NYU TANDON SCHOOL OF ENGINEERING

FRE-GY 7851
Interest Rate Derivatives

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Assignment 1
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Contents

1 Duration and Convexity formulas

Demonstrate Duration and Convexity formulas from their definition in the left columns, in the discrete and continuous case for ZCB and CBB (see pages 11 and 14).

Solution: In this section, we will demonstrate how to derive Duration and convexity formulas from their equations in the discrete and continuous case.

I : Zero Coupon Bond or ZCB

A. Duration

$$\text{ZCB Duration}, \quad D_Z(0;T) = -\frac{1}{Z}\frac{dZ}{dy} \tag{1}$$

1. Deterministic Continuous case

$$\text{ZCB Value}, \quad Z(0;T) = e^{-yT} \tag{2}$$

(assume, ZCB Principal = 1, @T)

differentiating **(2)** with respect to yield y, we get

$$\begin{aligned} \frac{dZ}{dy} &= -Te^{-yT} \\ &= -TZ \end{aligned} \tag{3}$$

substituting **(3)** back in **(1)**, we get

$$\begin{aligned} D_Z(0;T) &= -\frac{1}{Z} \times (-TZ) \\ &= T \end{aligned}$$

2. Deterministic Discrete case

$$\text{ZCB Value}, \quad Z(0;T) = \frac{1}{(1+y)^T} \tag{4}$$

(assume, ZCB Principal = 1, @T)

differentiating **(4)** with respect to yield y, we get

$$\begin{aligned}\frac{dZ}{dy} &= -T \times \frac{1}{(1+y)^{T+1}} \\ &= \frac{-TZ}{(1+y)}\end{aligned} \tag{5}$$

substituting **(5)** back in **(1)**, we get

$$\begin{aligned}D_Z(0;T) &= -\frac{1}{Z} \times \frac{-TZ}{(1+y)} \\ &= \frac{T}{(1+y)}\end{aligned}$$

B. Convexity

$$\text{ZCB Convexity}, \quad C_Z(0;T) = \frac{1}{Z}\frac{d^2Z}{dy^2} \tag{6}$$

1. Deterministic Continuous case

Since we require second derivative as per the convexity formula, we differentiate **(3)** with respect to yield y

$$\begin{aligned}\frac{d^2Z}{dy^2} &= T^2 e^{-yT} \\ &= T^2 Z\end{aligned} \tag{7}$$

substituting **(7)** back in **(6)**, we get

$$\begin{aligned}C_Z(0;T) &= \frac{1}{Z} \times T^2 Z \\ &= T^2\end{aligned}$$

2. Deterministic Discrete case

Since we require second derivative as per the convexity formula, we differentiate **(5)** with respect to yield y

$$\begin{aligned}\frac{d^2Z}{dy^2} &= \frac{T(T+1)}{(1+y)^{T+2}} \\ &= \frac{T(T+1)Z}{(1+y)^2}\end{aligned} \tag{8}$$

substituting **(8)** back in **(6)**, we get

$$\begin{aligned} C_Z(0;T) &= \frac{1}{Z} \times \frac{T(T+1)Z}{(1+y)^2} \\ &= \frac{T(T+1)}{(1+y)^2} \end{aligned}$$

II : Coupon Bearing Bond or CBB

A. Duration

$$\text{CBB Duration,} \quad D_B(t;T) = -\frac{1}{B}\frac{dB}{dy} \tag{9}$$

1. Deterministic Continuous case

$$\text{CBB Value,} \quad B(t;T) = P_T e^{-y(T-t)} + \sum_{\substack{i=1 \\ t_i>t}}^{N} C_i e^{-y(t_i-t)} \tag{10}$$

differentiating **(10)** with respect to yield y, we get

$$\frac{dB}{dy} = -P_T(T-t)e^{-y(T-t)} + \sum_{\substack{i=1 \\ t_i>t}}^{N} -(t_i-t)C_i e^{-y(t_i-t)} \tag{11}$$

On dividing both sides with -B(t;T) in **(11)**, we get

$$\begin{aligned} -\frac{1}{B}\frac{dB}{dy} &= (T-t)\left[\frac{-P_T e^{-y(T-t)}}{B(t;T)}\right] + \sum_{\substack{i=1 \\ t_i>t}}^{N} -(t_i-t)\left[\frac{C_i e^{-y(t_i-t)}}{B(t;T)}\right] \\ &= D_B(t;T) \end{aligned}$$

2. Deterministic Discrete case

$$\text{CBB Value,} \quad B(t;T) = \frac{P_T}{(1+y)^{(T-t)}} + \sum_{\substack{i=1 \\ t_i>t}}^{N} \frac{C_i}{(1+y)^{(t_i-t)}} \tag{12}$$

differentiating **(12)** with respect to yield y, we get

$$\frac{dB}{dy} = \frac{-P_T(T-t)}{(1+y)^{(T-t+1)}} + \sum_{\substack{i=1 \\ t_i>t}}^{N} \frac{-(t_i-t)C_i}{(1+y)^{(t_i-t+1)}} \tag{13}$$

On dividing both sides with -B(t;T) in **(13)**, we get

$$-\frac{1}{B}\frac{dB}{dy} = \frac{(T-t)}{(1+y)}\left[\frac{P_T}{B(t;T)(1+y)^{(T-t)})}\right] + \sum_{\substack{i=1 \\ t_i>t}}^{N}\frac{(t_i-t)}{(1+y)}\left[\frac{C_i}{B(t;T)(1+y)^{(t_i-t)}}\right]$$

$$= D_B(t;T)$$

B. Convexity

$$\text{CBB Convexity,} \quad C_B(t;T) = \frac{1}{B}\frac{d^2B}{dy^2} \tag{14}$$

1. Deterministic Continuous case

Since we require second derivative as per the convexity formula, we differentiate **(11)** with respect to yield y

$$\frac{d^2B}{dy^2} = P_T(T-t)^2e^{-y(T-t)} + \sum_{\substack{i=1 \\ t_i>t}}^{N}(t_i-t)^2C_ie^{-y(t_i-t)} \tag{15}$$

Upon dividing both sides with B(t;T) in **(15)**, we get

$$\frac{1}{B}\frac{d^2B}{dy^2} = (T-t)^2\left[\frac{-P_Te^{-y(T-t)}}{B(t;T)}\right] + \sum_{\substack{i=1 \\ t_i>t}}^{N}(t_i-t)^2\left[\frac{C_ie^{-y(t_i-t)}}{B(t;T)}\right]$$

$$= C_B(t;T)$$

2. Deterministic Discrete case

Since we require second derivative as per the convexity formula, we differentiate **(13)** with respect to yield y

$$\frac{d^2B}{dy} = \frac{P_T(T-t)(T-t+1}{(1+y)^{(T-t+2)}} + \sum_{\substack{i=1 \\ t_i>t}}^{N}\frac{(t_i-t)(t_i-t+1C_i}{(1+y)^{(t_i-t+2)}} \tag{16}$$

Upon dividing both sides with B(t;T) in **(16)**, we get

$$\frac{d^2B}{Bdy^2} = \frac{(T-t)(T-t+1)}{(1+y)^2}\left[\frac{P_T}{B(t;T)(1+y)^{(T-t)}}\right] + \sum_{\substack{i=1 \\ t_i>t}}^{N} \frac{(t_i-t)(t_i-t+1)}{(1+y)^2}\left[\frac{C_i}{B(t;T)(1+y)^{(t_i-t)}}\right]$$

$$= C_B(t;T)$$

2 Research and Explain:

2.1 Effective Fed Fund Rates

Banks and other depository institutions in the United States usually have a regulatory requirement to maintain a percentage of their deposit liabilities as reserve balance. The reserve balance requirement primarily consists of cash physically held by a bank (also known as vault cash) and the bank's balance held in its account with the central bank.

The reserve requirements of depository institutions are constantly changing as deposits are added and withdrawn on a daily basis. As such, banks with deficit reserve balance will often need to borrow from other depository institutions with a surplus balance in order to meet regulators' minimum reserve requirements. The federal funds rate is the rate at which depository institutions

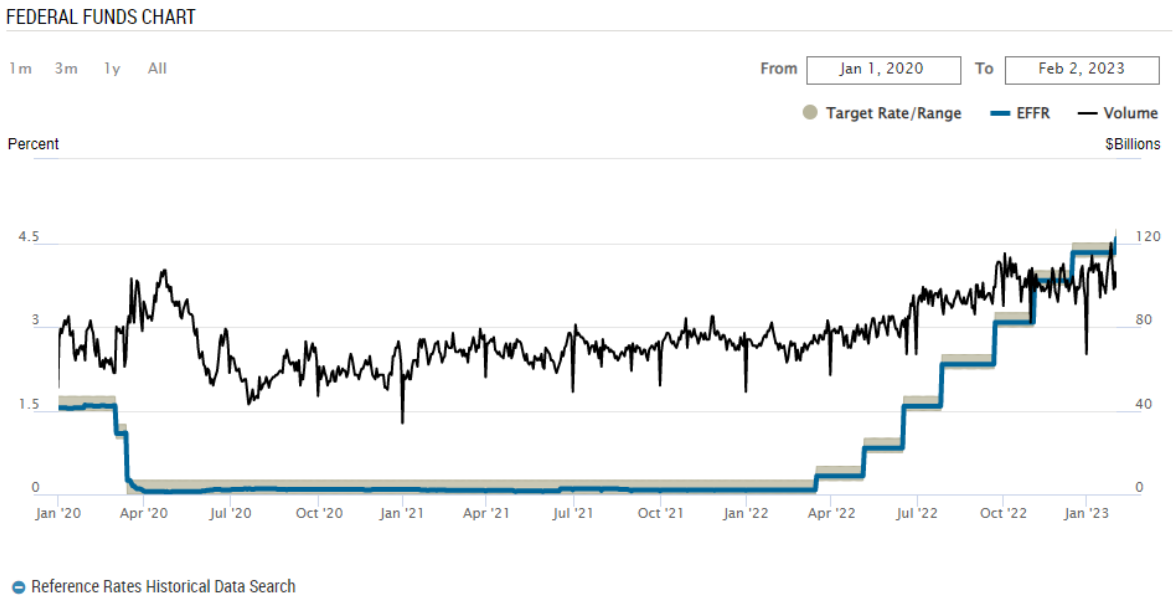

Figure 1: EFFR vs Target rate.
Source: https://www.newyorkfed.org/markets/reference-rates/effr

lend these reserves to other depository institutions overnight on an uncollateralized basis. EFFR or the Effective Federal Funds rate is calculated as the volume weighted median of these overnight

federal funds transactions. Note that The NY Fed publishes the EFFR for the prior business day on the New York Fed's website at approximately 9:00 a.m. The Federal Open Market Committee establishes the target rate, for trading in the federal funds market.

2.2 Fed Fund Target Rate (FFTR and the FOMC)

The FOMC or the Federal Open Market Committee consists of twelve members–the seven members of the Board of Governors of the Federal Reserve System; the president of the Federal Reserve Bank of New York; and four of the remaining eleven Reserve Bank presidents, who serve one-year terms on a rotating basis.

The federal funds target rate is the target range for the federal funds rate set by the FOMC. As the federal funds target rate is a range, therefore, it has an upper and lower limit. The current federal funds rate is between 4.25% to 4.50%.

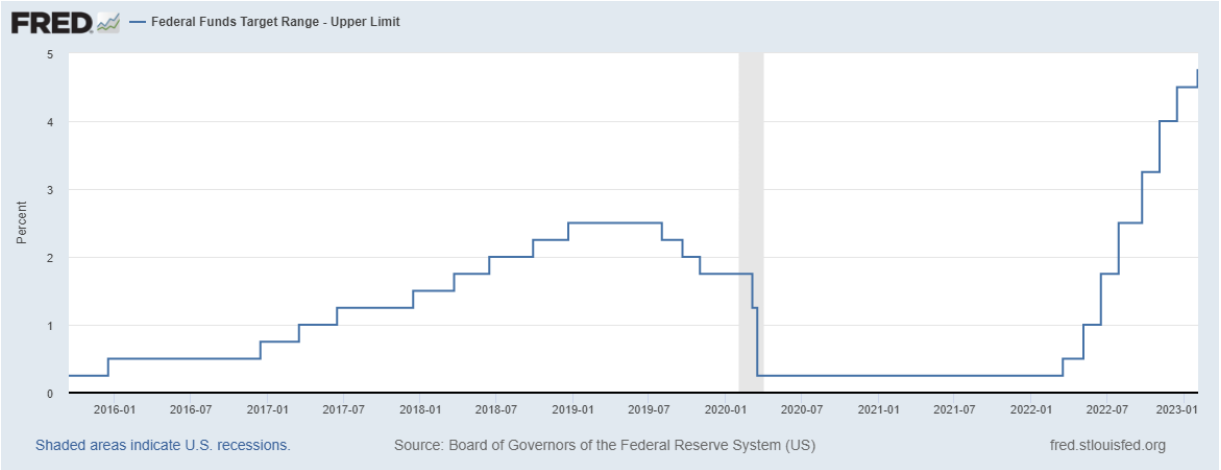

Figure 2: FRED Economic data : St Louis FED.
Source: https://fred.stlouisfed.org/series/DFEDTARU

The target rate is determined eight times a year in FOMC meetings, but it may be adjusted more often depending on the economic landscape at the time. The effective and target rates do not always coincide. The Federal Reserve may engage in open market operations (buying or selling the US Treasury securities) to eliminate the discrepancy between the two rates. The federal funds target rate is used as a benchmark for overnight interest rates, and the Federal Reserve uses its monetary policy tools to influence the federal funds rate to help achieve its policy objectives.

2.3 Fed Discount Rate (FDR, aka base rate, aka repo rate). Detail primary credit rate, secondary credit rate, and seasonal credit rate.

Depository institutions (banks, credit unions, etc.) may need to borrow money in the short term to support their cash positions, maintain liquidity, and even shore up reserve balances. The rate at which these institutions can borrow from the Fed through the Federal Reserves' lending facility–the discount window, is known as the discount rate. All discount window loans are fully secured (i.e. collateralised). Note that discount rate can also be used to shore up reserve balance; however, as banks will not likely borrow at a higher rate than they can borrow from the Fed, the discount rate acts as a ceiling for the federal funds rate.

The Federal Reserve Banks offer three types of discount window credit to depository institutions: primary credit, secondary credit, and seasonal credit, each with its own interest rate (i.e. discount rate).

Primary credit is a lending program which serves as the principal safety valve for ensuring adequate liquidity in the banking system. Only depository institutions that are in generally sound financial condition can avail of this program, and there are no restrictions on the use of funds borrowed under it. Primary credit is priced relative to the Federal Funds Target rate set by the FOMC.

Secondary credit is the lending program under which the Federal Reserve serves eligible financial institutions that do not qualify for primary credit (i.e. banks that are in financial trouble and/or are experiencing severe liquidity problems). It is extended on a very short-term basis, typically overnight, at a higher rate than the primary credit rate (usually 50bps). This program entails a higher level of Fed oversight than the primary credit program with higher haircuts on collateral pledged to secure secondary credit.

Seasonal credit is the lending program that provides a reliable credit source to small depository institutions (deposits of $500 million or less) to help manage demonstrated liquidity pressures caused by significant seasonal swings in their loans and deposits. Note that critically undercapitalized institutions are usually not eligible for seasonal credit. Institutions that need a temporary boost in funds to meet local borrowing needs– such as those related to farming, resort, municipal financing and other seasonal types of business – frequently qualify for the seasonal credit program. The interest rate applied to seasonal credit is a floating rate based on market rates.

2.4 LIBOR, SOFR, and OIS rate

LIBOR, which is an acronym of London Interbank Offer Rate, refers to the interest rate that UK banks charge other financial institutions for short-term unsecured loans. The loan maturities vary from one day to one year. LIBOR acts as a benchmarking base for short-term interest rates for prices of securities such as currency swaps, interest rate swaps, or mortgages.

Prior to February 2014, LIBOR was administered by the British Bankers' Association, and LIBOR consisted of 150 separate rates (15 maturities and 10 currencies). To calculate the LIBOR rate, a representative panel of global banks submit an estimate of their borrowing costs to the Thomson Reuters data collection service each morning at 11:00 a.m. The calculation agent would throw out the highest and lowest 25 percent of submissions and then averages the remaining rates to determine LIBOR. Calculated for 10 different currencies at 15 different maturity lengths from overnight to one year, LIBOR was the most relied upon global benchmark for short-term interest rates. However, reforms were triggered by controversy over how some banks were reporting the rates at which they "believed" they could borrow and because of some underlying problems with the LIBOR concept.

From 2014, reform recommendations placed LIBOR under the administration of InterContinental Exchange (ICE). Currently, every weekday at about 11 a.m., 17 large banks in London, under the auspices of the ICE Benchmark Administration, report the rate at which they believe they can borrow a "reasonable" amount of dollars from each other in the so-called London interbank market. They report rates for seven borrowing terms that range from overnight to one year as well as five currencies. The four highest and four lowest are thrown out, and the rest are averaged. ICE then announces that average rate at which banks say they can borrow dollars for each of the seven maturities. The average—often referred to in the singular even though there are 35 rates—constitutes the ICE London interbank offered rate (ICE LIBOR).

LIBOR has been in the process of being slowly wound down since 2021. A host of reference rates are being looked at as replacement including SOFR (discussed below).

SOFR which stands for Secured Overnight Financing Rate (SOFR) is a broad measure of the cost of borrowing cash overnight collateralized by Treasury securities. It is defined as the average rate at which institutions can borrow US dollars overnight while posting US Treasury bonds as collateral.

The SOFR is calculated as a volume-weighted median of transaction-level tri-party repo data collected from the Bank of New York Mellon as well as GCF repo transaction data and data on bilateral Treasury repo transactions cleared through FICC's DVP service, which are obtained from the U.S. Department of the Treasury's Office of Financial Research (OFR). Each business day, the New York Fed publishes the SOFR on the New York Fed website at approximately 8:00 a.m. ET. The SOFR is intended to replace the US dollar London Interbank Rate (USD LIBOR) in future financial contracts as a benchmark interest rate. It was selected as a replacement rate by the Alternative Reference Rates Committee (ARRC) chaired by the New York Federal Reserve in 2017. The SOFR differs from US LIBOR in that while the former is a secured borrowing rate, the latter is a rate for unsecured borrowing (where no collateral is posted).

A standard Overnight Indexed Swap (OIS) is a fixed/floating interest rate swap where the periodic fixed payments are tied to a given fixed rate while the periodic floating payments are tied to a floating rate calculated from a daily compounded overnight rate over the floating coupon period. **OIS rate** is the floating rate in this swap which is calculated as the overnight compounding of the short-term risk free rate such EFFR for USD (unsecured) or SOFR (secured). OIS rates in other currencies are referenced by the corresponding overnight rates such as EONIA (Euro Overnight Index Average) for EUR or SONIA (Sterling Overnight Index Average for GBP).

2.5 How is OIS rate calculated?

Following the great financial crisis, the OIS rate (R) became the ubiquitous risk free rate in the markets. In an OIS swap, the floating rate is an overnight compounding of the short-term risk free rate rt (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. Formula for calculating OIS rate is given below

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

2.6 What changed a couple of years ago in the OIS calculation (alternative leg)?

A few years ago in 2018, the Alternative Rates Reference Committee decided to green flag trading in the first derivatives instruments in OIS that reference SOFR. This was part of building liquidity in the SOFR as replacement rate for LIBOR in derivatives market. Prior to this, OIS had been referencing EFFR.

2.7 What is the TED spread?

TED spread is an acronym for the Treasury-EuroDollar spread. TED spread is the difference between the interest rate on short-term U.S. government debt and the interest rate on interbank loans. The TED spread is a widely used measure of credit risk in the financial market. The TED spread is commonly used as an indicator of the financial health of the economy and reflects the perceived risk of default on interbank loans.

Calculation: The TED spread is calculated as the difference between the three-month LIBOR and the three-month Treasury bill rate. The Treasury bill rate is considered to be risk-free, and the LIBOR is the unsecured rate at which banks lend to each other and therefore captures credit risk.

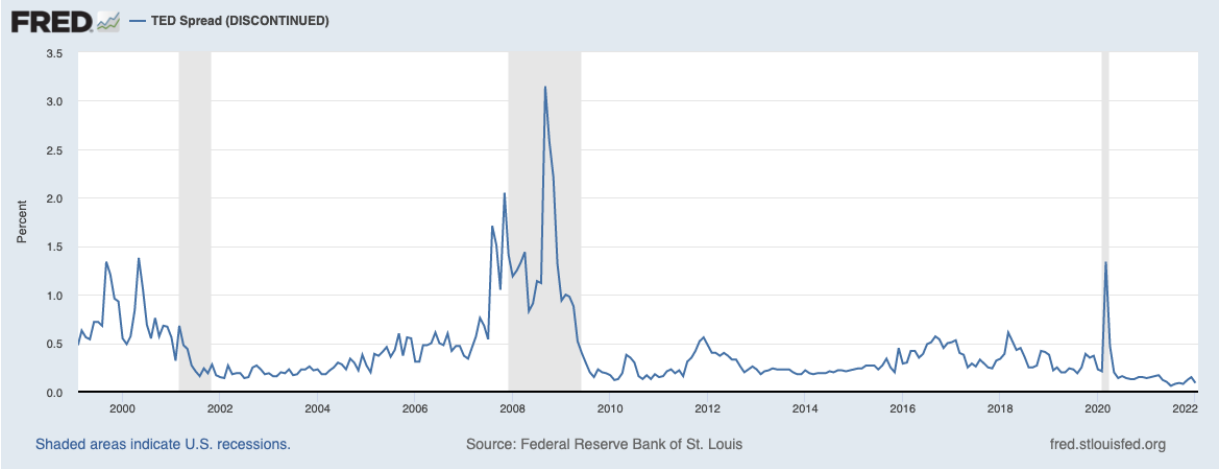

Figure 3: TED spread 2001-21.
Source: https://fred.stlouisfed.org/series/TEDRATE

Fluctuation: The TED spread fluctuates over time, but generally has remained within a range of 10 and 50 basis points (0.1% and 0.5%) except in times of financial crisis. In such periods, the spread often widens as the default risk increases, indicating that liquidity is being withdrawn from the market. Conversely, a narrow spread suggests stability in the economy and declining default risk.

Impact on the Market: A rising TED spread is often a sign of a downturn in the U.S. stock market, as it suggests increased credit risk in the economy. Conversely, a declining TED spread is indicative of improved financial stability and a better investment climate, leading to an increase in investments in the stock market.

The Intercontinental Exchange (ICE), the authority responsible for LIBOR, has announced that all contracts using LIBOR should be wrapped up by June 2023. Hence, banks are transitioning

away from LIBOR and may use a different rate in the future. Therefore, TED spread will become less relevant in the future as measure of credit risk in the financial system.

3 About LIBOR & SOFR (see Wilmott Article on LIBOR)

3.1 What is the origin of LIBOR? SOFR ?

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 dollar 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.

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. By 2011, BBA's LIBOR published term rates for ten currencies with fifteen tenors spanning from one day to one year.

SOFR's origin are in the downfall of LIBOR. Following the LIBOR misconducts and the multiple reviews from Financial governing bodies that followed, 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. 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 as replacement for LIBOR. 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.

3.2 How long has it been around and for what purpose?

As mentioned in the previous section, LIBOR, and other "IBORs", originated in the 60s with term rates on syndicated loans, then they grew essentially from usage in the Eurocurrency markets. So they had been around for more than 50 years before their subsequent phase off started. Their main purpose is three-fold:

1. LIBOR was the reference rates for unsecured wholesale funding.

2. LIBOR was the benchmarks for most floating rate cash instruments, such as in loans, bonds and structured products.

3. LIBOR was 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.

3.3 What are the volumes and volatility of LIBOR cash market for USD O/N, 3M, 6M? What are the volumes of SOFR? How are LIBOR and SOFR calculated?

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). As of March 2016, LIBOR had almost $8T exposure in the Cash market across various maturities (see figure below).

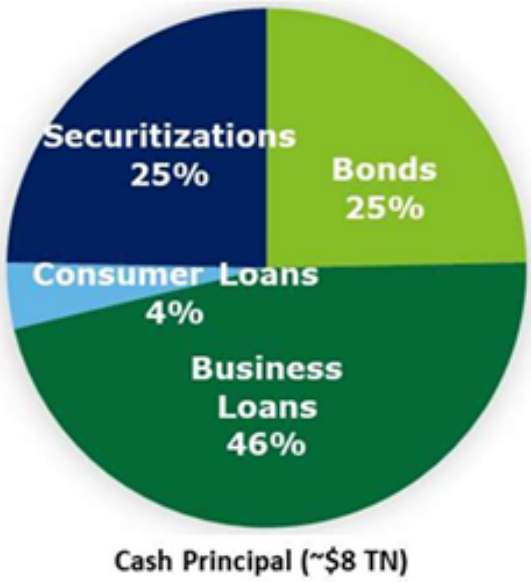

Figure 4: Outstanding Exposures for USD LIBOR in Cash market.
Source: NYFRB, Second Report of the Alternative Reference Rate Committee, March 2016
https://fred.stlouisfed.org/categories/22

Historical volatility for LIBOR Overnight and 3m tenor have been shown in graph below in comparison with that of SOFR. SOFR seems to be much more volatile than LIBOR in both maturities.

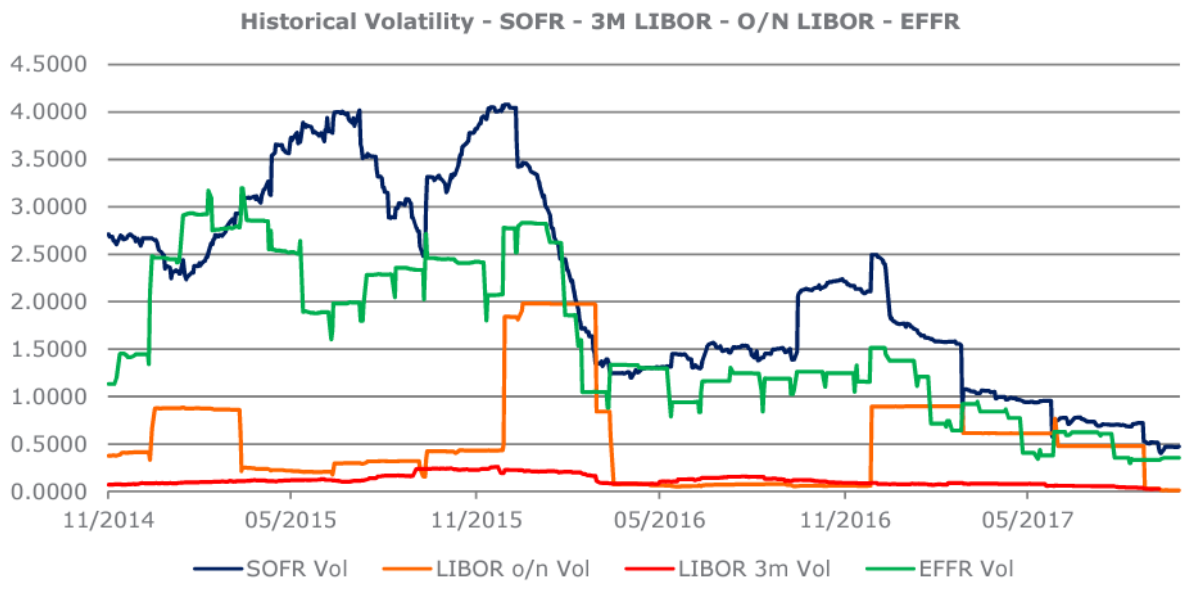

Figure 5: Historical Volatility Comparison between SOFR and LIBOR
Source: ICE Benchmark Administration Limited(IBA)
https://fred.stlouisfed.org/categories/22

SOFR derivatives market is emerging, with CME's 1-month and 3month 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

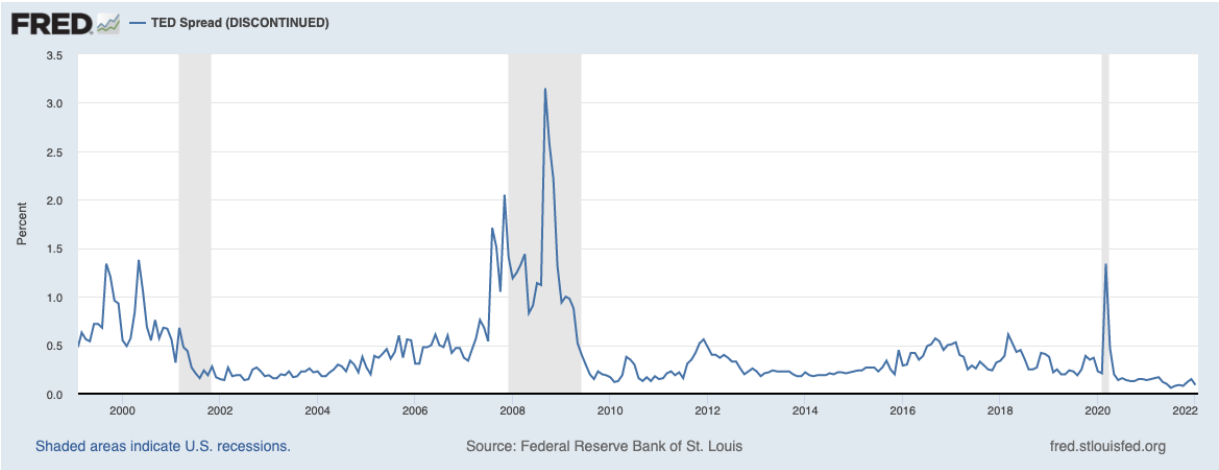

Figure 6: Transaction Volumes Underlying SOFR
Source: ICE Benchmark Administration Limited(IBA)
https://fred.stlouisfed.org/categories/22

daily notional trading, with up to 12,000 contracts in open interest.

LIBOR calculation:

ICE Benchmark Administration (IBA) became the administrator of LIBOR in 2014, implementing the FCA's reforms with Panel Banks and regulators. 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 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.

SOFR calculation:

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.

3.4 What is the Eurodollar LIBOR Derivatives market, and what size is it? (answer for USD, and globally in aggregate, see Basel/BIS for reports)

Eurodollar LIBOR derivatives market which comprises of derivative securities such as futures and options where the underlying reference rate is USD LIBOR. In the ARRC's Second Report, the ARRC estimated that, as of the end of 2016, there were $199 trillion in outstanding exposures to USD LIBOR. Most of this (95 percent) arose from derivatives referencing USD LIBOR.

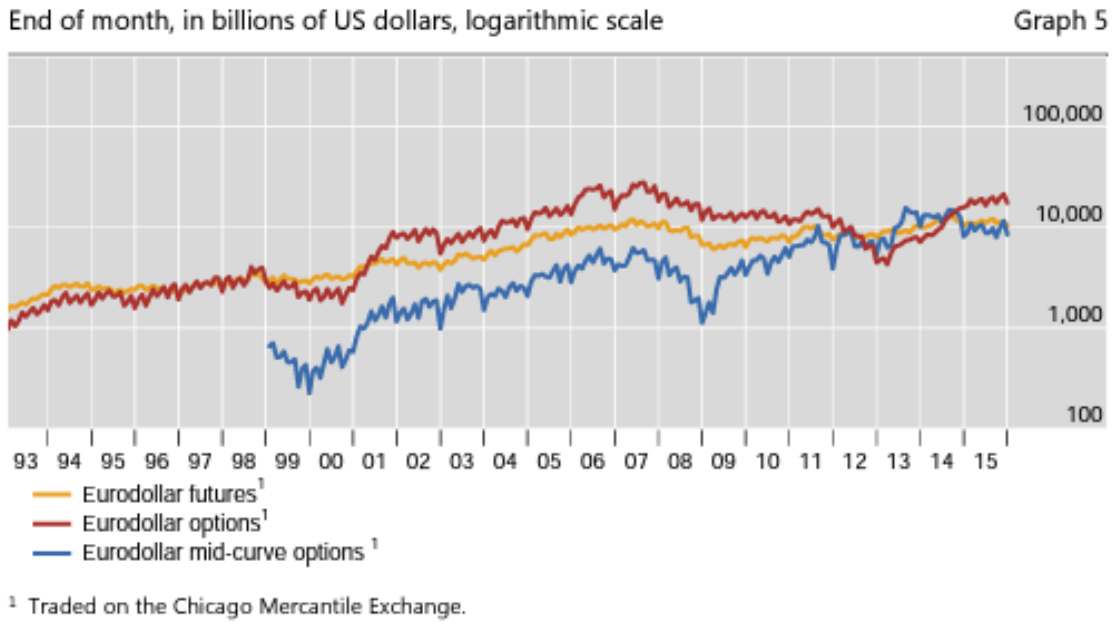

Figure 7: Open interest in eurodollar futures and options
Source: BIS Working Papers No 578
https://www.bis.org/publ/work578.pdf

As of July 2018, the CME had about $5B in daily notional trading, with up to 12,000 contracts in open interest.

3.5 Explain what happened during the 2008 LIBOR crisis (Wheatley Review, 2012).

Barclays and fifteen other global financial institutions came under investigation by a handful of regulatory authorities—including those of the United States, Canada, Japan, Switzerland, and the UK—for colluding to manipulate the Libor rate beginning in 2003. Barclays reportedly first manipulated Libor during the global economic upswing of 2005–2007 so that its traders could make profits on derivatives pegged to the base rate. The FSA subsequently fined Barclays Bank plc £59.5 million for significant failings relating to LIBOR and EURIBOR.

One of the first impacts of the Libor investigation was to raise questions over the role of central banks, in particular the Bank of England, in failing to address, or even abetting, problems with the system. The New York Fed had communicated its concerns over Libor manipulation to the Bank of England in 2008, and had suggested reforms to the system that weren't followed up. Then in 2012 post LIBOR crisis, Bank of England officials strenuously denied allegations that the central bank had encouraged some UK banks to underreport their borrowing costs at the height of the 2008 crisis.

Subsequent changes to Libor were based on the recommendations of a UK government report led by UK financier Martin Wheatley, who became the first head of the newly founded Financial Conduct Authority (FCA).

The wheatley review had a number findings, we list a salient few below -

1. **Failures of the current LIBOR regime:** LIBOR is a representation of unsecured inter-bank borrowing costs,and it involves an element of judgement and inference on the part of the contributor bank. This requires a discretion which can be misused. Some contributing banks have sought to exploit the conflicts of interest that arose from their respective roles as contributor to the rate, user of the rate, and wider participant in the market. This is obvious as contributing banks are both users of and contributors to LIBOR.

2. **Weaknesses in the LIBOR mechanism:** There is no method to corroborate the submissions as the rates are not based on market transactions

3. **Limitations in the existing governance and regulation framework:** There is no centralised oversight for LIBOR, with day to day running looked after by BBA and data collection, checks and publishing being done by Thomas Reuters. There were also more issues with transparency and internal compliance processes within these organisations.

3.6 Who regulates and who administers LIBOR before and after? Why (see BBA, FCA, ICE, IBA)? Explain the different roles of each one.

Although LIBOR had been around since the 60s, it was only a few decades later that BBA took control over its administration. 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. By 2011, BBA's LIBOR published term rates for ten currencies with fifteen tenors spanning from one day to one year. Prior to the crisis, LIBOR was administered by the BBA, but the regulatory framework at the time did not allow the Financial Services Agency (FSA) to regulate activities related to LIBOR. Actually, the activities of contributing to or administering LIBOR (or any similar benchmark) were not deemed "regulated activities" as defined under the Financial Services and Markets Act 2000 (FSMA) at the time of the crisis. LIBOR activities were therefore, in essence, self-regulated by the BBA.

However, post 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.

FCA is currently responsible for regulating and managing the LIBOR transition and subsequent wind down. It was set up on 1 April 2013, taking over conduct and relevant prudential regulation from the Financial Services Authority (FSA). The IBA was originally a unit of NYSE Euronext, which won the contract to run and administrate the LIBOR benchmark rate calculation process after the rate manipulation scandal. The **InterContinental Exchange (ICE)**, which is a global exchange, clearing, financial data and technology company, took the unit over from NYSE Euronext when ICE acquired the company, renaming it the ICE Benchmark Administration. IBA is the current benchmark administrator for LIBOR and publishes LIBOR midday in London, based on IBA's trimmed arithmetic mean of submissions from 11 to 16 banks for any given currency.

3.7 What are and how does the IBA address LIBOR's Issues?

The Intercontinental Exchange (ICE) took over the administration of LIBOR from the British Bankers' Association (BBA) in 2013. The IBA (Intercontinental Exchange Benchmark Administration) was created by ICE to address the issues with LIBOR, which was previously self-regulated by the BBA. IBA became responsible for implementing the FCA's reforms with Panel Banks and

regulators.

Significant issues around the failure of LIBOR's regime, methodology and governance were found in teh Wheatley review of 2012 (Please refer to section 3.5 for more details). The IBA aims to improve the credibility, transparency, and accountability of LIBOR by implementing a number of changes to the benchmark's methodology, governance, and oversight. These changes include:

- Strengthening the calculation methodology by reducing the discretion of the banks that submit rates and increasing the use of observable transactions.
- Improving governance by creating a new Oversight Committee and a new Code of Conduct for the Panel Banks.
- Enhancing transparency by publishing more detailed information about the calculation process and the underlying data.
- Strengthening the regulatory oversight of LIBOR by the Financial Conduct Authority (FCA).
- Enhancing governance framework by specifically putting in place a committee for the independent challenge of LIBOR's operations, as well as a waterfall methodology with governance and controls around the production of LIBORs.

The IBA's efforts to address the issues with LIBOR have been widely recognized and praised by market participants, regulators, and other stakeholders. However, there is still more work to be done to ensure that LIBOR remains a robust and reliable benchmark for financial contracts.

3.8 Are IBA solutions viable in the long term and why?

The viability of IBA's solutions to address the issues with LIBOR in the long term is not clear. The IBA has made significant efforts to improve the robustness and reliability of the benchmark, but there are still challenges and limitations to its methodology, particularly for some currency-tenor pairs where there is a lack of a liquid market. The lack of transaction data has been addressed through the use of expert judgment and an objective methodology, but this approach may not be sustainable in the long term. The IOSCO (International Organization of Securities Commissions) has recommended that currency workgroups identify new or existing IOSCO

compliant ARRs benchmarks to replace IBORs in certain contracts and proposes a plan for fall-back rates and a phased transition away from IBORs. Market participants are also developing alternative benchmarks to minimize disruptions in case of the permanent cessation of LIBOR publication. Whether the IBA's solutions are viable in the long term will depend on the success of these efforts and the ability to maintain trust in the benchmark.

3.9 What are the criteria for IOSCO acceptable benchmarks? IOSCO Benchmark Report

International Organization of Securities Commissions (IOSCO),is an association of organizations that regulate the world's securities and futures markets. Members are typically primary securities and/or futures regulators in a national jurisdiction or the main financial regulator from each country.

In 2013, IOSCO published P̈rinciples for Financial Benchmarks (Final Report) ;̈ which sets out Principles that are intended to create an overarching framework of standards for Benchmarks used in financial markets. Specifically, the IOSCO Board sought to articulate policy guidance that addresses conflicts of interest in Benchmark-setting processes, as well as transparency and openness when considering issues related to Benchmark transition.

The Principles address Benchmark governance, Benchmark and Methodology quality and accountability mechanisms. IOSCO acceptable benchmarks should satisfy following criteria under each of these principles listed below -

1. **benchmark quality :** The Principles pertaining to this are intended to promote the quality and integrity of Benchmark determinations through the application of design factors that result in a Benchmark that reflects a credible market for the Interest measured by that Benchmark. Criteria for this may include liquidity, transaction volume, resilience through period of illiquidity or resilience through changes in the regulatory environment or in the monetary policy framework.

2. **methodological quality :** The Principles pertaining to this are intended to promote the quality and integrity of Methodologies by setting out minimum information that should be addressed within a Methodology. The Principles require that information be Published or Made Available so that Stakeholders may understand and make their own judgments concerning the overall credibility of a Benchmark; this includes version control. Criteria

for this may include standardized data terms, transparency and availability of current and historical data.

3. **accountability :** The Principles pertaining to this require that administrators establish complaints processes, documentation standards and audit reviews intended to provide evidence of compliance by the Administrator with its quality standards, as defined by the Principles and its own policies.

4. **governance :** The Principles pertaining to this are intended to ensure that administrators have appropriate governance arrangements in place to protect the integrity of the Benchmark determination process and to address conflicts of interest.

3.10 Explain similarities and differences between SOFR, SONIA, SARON, TONA, ESTER.

SOFR, SONIA, SARON, TONA, and ESTER are all benchmark reference interest rates used to measure and track the cost of borrowing money in different countries.

Similarities:

- They are all overnight rates, meaning they measure the cost of borrowing and lending overnight. Additionally, they are all used as reference rates in financial contracts, including futures and derivatives, and are used to price a wide range of financial products.

- They are all benchmark rates that are based on actual market transactions and therefore reflect the market's consensus on the cost of borrowing and lending. This makes them more reliable and transparent compared to benchmark rates that are based on estimates.

- They are all administered by central banks or organizations with close ties to central banks, which provides an additional layer of credibility and oversight to their determination process.

Differences:

- Different benchmark rates can also have different historical trends, reflecting the unique characteristics of the underlying markets and participants.

- SOFR is primarily in the United States, while SONIA is used in the United Kingdom, SARON in Switzerland, TONA in Tokyo, and ESTER in the Eurozone

- The underlying currency for each rate is different - SOFR(USD), SONIA(GBP), SARON(CHF), TONA(JPY), ESTER (EUR).
- While SOFR and SARON are secured borrowing rates, SONIA, TONA and ESTER are unsecured borrowing rates.

3.11 What are the two key differences between $-LIBOR and SOFR? How do they impact the Cash product market? How does it impact the Derivatives market?

LIBOR (London Interbank Offered Rate) and SOFR (Secured Overnight Financing Rate) are two important benchmark interest rates used in financial markets. The two key differences between them are:

1. **Calculation methodology:**LIBOR is based on a survey of a panel of banks and reflects their estimate of the cost of borrowing from other banks, whereas SOFR is based on actual transactions and reflects the cost of borrowing cash collateralized by Treasury securities.
2. **Credit risk:** LIBOR includes a credit risk component that reflects the perceived creditworthiness of the borrowing bank, whereas SOFR does not, as it is based on transactions that are collateralized.

The impact of these differences on the Cash product market and the Derivatives market is significant:

- **Cash product market:**The transition from LIBOR to SOFR is expected to have a major impact on the cash product market, particularly in the US, as SOFR is a more accurate reflection of the cost of borrowing cash overnight and is expected to provide more stability and transparency to the market. However, ARRC has provided guidance for a robust LIBOR fallback contract language , primarily aimed toward newly issued cash products such as business loans, securitizations, or floating rate notes previously referencing LIBOR. Contract fallback language should reduce disruptions, such as valuation changes or litigation risk, and include specific triggers to successor rate(s). However, amending contracts with fallback language may also lead to increased transition costs or operational risk.
- **Derivatives market:** The transition from LIBOR to SOFR is also expected to impact the derivatives market, as many financial products, such as interest rate swaps and futures,

are based on LIBOR. The change to SOFR will require these products to be repriced and potentially restated to reflect the new benchmark rate. This may result in significant operational and compliance challenges for market participants.

In conclusion, the transition from LIBOR to SOFR is a significant event for the financial markets and will have far-reaching consequences for cash product and derivatives markets.

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