MOODY'S
ANALYTICS

WHITEPAPER
09 NOVEMBER, 2023

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Digital Asset Monitor

SUMMARY

Effective, timely and forward-looking financial risk management is essential to the stability and resilience of every financial ecosystem. In no market is this more evident than the digital asset and decentralized finance (DeFi) platforms, where stablecoins act as the cornerstone of stability and bridge to real-world assets. Despite their name, instability and depegging events have shocked DeFi ecosystem on more than one occasion, indicating a need for more robust and extensive risk management practices. The DeFi Integrated Risk Assessment (DIRA) model offers a framework for the assessment and monitoring of stablecoins financial health to enable more effective decisions by market players and to support broader stability in the digital asset market.

Digital Asset Monitor (DAM) system leverages the DIRA model to provide near-time risk assessment for over 20 fiat-backed stablecoins. DAM incorporates data from on-chain events, spot market trading, DeFi liquidity pools, and issuer attestations to produce a 24-hour forward-looking probability of depegging, informed by the 5 underlying DIRA sub-models: market-informed 24-hour probability of depegging, liquidity-informed 24-hour probability of depegging, issuer 1-year probability of default, aggregate custodian 1-year probability of default, and reserve asset default risk. The model is defined as “near-time” as risk signals are structured for real-time assessment; however, underlying data availability is limited to underlying entity reporting frequencies.

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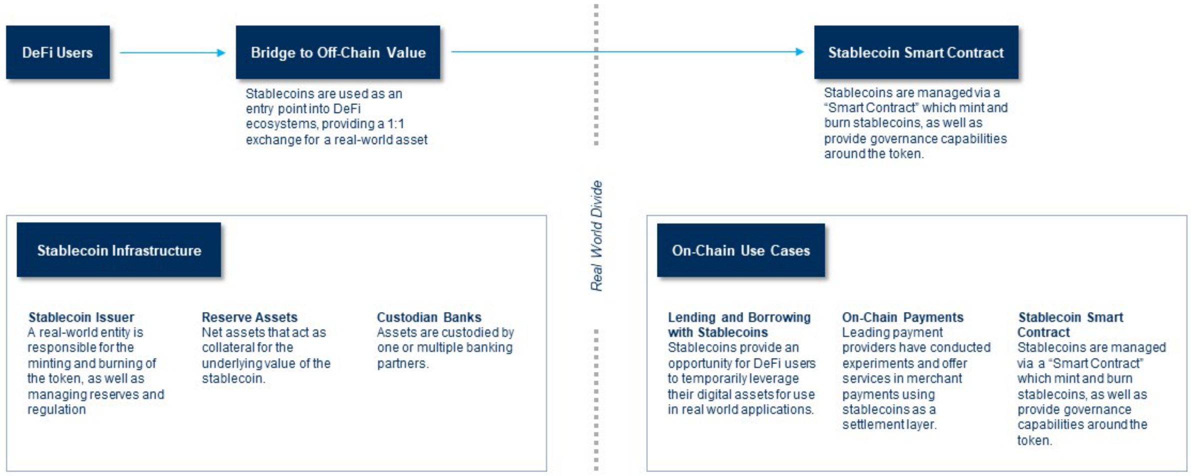
INTRODUCTION

The central promise of stablecoins is inherent to their title: stability. With the trust of the blockchain and digital asset ecosystem, stablecoins have gained significant popularity, exceeding a market cap of $100 billion USD and finding themselves in headlines with traditional finance heavyweights such as Visa and PayPal [1]. Despite their ubiquity, questions of regulation, comingling of funds, and opaque reporting, paired with the market trauma of Terra-Luna's TerraUSD $18 billion collapse [2], has led the core premise of stablecoins to be questioned: how stable are stablecoins?

The need to answer this question extends far beyond academic curiosity. Risk managers in the digital asset ecosystem are increasingly recognizing that stablecoins, due to their widespread adoption, have effectively become the lifeblood of decentralized finance (DeFi) ecosystems [3]. These digital assets underpin a wide array of financial activities, including payments, lending, borrowing, and trading. Consequently, their stability is not merely a matter of theoretical interest; it is an essential component of financial security that risk managers bear the responsibility of assessing effectively.

As an emerging asset acting as an experiment for broader real-world asset tokenization, an underwhelming number of risk opinions and analytics are available for stablecoins. While tracking price data and on-chain movement has been the go-to approach for many, these signals are often delayed or near-time to depegging events, and capture a fraction of the risk points inherent to the stablecoin infrastructure depicted in figure 1, leading to reactionary policies made after the fact, rather than proactive and defensive risk decisions. It is essential for any stablecoin risk management process to not only address on-chain transactions, market-depth, and liquidity, but also monitor the critical supporting components allowing for proper minting and redemption including the risk profile of the off-chain real-world assets collateralizing the token, the financial health of the issuer, and the financial health of entities providing custodial relationships.

Figure 1 Stablecoin Ecosystem Summary



Bridge to Off-Chain Value: Stablecoins are used as an entry point into DeFi ecosystems, providing a 1:1 exchange for a real-world asset

Stablecoin Smart Contract: Stablecoins are managed via a "Smart Contract" which mint and burn stablecoins, as well as provide governance capabilities around the token.

Stablecoin Issuer A real-world entity is responsible for the minting and burning of the token, as well as managing reserves and regulation

Reserve Assets Net assets that act as collateral for the underlying value of the stablecoin.

Custodian Banks Assets are custodied by one or multiple banking partners.

Lending and Borrowing with Stablecoins Stablecoins provide an opportunity for DeFi users to temporarily leverage their digital assets for use in real world applications.

On-Chain Payments Leading payment providers have conducted experiments and offer services in merchant payments using stablecoins as a settlement layer.

Stablecoin Smart Contract Stablecoins are managed via a "Smart Contract" which mint and burn stablecoins, as well as provide governance capabilities around the token.

The DeFi Integrated Risk Assessment (DIRA) model proposed here seeks to provide a near-time framework for wholistic risk monitoring of stablecoins. Developed from the ground-up around stablecoin infrastructure, the model combines real-time on-chain events and market data, with off-chain financial health indicators of issuers, reserve assets and custodial partners to provide a forward-looking 24-hour probability of depegging for a given stablecoin.

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[1] According to data by CoinGecko (coingecko.com), tokens belonging to the stablecoin category had a total market cap of $ 123,520,962,269 as of October 25, 2023.

[2] (Sandor & Genc, 2022)

[3] (Deloitte Touche Tohmatsu Limited, 2022)

MOTIVATION

The DIRA model is built as an adaptation of previous risk frameworks proposed by Moody's Investor Services and Moody's Analytics for the digital asset ecosystem. In a July 2023 Sector in-Depth report by Moody's Investors Service[4], an analysis of the digital bonds market is provided, and in it, four key risks are identified for digital bonds: platform risk (solution resiliency and business continuity planning), smart contract risk (smart contract design and error correction), asset representation risk (transfer of property rights and creditor's rights), and external risk (regulatory and cyber). In addition to these risks, the authors suggest conventional risk assessment for bonds should be applied as well.

The second framework which influenced the DIRA model was a previous framework proposed jointly by Moody's Analytics and Gauntlet for risk analysis of decentralized finance[5]. In this framework, two high level risk categories are proposed with specific risks underlying each category: Systemic risks (security contracts, governance, oracles, and cooperative risk) and idiosyncratic risks (currency, regulatory, and blockchain risks).

Both frameworks indicate a high-level need for any digital asset risk assessment: traditional financial assessment, paired with assessment of infrastructure and external threats.

Defining a Depegging Event

Unlike defaults and currency uncouplings, stablecoin depeggings lack a long-history of an agreed upon definition. At the same time, depegging events are the primary vehicle of loss for the asset, and developing both a common and robust definition of the term among industry players will enable more effective and comprehensive risk management processes for decision-making around stablecoins.

In the DIRA framework, a depegging event is defined as the following: Over a specified time-frame, a depegging event is said to occur if a stablecoin is traded at a maximum high or minimum low in excess of a decoupling threshold on any major exchange or liquidity pool. In DAM and the analysis of DIRA, a time-frame of 24 hours and a threshold of 3% is adopted, informed by best practices seen in the FX market.

Through the explicit definition of depegging, associated risks of stablecoins, which have been derived from the works outlined above, can be quantified to frequency and magnitude of depegging events. \

FRAMEWORK

The DIRA model aims to identify the internal operational and financial risk points critical to maintenance of a stablecoin peg (figure 2), and combine these factors with the external market conditions that can lead to excessive stress on this infrastructure, ultimately leading to a depegging event. Generalizability and the ability to quantify risks across fiat-backed stablecoins was a critical design element to allow for precise benchmarking and comparison of the emerging asset.

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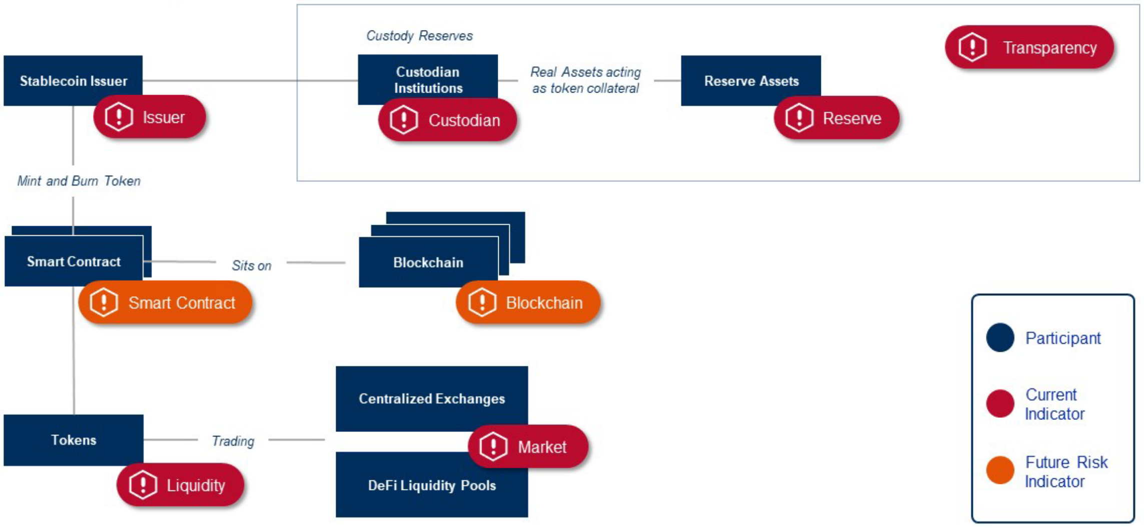
[4] (Gusdorf, Dyck, Colzani, & Berlot, 2023)

[5] (Francus, Chitra, Hamilton, & Dobel, 2022)

Figure 2 Risk In the Stablecoin Ecosystem



Beyond quantification, timely analysis is an essential component for any effective risk framework. Timeliness is especially relevant for the "always on" financial ecosystem and instantaneous settlement that is blockchain. Informed by the historic rapid collapse of on-chain assets such as FTX token[6], all DIRA-native risk metrics are 24-hours forward looking and capable of data-informed and automated assessment. Refresh rates and forward-looking probabilities for each sub-model are discussed in detail for their respective section.

In addition to the DIRA-native risk models developed around market and on-chain events, DIRA also significantly leverages the EDF-X Early Warning System[7] for monitoring the credit risk of both the issuing entity of the stablecoin, as well as those of the financial institutions with custodial responsibilities to the reserve assets, as disclosed in public attestations by the issuer. Combining a series of existing credit models, EDF-X, Moody's risk management platform, provides a standard, point-in-time probability of default for listed entities on a daily basis, and private entities on a monthly basis[8]. A comparative trigger value from EDF-X[9] is integrated into the system for benchmarking financial performance against a peer group. Figure 3 depicts the flow of data and primary model used against each signal.

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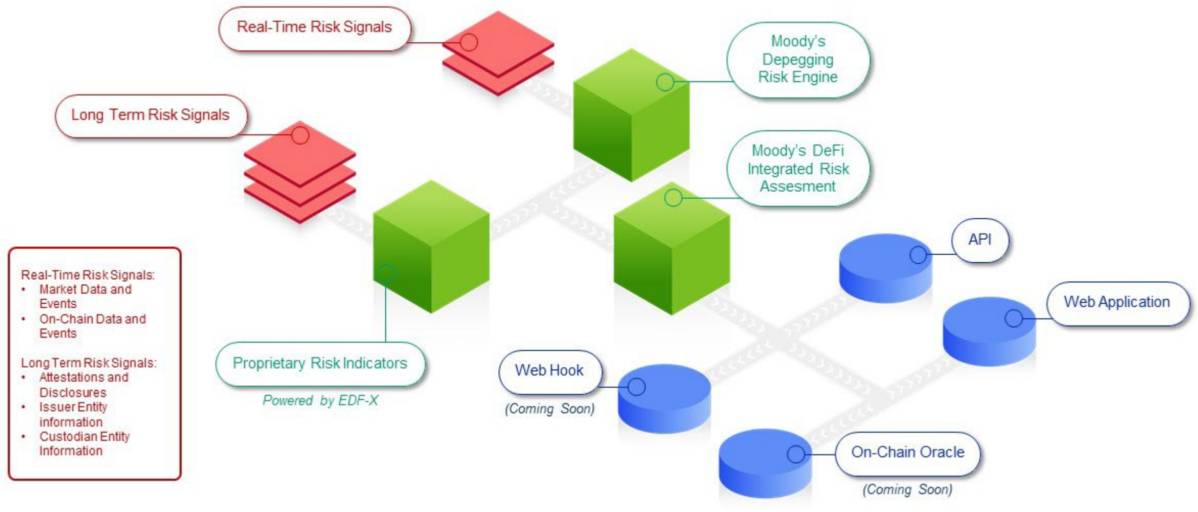
[6] (Davis, 2023)

[7] EDF-X is a risk management platform developed by Moody's Analytics. Full product information and details can be found at edfx.com.

[8] (Hamilton, Pieschacon, Xu, & Zhuang, 2022)

[9] The trigger is derived from a probability of default percentile based on country and industry peer groups and accounts for the current credit cycle (Hamilton, Pieschacon, Xu, & Zhuang, 2022)

Figure 3 DIRA Model Overview



Market-Informed 24-hour Probability of Depegging (MIPD)

The market-informed 24-hour probability of depegging acts as a predictive risk indicator informed by trading and price fluctuations in both individual stablecoins and broader digital asset market trends, in-practice, assessing the intra-day volatility of a token. To produce the model, a light gradient boosting machine classifier was trained using daily open, high, low, close prices and volume (OHLCV) profiles for selected stablecoins in combination with OHLCV profiles for Bitcoin (BTC) and Ether (ETH). This data was then paired with the 24-hour forward looking Boolean indicator for the occurrence of a depegging event.

Given the OHLCV profiles used in training, the model produces a 24-hour forward-looking probability of depegging for a stablecoin. In addition to a numeric score, the model produces a categorization of “Low”, “Moderate”, or “High” risk indicator based on the 25% and 90% bounds as observed in the model backtesting.

Liquidity-Informed 24-hour Probability of Depegging (LIPD)

Similar to the market-informed model, the liquidity informed 24-hour probability of depegging acts as a predictive risk indicator informed instead by on-chain activity of the stablecoin. To produce the model, a light gradient boosting machine classifier was trained using on-chain metrics including supply, total value locked in smart contracts, and percentage of tokens held by top holders. These metrics, in combination with several others as listed in Appendix 1 were selected for their correlations with on-chain liquidity crunches, and the ability for token holders to exit their position via on-chain methods, especially in stressed market scenarios. The liquidity data set was trained and paired with the same 24-hour forward looking Boolean indicator for the occurrence of a depegging event as seen in the market-informed model.

For prediction, the model takes as an input the liquidity indicators used for model training, producing a numeric 24-hour forward-looking probability of depegging for a stablecoin. Again, the model produces a categorization of “Low”, “Moderate”, or “High” risk indicator based on the 25% and 90% bounds as observed in the test data set.

Issuer 1-year Probability of Default (IPD)

The ability of a stablecoin to maintain its peg relies significantly on the ability and presence of the issuer to maintain operations of minting and burning, as well as keep the token in good-standing through regulatory requirements; therefore, understanding the financial health of the operating issuer can be a forward looking signal in predicting stability and future depegging events for a token. The issuer 1-year probability of default is estimated by EDF-X using market data and entity financials where available. The model also provides a trigger value for producing risk categorizations.

The DIRA framework derives issuing entity names directly from the latest financial attestation regarding a given stablecoin. Issuing entity names are then mapped to Orbis Database Identifiers, which are fed into the EDF-X EWS. Risk benchmarks are derived from EDF-X provided benchmarks based on the mappings in table 1.

TABLE 1 EDF-X RISK CATEGORIZATION MAPPINGS

EDF-X EWS	IPD
Low	Low
Moderate	Moderate
High	High
Severe	High

Aggregate Custodian 1-year Probability of Default (ACPD)

Just as the ability of an issuer to perform timely minting and burning is critical to the peg of a stablecoin, the solvency and ability to fulfill "stablecoin runs" by the entities providing custodial services for collateralizing the peg are essential. As seen in the run on USD Coin (USDC), which moved the stablecoin's price below $0.90 in March of 2023, and linked to the bankruptcy announcement of custodian Silicon Valley Bank[10], market faith in a stablecoin's custodians can lead to the direct depegging of that token.

Accounting for this critical risk point, DIRA incorporates the regular monitoring of custodial partner insolvency risk through 1-year probability of defaults, as provided by EDF-X EWS. In a similar method to issuer assessment, custodians are derived using the latest reserve attestation report of an issuer, and again mapped to Orbis IDs, allowing for the retrieval of the entities 1-year probability of default. The aggregate custodian probability of default is then calculated using

$$\mathrm{P} = \frac{\sum_{i=1}^{n} P_i V_i}{\sum_{i=1}^{n} V_i}$$

Where Pi is the 1-year probability of default for a custodian, Vi is the USD market-value of the reserve assets held by the custodian, and n is the number of custodians. For those issuers that do not specify where specific reserve assets are held, the value held by each listed custodian is assumed to be equal, simplifying to

$$\mathrm{P} = \frac{\sum_{i=1}^{n} P_i}{n}$$

For those issuers that do not disclose their custodial partners, no score can be calculated. Benchmark values of 'Low', 'Moderate', and 'High' are also produced through a similar aggregation using individual trigger values for custodians rather than probability of defaults.

Aggregate Reserve 1-year Probability of Default (ARPD)

The final, and possibly most fundamental, sub-model in the DIRA framework is the assessment of the collateral of a stablecoin, the reserves. Going beyond the market value of the reserves, DIRA utilizes an aggregation of the probability of default for reserve assets to understand the liquidity of reserve assets, and ultimately their adequacy to meet redemption requirements.

Reserve contents are derived using the latest attestation provided by the issuing entity and audited by a 3rd party. The assessment of reserves in DIRA framework requires that (a) total collateral market value is disclosed, (b) all collateral assets are either cash, cash-equivalents, or bonds, and (c) all non-cash assets acting as collateral are disclosed with identifiers when applicable. When these conditions are met, each asset is assigned an associated risk level, either using (a) the asset's Moody's Investors Service (MIS) credit rating, (b) the issuing entities MIS credit rating, or (c) for cash only, the issuing country's MIS credit rating. Each is risk level is

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[10] (Howcroft & Jaiswal, 2023)

then converted to implied probability of defaults as informed by a Moody's Analytics analysis of historical credit rating default frequencies[11]. Once risk levels are mapped to their implied probability of defaults, the aggregate reserve 1-year probability of default is calculated using

$$\mathrm{P} = \frac{\sum_{i=1}^{n} P_i R_i}{\sum_{i=1}^{n} R_i}$$

Where Pi is the assumed probability of default for an asset, Ri is the market value of the asset as disclosed by the issuer, and n is the total number of assets in the reserve.

DIRA 24-hour Probability of Depegging (DIRA-PDep)

Parameterized by the sub-models listed above, the DIRA 24-hour probability of depegging indicator acts as a predictive, integrated signal for depegging risk, informed and trained by the sub-model outputs of DIRA. To produce the output model, a logistic regression classifier was trained using as an input the daily results of each sub-model for each token. The 24-hour forward looking Boolean indicator for the occurrence of a depegging event was paired once again with this set, enabling training of the DIRA model.

Given the outputs of the DIRA sub-models, the DIRA model produces a net 24-hour forward-looking probability of depegging for a stablecoin. Once again, the model produces a categorization of "Low", "Moderate", or "High" risk indicator based on the 25% and 90% bounds as observed in the test data set.

TABLE 2 DIRA MODEL INPUT PARAMETERS

INPUT NAME	ASSOCIATED SUB-MODEL
Date / Time	N/A
Market-informed 24-hour probability of depegging	MIPD
Market-informed risk categorization	MIPD
Liquidity-informed 24-hour probability of depegging	LIPD
Liquidity-informed risk categorization	LIPD
Issuer 1-year probability of default	IPD
Issuer-informed risk categorization	IPD
Aggregate custodian 1-year probability of default	ACPD
Custodian-informed risk categorization	ACPD

TABLE 3 DAM MODEL SPECIFICATION AND FREQUENCIES

MODEL NAME	SYSTEM FREQUENCY	DATA AVAILABILITY FREQUENCY
MIPD	Hourly	Real-Time
LIPD	Hourly	Real-Time
IPD	Monthly	Monthly
ACPD	Daily	Daily
ARPD	Daily	Real-Time[12]
DIRA-PDep	Hourly	Real-Time

DAM Issuer Transparency Index

The DAM system provides an additional metric independent of the DIRA framework, specifically to contextualize and provide visibility into DIRA assessments. Informed by regulations and investor protection best practices, DAM provides the stablecoin

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[11] (Buitrago, Makarov, & Zhao, 2019)

[12] While innovations in the banking and accounting sector have enabled real-time account monitoring, settlement and operational restrictions reduce the feasibility of real-time attesting. Daily updates are seen as a more feasible and accurate approach for reserve accounting.

transparency index, a categorical analysis that assesses the disclosure and transparency practices of stablecoin issuers. This is especially relevant to providing context to missing or outdated scores, and highlights the need for standardization of best practices for stablecoin operations and investor protections.

The transparency index is calculated using

$$\mathrm{TI} = \left\lfloor \frac{\sum_{i=1}^{n} X_i}{n} \right\rceil$$

where Xi is the assigned value for each transparency item categorization and n is the number of transparency items. Full transparency checks are included in table 4.

TABLE 4 TRANSPARENCY INDEX CRITERIA

TRANSPARENCY ITEM	CATEGORY
(I) Legal issuing entity identifiable in Orbis company database	- Yes - No
(II) Publication of stablecoin collateral attestations	- Yes - No
(III) Frequency of Attestations	- Up to Daily - Up to Monthly - Quarterly or more
(IV) Disclosure of Custodians	- Yes with balances - Yes without balances - No
(V) Disclosure of Reserves Assets	- Yes with asset details - Yes without asset details - No disclosure of collateral assets

DATA

Depegging Event Methodology

In the assessment and training of DIRA, an initial historical set of depegging events was required. The dataset was first developed through the collection of open, high, low, close and volume (OHLCV) trading pair profiles on an hourly basis for a set of covered spot exchanges and DeFi liquidity pools[13]. Covered pairs included the combination of each stablecoin in the experiment set with US Dollars (USD), Tether (USDT), TrueUSD (TUSD), and USD Coin (USDC), both in base and quote positions. Once all profiles are collected, OHLC prices are normalized, first converting all non-USD base pairs to USD, then convering all non-USD stablecoins to their respective currencies using daily foreign exchange rates.

Following normalization, an aggregation method is employed on a daily basis for each token, producing an aggregate OHLCV profile, where a weighted average price is used for open and close values, a sum is used for volume, and a maximum and minimum are used for high and low prices, respectively. Each profile is then assessed for a depegging event using the definition described above. Stablecoins included and generalized data can be found in table 5.

Introducing Value at Risk (VAR) Metrics

Beyond understanding simply the occurrence of a depegging event, a secondary metric is also introduced to better understand the potential impact and depth of a depegging event. The Value at Risk (VAR) calculation aims to identify the potential for loss to a party participating in an uncoupled stablecoin trade. In the DIRA framework, Value at Risk is defined as:

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[13] Reference exchanges are provided by Amberdata, Inc. Full details on Amberdata exchange coverage can found at https://docs.amberdata.io/docs/market-data-coverage for centralized exchanges and https://docs.amberdata.io/docs/defi-dex-coverage for decentralized exchanges.

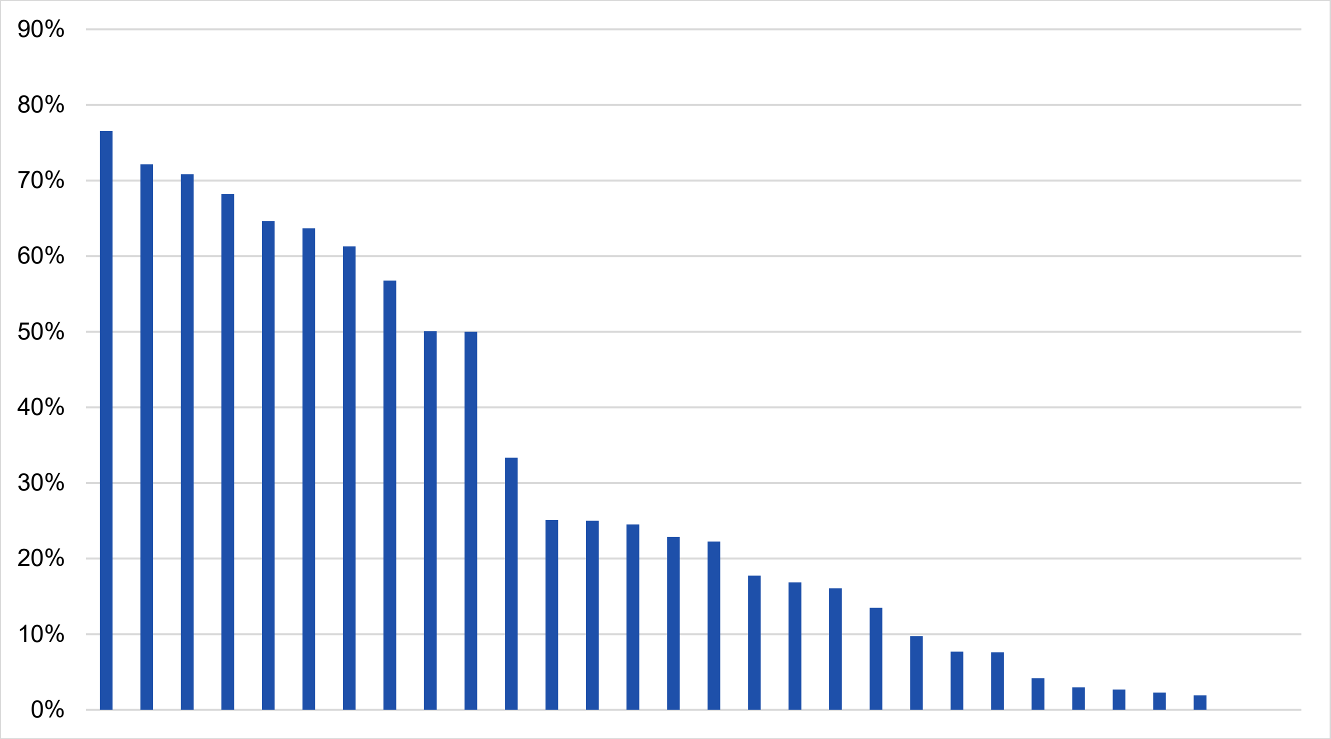
$$VaR = \sum_{i=1}^{n} v_i(1 - p_i)$$

Where n is the total number of profiles in a time period, pi is the profile price in its pegged currency, and vi is the profile volume in its pegged currency. In the DIRA analysis below and in DAM, a time frame of 24 hours is adopted and is calculated at the aggregate profile level, using only a single profile for a VAR analysis. Two methods for calculating VAR are introduced, High VAR which utilizes the high price of an OHLCV profile, and Open VAR which utilizes the open price of an OHLCV profile.

TABLE 5 TRAINING DATA SET

TOKEN SYMBOL	NUMBER OF RECORDS	NUMBER OF DEPEG EVENTS	PERCENTAGE OF DEPEG EVENTS	TOTAL OPEN VAR (USD)	TOTAL MAX VAR (USD)
BUSD	840	573	68%	$1,418,211,613	$53,173,000,000
DAI	168	119	71%	$9,144,165	$1,090,736,303
EUROC	447	274	61%	$7,717,834	$20,151,838
EUROe	167	7	4%	$63,403	$107,993
EURS	840	543	65%	$191,801,924	$319,159,324
EURT	840	606	72%	$272,508,687	$1,086,796,072
FDUSD	261	0	0%	$866,605	$8,246,062
FRAX	168	129	77%	$9,303,876	$78,772,813
GBPT	434	109	25%	$1,365,604	$1,513,377
GUSD	840	206	25%	$2,699,492	$14,387,404
IDRT	341	46	13%	$2,146	$2,565
LUSD	168	56	33%	$3,992,778	$16,287,762
MXNT	458	260	57%	$62,877	$77,112
OUSD	168	5	3%	$12,208	$33,081
PYUSD	261	5	2%	$7,989	$391,814
QCAD	26	2	8%	$5,092	$644
TAUD	722	55	8%	$11,375	$12,440
TCAD	660	15	2%	$352	$397
TGBP	840	149	18%	$21,782	$23,744
THKD	82	8	10%	$381	$412
TUSD	840	187	22%	$135,436,505	$2,801,970,749
USDC	840	535	64%	$1,380,863,176	$57,255,000,000
USDD	168	27	16%	$5,182,151	$26,058,804
USDP	261	44	17%	$13,506,171	$62,529,473
USDT	840	192	23%	$1,020,443,225	$20,231,000,000
XCHF	840	420	50%	$851,986	$1,082,721
XIDR	661	331	50%	$3,525	$3,525
XSGD	840	643	77%	$73,155,577	$82,336,590
ZUSD	261	7	3%	$11,817	$27,643

Figure 4 Observed frequency of depegging by stablecoin



RESULTS

After conducting model training and selection, assessment was performed primarily on the Overall DIRA model, as well as the DIRA-native MIPD and LIPD models. For brevity, individual assessment of the IPD, ACPD, and ARPD models were not explored in detail, as they leverage tested models that have been previously explored in their respective whitepapers[14]. The non-native sub-models are; however, still assessed in their predictive abilities for stablecoin depegging events.

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[14] (Hamilton, Pieschacon, Xu, & Zhuang, 2022)

MIPD Model Assessment

Figure 5 MIPD Accurate Predictions over Time

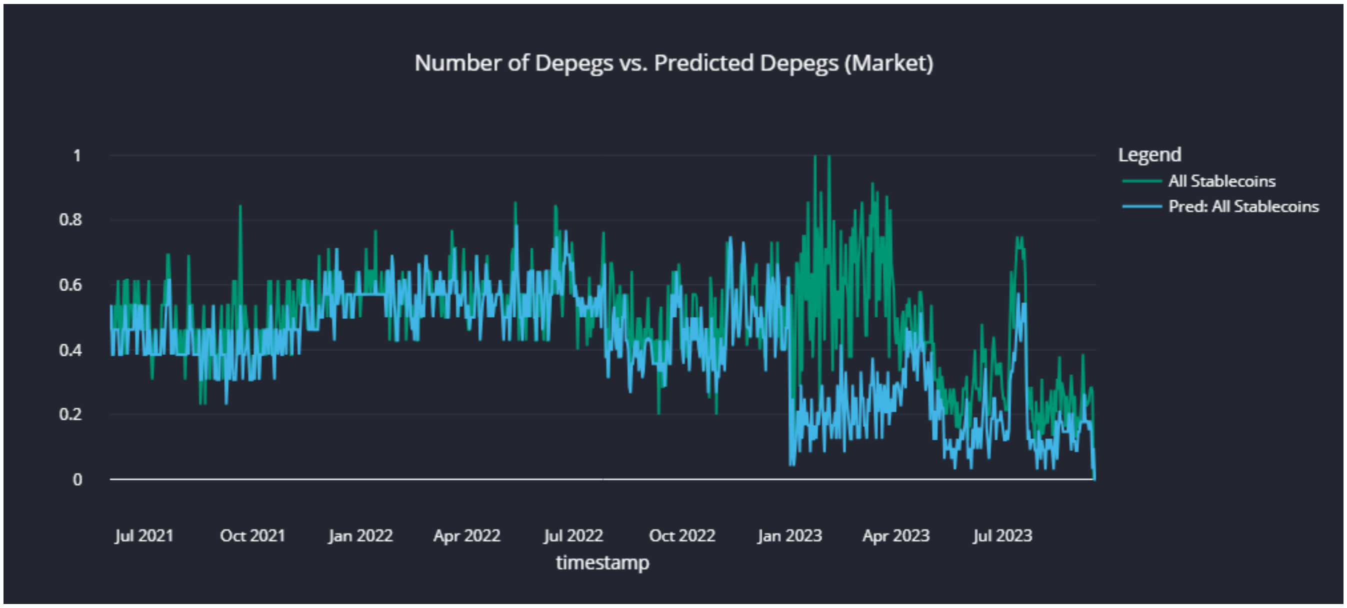
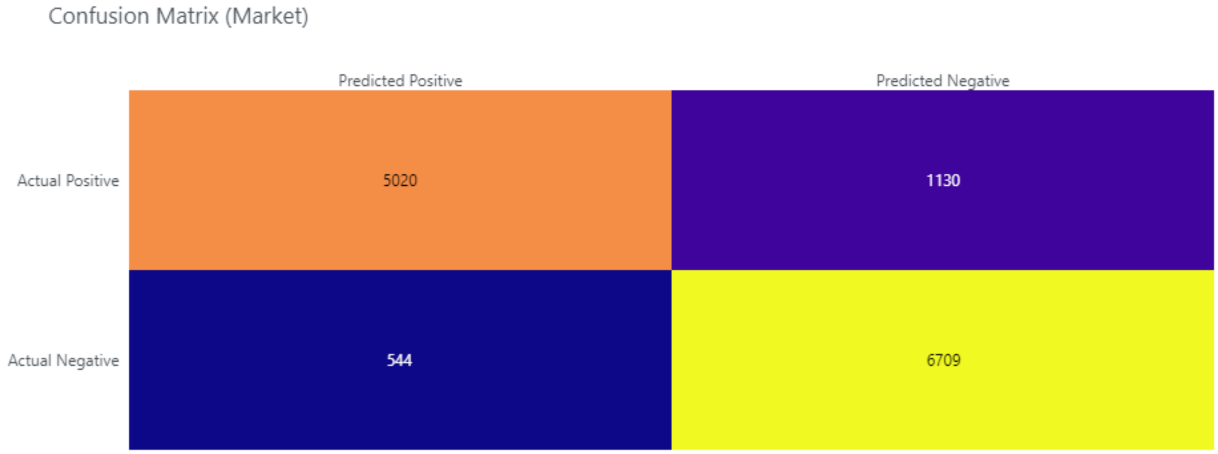


Figure 6 MIPD Confusion Marks



	Predicted Positive	Predicted Negative
Actual Positive	5020	1130
Actual Negative	544	6709

LIPD Model Assessment

Figure 7 LIPD Accurate Prediction over Time

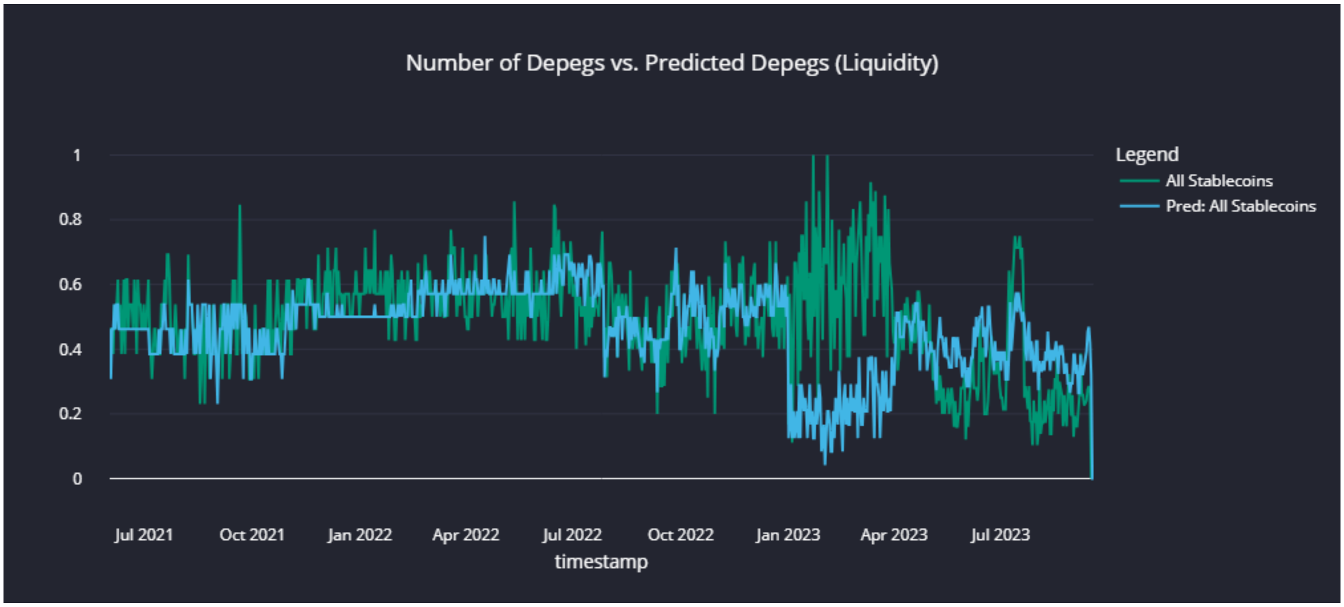
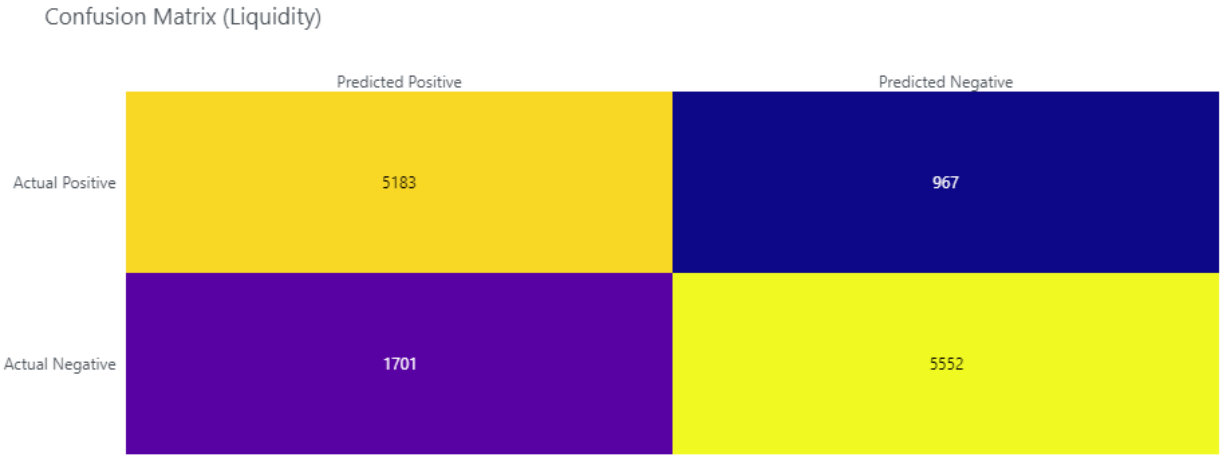


Figure 8 LIPD Confusion Matrix


Confusion Matrix (Liquidity)

	Predicted Positive	Predicted Negative
Actual Positive	5183	967
Actual Negative	1701	5552

DIRA Overall Model Assessment

Figure 9 DIRA Accurate Predictions over Time

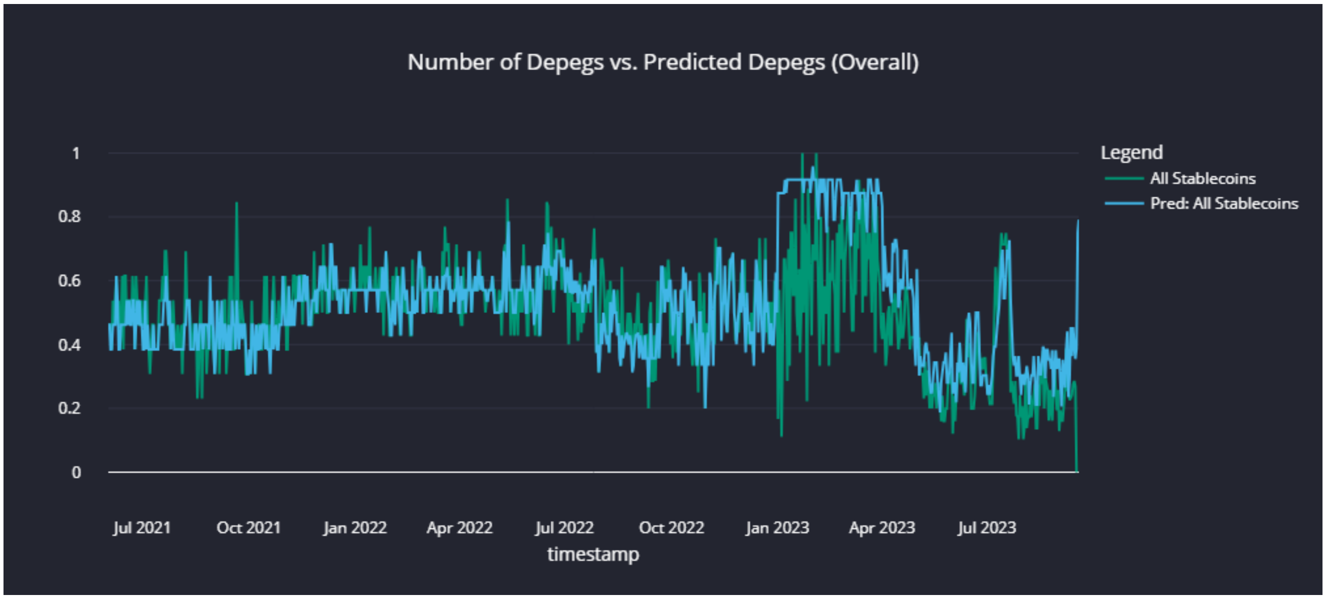
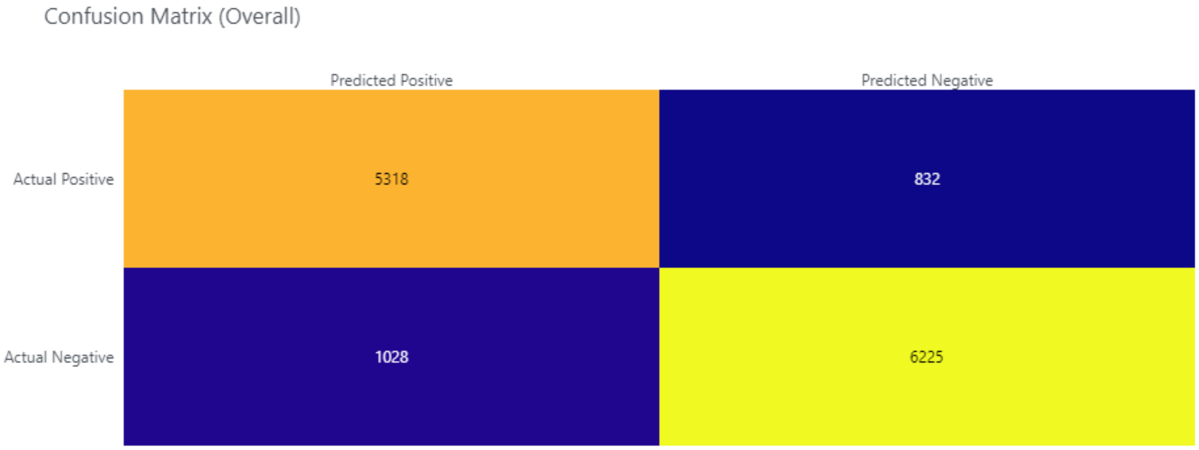


Figure 10 DIRA Confusion Matrix



Confusion Matrix (Overall)

	Predicted Positive	Predicted Negative
Actual Positive	5318	832
Actual Negative	1028	6225

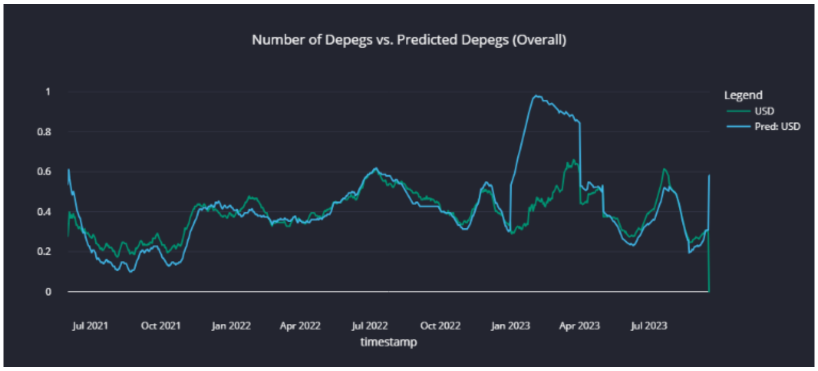
TABLE 6 MODEL PERFORMANCE FOR DEPEGGING PREDICTIONS WITH VARIABLE PROBABILITY TRIGGER SENSITIVITY

TRIGGER PROBABILITY SENSITIVITY	NUMBER OF EVENTS	FALSE NEGATIVES	TRUE NEGATIVES	FALSE POSITIVES	TRUE POSITIVES	PRECISION	RECALL	F1 SCORE	EVENTS SUCCESSFULLY PREDICTED
0.1	6150	228	4386	2867	5922	0.674	0.963	0.793	0.963
0.2	6150	384	5208	2045	5766	0.738	0.938	0.826	0.938
0.3	6150	551	5636	1617	5599	0.776	0.910	0.838	0.910
0.4	6150	689	5953	1300	5461	0.808	0.888	0.846	0.888
0.5	6150	832	6225	1028	5318	0.838	0.865	0.851	0.865
0.6	6150	1048	6481	772	5102	0.869	0.830	0.849	0.830
0.7	6150	1304	6726	527	4846	0.902	0.788	0.841	0.788
0.8	6150	1588	6913	340	4562	0.931	0.742	0.826	0.742
0.9	6150	2010	7118	135	4140	0.968	0.673	0.794	0.673

MODEL DISCUSSION

Figure 11 DIRA Efficacy with Non-USD Tokens

USD



Non-USD

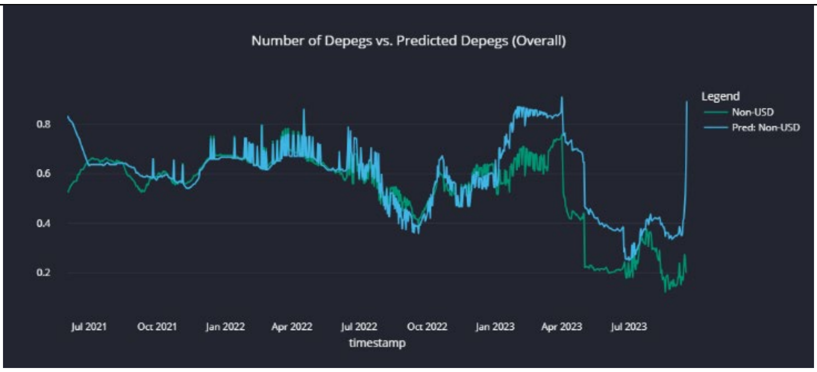
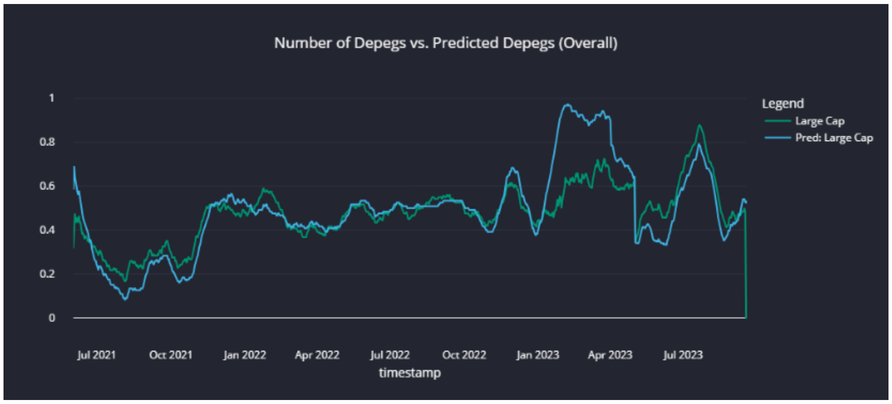
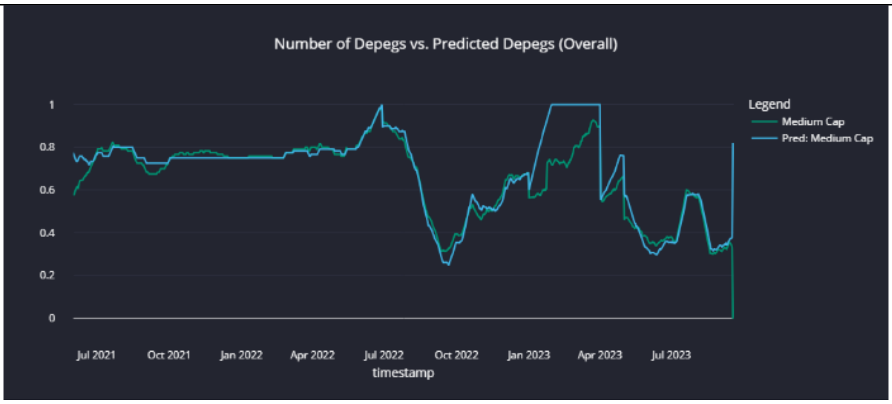


Figure 12 DIRA Efficacy among Market Capitalization Categorizations

Large Cap



Medium Cap



Small Cap

Limitations in DAM Implementation

While DAM has extensive coverage across tokens, custodians, and look-back periods, historical training and dataset creation required intentional assumptions to be made for feasible implementation. The primary assumption to account for was historical knowledge of custodian relationships and reserve assets, which lack a complete, standardized, and historical dataset today[15]. Given these parameters exist in non-standard attestations, accurate custodians and reserve assessments in the DIRA model training set only date back to January 1, 2022. All training data before this period assumes the same set of known custodians and a similar reserve makeup.

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[15] Public data availability of off-chain reserves and custodial relationships are at the issuer's discretion. This can impact the outcomes of the model, and issuer transparency indices can be used to understand underlying data availability.

A secondary limitation is in the analysis of VAR, in the precision and level with which it is calculated. In a more robust analysis of this metric, calculation should instead be performed at the order-book level, using

$$VaR = \sum_{i=1}^{t} v_i(1 - p_i)$$

Where vi is the volume of an individual trade, pi is the price of the asset in the pegged currency, and t is the total transactions for the stablecoin. In this assessment, VAR is a secondary comparative indicator, and does not implement this level of precision due to availability of data.

A final limitation to note in the overall DIRA framework is tracking of covered exchanges. Due to tracking OHLCV profiles at the exchange-level rather than the overall-market level, DIRA is inherently limited by the number of exchanges that can be monitored and covered. In the DAM system, over 90% of trade volume is covered in its historical exchange monitoring[16].

FUTURE WORK

Opportunities for multi-dimensional, categorized depegging

The current DIRA framework, and it's associated prediction models, performs Boolean assessment across two dimensions at the intersection of two points: a single time horizon, and single depegging threshold, 24 hours and 3% in the DAM system. In truth, the profile of a depegging event covers a wide range of dimensions, which future models may expand to include. Table 7 below describes potential added dimensions in further detail.

TABLE 7 DIMENSIONS OF A DEPEGGING EVENT

CATEGORY	POTENTIAL PREDICTION TARGETS
Duration	- Time horizon of forward looking probability - Concurrent minutes spent depegged - Concurrent trades spend depegged
Depth	- Number of asset pairs depegged - Specific asset pairs depegged
Severity	- Sign / direction of depeg - Magnitude of depeg
Location	- Blockchain of depeg event - Exchange of depeg event

Expansion of DIRA Inputs into Technical Risks

The goal of the DIRA framework is to assess both financial and operational risk of an asset. Thanks to the flexibility built into the DIRA model, DIRA can quickly be synthesized with additional risk metrics to provide an enhanced integrated assessment of stablecoin risk. Two operational points on the roadmap for DIRA are both technical in nature, smart contract risk assessment and blockchain risk assessment. While the latter covers a more macro-view of the stablecoins ability to generally operate its minting and burning functions in a timely manner, the former can provide a complex look into the capabilities of the issuer, potential security concerns, and built-in risk management protections. Ultimately, quantitative risk measurements around technical risk factors will better help to inform risk management decisions.

Expansion of Real World Assets

Real World Assets (RWAs) are tokenized tangible assets from the physical world. RWAs can include tokens of real assets like real estate, commodities, precious metals and art. RWAs also consist of capital market products such as private credit and U.S. Treasuries.

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[16] According to CoinGecko (coingecko.com), covered exchanges included 93% of total USD spot-market volume as of October 25, 2023.

RWAs reduces transaction costs by eliminating intermediaries and automating processes via smart contracts. It increases liquidity by turning traditionally less-liquid assets into tradeable tokens with option of fractional ownership and provides transparency through an immutable record of transactions.

Today in private credit, one asset class with high potential for tokenization, the market is valued at $1.5 trillion[17]; however, only 0.03% ($0.5 billion)[18] of this market is currently represented on the public blockchain, representing a significant opportunity for value transfer to on-chain systems.

While there is significant opportunity for RWAs, Tokenization faces significant challenges, slowing its widespread adoption. Primarily, these encompass limited infrastructure, high initial implementation costs, market immaturity, need for industry alignment and regulatory uncertainty.

Implications of Non-USD Stablecoins and CBDCs

Stablecoins pegged to the United States Dollar (USD) holds a 99% of the total market share in the stablecoin sector[19]. The top 5 stablecoins as of October 2023 are Tether (USDT), USD Coin (USDC), Dai (DAI), TrueUSD (TUSD), and Binance USD (BUSD). They are all pegged to USD with combined circulating supply of $120 billion. In contrast, the non-USD stablecoin with the highest market capitalization is Tether EURt (EURT) with $36M market capitalization.

The emergence of Central Bank Digital Currencies (CBDCs) has become a significant trend in the global financial landscape. 11 countries[20] have launched their CBDCs, 21 are in the pilot stage and 33 are in the development stage. This indicates a widespread interest and investment in this new form of digital currency. However, there is still considerable uncertainty about the technological infrastructure that will underpin these CBDCs, with it being unclear how many will be issued on blockchain. In terms of their use, CBDCs are being explored in two main categories: wholesale and retail. Wholesale CBDCs are intended for interbank payments and settlements. On the other hand, retail CBDCs are aimed at everyday consumers and businesses, providing a digital alternative to physical cash.

CBDCs have the potential to revolutionize the financial system by providing a new form of digital money that is directly issued by the central bank. The implications of this are particularly significant when considering the size of the money supply in major economies such as the USA and the European Union. As of now, the M1 money supply, which includes physical currency and demand deposits, stands at approximately $18.32 trillion in the USA and €10.55 trillion in the European Union. The introduction of a CBDC in these economies could potentially digitize a significant portion of this money supply.

CONCLUSION

The DIRA model is an effective predictor of stablecoin depegging events, and incorporation of DAM into digital asset risk management processes can provide a more robust, proactive view of potential stablecoin risks. As a model, DIRA is optimized for flexibility and generalizability, ultimately achieving automated, near-time risk assessment for a given stablecoin.

Signals from DAM, Moody's Analytics' proprietary monitoring system utilizing DIRA, has potential applications in multiple use cases across the digital asset ecosystem. Built for risk assessment; exchanges, wallets, and other custodial platforms can protect and inform users, through the integration of DAM into token onboarding processes and ongoing monitoring systems. Payment platforms and other businesses exploring or using stablecoins for transaction purposes can optimize their transaction workflows for loss mitigation through DAM-informed stablecoin selection and transaction timing. Finally, on-chain market players can utilize DAM in their selection of stablecoins for lending collateral, temporary holding positions between transactions, or use DAM to identify potential arbitrage opportunities.

Going forward, there are several potential opportunities to enhance the DIRA framework. A primary focus will be in the addition of technical-based risk indicators including smart-contract risk assessment and blockchain risk-assessment. Given the overlap of infrastructure between fiat-backed stablecoins and other RWAs, the DIRA model has high potential to expand to new asset classes,

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[17] (Lee & Sage, 2023)

[18] As of October 25, 2023, $564,959,407 of active loans were on-chain, according to RWA.xyz

[19] (Lee S. , 2023)

[20] (Atlantic Council, 2023)

including tokenized treasuries and over-collateralized stablecoins, such as DAI. Finally, further investigation should be performed into the feasibility of multi-dimensional classification for depegging risk prediction.

APPENDIX

TABLE 8 DIRA SUB-MODEL INPUT PARAMETERS

INPUT NAME	SOURCE	RELEVANT MODEL(S)
Date / Time	N/A	MIPD, LIPD
Token Open	Spot Markets, DeFi Liquidity Pools	MIPD, LIPD
Token High	Spot Markets, DeFi Liquidity Pools	MIPD
Token Low	Spot Markets, DeFi Liquidity Pools	MIPD
Token Close	Spot Markets, DeFi Liquidity Pools	MIPD
Token Volume	Spot Markets, DeFi Liquidity Pools	MIPD, LIPD
BTC Open	Spot Markets, DeFi Liquidity Pools	MIPD
BTC High	Spot Markets, DeFi Liquidity Pools	MIPD
BTC Low	Spot Markets, DeFi Liquidity Pools	MIPD
BTC Close	Spot Markets, DeFi Liquidity Pools	MIPD
BTC Volume	Spot Markets, DeFi Liquidity Pools	MIPD
ETH Open	Spot Markets, DeFi Liquidity Pools	MIPD
ETH High	Spot Markets, DeFi Liquidity Pools	MIPD
ETH Low	Spot Markets, DeFi Liquidity Pools	MIPD
ETH Close	Spot Markets, DeFi Liquidity Pools	MIPD
ETH Volume	Spot Markets, DeFi Liquidity Pools	MIPD
Circulating Supply	Tracked blockchains	LIPD
Free Float Supply	Tracked blockchains	LIPD
Total Supply	Tracked blockchains	LIPD
Max Supply	Tracked blockchains	LIPD
Total Liquidity (Native)	Tracked blockchains	LIPD
Total Liquidity (USD)	Tracked blockchains	LIPD
Total Liquidity Ratio	Tracked blockchains	LIPD
Market Cap	Tracked blockchains, Spot Markets	LIPD
Average Transferred Value (Native)	Tracked blockchains	LIPD
Average Transferred Value (USD)	Tracked blockchains, Spot Markets	LIPD
Total Transferred Value, last 24 hours (Native)	Tracked blockchains	LIPD
Total Transferred Value, last 24 hours (USD)	Tracked blockchains, Spot Markets	LIPD
Total Transfers	Tracked blockchains	LIPD
Top 10 Wallet Holder Balance	Tracked blockchains	LIPD
Top 10 Wallet Holder Balance Ratio	Tracked blockchains	LIPD
Issuing Entity	Latest Issuer Attestation	IPD
Custodian Entities	Latest Issuer Attestation	ACPD
Reserve Assets	Latest Issuer Attestation	ARPD
Reserve Asset Ratings	Moody's Investors Service	ARPD

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