017*

- Analyzed and improved the Control Management enterprise social network based on feedback created from employee engagement survey to create a central point of information for everyone in the division
- Improved the daily workflow for over 250 global employees by upgrading the enterprise social network
- Researched and assessed historical risk and control self-assessments for high-level discussions by senior leadership to minimize fraudulent and errored transactions throughout the bank

EXTRACURRICULAR EXPERIENCE

Wall Street Boot Camp **University Park, PA**
Participant *Aug 2016 – Dec 2016*

- Selected as one of 40 students out of 400 Smeal applicants to learn about and become better prepared for careers in the financial services industry through weekly sessions with distinguished professionals
- Attended weekly meetings with Wall Street professionals to discuss careers in fields such as Investment Banking, Sales and Trading, Equity Research, Asset Management, and Private Wealth Management

Penn State Investment Association (PSIA) **University Park, PA**
Consumer Discretionary Sector *Feb 2016 – May 2016*

- Evaluated a company to pitch with a team against 19 teams in a stock pitch competition and placed second
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WORK EXPERIENCE

Morgan Academic Support Center for Student-Athletes **University Park, PA**
Math, Economics, and Accounting Tutor *Aug 2016 – May 2018*

- Tutored Penn State student-athletes during accounting and economics drop-in hours for nine hours weekly
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