A User's Guide to AXI & FXI

Credit-spread reference benchmarks for the Secured Overnight Financing Rate

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This User's Guide to AXI & FXI is being made available to interested readers in both the private sector and Official sector to stimulate discussion and elicit comments. This document will be updated over time.

Abstract

This guide explains how market participants can use novel credit-spread reference benchmarks—the Across-the-Curve Credit Spread Index (AXI) and the Financial Conditions Credit Spread Index (FXI)—which work in conjunction with the Secured Overnight Financing Rate (SOFR). The development of AXI and FXI commenced in 2021, following a request from ten U.S. Regional banks for a credit sensitive supplement to SOFR. The indices are underpinned by a broad set of observable transactions from across the maturity curve ranging from overnight to five years, with weights that reflect both transaction and issuance volumes. Referencing this substantially larger pool of market transactions avoids the risks of illiquidity and statistical corruption or manipulation. These credit-spread reference benchmarks have been reliably produced and published under a diverse range of market conditions, including stress events such as the onset of the COVID-19 pandemic in 2020 and the regional banking sector turmoil in 2023. AXI and FXI address specific challenges in bank lending where the absence of a credit sensitive element leads to mismatches between banks' assets and liabilities that can hamper the provision of credit, especially during periods of economic stress. It has been shown that usage of AXI and FXI can mitigate this potential constraint on credit supply. This paper provides an overview of the need for these credit spread reference benchmarks in commercial lending markets, their unique construction design, their potential application in cash products and derivatives markets, and the independent confirmation of compliance with relevant internationally developed and agreed principles for financial benchmarks. The inclusion of AXI and FXI in SOFR-based lending products will enhance the efficiency, transparency, and stability of financial markets in alignment with U.S. policy objectives.

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Contents

1. Introduction

This document describes design considerations for cash products that may potentially incorporate the US Dollar Across-the-Curve Credit Spread Index (AXI) and the US Dollar Financial Conditions Credit Spread Index (FXI)[1] in the future, in combination with near-risk free Secured Overnight Financing Rate (SOFR)[2]. The document also describes design choices for AXI and FXI derivatives such as swaps and futures.

Historically, development of deep cash markets has coincided with the growth of liquid derivatives markets that hedge the associated exposures, and vice versa. Over the counter SOFR swaps have traded since July 2018 while one-and three-month SOFR futures have traded on the Chicago Mercantile Exchange (CME) since March 2018. Together, these derivatives allow for hedging of exposure to SOFR. We believe that adoption of AXI and FXI by financial institutions in cash products will need to be accompanied by a derivatives market that allows participants to risk manage exposures to AXI and FXI spreads.

A recurring theme in this document is the need to align future usage of AXI and FXI spreads in cash and derivative products to current practices in SOFR. Thus, we follow the SOFR user guide[3] closely to match conventions already being followed in cash products that reference SOFR. The proposed designs of AXI and FXI derivatives are based, for the most part, on the specifications of their corresponding SOFR equivalents.

In the following sections, we provide background and context to the introduction of SOFR and the need for AXI and FXI spreads. We justify why we expect demand for AXI and FXI derivatives to follow soon after, or in parallel with, incorporation of AXI and FXI in cash products, which prompts the need for further deliberation among stakeholders about design alternatives for these derivatives. We explore the details of AXI and FXI's potential incorporation in SOFR-based cash products. Finally, we conclude with a section on AXI and FXI derivatives where we describe potential choices for contract specification.

It is important to highlight that AXI and FXI are credit-spread reference benchmarks and are not interest rates. Therefore, the introduction of AXI and FXI into US-markets will not impact SOFR market liquidity. Furthermore, in a two-benchmark regime comprised of SOFR and AXI or FXI, market participants would trade both SOFR- and AXI or FXI-based instruments. Hence, AXI and FXI can grow without diverting any liquidity from SOFR.[4]

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[1] Berndt, Duffie, and Zhu (2023)

[2] SOFR is published by the Federal Reserve Bank of New York

[3] The Alternative Reference Rate Committee (2021)

[4] Tuckman (2023)

"SOFRx" describes a combination of SOFR plus AXI, a supplemental credit spread that reflects traded levels of investment grade *bank* debt. AXI's companion index, FXI, reflects actual traded levels of all investment grade debt spanning from overnight to 5 yrs and discussed further in Section 6. We use "SOFRy" to describe the combination of SOFR + FXI. SOFRx and SOFRy are SOFR-based rates

2. Background

In the years following the Global Financial Crisis of 2008, doubts were cast on the integrity of the widely followed London Interbank Offered Rate (LIBOR) benchmark due to the secular decline of liquidity in the short-term interbank lending markets, as well as instances of misconduct involving bank LIBOR submissions. After several years of consultations between the official sector and other stakeholders[5], these developments spurred a transition from LIBOR to near risk-free rates as the benchmarks referenced in various financial products. For US-markets, the new benchmark rate is SOFR. A key step during this process was the publication of SOFR by the Federal Reserve Bank of New York in 2018, and the transition was concluded in 2023 with the cessation of the publication of LIBOR.

The original purpose of LIBOR was to measure average bank borrowing costs, which included a risk-free rate component and an embedded spread between bank credit and the risk-free interest rate. A large majority of applications referencing LIBOR were interest rate derivatives that facilitated transfer of risk related to fluctuations in interest rates, which generally had little to do with the bank credit component of LIBOR. As such, the recent transition from LIBOR to SOFR was sufficient for the interest rate derivatives market.[6]

It is a different story, however, for lending applications that appear on bank balance sheets. For those, the rates need to reference the general level of interest rates (such as SOFR) *and* a spread component that reflects a bank's funding costs to minimize a potential mismatch between a bank's assets and liabilities, particularly in times of market stress.

In September 2019, a group of bank representatives wrote to banking regulators[7] reflecting these concerns. In response, the official sector convened a Credit Sensitivity Group (CSG) which, in a series of workshops, discussed issues related to designing and implementing

[5] For example, see the Final Report of the Market Participants Group on Reforming Interest Rate Benchmarks (Financial Stability Board, 2014)
[6] Duffie and Stein (2015)
[7] Marshall (2019)

credit-sensitive spreads that could be added to SOFR. The AXI and FXI spreads are two such measures and were conceived jointly by academics from the Stanford Graduate School of Business and the Australian National University[8] to assist with the US-dollar LIBOR transition.

3. Need for AXI and FXI Spreads and Derivatives

In this section, we provide more justification and intuition for the necessity of credit spread indices such as AXI and FXI and their associated derivatives. As noted above, a group of bank representatives wrote to regulators in 2019 to request the creation of a SOFR-based lending framework that included a credit risk premium. They stated:

> *"During times of economic stress, SOFR (unlike LIBOR) will likely decrease disproportionately relative to other market rates as investors seek the safe haven of US Treasury securities. In that event, the return on banks' SOFR-linked loans would decline, while banks' unhedged cost of funds would increase, thus creating a significant mismatch between bank assets (loans) and liabilities (borrowings). We believe a sensible and practical way to address these risks is to create a SOFR-based lending framework that includes a credit risk premium."*

Intuitively, banks deal in credit risk. They borrow at relatively low deposit rates (aided in part by federal deposit insurance), lend at higher rates, and capture the spread as a source of revenue. Bank leverage in the U.S. is typically in excess of 10:1. Regulatory capital requirements and other oversight mechanisms serve to limit related risks.

In a SOFR-only paradigm, levered balance sheets cause unique difficulties for banks in times of economic stress. Banks can face increased funding costs due to wider credit spreads which are not offset by proportionately higher loan asset yields, since SOFR—unlike LIBOR—does not include a credit risk premium. Leverage has the unfortunate effect of magnifying these asset-liability mismatches at the worst possible times, but the inclusion of a credit spread index in lending applications mitigates this incongruity.[9]

Next, we explain why the market for credit spread index derivatives will likely emerge and grow as an inevitable consequence of growth in SOFR cash products that reference these indices. It's historically been the case that regulatory developments and/or commercial needs have driven the growth of derivatives to manage risks associated with underlying cash markets in

[8] Berndt, Duffie, and Zhu (2023)

[9] Ghamami (2023)

various asset classes. Thus began a virtuous cycle wherein growth in derivatives drove more liquidity in the cash markets, since participants could hedge fluctuations in the underlying by transferring those risks from entities less willing to manage them. We list a few examples from recent history[10] below:

- The adoption of a target for money growth by the Federal Reserve in 1979 led to increased interest-rate volatility of Treasury bonds. That, in turn, raised the demand for CME treasury futures to hedge adverse movements in interest rates.
- Starting in 1994, the Federal Open Market Committee (FOMC) began to explicitly state its target level for the federal funds rate. That change spurred the growth of derivatives on the federal funds rates.
- The collapse of the Bretton Woods system of fixed exchange rates in 1971 increased the demand for hedging exchange rate risk. The CME allowed trading in currency futures in the following year.
- The increased reliance of most major international banks on the Eurodollar market for short term funds (and their role as market makers in Eurodollar deposits) drove the growth in Eurodollar futures trading for hedging purposes. Similarly, expansion in interest rate swap trading in the 1980s was another factor in the rise of the Eurodollar futures market. Since interest rate swap contracts usually referenced three- or six-month LIBOR, swap market dealers used Eurodollar futures to hedge their positions.
- The numerous emerging market financial crises in the 1990s were often accompanied by a sharp rise in corporate bankruptcies, dramatically increasing the demand for derivatives that hedged credit risk by investors globally.

Given these precedents, we believe that incorporating AXI or FXI into cash products will propel the emergence of a corresponding derivatives market in AXI and FXI, including futures and swaps.

4. Financial stability considerations

We begin this section with a review of the relevant literature. Duffie, Dworczak and Zhu (2016) show that the benefits of a benchmark can include raising social surplus by increasing the volume of beneficial trade, facilitating more efficient matching between dealers and customers, and reducing search costs. They also find that benchmarks provide important price transparency, which reduces information asymmetries and in doing so encourage greater market participation.

[10] Chui (2010)

In other related work, Duffie and Stein (2015) discuss the reform of interest-rate benchmark rates, and the natural role of a credit-sensitive reference rate for bank lending applications. Jermann (2019) notes that loans indexed to LIBOR offer lenders insurance against funding shocks and that SOFR does not have this property. Jermann (2021) argues that the credit sensitivity of LIBOR helped lenders during the global financial crisis (GFC) while SOFR—which is not credit sensitive—would not have provided the same support.

More recent work by Cooperman, Duffie, Luck, Wang and Yang (2023)[11] uses data from the Federal Reserve's FR2052a report and Y14Q data collection to show that the inclusion of a credit sensitive element in the base rate of revolving lines of credit (the primary form of lending in the United States) enhances the efficiency, transparency, and stability of U.S. financial markets. They found that a credit sensitive element promotes the provision of credit by banks and lowers the expected overall average cost of financing for borrowers.

Banks, Khairnar and Sian (2024) show that a reduction in the supply of credit that is greater than warranted by the changes in the macroeconomic outlook can exacerbate a downturn in the economy, and lead to further defaults. For example, if businesses cut spending and employment, this could potentially amplify an economic slump.

The ability of American borrowers to access funding in difficult times is crucial to avoiding financial distress, with banks playing a key role as liquidity providers. A dampening of credit supply is a serious concern because it is linked to economic growth and financial stability. The inclusion of a reliable credit sensitive element would appear to be consistent with U.S. Official sector policy goals. Federal Reserve Vice Chair for Supervision Michael S. Barr recently stated that "it is critical that banks have the capacity to continue lending to households and businesses through times of stress."[12]

It is well-known that credit market stress has macroeconomic consequences. Ghamami (2023) shows that in the absence of sustainable and representative credit benchmarks as supplements to SOFR, the LIBOR-SOFR transition might worsen these macroeconomic consequences. During periods of stress or following macroeconomic shocks, while aggregate bank lending could grow, aggregate firm investment could drop. Ghamami shows that this dynamic could be intensified under large corporate SOFR-linked credit lines due to higher

[11] See related Liberty Street Economics blog, *How the LIBOR Transition Affects the Supply of Revolving Credit* available at https://libertystreeteconomics.newyorkfed.org/2023/02/how-the-libor-transition-affects-the-supply-of-revolving-credit/

[12] See Michael S. Barr, "The Next Steps on Capital" (speech at the Brookings Institution, Washington, D.C., September 10, 2024)

drawdowns. Underlying the boost in aggregate credit growth is a term loan crunch with adverse impact on small to medium-sized enterprises (SMEs). In the absence of robust credit benchmarks as supplements to SOFR, the LIBOR-SOFR transition could exacerbate the credit expansion – investment contraction dynamic and the adverse impact on SMEs during crisis episodes or following macroeconomic shocks.

The next section is based on independent research by Berndt, Duffie and Zhu (2024) who outline the construction of AXI and FXI and show why these indices are robust, representative and sustainable.

5. AXI construction methodology

As described above, the transition from LIBOR to SOFR posed more substantive challenges for SOFR-only lending applications as they can lead to increased asset-liability mismatches on bank balance sheets. AXI credit spreads were developed as a solution to be add-ons to baseline SOFR in such applications and were one of the proposals discussed at the Federal Reserve Bank of New York's Credit Sensitivity Group Workshops.[13]

Large banks no longer fund themselves at LIBOR in the same way that they used to, and there are not enough transactions with which to calculate LIBOR. Regulations have induced banks to "term out" most of their unsecured funding to longer maturities (Committee on the Global Financial System, 2018).[14] The funding structure of global banks has changed significantly since the 2007-2008 financial crisis. Large U.S. banks may continue to further reduce their reliance on less stable short-term wholesale funding. The finalized net stable funding ratio (NSFR) which came into effect in the U.S. is an indication of the continued shift toward more stable and longer-term funding structures (Quarles, 2020).[15]

AXI is a measure of the recent average cost of wholesale unsecured debt funding for publicly listed U.S. bank holding companies and their commercial banking subsidiaries. The index is a weighted average of credit spreads for unsecured debt instruments with maturities ranging from overnight to five years, with weights that reflect both transactions volumes and issuance volume. The goal of the methodology behind AXI spreads is to compute a single spread (not term settings as in LIBOR) that measures the weighted average cost of wholesale

[13] Federal Reserve Bank of New York website - Transition from LIBOR: Credit Sensitivity Group Workshop https://www.newyorkfed.org/newsevents/events/markets/2020/0225-2020.
[14] Report prepared by a Working Group established by the Committee on the Global Financial System - *Structural changes in banking after the crisis.* https://www.bis.org/publ/cgfs60.pdf
[15] https://www.federalreserve.gov/newsevents/speech/files/quarles20201211a.pdf

unsecured debt funding for US banks in maturities from overnight to five years. Criteria satisfied by AXI include:

- Hedging effectiveness: The index is highly correlated with U.S. bank cost of funds, as determined by recent market credit spreads for wholesale unsecured issues of U.S. banks and bank holding companies.
- Robustness: It is computed from a large enough pool of market transactions meaning that the index can be a foundation for actively traded derivatives instruments used by banks and their borrowing customers to hedge their floating rate spread exposures, without significant risk of statistical corruption or manipulation.
- Adaptability to changes in issuance patterns: The index maintains the first two properties within reason, even as banks change the maturity and instrument composition of their issuances in response to changes in regulation and market conditions. For instance, if current funding is weighted towards short term issuances then the spread weights short term higher than long term and vice-versa.

Next, we describe the construction of AXI spreads. Our overview is brief, and further technical details can be found in the original paper and/or at the Benchmark Administrators website.

The AXI spread on a given date is essentially a weighted combination of a short term and a long term spread. The short-term spread is constructed using recent issuances and secondary transactions of commercial paper and certificates of deposits of US banking entities, with maturities of less than a year (with some exceptions). For these data points, spreads to the relevant portion of the treasury yield curve are computed, and after outlier removal, a weighted short-term spread and weighted average short-term maturity are calculated with weights depending on principal values of transactions.

The longer-term spread is computed slightly differently. It uses secondary transactions of senior unsecured corporate bonds by US banking entities, with remaining maturities between one and five years, again with some exceptions. These transactions are grouped into four buckets based on time to maturity: 1–2 years, 2–3 years, 3–4 years and 4–5 years. Spreads to the relevant portion of the treasury yield curve are calculated, and after outlier removal, median spreads are computed for each bucket. Weights based on the ratio of primary issuance in a bucket to total primary issuance are used to merge the four median spreads into a single long term spread and maturity.

For each maturity bucket m, compute the volume-weighted median credit spread s_m among

all secondary market transactions in the trailing month of included instruments types whose remaining maturities are in the indicated bucket. The bond-component of AXI is

$$S = \sum_m q_m s_m$$

where q_m is the fraction in maturity bucket m of total issuance in the previous year, except for money-market maturities.

Finally, the AXI spread is computed as the weighted combination of the short term and long term spreads. The weights themselves depend on short- and long-term volumes and maturities. This choice of weights ensures that if issuance or maturity patterns change, then the AXI spread automatically adjusts accordingly.

Links have been published so that market participants can obtain samples of input files for both the long-term bond component from the Financial Industry Regulatory Authority (FINRA) and the short-term component from the Depository Trust & Clearing Corporation, as well as regularly published summary files.[16] Contemporaneous data released publicly by FINRA through Trade Reporting and Compliance Engine (TRACE) is subject to mandatory dissemination caps. So, to provide market participants with transparency on contemporaneous volume data, an uncapped transaction volume multiplier (UTVM) is published and regularly updated.[17] Relevant regulators have access to contemporaneous uncapped data.

AXI was officially launched on July 12, 2022, and has been calculated and published each business day since at approximately 9 AM ET, using the prior day's transaction data. The indices are accessible via Bloomberg (ticker: AXIIUNS), LSEG Data & Analytics (RIC: .IIAXI) and directly via the Benchmark Administrator.

[16] See FAQ 29 on the Invesco AXI website: https://www.invescosofracademyaxi.com/

[17] The UTVM can be multiplied with the relevant USD-AXI / USD-FXI long-term component capped transaction data to approximate the actual traded volumes for the actual long term component. The UTVM is calculated by comparing the most recent quarter of uncapped data available to the equivalent capped data.

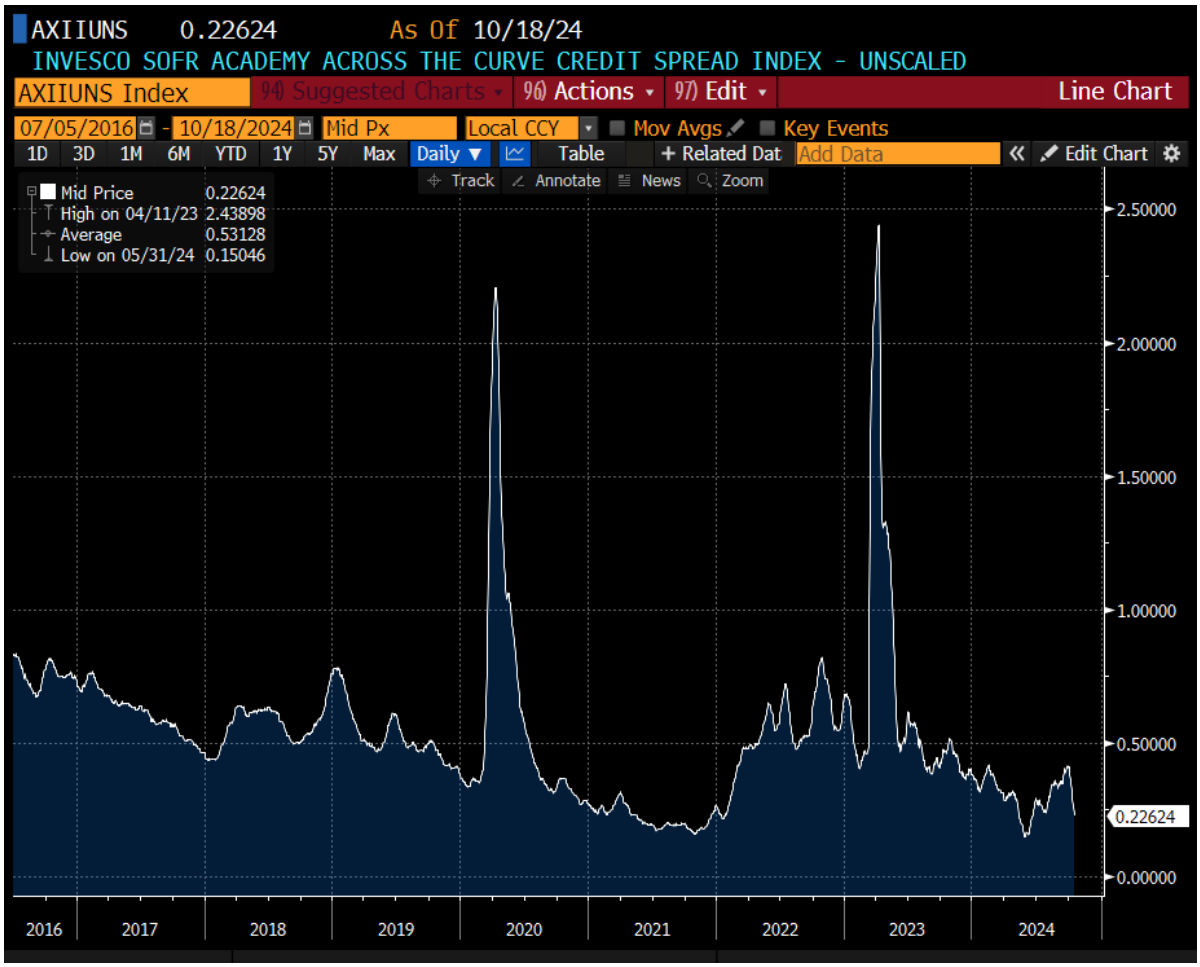

FIGURE 1. AXI unscaled full history[18]. Source: Invesco Indexing via Bloomberg

6. The Financial Conditions Credit Spread Index (FXI)

The companion index to AXI is the Financial Conditions Credit Spread Index (FXI), pronounced "Fixie". FXI follows the same methodology as AXI, but the underlying transactions are expanded beyond banks to include all non-bank financial intermediaries (NBFIs) as well as corporate funding transactions. Widening the scope to include all corporate debt issuers results in an even more robust credit spread index.

The benefits of a reliable and representative credit sensitive element should not be limited to the banking sector. FXI may be helpful for NBFI's who are playing an increasingly important

[18] 2016 is the inception of the FINRA's TRACE data. Plans are in place to build a longer proxy history of the indices further back in time in similar fashion that Bowman (2019) does for SOFR.

role in the provision of credit in the United States economy relative to banks.[19] Acharya, Cetorelli & Tuckman (2024) use data from the Financial Stability Board (FSB), to show that the global financial assets of NBFIs have grown faster than those of banks since 2012, to about $239 trillion and $183 trillion in 2021, respectively. In percentage terms, the share of the NBFI sector has grown from about 44% in 2012 to about 49% as of 2021, while banks' share has shrunk from about 45% to about 38% over the same time period.

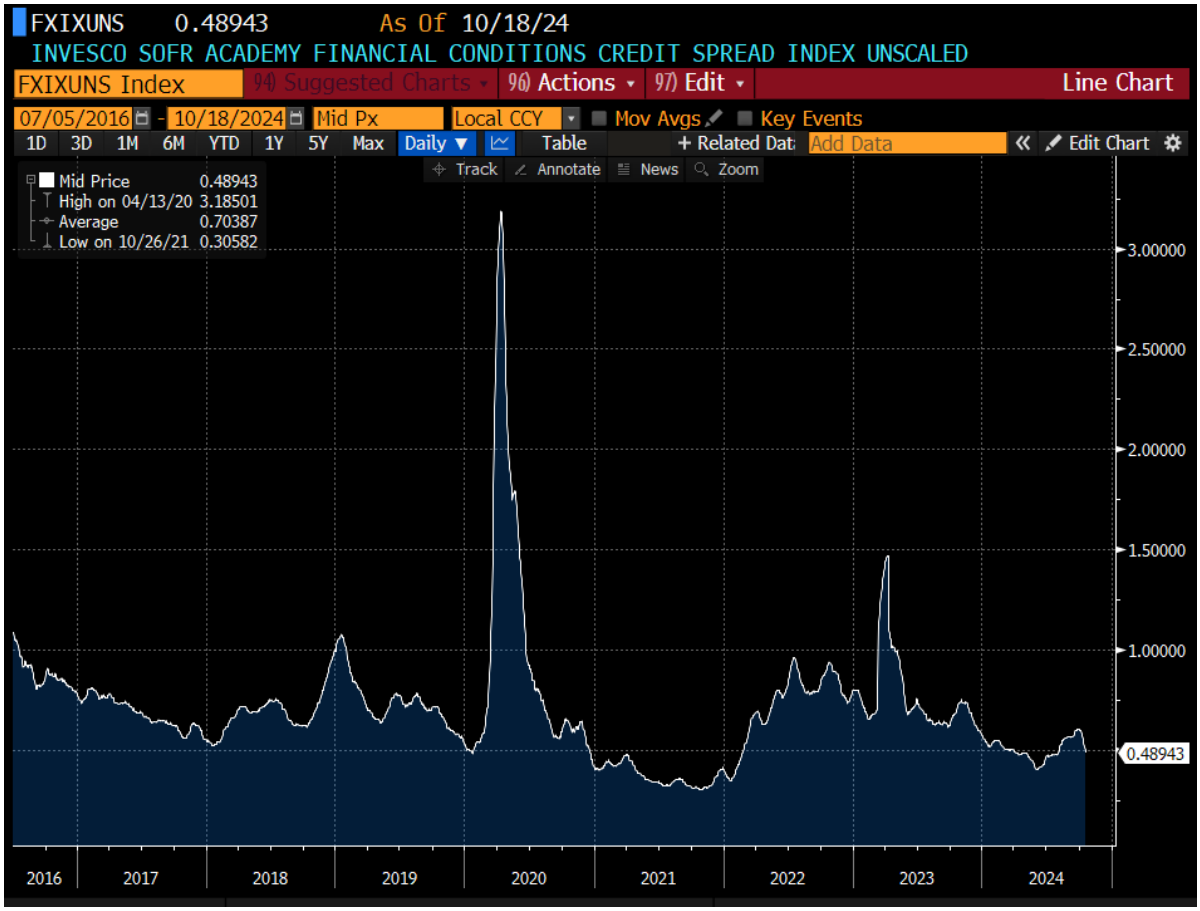

FIGURE 2. FXI unscaled full history. Source: Invesco Indexing via Bloomberg

FXI was officially launched on July 12, 2022, and has been calculated and published each business day since at approximately 9 AM ET, using the prior day's transaction data. The indices are accessible via Bloomberg (ticker: FXIXUNS), LSEG Data & Analytics (RICs: & .IIFXI) and directly via the Benchmark Administrator. AXI and FXI are in no way 'LIBOR substitutes.' Rather, they are robust and reliable benchmark credit spreads built from a broad maturity spectrum of underlying transactions that can be used in conjunction with SOFR.

[19] Acharya, Cetorelli & Tuckman (2024)

The indices have been designed based on a deep understanding of credit markets, financial stability, and large bank funding structure dynamics.

6.2 The AXI-FXI basis

During normal market conditions, FXI tends to print marginally higher than AXI, and their behavior tends to be highly correlated. However, there are times when the performance of AXI and FXI can diverge, due in part to the nature of the macroeconomic stress. For example, during Global Financial Crisis in 2008-2009, AXI moved higher than FXI. At the onset of Covid pandemic shock in 2020, FXI moved higher than AXI, and during the Regional Banking crisis of March 2023, AXI moved higher than FXI (See Figure 3). Alex Roever (2024) notes that FXI is a broad-based corporate credit index constructed from actual trades on US corporate bonds, and as such, tends to have a heightened sensitivity to market events compared to traditional mark-to-model alternatives.

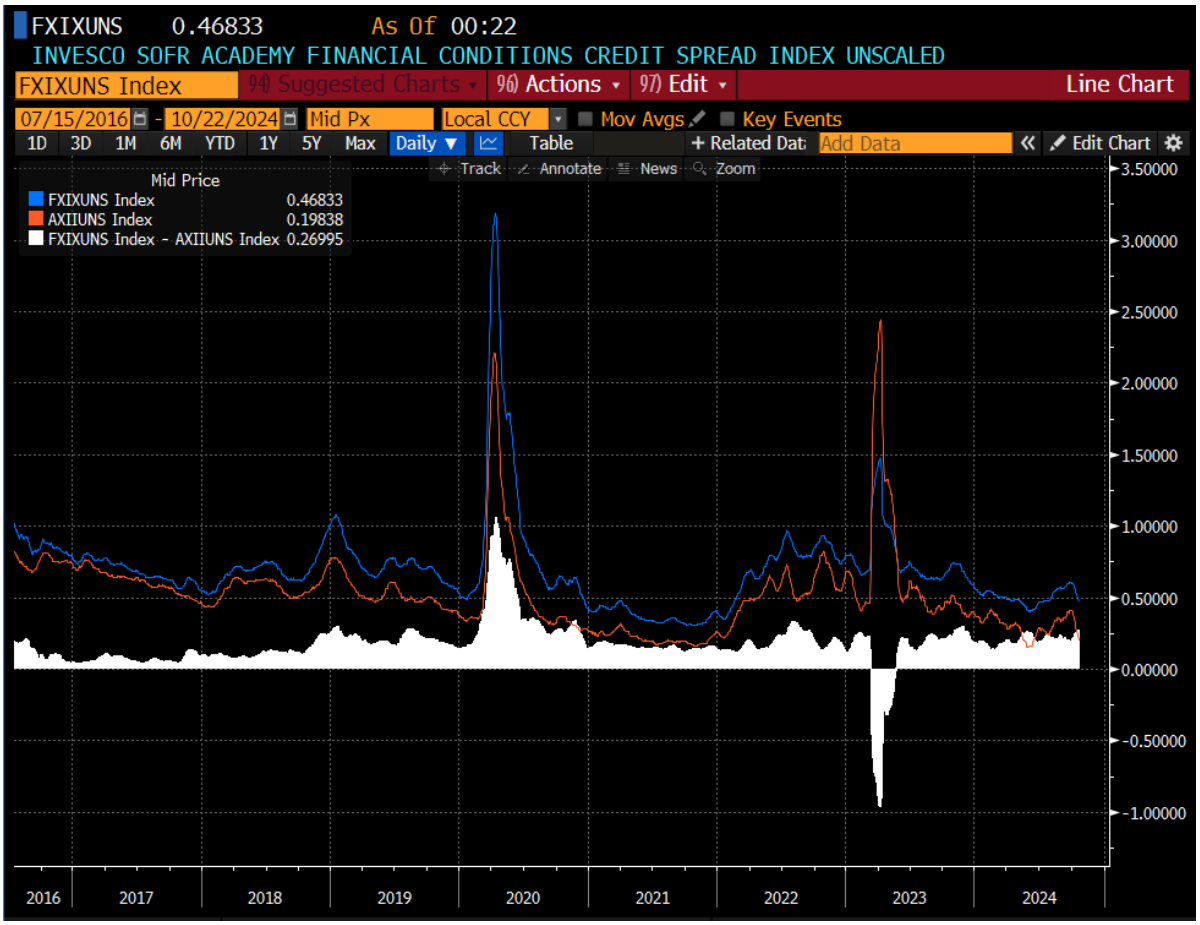

FIGURE 3. AXI-FXI basis unscaled full history. Source: Invesco Indexing via Bloomberg

7. Compliance with IOSCO Principles for Financial Benchmarks

The Board of the International Organization of Securities Commissions (IOSCO), an international body that brings together the world's securities regulators and is recognized as the global standard setter for financial markets regulation, published its final report entitled "Principles for Financial Benchmarks" on 17 July 2013 (the "Final Report").[20] The objective of the Final Report was to create an overarching framework of principles for benchmarks used in financial markets. The Final Report sets out internationally developed and agreed upon principles for financial benchmarks (the "IOSCO Principles"). AXI and FXI are in compliance with the IOSCO Principles.

In February 2024, IBM Promontory[21] were engaged to perform an independent limited assurance review of AXI and FXI's degree of implementation of certain IOSCO Principles. IBM Promontory's review considered IOSCO's messages and findings from September 2021[22] and July 2023[23], as well as potential "inverted pyramid" risk. As previously confirmed in a public statement,[24] neither AXI nor FXI were included in the scope of IOSCO's July 2023 review.

Of the IOSCO's nineteen Principles, there are three that relate specifically to the benchmark itself, rather than the Benchmark Administrator. These are benchmark design (Principle 6), data sufficiency (Principle 7) and transparency (Principle 9). IBM Promontory concluded that all three of these Principles are fully implemented for AXI and FXI.[25]

Principle	AXI Determination	FXI Determination
Benchmark Design	Fully Implemented	Fully Implemented
Data Sufficiency	Fully Implemented	Fully Implemented
Transparency of Benchmark Determinations	Fully Implemented	Fully Implemented

Source: IBM Promontory 2024 AXI/FXI Limited Assurance Review Report

[20] https://www.iosco.org/library/pubdocs/pdf/IOSCOPD415.pdf
[21] https://www.ibm.com/case-studies/sofr
[22] https://www.iosco.org/library/pubdocs/pdf/IOSCOPD683.pdf
[23] https://www.iosco.org/library/pubdocs/pdf/IOSCOPD738.pdf
[24] Invesco Indexing (2023). https://www.invescoindexing.com/en/news/IOSCO-s-Statement-on-Alternatives-to-USD-Libor
[25] IBM Promontory (2024). https://www.invescosofracademyaxi.com/dam/jcr:937b7c6d-6e4c-4a73-ba85-08fb2387881c/AXI-FXI-Limited-Assurance-Review-Report-and-Follow-up-Review-Memo-June-

In addition to IBM Promontory's dedicated review, the Benchmark Administrator completed independent assurance reviews against IOSCO Principles, conducted by PricewaterhouseCoopers LLP in 2022, 2023 and 2024.

It is important to note that AXI and FXI are not proxies for any interest rate and will not replace the large interest rate swap market where SOFR is now firmly embedded. For example, if a market participant wishes to hedge their interest rate risk against changes in the federal funds rate, they would take a position in a financial instrument that references SOFR, not AXI or FXI. This is a key consideration in connection with the "concept of proportionality." The underlying transaction volumes demonstrate that AXI and FXI are highly robust, and the level of market activity proportionally smaller. Usage of AXI and FXI will therefore be appropriate in a way that will be proportionate to their underlying markets.

8. AXI and FXI Cash Products

Here we outline how market participants can incorporate AXI and FXI spreads into SOFR cash products. The SOFR user guide[26] outlines in detail the various considerations for usage of SOFR in cash products. We reproduce those here since market participants interested in referencing AXI or FXI along with SOFR will need to consider similar issues:

Averaging: Financial products, either explicitly or implicitly, should use the average of SOFR and AXI/FXI spreads (rather than a single day's reading of the rate) in determining the floating rate payments that are to be paid or received.

Payment Structure: Users need to determine the period of time over which the daily SOFRs and AXI/FXI are observed and averaged. An "in-advance structure" references an average of SOFR+AXI (SOFRx) or SOFR + FXI (SOFRy) observed before the current interest period begins, while an "in- arrears structure" references an average of SOFRx or SOFRy over the current interest period but observed at the end.

8.1 Averaging

There are two primary reasons why financial products use an average of the daily rate:

– First, an average of daily rates and spreads will better reflect trends in interest rates over a

[26] ARRC (2021)

given period of time. For example, SOFR swaps and futures have traded since 2018 and they allow users to hedge future interest rate movements over a fixed period of time by basing their settlement on the average of the daily rates that occur over the period. In the future, we expect AXI swaps and futures to hedge movements in average spreads.

– Second, average rates smooth out idiosyncratic, day-to-day fluctuations in market rates, making them more suitable for use.

This second point is illustrated in figure 4. It shows the daily movement of SOFR+AXI and 1-month, 3-month and 6-month compounded averages of SOFR+AXI (we define compounded averaging below). On a daily basis, SOFR +AXI exhibits some amount of idiosyncratic variability, reflecting market conditions that day. However, the averages that are typically referenced in financial contracts are smoother than the movements in overnight SOFR + AXI.

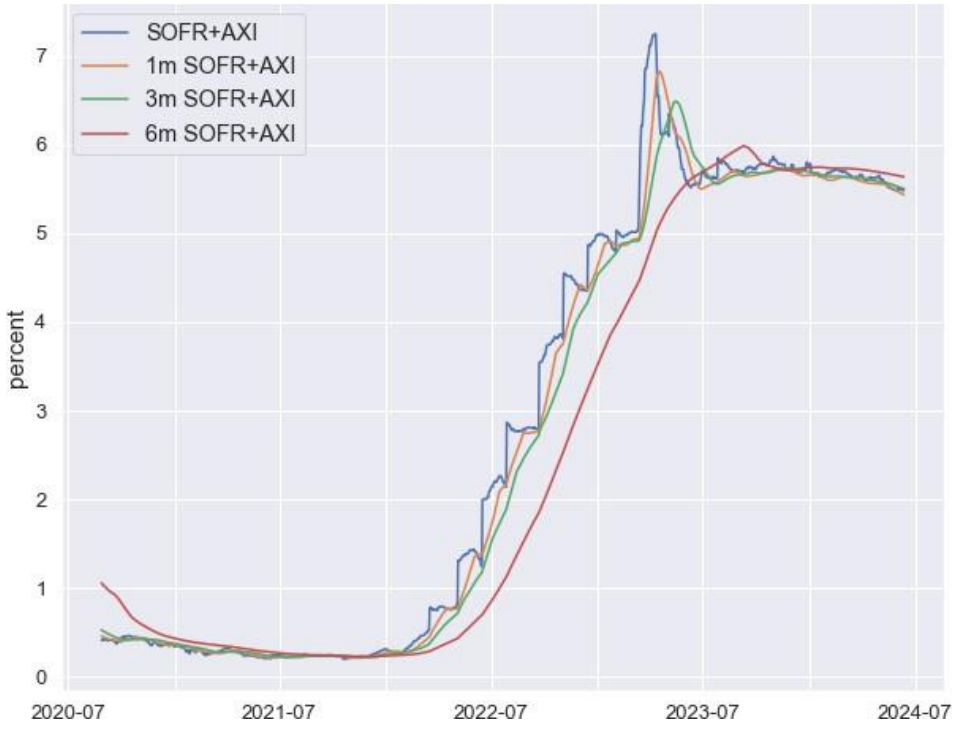

FIGURE 4. Movements in Daily SOFR+AXI Averages

Simple versus Compound Averaging. Although financial products tend to use average rates, issuers and lenders face a technical choice between a simple or compound average when they use SOFR and AXI/FXI spreads in cash products.

With simple averaging, interest is charged based only on the principal outstanding, while with compound averaging, interest is charged based on both outstanding principal and

accumulated unpaid interest. On any non-business day, simple interest applies, at a rate equal to the SOFR+AXI value for the preceding business day.

Tables 1 and 2 below define and demonstrate the basic distinction between the two concepts for a 1-week loan referencing SOFR+AXI:

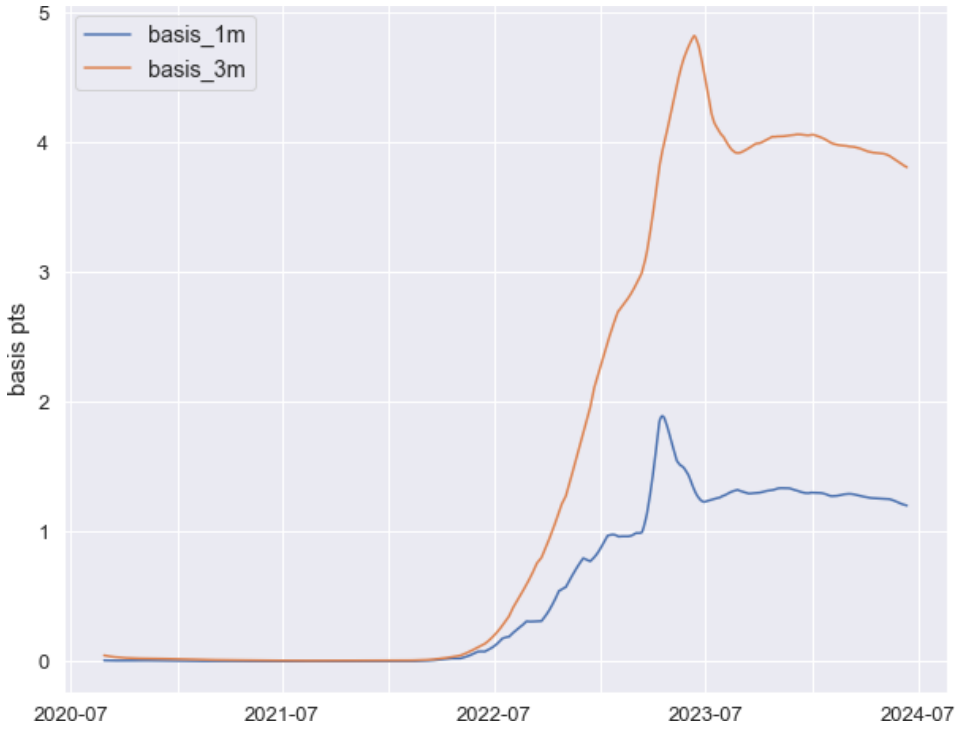

FIGURE 5. Basis between Compound and Simple SOFR+AXI

Date	SOFR	AXI	SOFR+AXI Rate (Not Annualized)	Principal	Principal + Accumulated Interest	Interest Charge for Next Business Day
Mon, Mar 2, 2020	1.59	0.37	$\frac{0.0196}{360} = 0.005444\%$	$1,000,000	$1,000,000	$54.44
Tue, Mar 3, 2020	1.64	0.38	$\frac{0.0202}{360} = 0.005611\%$	$1,000,000	$1,000,054.44	$56.11
Wed, Mar 4, 2020	1.23	0.39	$\frac{0.0162}{360} = 0.004500\%$	$1,000,000	$1,000,110.55	$45.00
Thu, Mar 5, 2020	1.12	0.40	$\frac{0.0152}{360} = 0.004222\%$	$1,000,000	$1,000,155.55	$42.22
Fri, Mar 6, 2020	1.10	0.42	$3 * \frac{0.0152}{360} = 0.012667\%$	$1,000,000	$1,000,197.77	$126.67
Mon, Mar 9, 2020	-	-	-	$1,000,000	$1,000,324.44	-

TABLE 1. Calculating Simple Interest

Payment due on Mon Mar 9 2020: $1,000,324.44

Annualized simple rate of interest:

$$\frac{360}{7}\left[\frac{0.0196}{36}+\frac{0.0202}{36}+\frac{0.0162}{36}+\frac{0.0152}{36}+3\times\frac{0.0152}{36}\right]=1.6685\%$$

Date	SOFR	AXI	SOFR+AXI Rate (Not Annualized)	Principal	Principal + Accumulated Interest	Interest Charge for Next Business Day
Mon, Mar 2, 2020	1.59	0.37	$\frac{0.0196}{360}=0.005444\%$	$1,000,000	$1,000,000	$54.44
Tue, Mar 3, 2020	1.64	0.38	$\frac{0.0202}{360}=0.005611\%$	$1,000,000	$1,000,054.44	$56.12
Wed, Mar 4, 2020	1.23	0.39	$\frac{0.0162}{360}=0.004500\%$	$1,000,000	$1,000,110.56	$45.00
Thu, Mar 5, 2020	1.12	0.40	$\frac{0.0152}{360}=0.004222\%$	$1,000,000	$1,000,155.56	$42.23
Fri, Mar 6, 2020	1.10	0.42	$3*\frac{0.0152}{360}=0.012667\%$	$1,000,000	$1,000,197.79	$126.69
Mon, Mar 9, 2020	-	-	-	$1,000,000	$1,000,324.48	-

TABLE 2. Calculating Compound Interest

Payment due on Mon Mar 9, 2020: $1,000,324.48

Annualized simple rate of interest:

$$\frac{360}{7}\left[\left(1+\frac{0.0196}{360}\right)\left(1+\frac{0.0202}{360}\right)\left(1+\frac{0.0162}{360}\right)\left(1+\frac{0.0152}{360}\right)\left(1+3\times\frac{0.0152}{360}\right)-1\right]=1.6687\%$$

These tables demonstrate that the basis between the two interest concepts is small at lower interest rates and over short periods of time. This is also seen in figure 5, which plots the rolling 1-month and 3-month basis between simple and compound interest averages of SOFR+AXI. The basis was close to zero during the Covid crisis when rates were low, and it has averaged a few basis points since rates have risen dramatically.

8.2 Payment Structure

The in-advance payment convention is termed as such because the floating-rate payment is set prior to the start of the interest period. In the past under LIBOR, most contracts set the floating rate based on a value of LIBOR similarly determined before the beginning of the interest period. But not all LIBOR contracts took this form; some LIBOR swaps referenced values of LIBOR determined at the end of the interest period, otherwise known as in-arrears.

These conventions may be used with overnight SOFR and AXI/FXI spreads as well. An in-advance payment structure based on SOFR+AXI references an average of the SOFR+AXI

observed before the current interest period began, while an in-arrears structure references it over the current interest period.

The tradeoff between in-arrears and in-advance is that many borrowers wish to know their payments ahead of time and so prefer in-advance, while lenders typically prefer actual returns based on rates over the interest period (i.e., in-arrears) and will tend to view rates set in-advance as "out of date".

The SOFR user guide[27] describes various conventions followed for in-arrears and in- advance payments. We defer to it for detail but describe them briefly below for convenience:

- Plain arrears: Assume that interest period ends on day T then payment is due on T +1 when the SOFR and AXI spread for day T is published. This has the disadvantage of requiring payment on the same day that the final payment amount is known, and as a result it is often not operationally practical.
- Payment Delays: Interest is calculated in the same way as in a plain arrears framework, with the SOFR+AXI rate for each given day in the interest period applied to calculate interest for that business day, but interest is paid k days after the start of the next period.
- Lockouts: Interest is calculated in the same way as in a plain arrears framework for most days save the last k days. For these days, the rate is frozen at the rate observed k days before the period ends.
- Lookbacks: For each day in the interest period, the SOFR+AXI rate from k business days earlier is used to accrue interest. There are two versions of Lookbacks: With and without observation shift. They differ in their treatment of the number of calendar days a rate is applied. Again we defer to the user guide for details.

In comparison to in-arrears, conventions for in-advance payment structures are easier to implement, but there are still some choices. The two most familiar methods are the last reset and last recent methods:

- Last Reset: Use the averaged SOFR+AXI over the last interest reset period as rate for current interest period
- Last Recent: Use the averaged SOFR+AXI from a shorter recent period as rate for current interest period

In addition to in-arrears and in-advance, the user guide also describes "hybrid" payment structures that may conceptually be understood as techniques to reduce the basis between

[27] ARRC (2021)

in-advance and in-arrears structures, thereby reducing risks for lender. They work by combining an in-advance payment setting with adjustments, which is added either to subsequent interest payments or to outstanding principal.

8.3 Scaling considerations

The average weighted maturity of AXI and FXI will continue to shift over time in tandem with the evolution of large bank funding composition. AXI and FXI automatically adjust for this, and the indices weight the part of the yield curve that contains the most transactions. At any point, banks may shift their funding further in or out the curve in response to new market conditions, structural changes in the yield curve, or new regulations.

Regulators have expressed concerns with potential benchmarks that are similar to LIBOR, built around specific money market tenors that could become illiquid or be manipulated. After the Global Financial Crisis in 2008, banks moved to fund themselves further out the yield curve. AXI and FXI are constructed from transactions across the yield curve, from overnight to five years, which maximizes the number of underlying input transactions and substantially widens the underlying scope.

Berndt, Duffie & Zhu (2023) note that "Bond yield spreads tend to move in a wider range than money-market credit spreads such as LIBOR. It therefore makes sense to scale down an across-the-curve credit spread index when contracting monthly, quarterly, or semi-annual floating-rate interest payments" and reference a scaling factor as desired.[28] For example, a bank loan linked to an across-the-curve credit spread index X would have a floating interest payment R(t) on date t of the contractual form:

$$R(t) = \text{SOFR}_n(t) + B_n X(t) + \text{borrower fixed spread},$$

where Bn is a constant scaling factor specific to the n-month length of coupon periods and SOFR$n(t)$ is SOFR for the n-month coupon period ending on date t, obtained from daily SOFR compounded in arrears over the coupon period. With this construction of loan terms, floating-rate risk can be managed with combinations of derivatives linked to SOFR and derivatives linked to X. For example, a loan of principal P paying a fixed spread over $\text{SOFR}_n + B_n X$ can be swapped to a fixed rate by entering a SOFR payer swap with notional P and an X payer swap

[28] Berndt, Duffie & Zhu (2023)

with notional B_nP. To use a numerical example, suppose that 3-month AXI is equal to 0.5 times unscaled AXI. A bank making a $10 million loan based on 3-month AXI can hedge the interest rate risk by buying $5 million notional of the AXI futures contract.

The ostensible disadvantage of fixing a scaling factor is a divergence of implied credit spreads from instruments of similar maturity. In the case of the 3-month AXI, credit spreads on 3-month commercial paper might differ. For example, in a liquidity crisis, short-term credit spreads are likely to spike relative to the long end, so the scaled 3- month AXI might be substantially lower than credit spreads on 3-month commercial paper. However, this imperfect correlation with short-term funding credit is by design and a benefit of the methodology. It will dampen the unexpected surge in funding cost that borrowers must bear in a funding crisis. Moreover, the borrower-specific spread on top of pre-scaled AXI can be adjusted to so that the all-in credit spread reflects the lender's view of fair value over the tenure of the loan.

Market participants are free to determine their own scaling factors AXI. For example, a bank may use 0.5 times AXI on a loan with a quarterly interest frequency. We will not dictate contract terms; rather, we offer enough variety of possible solutions to meet market needs.

Given that credit spreads cannot go negative, one would envisage the AXI curve being positively sloped. This implies appropriate scaling factors to achieve a portion of AXI in standard money market tenor contracts such as 1-month, 3-months and 6-months should be less than 1. The statistical information in the appendix of this guide shows that the long-term unscaled median for the core AXI index is approximately 53 basis points[29]. The ARRC / ISDA endorsed fallback for 3-month LIBOR to SOFR was approximately 26 basis points (representing the 5-year historical median of the difference between LIBOR and SOFR). So, applying half of AXI in a quarterly (3-month) contract may be a reasonable approximation. Sharing the marginal cost of funds equally could be a sensible compromise between a borrower and a lender.

Over time, market participants may coalesce around an industry standard amount of AXI to be included in monthly, quarterly, or semi-annual floating-rate interest payments. It may be helpful in the future for an appropriate forum comprised of relevant U.S. market participants to recommend a set of scaling factors, to be reassessed periodically, or through an industry consultation process.

[29] Quantitative statistics on historical index performance are provided in the appendix of this document

8.4 Example of a SOFR + AXI Term Loan

Whilst the core use case for AXI is pre-committed revolving lines of credit where the borrower can draw down at any time, in practice many credit facilities include term loans which are fully funded at the inception of the loan. It is therefore possible that certain market participants may desire to include a portion of AXI in SOFR-based term loans. Consider the following example:

Current 3-month Term SOFR:	4.85%
Current AXI:	52 bps
Rateset frequency:	Quarterly
Desired 3-month scaling factor:	0.5 (half of AXI)
Borrower specific credit spread:	400 bps
Term loan pricing:	SOFR + (0.5 x AXI) + 400 bps
Pricing today:	9.11% (4.85% + 0.26% + 4.00%)

Full movement of funds is provided to the borrower upon the inception of the term loan, and includes a portion of AXI, which would move over time in conjunction with the lender's marginal costs of funds, resetting on each rate set date (in this case quarterly) for the life of the loan.

8.5 Example of a SOFR + AXI Revolving Credit Facility

In their recent paper 'Bank Funding Risk, Reference Rates, and Credit Supply', co-authors Cooperman, Duffie, Luck, Wang & Yang (2023) set the scene well:

> *"In the US, most bank credit to corporate borrowers takes the form of revolving credit lines that give borrowers the option to draw any amount of credit, up to an agreed line limit, at any time before maturity and at committed pricing terms. Until 2022, the majority of US corporate loans, including revolvers, had interest rates set to the London interbank offered rate (LIBOR) plus a fixed spread. In most of the world, however, banking has made a transition from credit-sensitive interest rate benchmarks such as LIBOR to new "risk-free" benchmark reference rates such as the secured overnight financing rate (SOFR). Credit-sensitive reference rates like LIBOR reduce borrowers' incentives to draw on committed credit lines when the banks' costs of funding drawdowns are high, for example during the global financial crisis (GFC) and the COVID recession. Risk-free loan reference rates, in*

contrast, typically fall when markets are stressed, encouraging borrowers to draw more heavily on credit lines just when bank funding costs rise sharply. Because of this, a collection of large US banks argued that transitioning to risk-free reference rates may reduce ex-ante incentives for providing bank credit."

As a result of this, many banks, particularly large U.S. regional banks have expressed concern with issuing revolving lines of credit linked to SOFR-only. They communicated their preference for the inclusion of a credit sensitive element to be used in conjunction with SOFR. A reasonable compromise solution between a borrower and lender could be to reference a portion of AXI in a SOFR-based revolving line of credit. Consider the following example:

Current SOFR:	4.85%
Current AXI:	52 bps
Rateset frequency:	Quarterly
Desired 3-month scaling factor:	0.5
Borrower specific credit spread:	200 bps
Revolver pricing:	SOFR + (0.5 x AXI) + 200 bps
Pricing drawn today:	7.11% (4.85% + 0.26% + 2.00%)

SOFR and AXI are both floating, and the borrow specific credit spread is usually only adjusted in connection with changes linked to the credit worthiness of the borrower. Please note that if a forward-looking Term version of SOFR is used, and the relevant Benchmark Administrator has implemented scope of used restrictions for that Term SOFR, those restrictions would continue to apply for the Term SOFR portion of the risk. No such restrictions apply to usage of overnight SOFR published by the NY Fed (simple daily, or compounding in arrears), or to AXI.

8.6 Example of a SOFR + FXI Revolving Credit Facility

As previously highlighted in Section 6, the companion index to AXI called FXI will be more appropriate for NBFIs as it correlates highly with their marginal costs of funds. As noted earlier, AXI and FXI do not always move in sync. For example, the market stress resulting from the March 2023 collapse of Silicon Valley Bank did not generally spill over from the banking system into the wider economy. Broader contagion was prevented, in part because of the swift action of U.S. regulators.[30] So, AXI moved markedly higher while FXI did not react

[30] See the Group of Thirty's Working Group on the 2023 Banking Crisis

to the same extent. Therefore, a lender in the private markets may wish to reference SOFR in conjunction with a portion of FXI (rather than AXI) in a revolving line of credit. Consider the following example:

Current SOFR:	4.85%
Current FXI:	69 bps
Rateset frequency:	Monthly
Desired 1-month scaling factor:	0.3
Borrower specific credit spread:	600 bps
Revolver pricing:	SOFR + (0.3 x FXI) + 600 bps
Pricing drawn today:	11.057% (4.85% + 0.207% + 6.00%)

SOFR and FXI are both floating, and the borrower specific credit spread is usually only adjusted in connection with changes linked to the credit worthiness of the borrower. Please note that if a forward-looking Term version of SOFR is used, and the relevant Benchmark Administrator has implemented scope of used restrictions for that Term SOFR, those restrictions would continue to apply for the Term SOFR portion of the risk. No such restrictions apply to usage of overnight SOFR published by the NY Fed (simple daily, or compounding in arrears), or to FXI.

8.7 Recommended loan conventions

In general, AXI and FXI conventions for use in loans will align with existing industry standards. The AXI and FXI spread is known in advance of the interest period, much like it was for LIBOR in the past and Term SOFR-based loans today, and thus most of the loan conventions can mirror LIBOR and Term SOFR loan conventions. It is also worth noting that parties may still need to make certain modifications so that they are administratively feasible in particular transactions.

- Business day definition: "U.S. Government Securities Business Day" should be defined as any day except for a Saturday, Sunday, or a day on which the Securities Industry and Financial Markets Association (SIFMA) recommends that the fixed income departments of its members be closed for the entire day for purposes of trading in U.S. government securities
- Temporary unavailability of AXI or FXI: There should be a temporary fallback if AXI or FXI are not available as of 5 pm (New York time) on an interest rate determination date, such as falling back to the applicable AXI or FXI that was published on the first preceding U.S. Government Securities Business Day, as long as such day is not more than three U.S. Government Securities Business Days prior to the interest rate determination date. Alternatively, some parties may prefer to use interpolation where AXI or FXI for a particular

tenor is temporarily unavailable.

- AXI and FXI determination date: The recommended convention is to use the spread published two U.S. Government Securities Business Days prior to the first day of the interest period and held for the entirety of the interest period, similar to the Term SOFR convention.
- Drawdown notices: For AXI and FXI, the recommended convention is for the borrower to provide notice of a borrowing request three U.S. Government Securities Business Days prior to the borrowing date, similar to the LIBOR and Term SOFR convention today
- Rounding: Term SOFR and AXI / FXI are published to five decimal places and dollar amounts can be calculated to two decimal places and, thus, parties may consider using their current rounding practices.
- Day count convention: Day count recommendation is Actual/360 days for AXI and FXI, which is the standard convention in U.S. money markets. However, it is possible to use other day counts such as Actual/365.

9. AXI Derivatives

In this section, we discuss design choices for AXI and FXI derivatives such as futures and swaps. As mentioned earlier, the development of cash and derivatives markets usually happen concurrently given their self-reinforcing feedback loops. SOFR swaps and futures have been traded since 2018 and daily volumes have steadily increased. Similar markets for AXI and FXI derivatives are expected so that fluctuations in AXI and FXI spreads referenced in cash products can be effectively hedged.

In designing AXI and FXI derivatives, it is worth bearing in mind that AXI and FXI spreads were created to be used in conjunction with SOFR in cash products, meaning that it's only logical for AXI and FXI derivative features be similar to their existing SOFR equivalents. This ensures cash products referencing SOFR and AXI / FXI can be hedged independently but in similar and well understood fashion by corresponding SOFR and AXI / FXI derivatives. Furthermore, newly introduced AXI and FXI derivatives will benefit from their familiarity to market participants, thereby minimizing barriers to their initial usage.

AXI and FXI are sufficiently robust to support a derivatives market and there are no scope of use restrictions on their usage. If AXI or FXI are used in combination with Term SOFR, the Term SOFR Scope of Use Best Practice Recommendations would apply in cases where the ARRC felt they were appropriate for Term SOFR. One of the advantages of the AXI/FXI regime is that financial products can trade independently of SOFR, without diverting market liquidity from SOFR or Term SOFR.

To set the stage, we first describe the generic SOFR interest rate swap briefly and then describe the AXI swap in more detail where we define five ways to make floating leg payments. We go through an example that shows an application of AXI or FXI swaps and we calculate payments for each choice of floating leg payment. We conclude with a discussion of design choices for AXI and FXI futures.

9.1 SOFR Swaps

In a standard SOFR swap, two parties agree to exchange a series of interest payments on a notional amount. Figure 6 shows an example of a three year SOFR swap where counterparty A pays counterparty B the fixed swap rate of 1.8% annually for three years on a notional amount of $100 million. In return, counterparty B pays Counterparty A compounded SOFR annually for three years on the same notional. The annual cash flows use the actual/360 convention on both its fixed and floating legs. No cash is exchanged on the trade or settlement date.

Counterparty A is said to pay fixed and receive floating, while Counterparty B is said to receive fixed and pay floating. The $100 million in the swap is called the notional amount of the swap. It is never paid or received by either counterparty and is used only to compute the fixed and floating rate payments made by the counterparties. The swap settles on March 2nd 2020 and annual payments are made on March 2nd of 2021, 2022 and 2023.

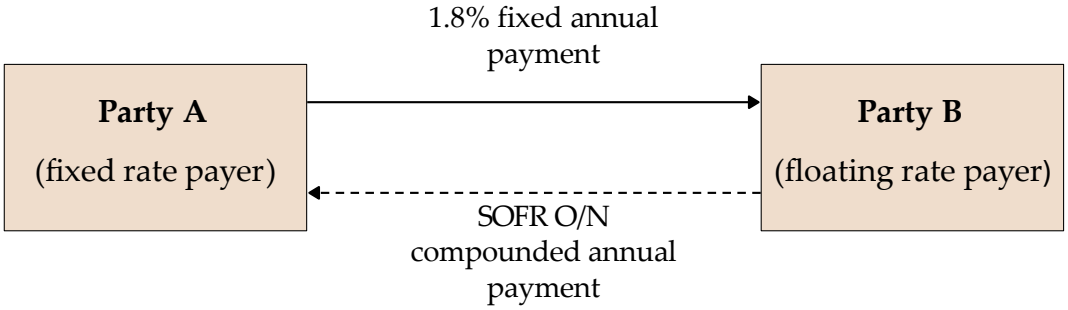

FIGURE 6. Three Year Standard SOFR Swap

Table 3 shows the dates and cash flows exchanged on the fixed and floating legs. The payments on the fixed leg are known in advance and is equal to $\$100,000,000 \times 1.8\% \times \frac{365}{360} = \$1,830,000$. The floating leg payments is proportional to the realized compounded SOFR rates during the interest rate period and this is not known till the end of the period. The realized compounded SOFR rate is calculated using the expression: $\frac{365}{360} \times [\prod_{i=1}^{365}(1 + \frac{SOFR_i(\%)}{100 \times 360}) - 1]$ where $SOFR_i(\%)$ is the realized SOFR on day index i. The annual floating payments corresponding to realized SOFR is shown in the table.

This swap is an example of an "overnight index swap" (OIS) because floating payments are indexed to an overnight rate, which changes daily with market conditions. This is in contrast to most LIBOR swaps in the past which were examples of "fixed for floating swaps" wherein the floating leg payment was based on a term LIBOR rate and not an overnight rate.

Additionally, the swap is an example of a "set in-arrears, pay in-arrears" contract since the floating leg payment is known and paid at the end of the interest rate period. Whereas typical LIBOR swaps in the past were examples of "set in-advance, pay in-arrears" contracts since the LIBOR rate for the floating leg was known in advance of the interest rate period and the payments are made at the end of the period.

SOFR swaps that mature in an exact number of years make annual payments. Swaps that mature in less than one year make one payment at maturity. And SOFR swaps that mature in more than one year, but not in an exact number of years, typically make one stub payment followed by annual payments to maturity. A 1.5-year swap, for example, would likely make a stub payment after six months and another payment one year later[31].

Payment Dates	Fixed Rate	Fixed Payments	Realized SOFR Rate	Floating Payments
Tue, Mar 2, 2021	1.80%	$1,830,000	0.113788%	$113,788
Wed, Mar 2, 2022	1.80%	$1,830,000	0.039380%	$39,380
Thu, Mar 2, 2023	1.80%	$1,830,000	2.473383%	$2,473,383

TABLE 3. Swap Payments and Dates

[31] Tuckman (2022)

9.2 AXI and FXI Swaps[32]

The AXI and FXI swap is similar to a SOFR swap in that fixed payments are exchanged annually for floating rate payments. The difference lies in the definition of the floating leg. The SOFR swap uses the realized compounded SOFR to calculate floating payments, whereas the AXI and FXI swap uses a suitably representative metric of average realized AXI or FXI spreads during the interest rate period.

Here we present five different ways to specify average realized AXI spreads over an interest rate period. Let N be notional and let T be the number of days in the interest rate period.

Method 1. : We define floating leg as difference between compounded SOFR plus AXI and compounded SOFR. So floating leg payment = $N \times \frac{T}{360} \times [\prod_{t=1}^{T}(1 + \frac{SOFR(i)}{360} + \frac{AXI(i)}{360}) - \prod_{t=1}^{T}(1 + \frac{SOFR(i)}{360})]$.

Method 2. : We define floating leg payment as $N \times \frac{T}{360} \times AXI(0)$. Here $AXI(0)$ is the AXI spread observed on first day of the interest rate period.

Method 3. : We define floating leg as simple average of realized AXI spreads over the interest rate period. Thus floating leg payment = $N \times \frac{T}{360} \times [\frac{\sum_{t=1}^{T} AXI(i)}{T}]$.

Method 4. : We define floating leg as compounded average of realized AXI spreads over the interest rate period. Thus floating leg payment = $N \times \frac{T}{360} \times [\prod_{t=1}^{T}(1 + \frac{AXI(i)}{360}) - 1]$.

Method 5. : We define floating leg as difference between compounded fixed rate plus AXI and compounded fixed rate. Ideally this fixed rate should be set as expected average levels of overnight SOFR realized during the interest rate period. For purposes of illustration, if we assume that the fixed rate is 4% then floating leg payment = $N \times \frac{T}{360} \times [\prod_{t=1}^{T}(1 + \frac{4\%}{360} + \frac{AXI(i)}{360}) - \prod_{t=1}^{T}(1 + \frac{4\%}{360})]$

9.3 Discussion of Methods

Method 1 is most accurate because, in an economic sense, it represent the true realized compounded AXI spreads during the interest rate period. The disadvantage is that the

[32] We thank Bruce Tuckman of NYU for helpful comments and suggestions

floating payment expression has both SOFR and AXI spreads in it, meaning that they cannot be separated out. Such separability is desirable because it allows for AXI swaps to reference only AXI spreads as the underlying and not SOFR as well.

Method 2 is most simple among the five methods since average AXI spreads for the entire interest rate period are set to the realized AXI spread on the first day of the period. This is almost an in-advance structure and is therefore convenient for borrowers because they have ample notice of floating payments that are due. The disadvantage is that for lenders, the AXI spread set on first day of the interest rate period may not be representative of the realized AXI spreads during the period. For instance in 2020, AXI spreads set at the beginning of the year in January were not representative of movements later in the year. This was especially the case in March and April when the Covid crisis pushed up AXI spreads to over ten times the levels seen in January.

Methods 3 and 4 remove this aforementioned weakness of method 2 because they compute the simple and compounded averages of realized AXI spreads over the interest rate period. There are additional advantages to choosing methods 3 or 4. In the future, it is anticipated that AXI futures will be introduced and trade on one of more exchanges. These futures are expected to settle on a metric of realized average AXI spreads during the delivery month, similar to the SOFR futures that currently trade on the CME. Such AXI futures are then natural hedges for floating leg AXI swap payments as formulated in methods 3 and 4.

Method 5 is a variation of method 1, the difference being that the expression for the AXI floating payment in method 5 is independent of SOFR, thus ensuring that AXI swaps reference AXI exclusively (which is desirable). The fixed rate in this expression may be chosen as the best guess estimate of future realized SOFR during the interest rate period.

Figure 7 plots the realized 1-year realized AXI spreads calculated using the five methods defined above. As expected, method 2 is most volatile as the AXI spread set on the first day is occasionally quite far from the realized spread over the entire year. In the graph, the volatility of method 2 obscures the differences between the rest of the methods. Figure 8 shows the same plot without method 2. We observe that the basis between the remaining methods is generally small and averages a few basis points at most.

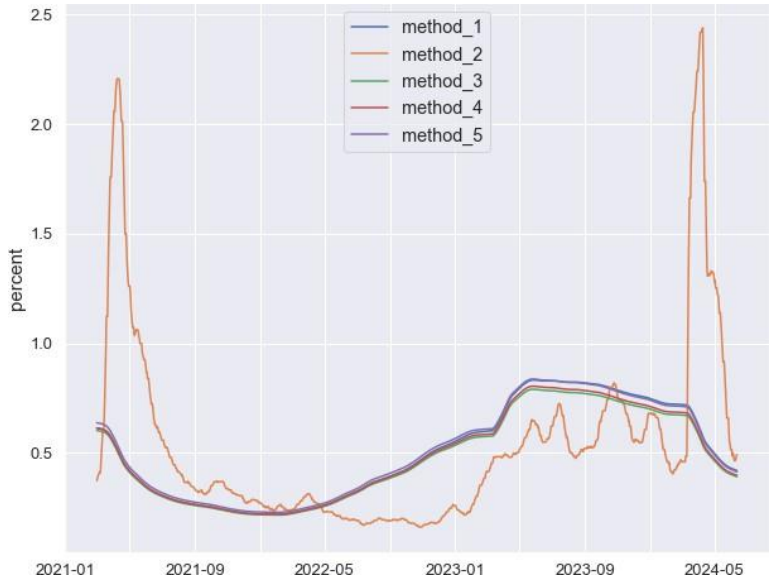

FIGURE 7. Realized 1-year Compounded AXI Spreads for All Five Methods

9.4 Example application of an AXI swap

To make matters more concrete, we describe an application of risk management via AXI swaps in this section and calculate floating leg payments for each of the five methods that we defined above.

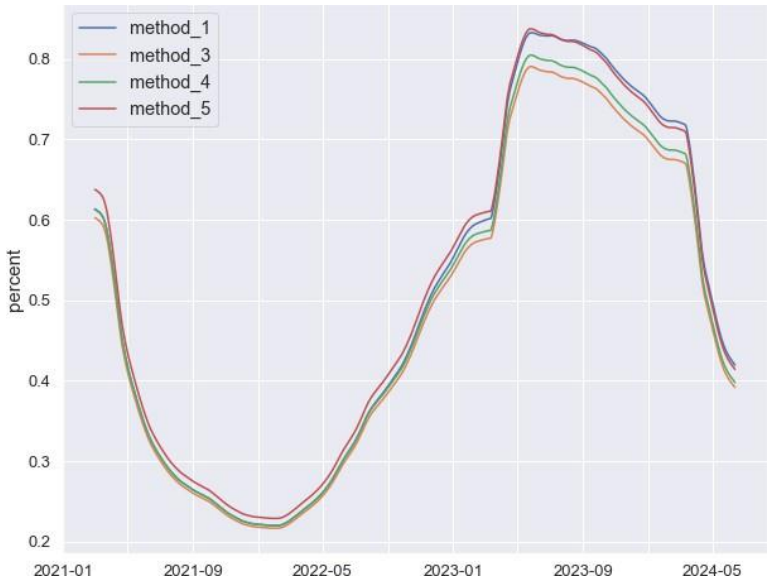

FIGURE 8. Realized 1-year Compounded AXI Spreads for Methods 1,3,4 and 5

Banks prefer to make floating-rate loans to customers. From the perspective of asset–liability management, floating-rate assets naturally hedge deposits, which are floating-rate liabilities, and these constitute a primary source of bank funding. Many borrowers, on the other hand, would rather lock in a fixed interest rate over the term of their borrowings.[33]

The reconciliation of bank and borrower objectives is achieved via two interest rate swaps. The bank makes a floating-rate loan to the borrower, on which the borrower pays SOFR+AXI. The borrower swaps out the SOFR+AXI floating rate expense for fixed rates via a SOFR and an AXI swap with dealers A and B who receive fixed and pay realized rates on SOFR and AXI spread respectively. Thus as desired, the bank delivers the original floating-rate loan and the borrower has exchanged a floating rate liability for fixed rates.

We note here that the hedging of SOFR+AXI by SOFR swaps and AXI swaps introduces a small basis because, except for method 1, the expression for the annual floating rate liability of the borrower will not be exactly matched by the sum of floating payments received from the swap hedges with dealers A and B.

In more detail, the annual floating rate liability of the borrower is:
$N \times \frac{T}{360} \times [\prod_{t=1}^{T}(1 + \frac{SOFR(i)}{360} + \frac{AXI(i)}{360}) - 1]$.

Whereas the SOFR payment received from dealer A is:
$N \times \frac{T}{360} \times [\prod_{t=1}^{T}(1 + \frac{SOFR(i)}{360}) - 1]$.

And finally the AXI floating payment received from dealer B depends on choice of the five methods defined previously. For instance, if method 4 were chosen then AXI floating payment is:
$N \times \frac{T}{360} \times [\prod_{t=1}^{T}(1 + \frac{AXI(i)}{360}) - 1]$.

It is clear from the expressions that the sum of the hedges from dealers A and B will not equal the floating rate liability of the borrower. We quantify this basis in Table 4 for a three year $100 million floating rate from Mar 2 2020 to Mar 2 2023 for each of the five methods. The hedge from Method 1 exactly replicates the borrower floating liability to bank. Method 2 has highest basis whereas methods 3,4 and 5 each have small residual basis.

[33] Tuckman (2022)

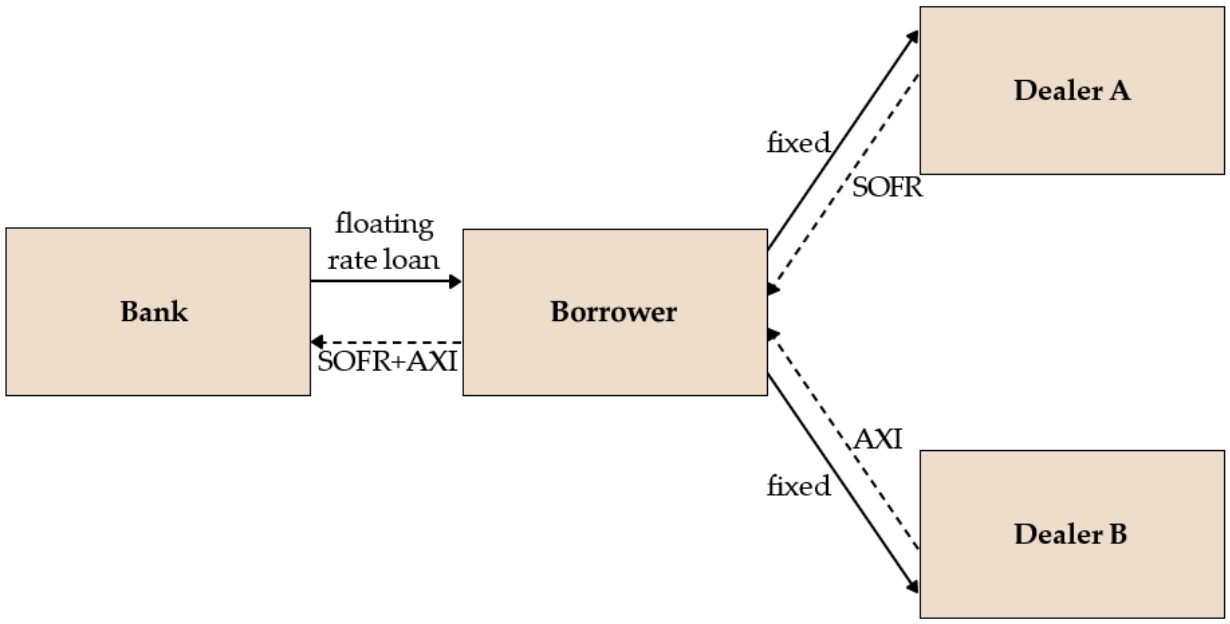

FIGURE 9. AXI Swap Application. Borrower Swaps out Floating Rate Liability SOFR+AXI for a Fixed Rate Liability via a SOFR Swap and an AXI Swap

Date	SOFR+AXI paid to Bank	Method 1 + SOFR from A	Method 2 + SOFR from A	Method 3 + SOFR from A	Method 4 + SOFR from A	Method 5 + SOFR from A
Mon, Mar 2, 2020	$735,376	$735,376	$500,055	$724,316	$726,175	$759,947
Tue, Mar 3, 2020	$269,344	$269,344	$283,111	$265,850	$266,106	$278,609
Wed, Mar 4, 2020	$3,081,648	$3,081,648	$2,893,282	$3,057,365	$3,059,068	$3,091,368

TABLE 4. Borrower Liabilities to Bank and Swap Hedge Payments

8.5 AXI and FXI Futures

Exchange traded AXI and FXI futures have a number of potential applications. They may be used to hedge the rise or fall in AXI and FXI spreads, to hedge floating payments in AXI and FXI swaps, for speculative purposes etc. Like AXI and FXI swaps, it is probable that the referencing of AXI and FXI spreads in cash products will soon be followed by the introduction of AXI and FXI futures on an exchange such as the CME or the FMX Futures Exchange.

In previous sections, we discussed the advantages of aligning features of SOFR and AXI or FXI derivatives. It follows then that exchange traded AXI or FXI futures should mimic features of existing SOFR futures, which we explore next.

Currently there are two types of SOFR futures: one-month and three-month.[34] The one-month SOFR futures contract, which trades on the CME, is designed to take and/or hedge exposure to SOFR (or other rates highly correlated with it) over one month. This future trades until the last business day of the month in which it expires, known as its delivery month. It is cash settled at the simple average of the realized SOFR rates over the expiry month and, like all futures, is subject to daily settlement. Finally, the contract is scaled to hedge a $5 million 30-day investment. This essentially means that the P&L (profit and loss) on one contract from a one-basis-point change in the contract's rate is set equal to:

$$\$5,000,000 \times 1\text{bp} \times \frac{30}{360} = \$41.67.$$

Like one-month SOFR futures, three-month contracts too trade on CME and are designed to hedge exposure to SOFR. There are some differences, however. First, as is obvious, three-month contracts hedge exposure over three months. Second, the settlement rate of the three-month contract is based on daily compounded SOFR over the reference period of three months and not on a simple average of SOFR. And finally, the three-month contract is scaled to hedge a $1 million 90-day investment, which means that the P&L on one contract from a one-basis-point decrease in the final settlement rate is set equal to:

$$\$1,000,000 \times 1\text{bp} \times \frac{90}{360} = \$25.$$

In due course, for AXI we anticipate that new 1-month and 3-month futures will follow the contract specifications for SOFR futures listed above, thereby easing their introduction into the market. Futures against the core unscaled indices may also be helpful. We also believe these futures, together with AXI swaps, are natural starting products in the space for AXI derivatives that will inevitably emerge following the introduction of AXI in cash products. Feedback from market participants indicated that AXI swaps pricing could become more expensive in the absence of a corresponding futures market.

10. Reference rate due diligence

The Financial Stability Oversight Council's 2023 Annual Report[35] states that if market participants wish to use a rate other than SOFR, they should conduct a comprehensive evaluation before adopting that rate. AXI and FXI are credit spreads and not interest rates, nor are they proxies for any interest rate. If a loan references AXI or FXI it will also reference SOFR (hence the interest rate portion of a loan remains solely reliant on SOFR).

[34] Tuckman (2022)
[35] FSOC (2023)

Market participants considering using AXI or FXI should perform and document evidence of due diligence on AXI and FXI prior to usage in financial products. This evaluation may include observation of the performance of AXI and FXI during prior periods of market stress, periodic monitoring of the underlying statistical robustness and integrity of the indices through observing the publicly available 'enhanced transparency metrics table' (See Figure 10 below) which is updated each business day on the AXI /FXI website[36] and may reference any independent review such as by IBM Promontory in 2024.

USD-AXI and USD-FXI enhanced transparency metrics table

The following table reflects key underlying metrics of USD-AXI and USD-FXI

Benchmark		USD-AXI	USD-FXI
Reference date		05-Mar-2024	05-Mar-2024
Unscaled rate average maturity (years)		1.72639	2.34351
Short term component	Transaction volume (USD millions)	595,550	1,678,931
	Maturity (years)	0.04419	0.04606
	Number of transactions	15,562	80,490
Long term component	Capped transaction volume (USD millions)*	10,082	96,640
	Uncapped transaction volume multiplier**	1.26485	1.26204
	Maturity (years)	3.09742	2.97389
	Number of transactions	77,867	685,630

FIGURE 10. Sample of Daily Published Key Underlying Metrics for AXI and FXI

[36] https://www.invescosofracademyaxi.com/

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12. Disclaimer

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13. Statistical information

TABLE 5: Statistical information for USD-AXI for the period June 30, 2016, through January 12, 2024. The long-term component volume data from TRACE are uncapped before September 30, 2021, and capped afterwards.

USD-AXI	Underlying transaction volumes			Underlying trade count			USD-AXI (raw index)
	Short-term component (USD)	Long-term component (USD)	Total volume (USD)	Short-term component	Long-term component	Total trade count	
Mean	426,936,446,169	16,972,841,132	443,909,287,300	15,390	86,240	101,630	0.561357
Median	378,325,260,561	16,987,578,642	399,654,830,004	15,536	86,398	101,372	0.528075
Std Dev	121,460,308,987	5,202,639,630	118,251,563,124	725	2,549	2,506	0.309414
High	670,984,609,219	32,788,140,525	684,520,647,719	16,591	91,149	105,973	2.438977
Low	251,477,156,025	7,642,494,928	265,416,781,025	14,150	79,780	95,440	0.160913
1st Percentile	263,607,428,482	8,324,719,820	278,042,352,992	14,163	80,184	95,919	0.173774
25th Percentile	322,532,600,800	12,736,833,494	341,291,342,195	14,720	84,830	99,758	0.40582
75th Percentile	558,980,204,500	20,588,442,750	571,973,127,901	15,816	87,319	103,548	0.645886
99th Percentile	644,793,928,477	30,304,965,825	658,251,771,647	16,589	91,084	105,833	2.090105

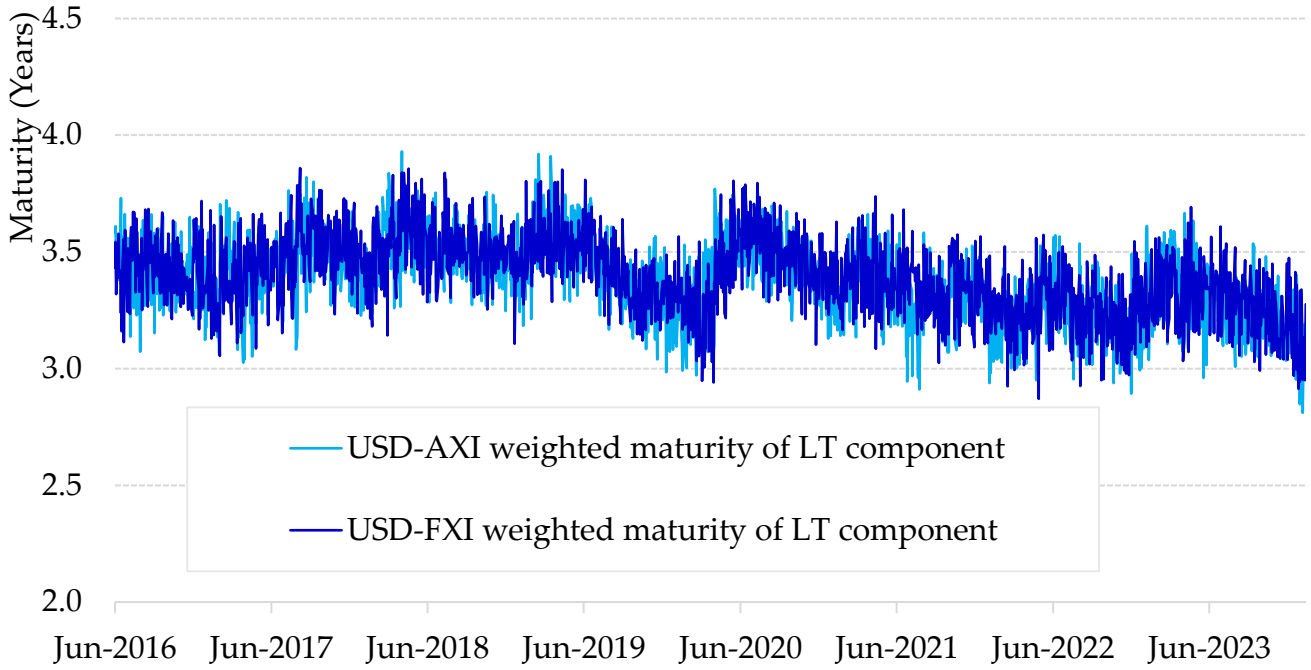
Data source: Invesco Indexing LLC

TABLE 6: Statistical information for USD-FXI for the period June 30, 2016, through January 12, 2024. The long-term component volume data from TRACE are uncapped before September 30, 2021, and capped afterwards.

USD-FXI	Transaction volumes			Trade count			USD-FXI (raw index)
	Short-term component (USD)	Long-term component (USD)	Total volume (USD)	Short-term component	Long-term component	Total trade count	
Mean	1,406,172,153,914	92,792,945,028	1,498,965,098,942	81,191	572,215	653,406	0.727986047
Median	1,404,708,431,807	91,556,546,414	1,492,509,906,385	80,634	567,353	647,715	0.695225191
Std Dev	214,099,286,649	15,095,565,978	212,537,966,946	1,996	11,689	13,383	0.341085337
High	1,888,765,628,300	146,236,928,403	1,998,290,336,708	84,410	591,709	675,547	3.185005915
Low	959,475,782,671	55,589,019,392	1,052,838,109,393	77,186	555,692	635,103	0.305822732
1st Percentile	1,010,797,604,485	66,259,968,946	1,095,780,537,979	77,413	556,137	635,109	0.313907038
25th Percentile	1,240,135,380,829	81,974,550,312	1,340,764,391,286	79,621	561,604	641,831	0.587404708
75th Percentile	1,519,684,759,220	100,468,025,798	1,605,223,279,719	83,151	585,432	668,583	0.797326561
99th Percentile	1,854,446,583,677	135,821,572,637	1,959,424,753,969	84,304	591,500	675,537	2.450175153

Data source: Invesco Indexing LLC

FIGURE 11: Variable weighted average maturity of the long-term (LT) bond component of USD-AXI and USD-FXI



Data source: Invesco Indexing LLC

14. International AXI and FXI feasibility studies

It makes sense to explore other jurisdictions where a local currency AXI and or FXI can be constructed and may be helpful. In order to do so, a robust academic assessment should be conducted to ascertain the likely robustness of the indices, and also to tailor the original US-dollar approach to the respective markets, which may also require certain customization. Studies have been successfully completed for China, Europe, Japan and Mexico. Brazil, India and South Korea are in progress.

Li, Zhang, Zhang, and Zhang (2022) have demonstrated the applicability of AXI and FXI for Chinese RMB borrowing applications (prototype data available via WIND, tickers: CNAXI.WI & CNFXI.WI).[37] Saroyan and Cont (2023) have shown the applicability to the European market,[38] Okimoto & Takaoka (2023) have applied the concept to Japan,[39] and Cacho-Díaz and Rodríguez Pueblita (2024) show how the design can apply to Mexican markets.[40] Across all currencies, AXI & FXI will exist only as a robustly defined benchmark credit spread, to ensure continued reliance on the local respective (near) risk-free rate.

TABLE 7: Status of feasibility studies for international AXI's and FXI's

Currency	Near Risk-Free Rate	AXI / FXI	Academic Leadership	Status
Chinese Renminbi	Depository-Institutions Repo Rate (DR)	CNAXI & CNFXI	• Postdoctoral Researcher Zhiyong Li • Doctoral student Zijian Zhang • Professor Fudong Zhang • Professor Xiaoyan Zhang	CNAXI and CNFXI prototypes launched June 2024
Euro	Euro short-term rate (€STR)	EURAXI & EUR-FXI	• Professor Rama Cont • Dr Susanna Saroyan	Feasibility study complete
Japanese Yen	Tokyo Overnight Average Rate (TONAR)	JPY-FXI	• Professor Tatsuyoshi Okimoto • Professor Sumiko Takoka	Feasibility study complete

[37] https://sofracademy.com/chinese-axi/
[38] https://sofracademy.com/european-axi/
[39] https://sofracademy.com/japanese-fxi/
[40] https://sofracademy.com/mexican-axi/

Mexican Peso	TIIE-28 rate published by Banco de Mexico	MXAXI & MXFXI	• Professor José Carlos Rodríguez Pueblita • Julio A. Cacho-Diaz	Feasibility study complete
Indian Rupee	Market Repo Overnight Rate (MROR)	INR-AXI	• Professor Nagpurnanand Prabhala • Professor Sudip Gupta	Feasibility study in progress
Brazilian Real	CDI Rate - Brazilian interbank deposit	BRL-AXI	• Professor Márcio Garcia • Professor Alan De Genaro	Feasibility study in progress
South Korean Won	Korea Overnight Financing Repo Rate (KOFR)	KRW-AXI	• Professor Jun Kyung Auh • Professor Jongsub Lee	Feasibility study in progress
Canadian Dollar	Canadian Overnight Repo Rate Average (CORRA)	CAD-AXI	• Professor Redouane Elkamhi • Professor Yoshio Nozawa	On hold
Pound Sterling	Sterling Overnight Index Average (SONIA)	GBP-AXI	• Professor Rama Cont • Dr Susanna Saroyan	On hold