As of 03/31/2020

Liquidity
Trends and Sensitivities

School and Institutional
Trust Funds Office

Liquidity Trends and Sensitivities

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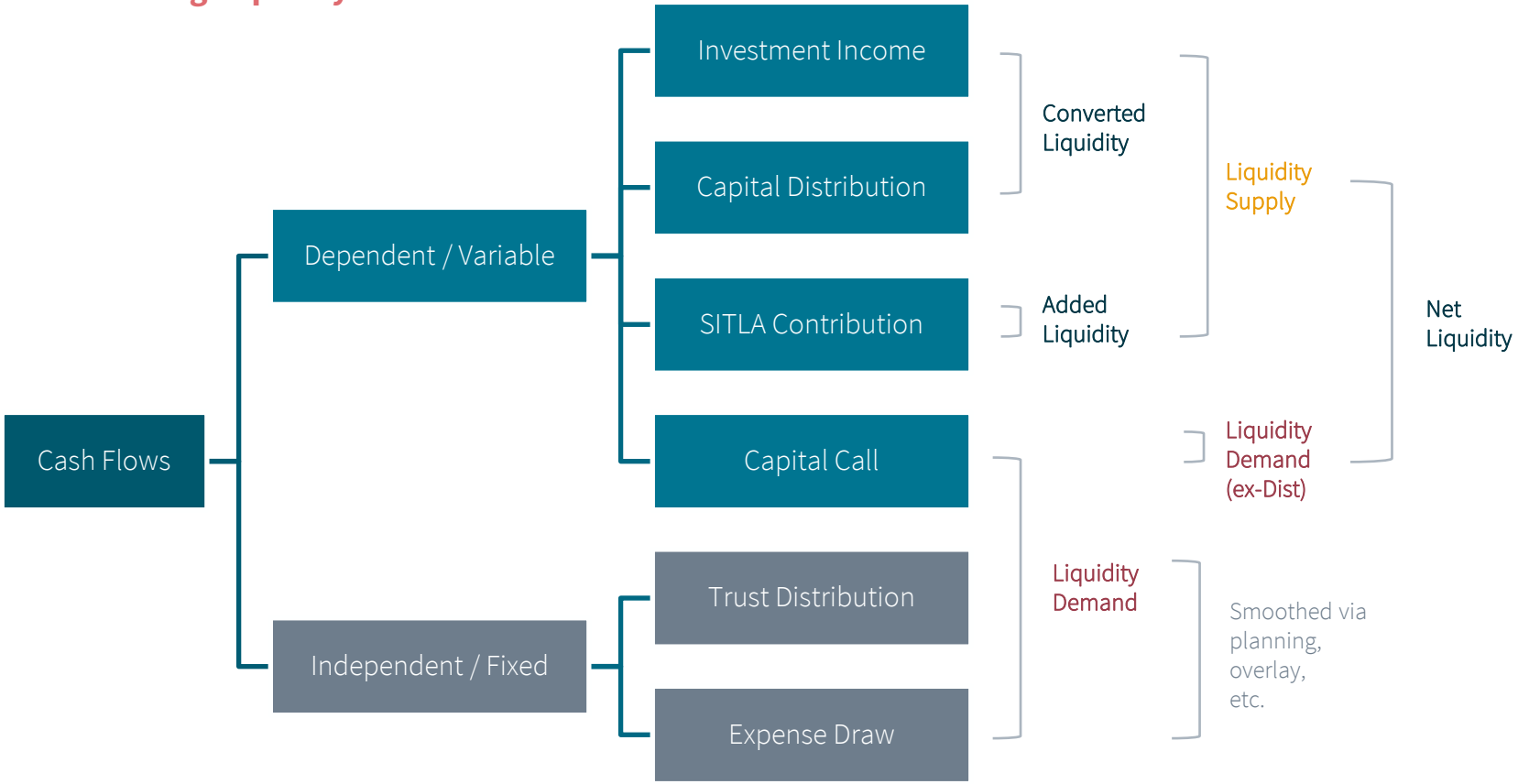
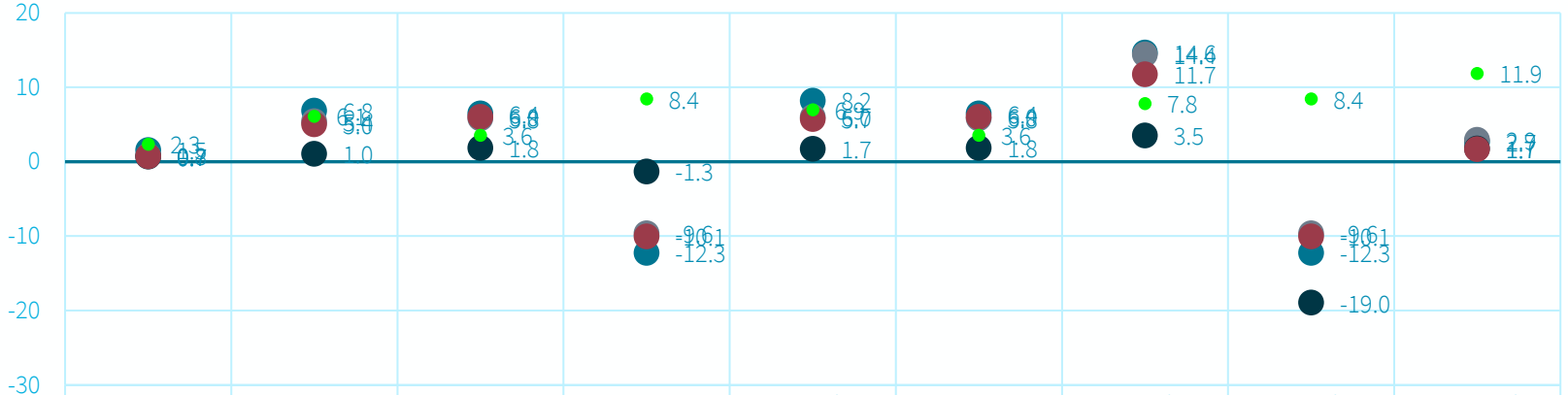
Liquidity Overview

Factors Affecting Liquidity

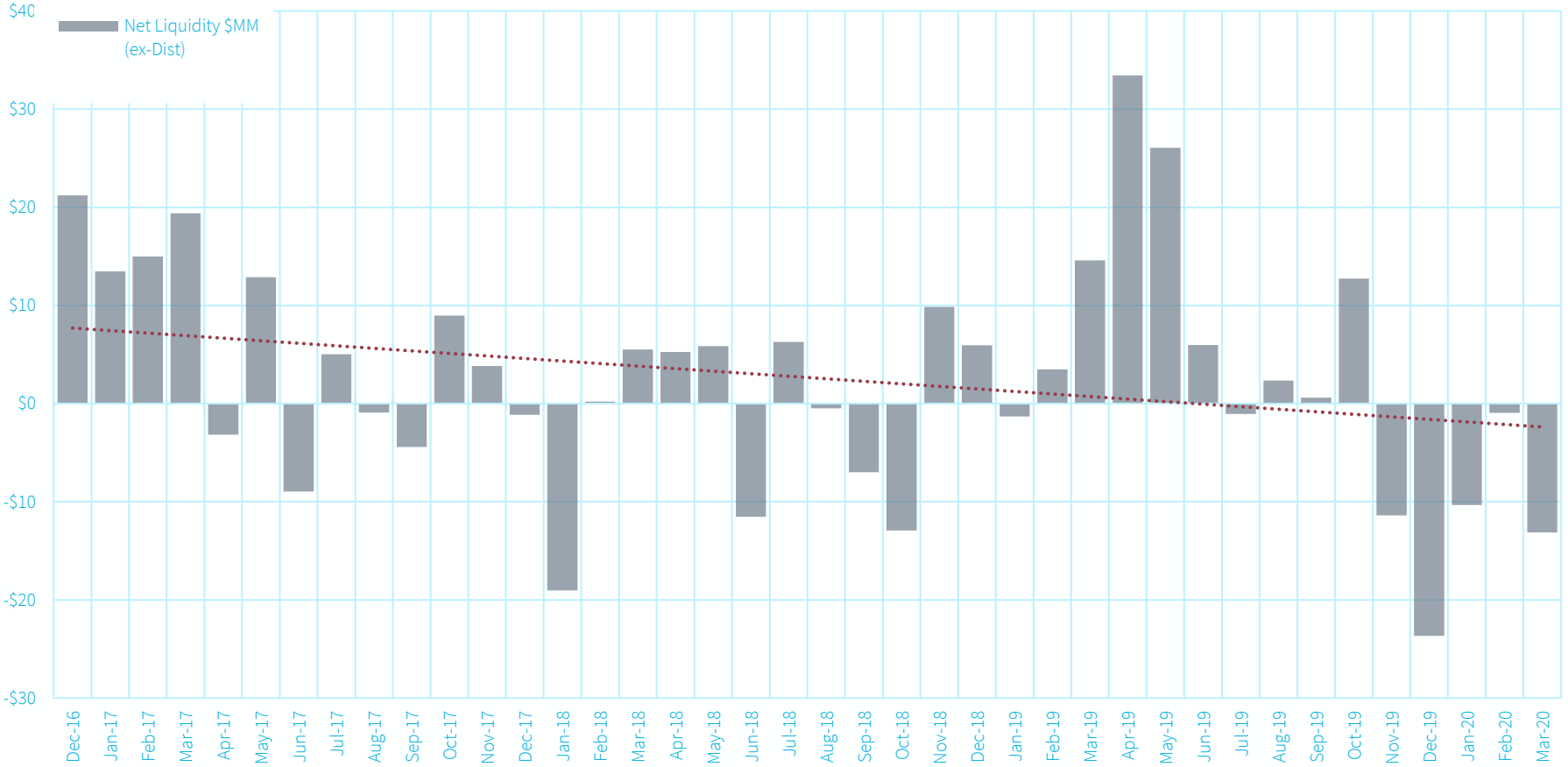


Portfolio Monthly Liquidity Ranges ($MM)



	Investment Income	Capital Distributions	SITLA Contributions	Capital Calls	Total Converted Liquidity	Total Added Liquidity	Total Liquid Supply	Total Liquid Demand	Net Liquidity $MM (ex-Dist)
Observed Average	1.5	6.8	6.4	-12.3	8.2	6.4	14.6	-12.3	2.7
Observed Median	0.8	5.4	5.8	-9.6	6.0	5.8	14.4	-9.6	2.9
Fitted RV Average*	0.7	1.0	1.8	-1.3	1.7	1.8	3.5	-19.0	1.7
Fitted RV Median*	0.7	5.0	6.0	-10.1	5.7	6.0	11.7	-10.1	1.7
Observed Sigma	2.3	6.1	3.6	8.4	6.9	3.6	7.8	8.4	11.9

* Fitted random variable computes parameters from observed data to build Weibull distributions. Weibull is a highly flexible distribution that can take the form of almost any observed histogram and help us model outcomes. Its applications include manufacturing reliability/failure rates, extreme value theory, and weather forecasting. Fitted distributions are shown in more detail beginning page 12 and we can see how sometimes Weibull is a better fit for observed values. The point is to consider the above centering metrics as a range.


Net Liquidity $MM
(ex-Dist)
$40
$30
$20
$10
$0
-$10
-$20
-$30
Dec-16
Jan-17
Feb-17
Mar-17
Apr-17
May-17
Jun-17
Jul-17
Aug-17
Sep-17
Oct-17
Nov-17
Dec-17
Jan-18
Feb-18
Mar-18
Apr-18
May-18
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Feb-19
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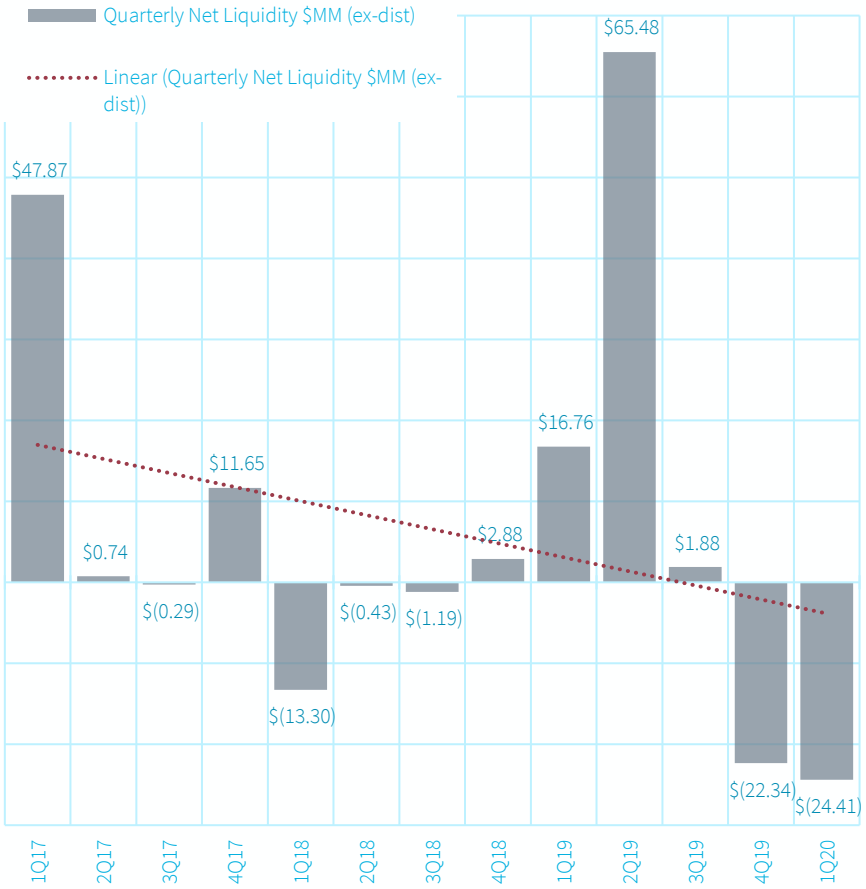
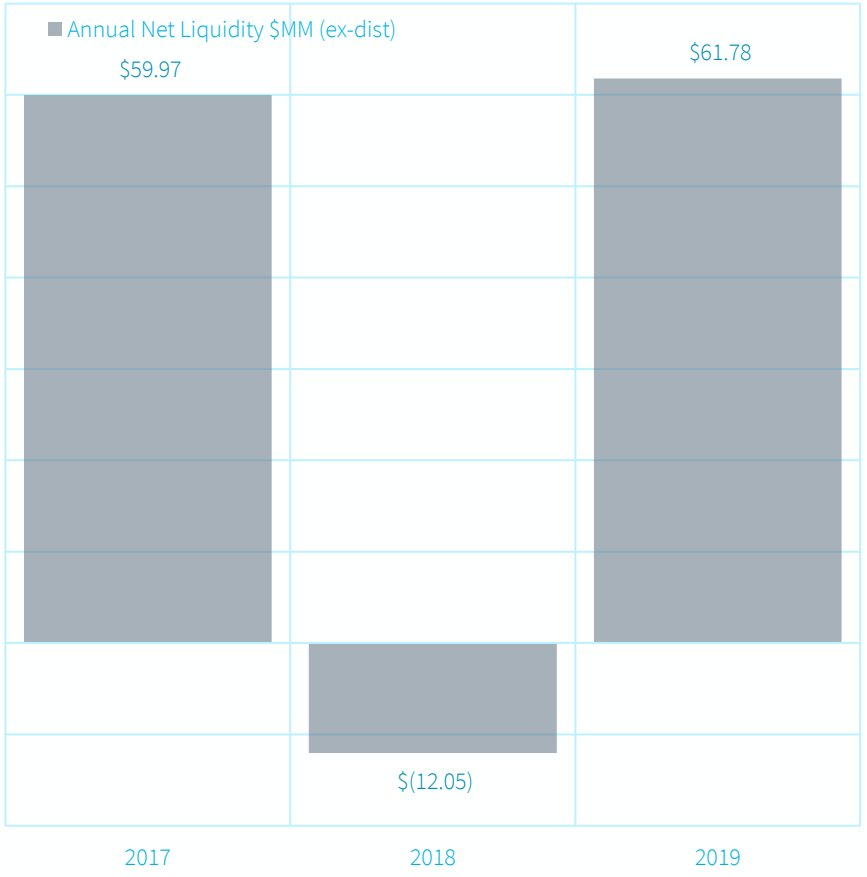
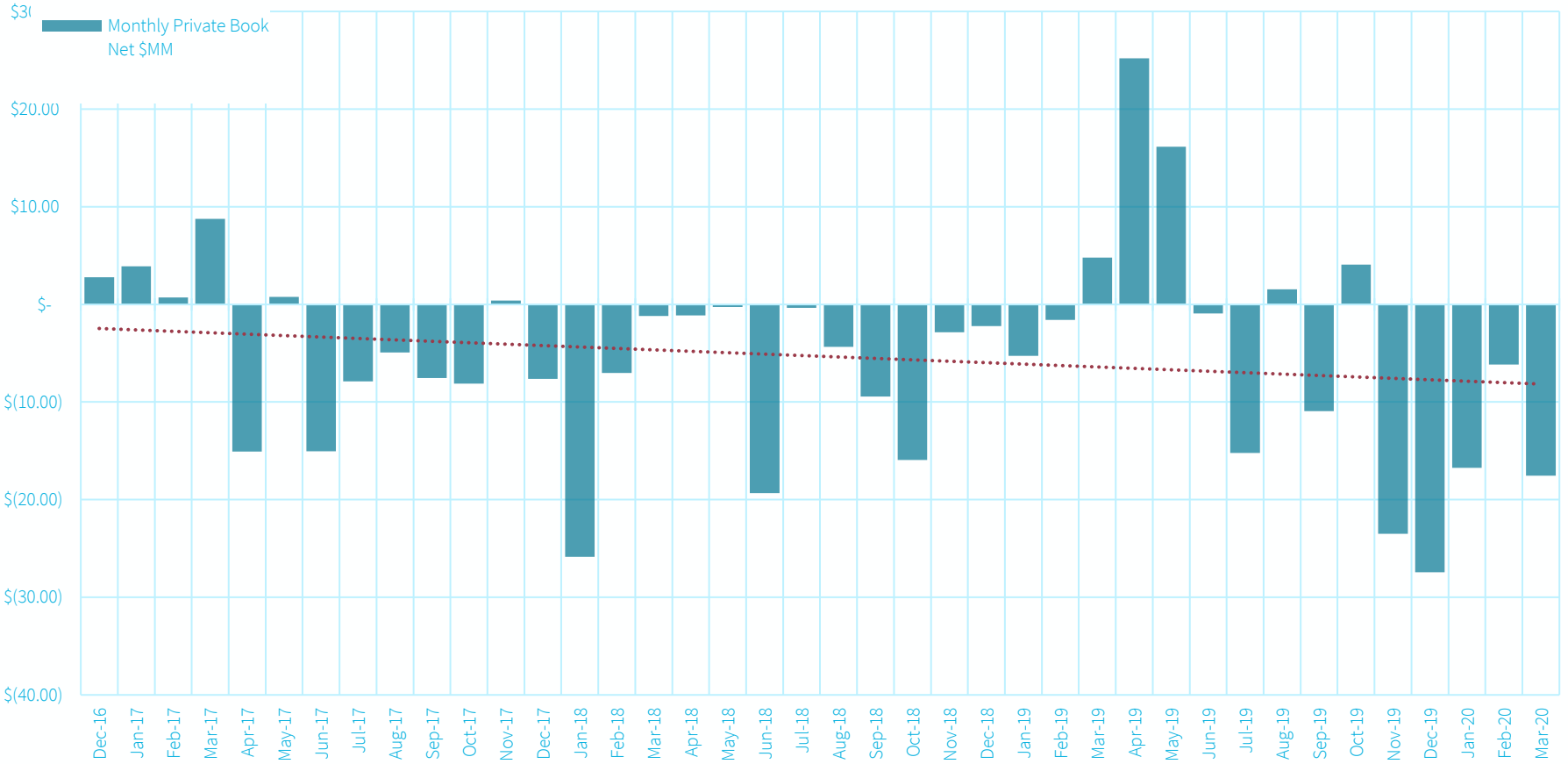
Jul-19
Aug-19
Sep-19
Oct-19
Nov-19
Dec-19
Jan-20
Feb-20
Mar-20


Quarterly Net Liquidity $MM (ex-dist)
Linear (Quarterly Net Liquidity $MM (ex-dist))
$47.87
$0.74
$(0.29)
$11.65
$(13.30)
$(0.43)
$(1.19)
$2.88
$16.76
$65.48
$1.88
$(22.34)
$(24.41)
1Q17
2Q17
3Q17
4Q17
1Q18
2Q18
3Q18
4Q18
1Q19
2Q19
3Q19
4Q19
1Q20


Annual Net Liquidity $MM (ex-dist)
$59.97
$(12.05)
$61.78
2017
2018
2019


$3(
Monthly Private Book Net $MM
$20.00
$10.00
$-
$(10.00)
$(20.00)
$(30.00)
$(40.00)
Dec-16
Jan-17
Feb-17
Mar-17
Apr-17
May-17
Jun-17
Jul-17
Aug-17
Sep-17
Oct-17
Nov-17
Dec-17
Jan-18
Feb-18
Mar-18
Apr-18
May-18
Jun-18
Jul-18
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Jan-19
Feb-19
Mar-19
Apr-19
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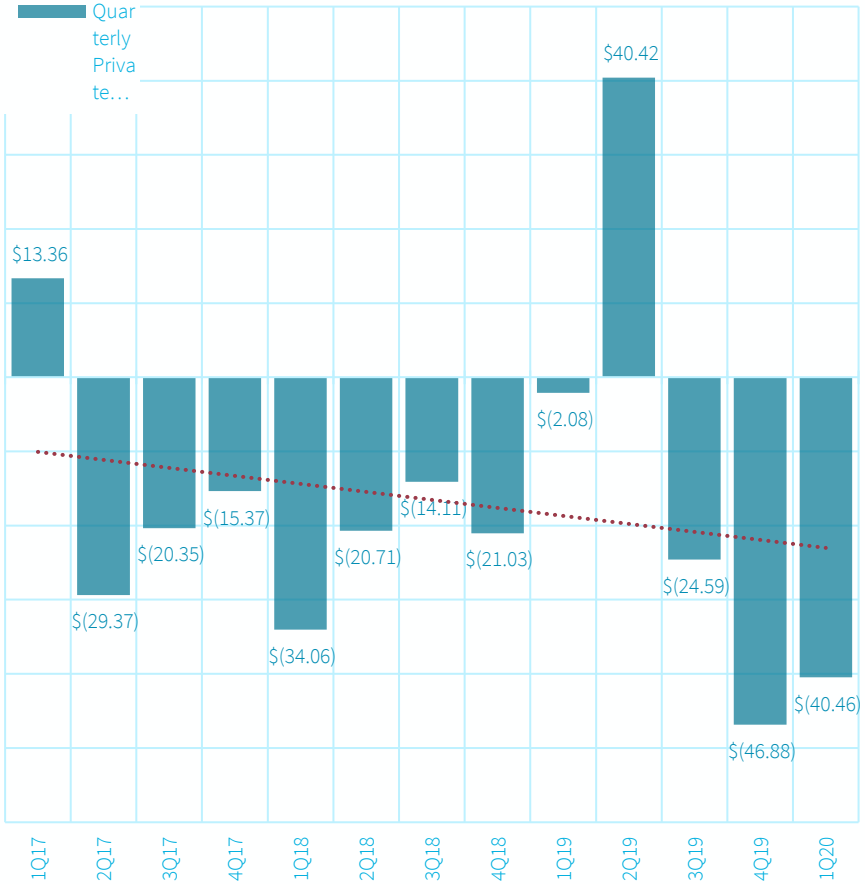
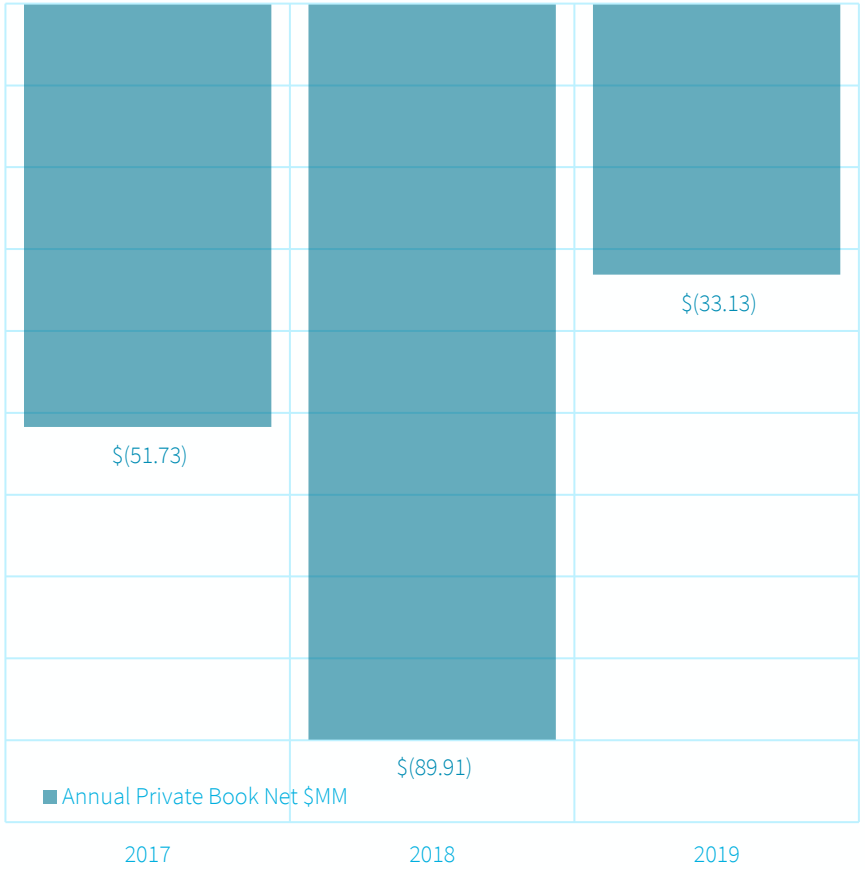
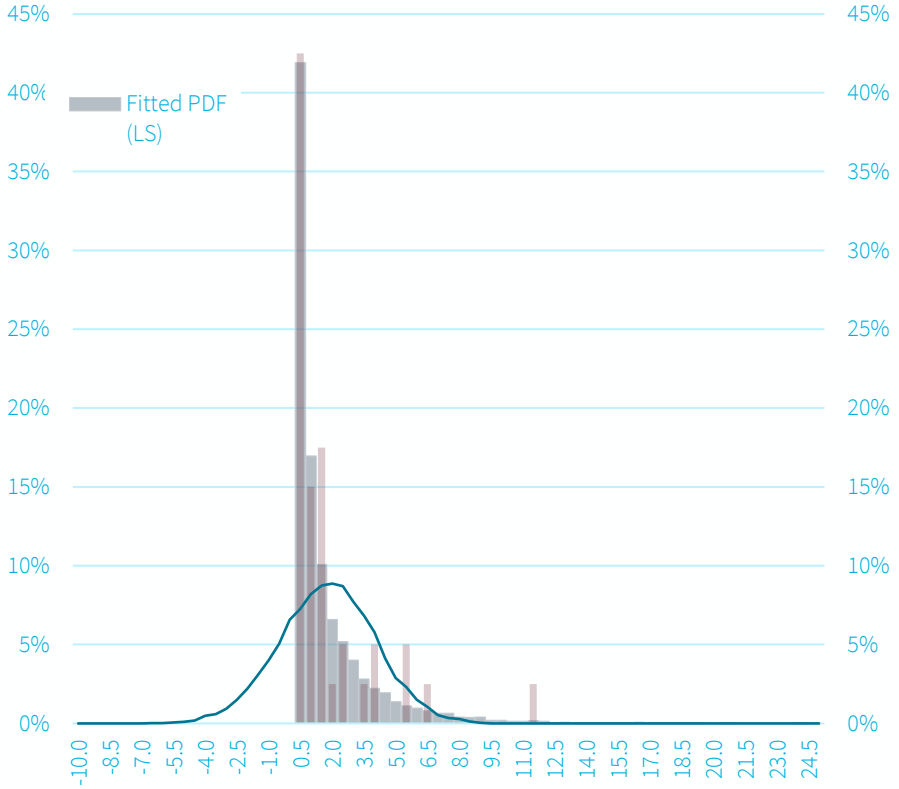
Feb-20
Mar-20

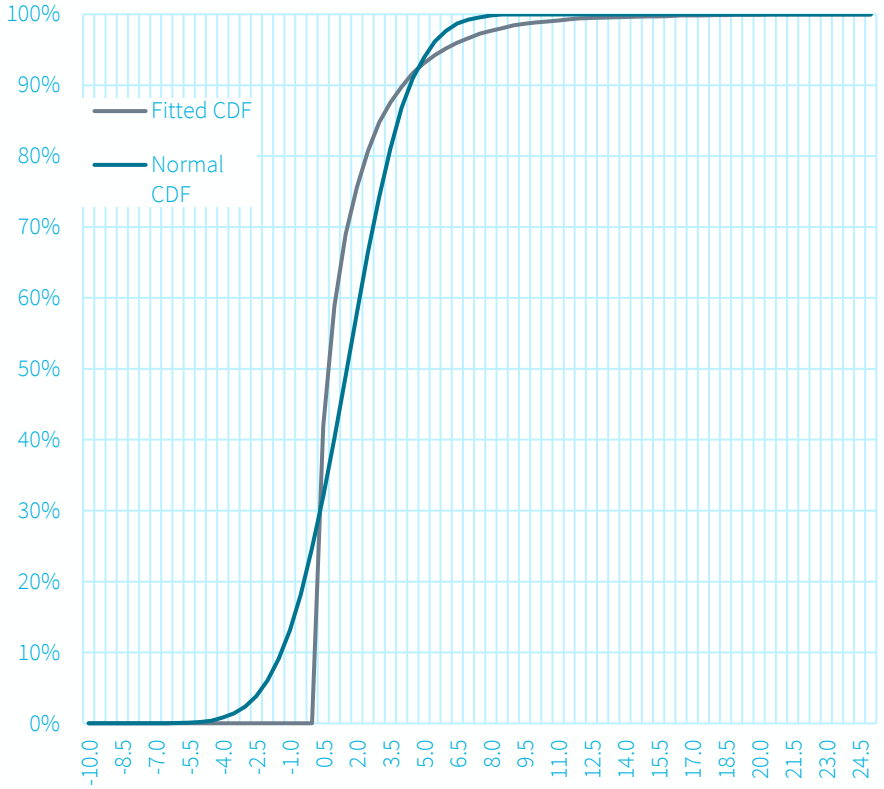

Quarterly Private te…
$13.36
$(29.37)
$(20.35)
$(15.37)
$(34.06)
$(20.71)
$(14.11)
$(21.03)
$(2.08)
$40.42
$(24.59)
$(46.88)
$(40.46)
1Q17
2Q17
3Q17
4Q17
1Q18
2Q18
3Q18
4Q18
1Q19
2Q19
3Q19
4Q19
1Q20


$(51.73)
$(89.91)
$(33.13)
Annual Private Book Net $MM
2017
2018
2019

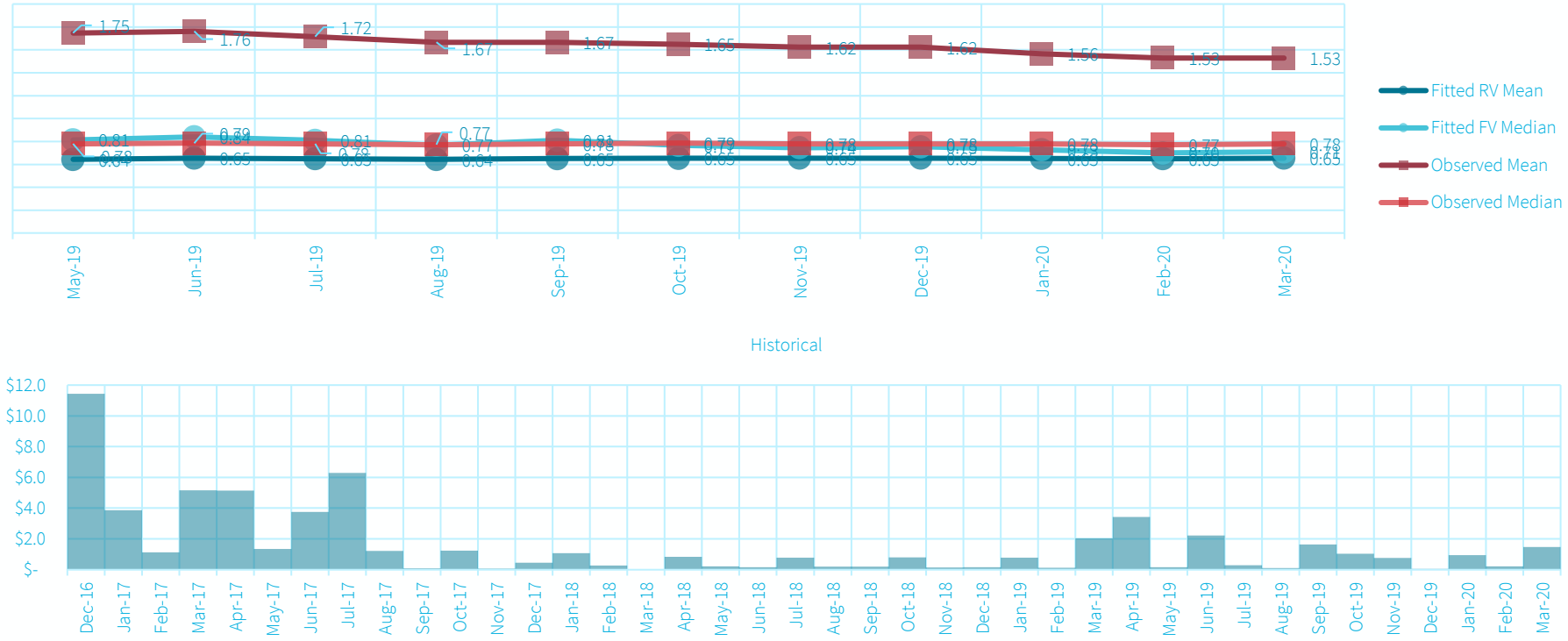
Dependent Liquidity Components
Distributions, trends, sensitivities

Investment Income
Distributions

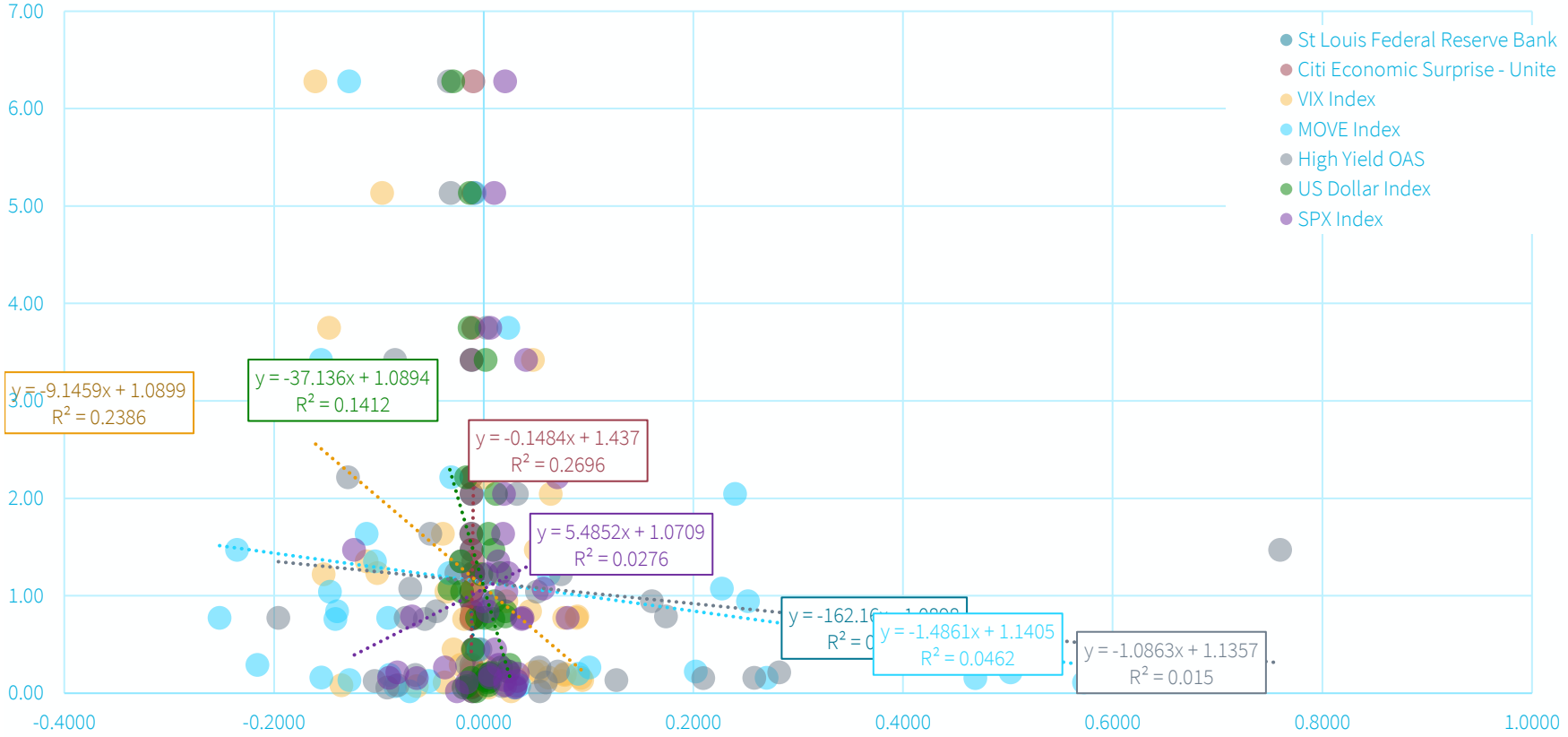




Investment Income
Trends



Investment Income
Sensitivities

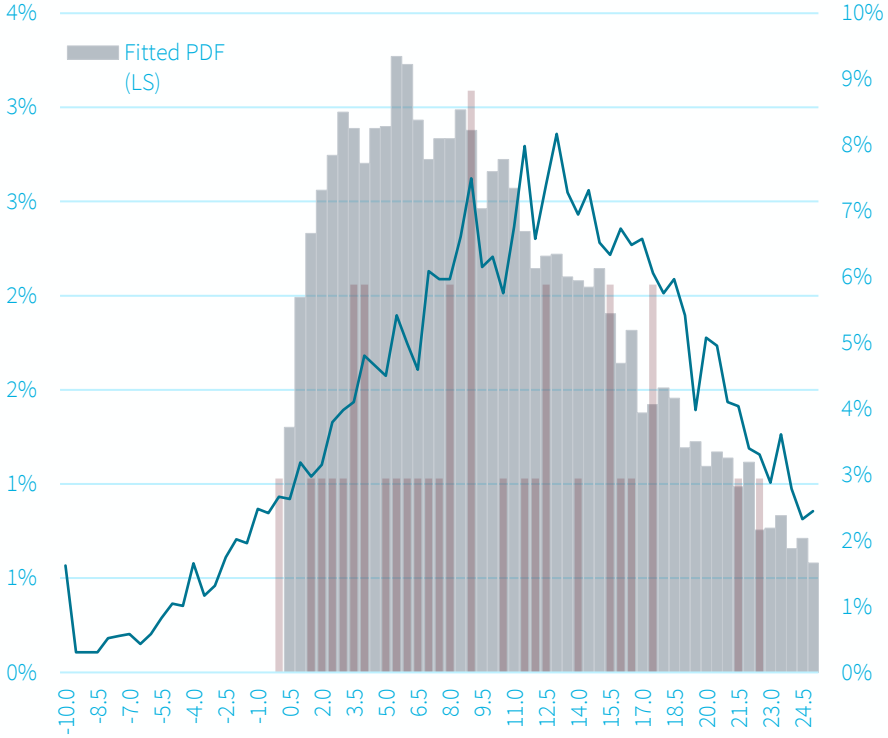


Investment Income
Correlation (Rolling 30-Month)

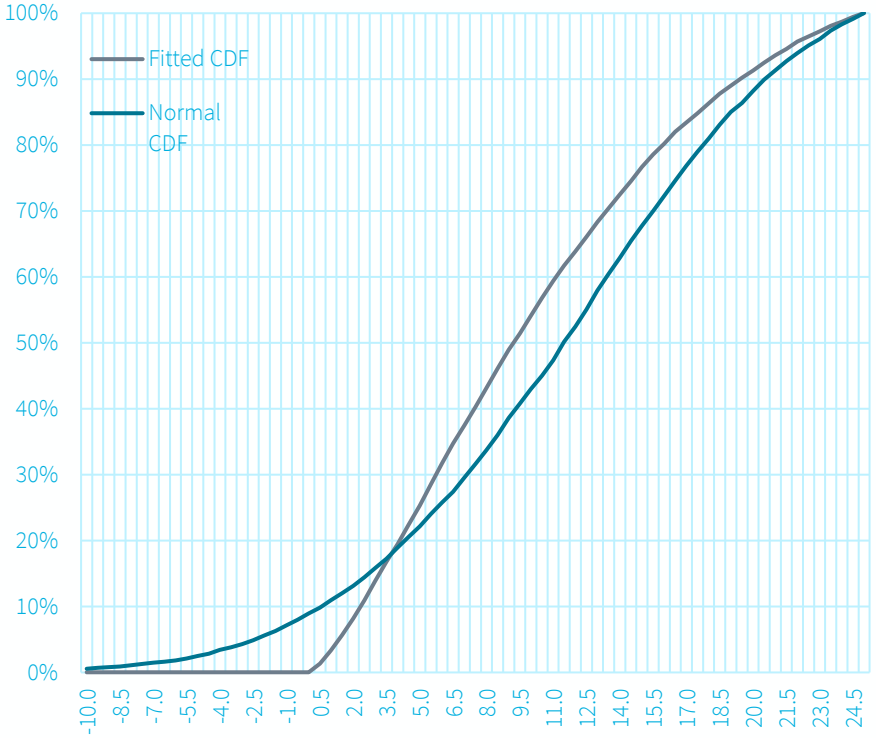
	St Louis Fed Finanacial Conditions	Citi Financial Surprise	VIX Index	MOVE Index	SPX Index	High Yield OAS	US Dollar Index
3/31/2020	-0.14	-0.09	-0.02	0.02	0.17	0.11	0.23
2/28/2020	-0.18	-0.03	-0.21	-0.02	0.24	-0.10	0.22
1/31/2020	-0.14	-0.07	-0.22	0.06	0.21	-0.05	0.22
12/31/2019	0.21	-0.38	-0.33	-0.10	-0.13	-0.09	0.01
11/29/2019	0.29	-0.46	-0.38	-0.10	-0.20	-0.12	0.03
10/31/2019	0.29	-0.46	-0.39	-0.11	-0.21	-0.12	0.04
9/30/2019	0.41	-0.50	-0.42	-0.06	-0.34	-0.10	0.17
8/30/2019	0.51	-0.52	-0.43	-0.04	-0.47	-0.06	0.29
7/31/2019	0.50	-0.53	-0.42	0.05	-0.45	-0.05	0.33
6/28/2019	0.49	-0.54	-0.41	0.05	-0.44	-0.05	0.37

Capital Call
Distributions

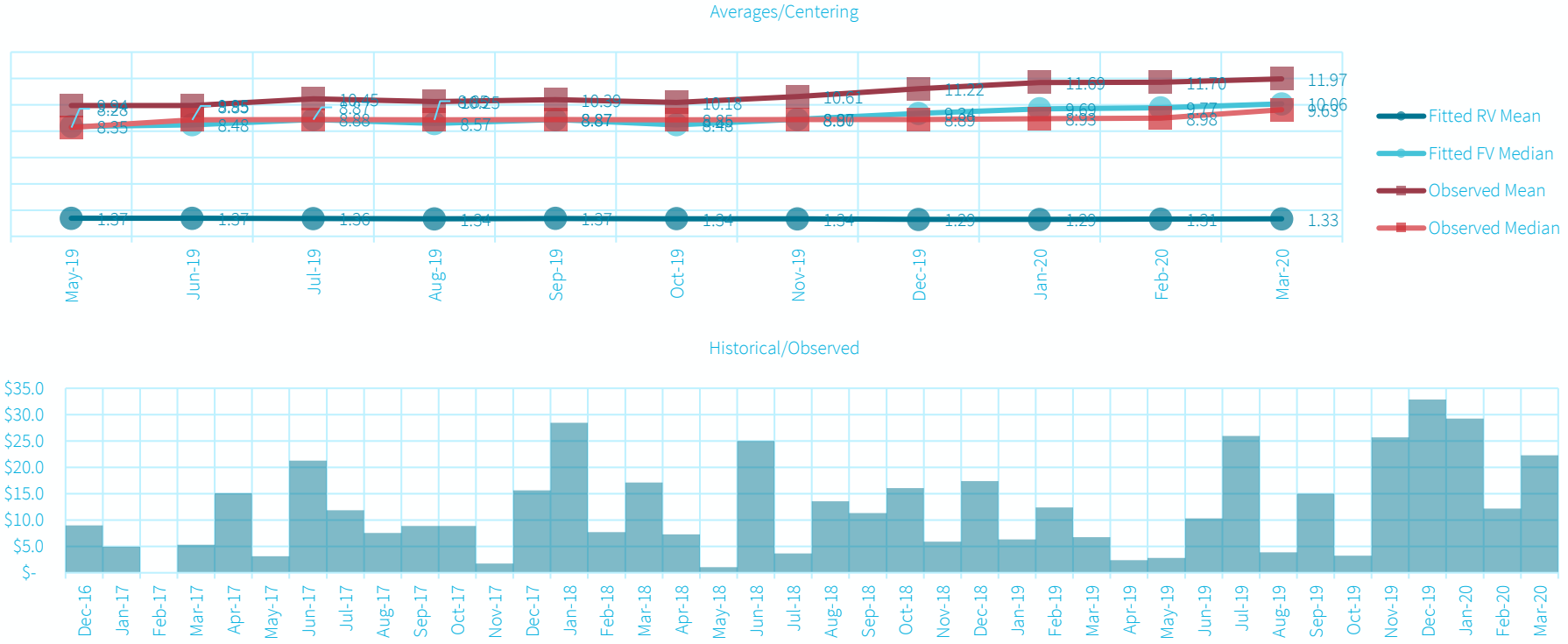
Collected Distributions



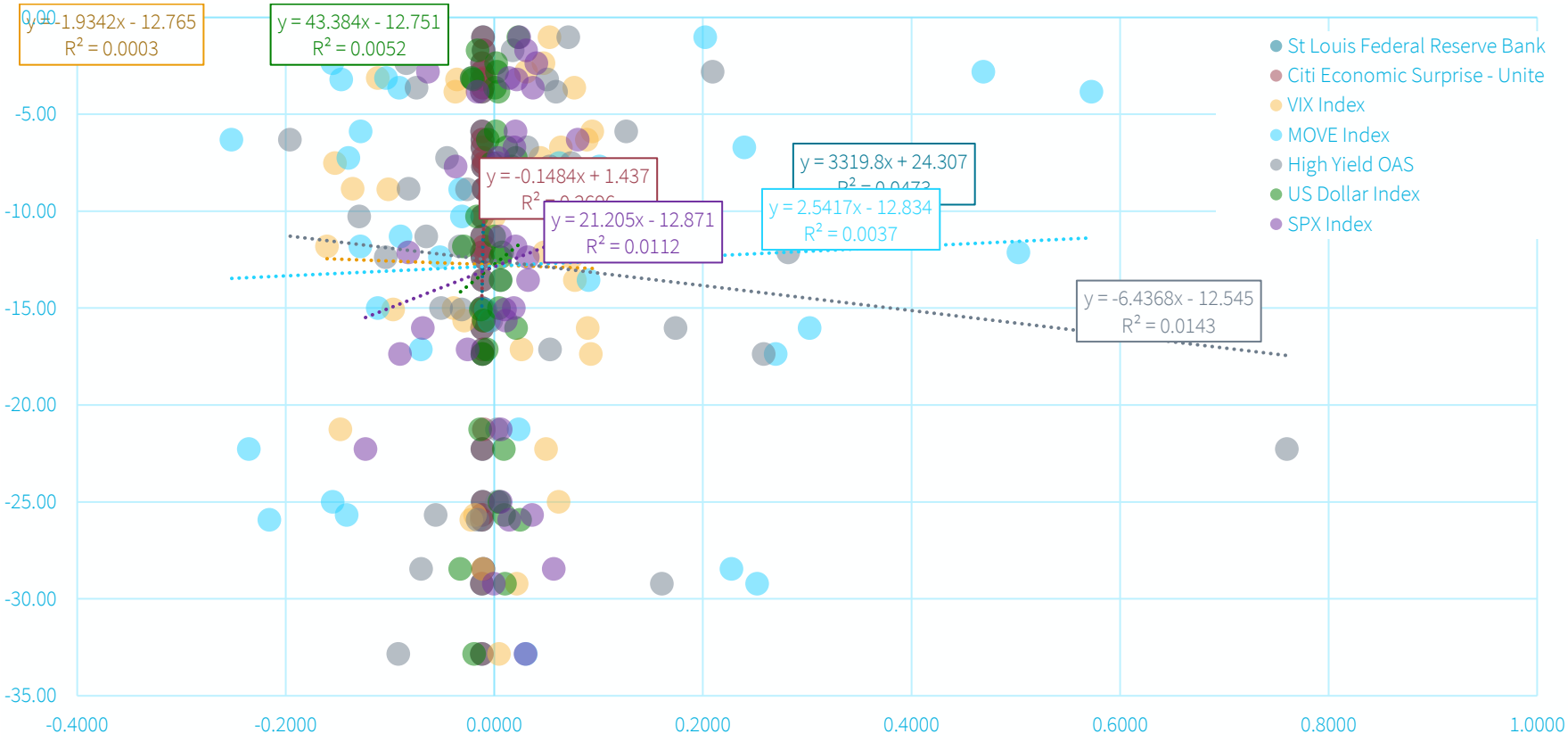
Capital Calls



Capital Call
Trends



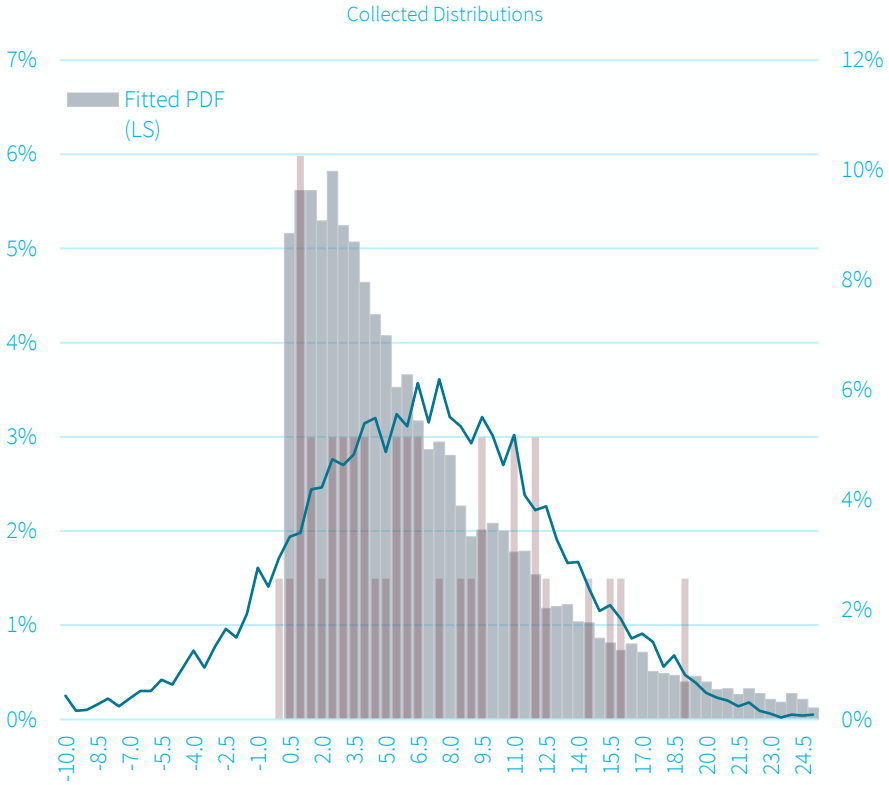
Capital Call
Sensitivities

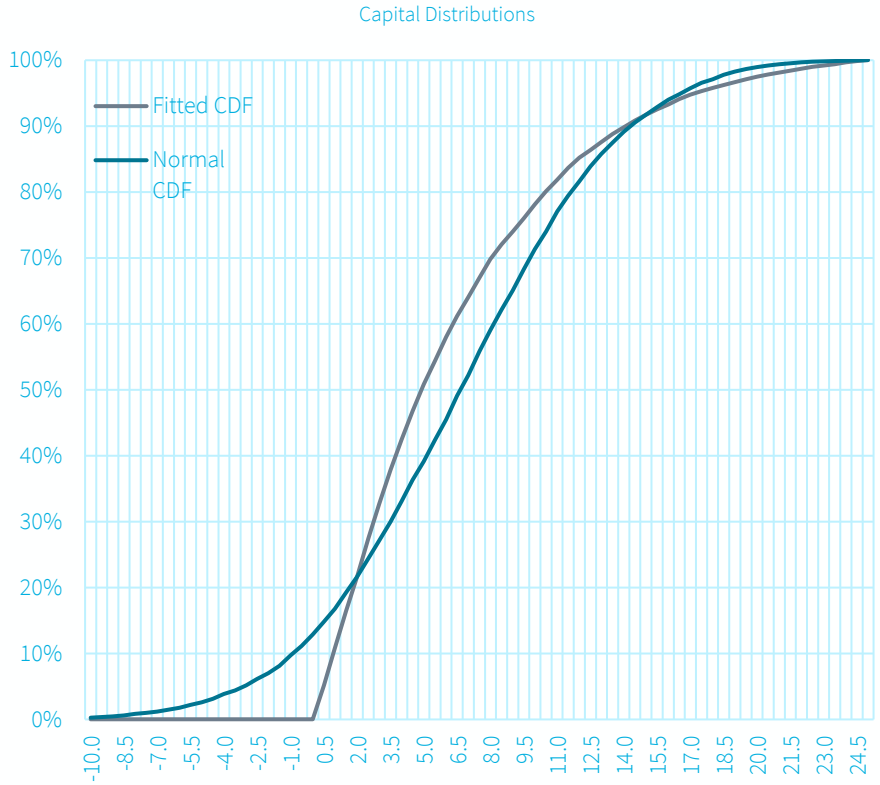


Capital Call
Correlation (Rolling 30-Month)

	St Louis Fed Finanacial Conditions	Citi Financial Surprise	VIX Index	MOVE Index	SPX Index	High Yield OAS	US Dollar Index
3/31/2020	0.18	0.06	-0.17	-0.07	-0.36	-0.12	-0.02
2/28/2020	0.19	0.03	-0.06	-0.02	-0.41	0.09	0.02
1/31/2020	0.22	-0.02	-0.13	-0.05	-0.42	0.10	0.00
12/31/2019	0.15	-0.01	-0.07	0.05	-0.31	0.14	0.05
11/29/2019	-0.04	0.07	-0.07	0.07	-0.05	0.08	0.09
10/31/2019	-0.05	0.01	-0.15	0.07	0.03	0.08	0.20
9/30/2019	-0.04	0.04	-0.11	0.03	0.00	0.06	0.14
8/30/2019	-0.02	0.01	-0.12	0.08	-0.02	0.07	0.22
7/31/2019	0.03	0.02	-0.16	-0.04	-0.07	0.06	0.18
6/28/2019	-0.08	0.01	-0.14	-0.04	0.07	0.06	0.31

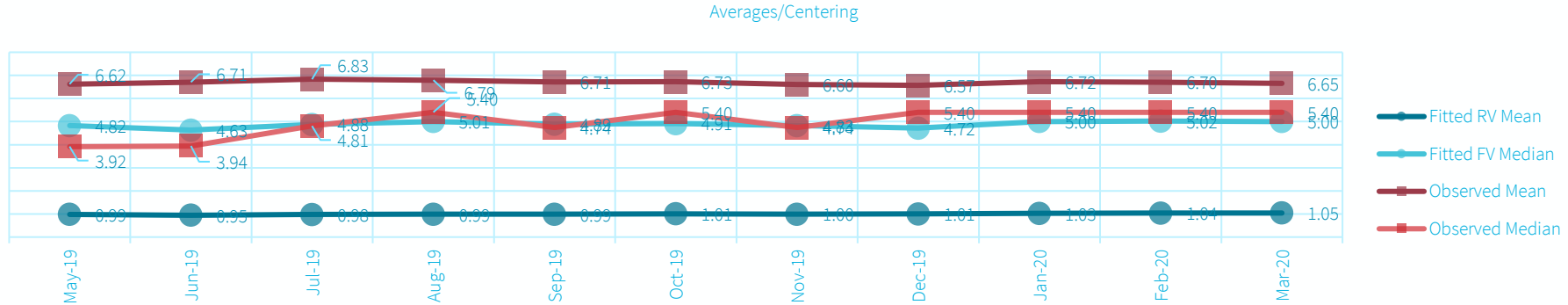
Capital Distribution
Distributions

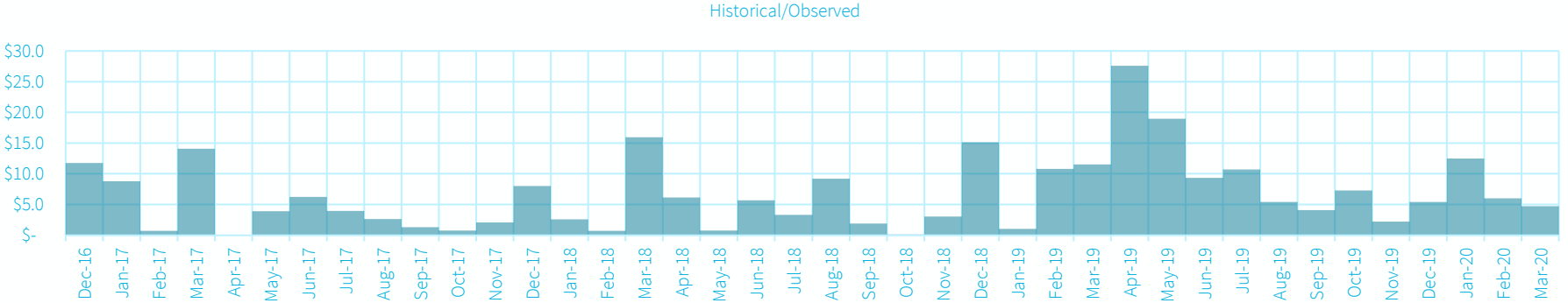




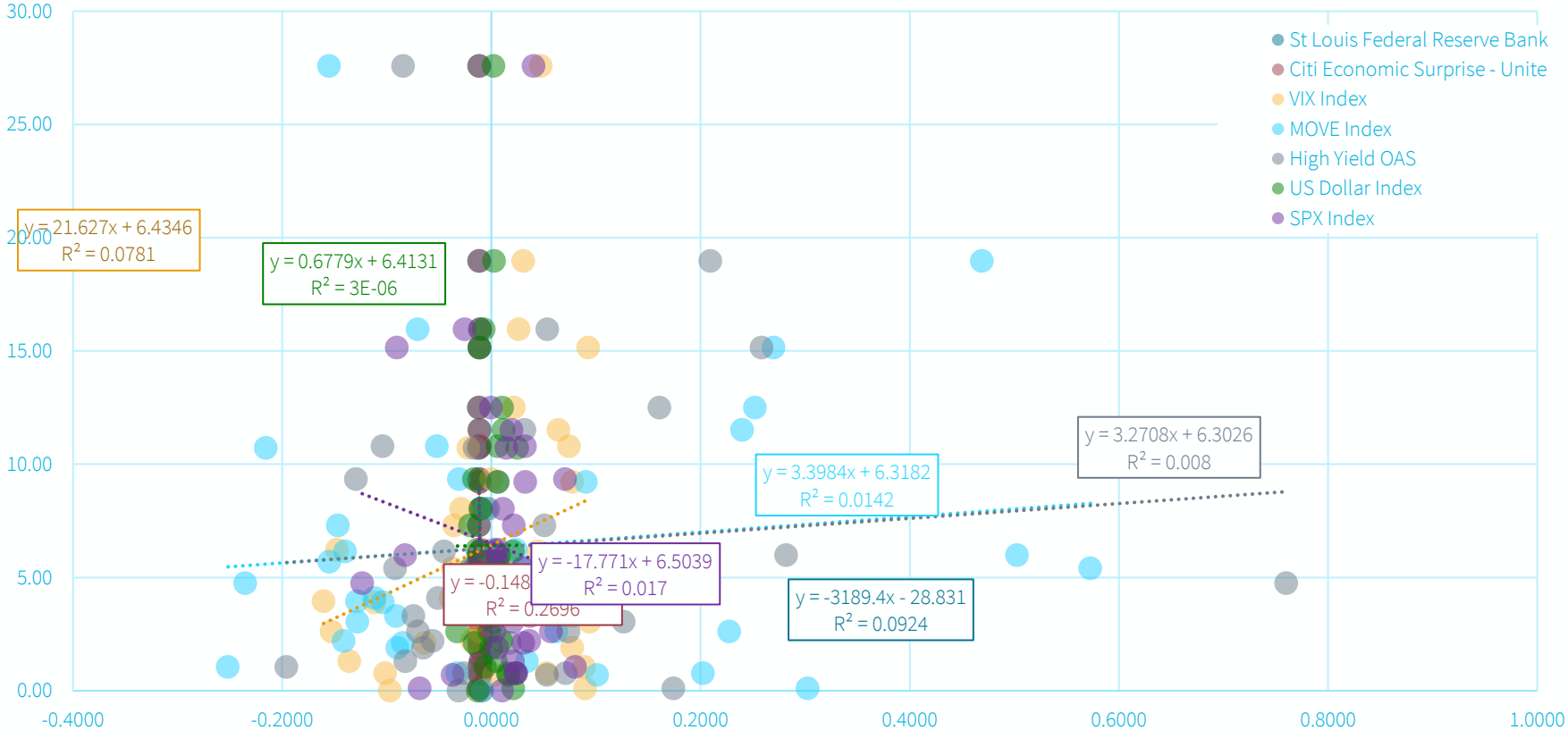
Capital Distribution

Distributions





Capital Distribution
Sensitivities

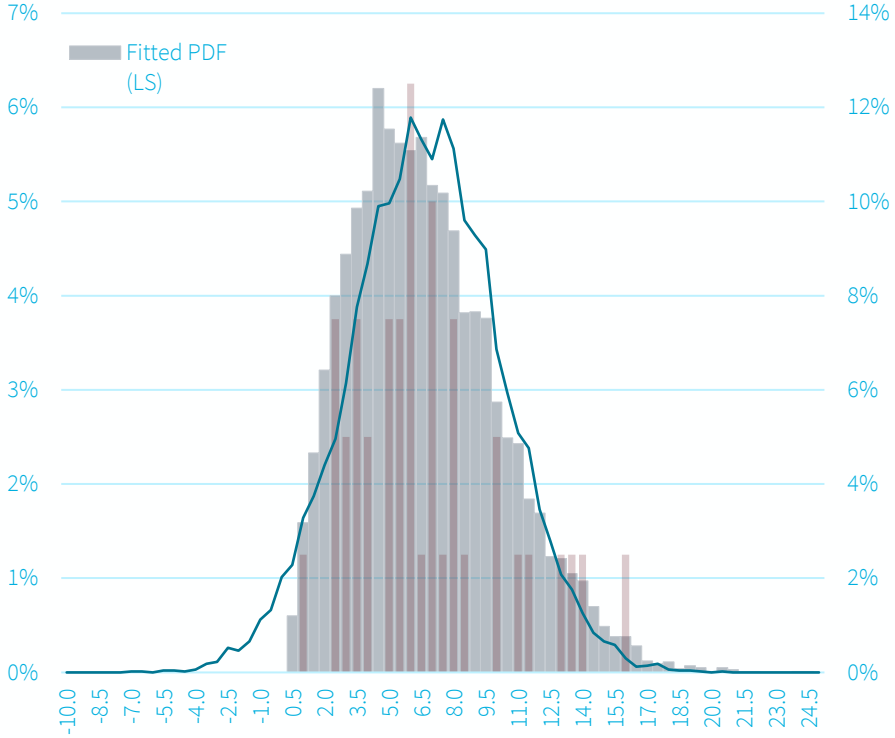


Capital Distribution
Correlation (Rolling 30-Month)

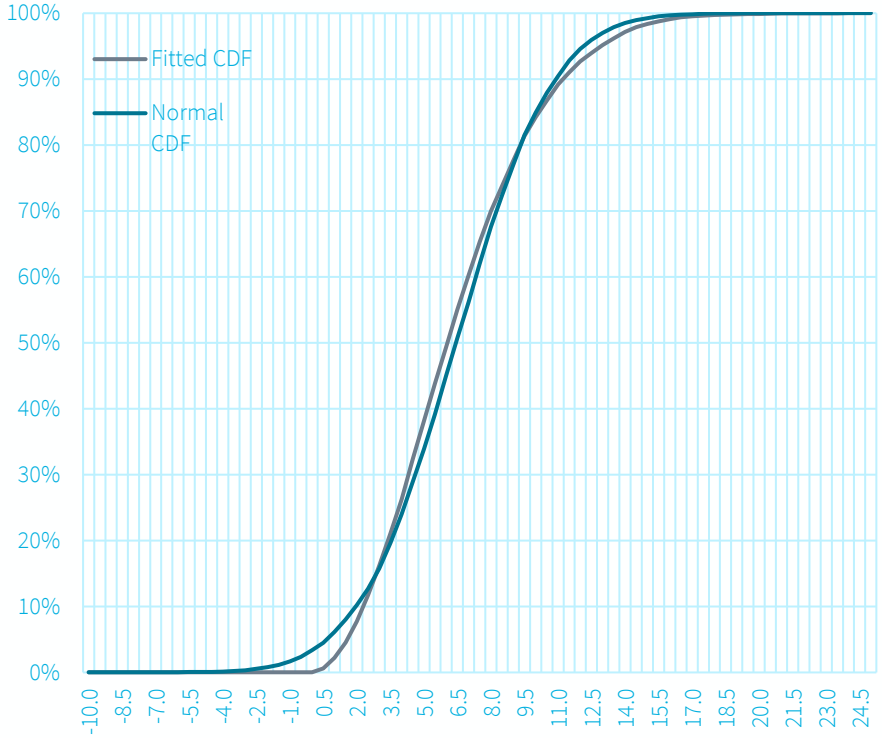
	St Louis Fed Finanacial Conditions	Citi Financial Surprise	VIX Index	MOVE Index	SPX Index	High Yield OAS	US Dollar Index
3/31/2020	-0.24	0.15	0.00	0.05	0.13	0.06	0.18
2/28/2020	-0.28	0.22	0.12	0.09	0.17	0.29	0.22
1/31/2020	-0.32	0.25	0.26	0.16	0.21	0.34	0.25
12/31/2019	-0.30	0.26	0.25	0.13	0.17	0.34	0.24
11/29/2019	-0.30	0.25	0.24	0.13	0.20	0.34	0.24
10/31/2019	-0.35	0.26	0.24	0.14	0.29	0.34	0.26
9/30/2019	-0.39	0.29	0.27	0.12	0.34	0.33	0.20
8/30/2019	-0.33	0.23	0.25	0.17	0.28	0.34	0.28
7/31/2019	-0.35	0.23	0.26	0.26	0.30	0.35	0.31
6/28/2019	-0.33	0.24	0.26	0.26	0.28	0.35	0.29

SITLA Contribution
Distributions

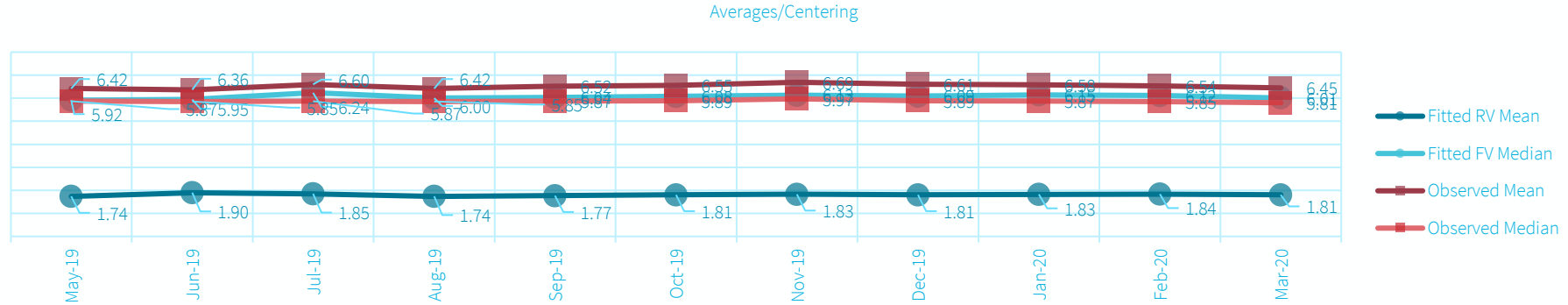
Collected Contributions

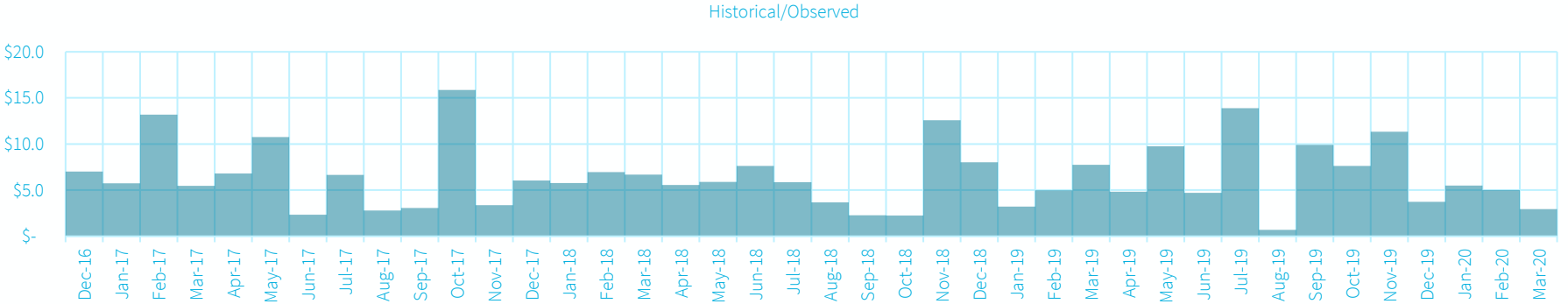


SITLA Contributions

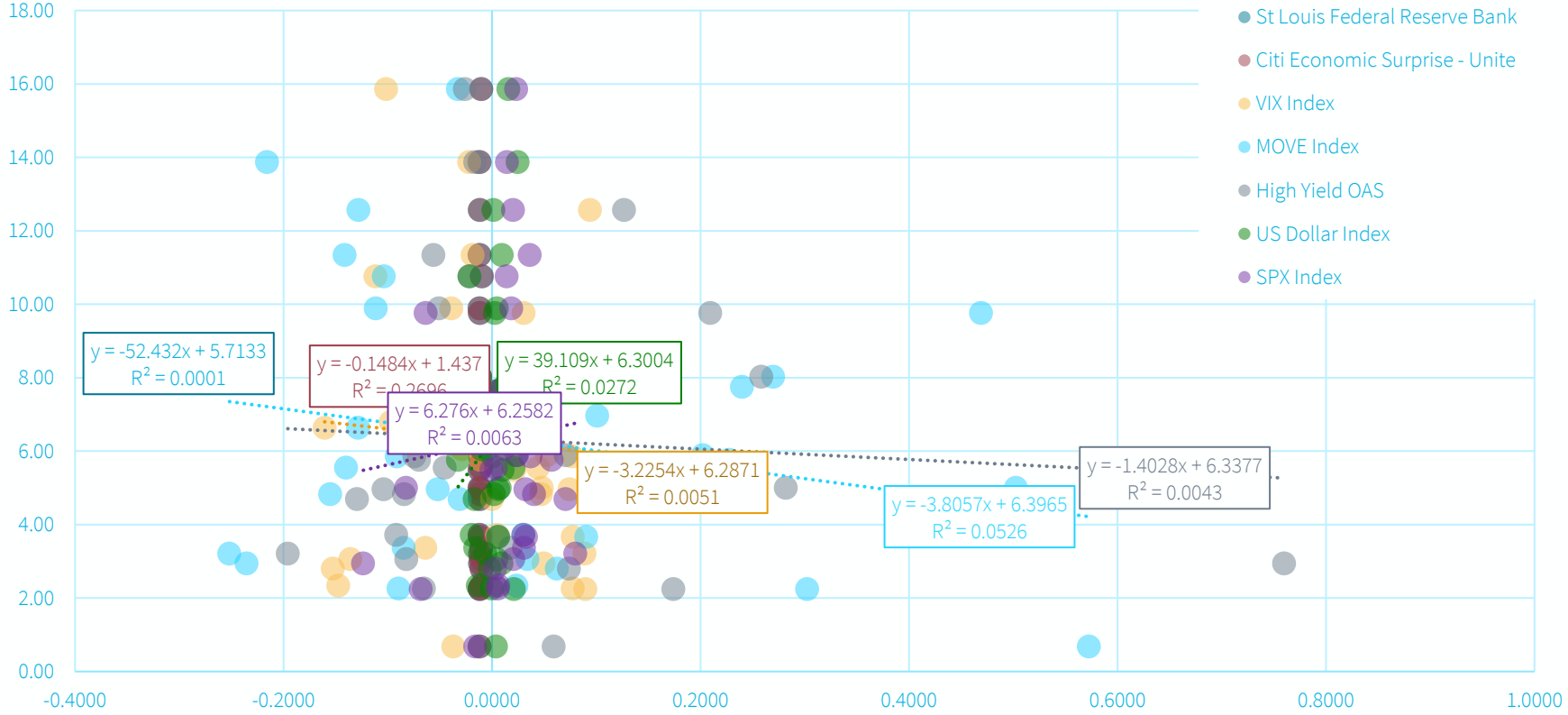


SITLA Contribution
Trends





SITLA Contribution
Sensitivities



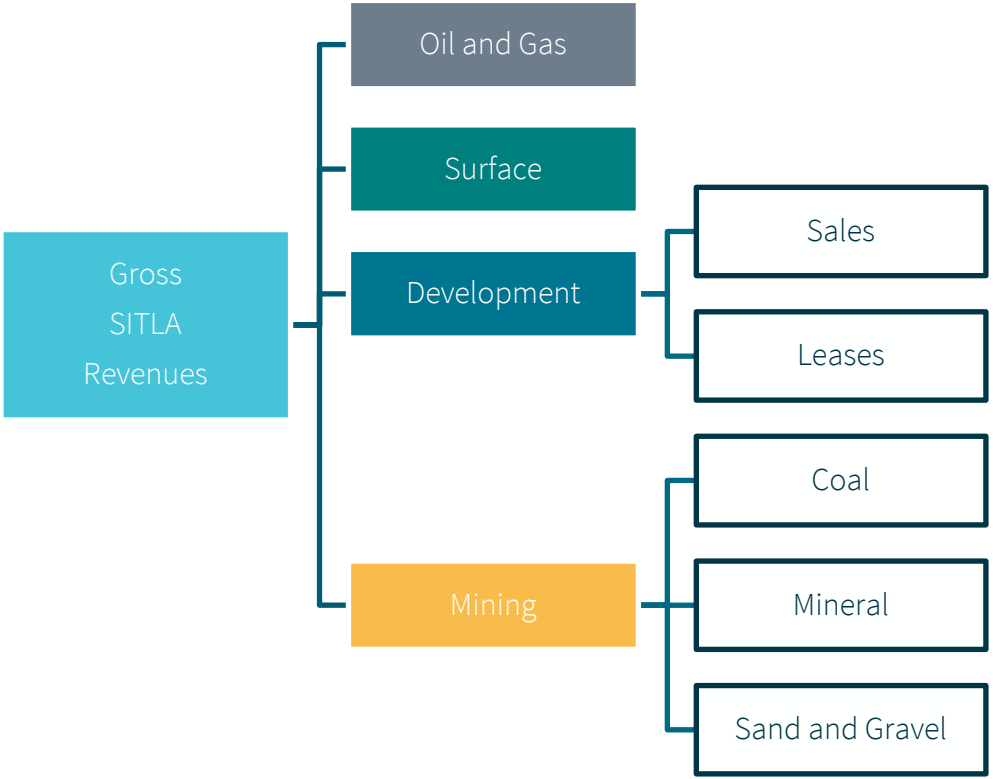
SITLA Contribution

Correlation (Rolling 30-Month)

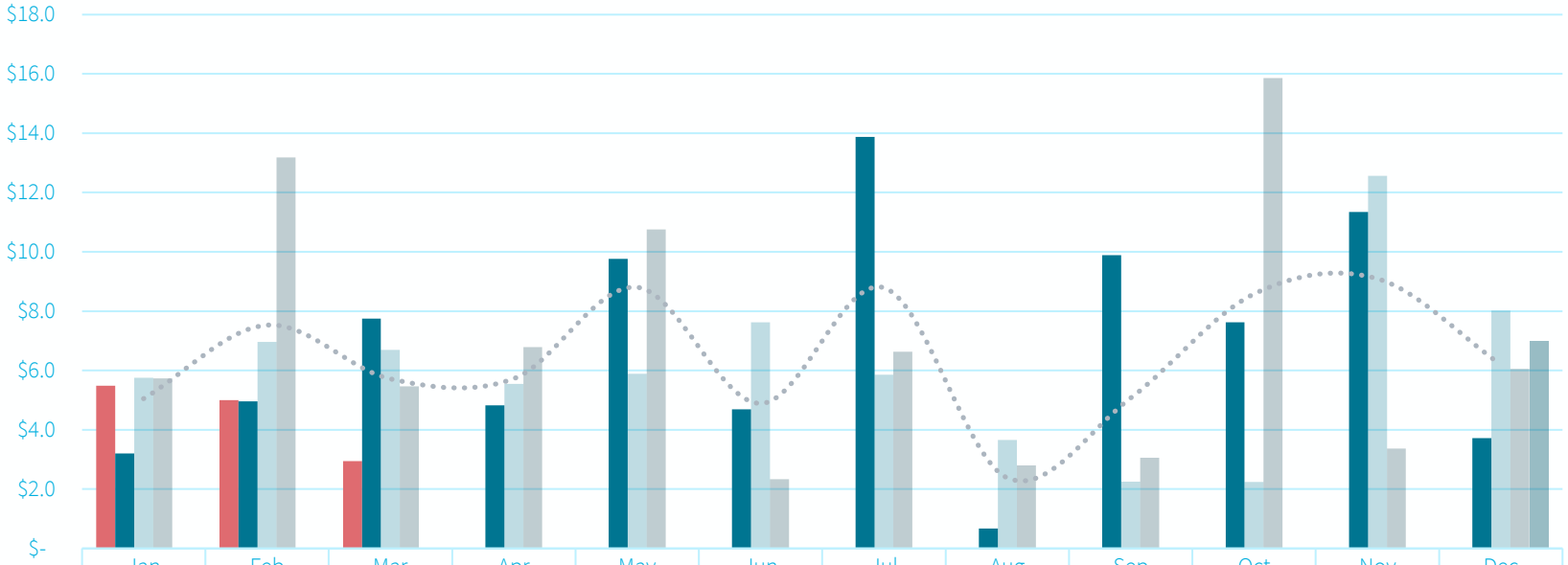
	St Louis Fed Finanacial Conditions	Citi Financial Surprise	VIX Index	MOVE Index	SPX Index	High Yield OAS	US Dollar Index
3/31/2020	0.09	-0.33	-0.21	-0.13	-0.05	-0.12	0.10
2/28/2020	0.01	-0.18	-0.06	-0.06	-0.02	0.13	0.17
1/31/2020	-0.07	-0.07	0.05	0.01	0.05	0.18	0.22
12/31/2019	-0.08	-0.06	0.06	0.03	0.07	0.19	0.22
11/29/2019	-0.18	0.01	0.09	0.04	0.21	0.17	0.23
10/31/2019	-0.04	-0.03	0.07	0.02	0.03	0.16	0.20
9/30/2019	-0.01	-0.03	0.07	0.02	0.00	0.16	0.19
8/30/2019	0.02	-0.01	0.06	-0.07	-0.04	0.16	0.12
7/31/2019	-0.06	-0.03	0.13	0.16	0.04	0.20	0.22
6/28/2019	0.06	-0.02	0.10	0.18	-0.11	0.21	0.13

SITLA Breakout

SITLA Contribution Components



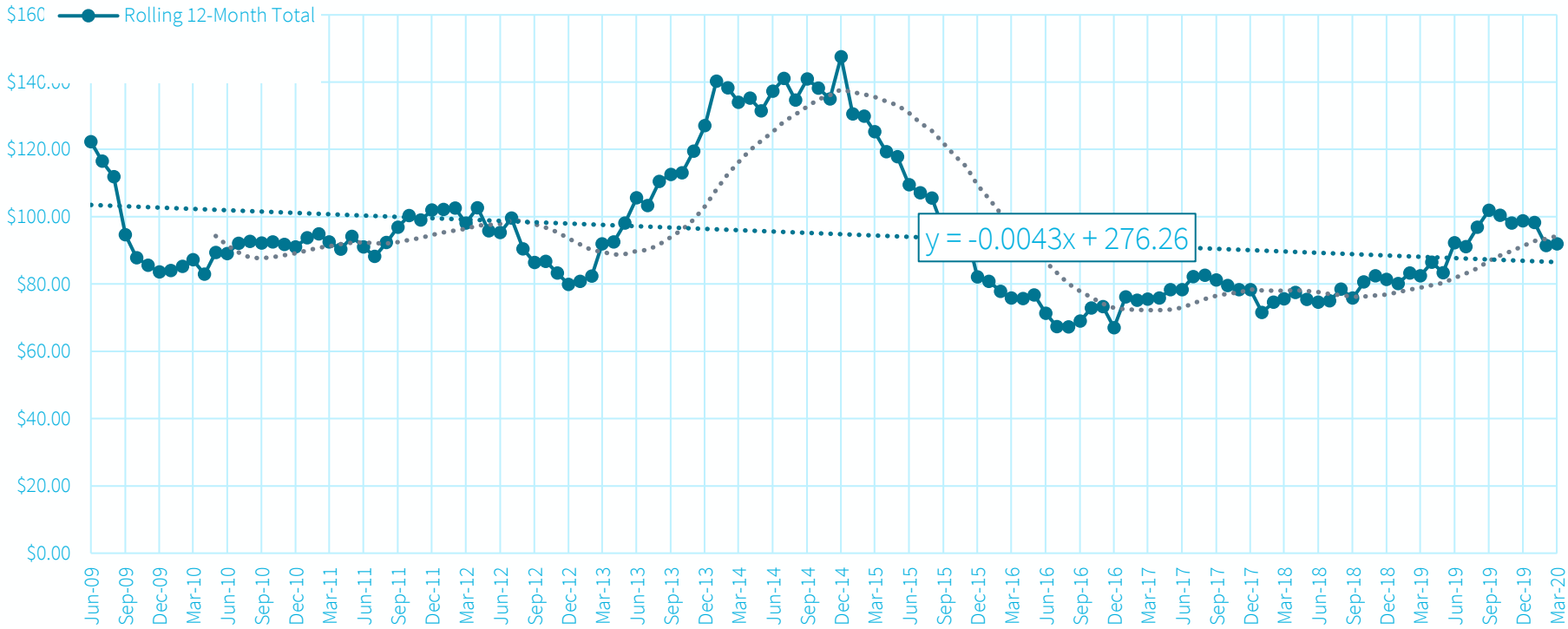
SITFO Historical SITLA Contribution



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2020	$5.5	$5.0	$2.9									
2019	$3.2	$5.0	$7.8	$4.8	$9.8	$4.7	$13.9	$0.7	$9.9	$7.6	$11.3	$3.7
2018	$5.8	$7.0	$6.7	$5.5	$5.9	$7.6	$5.9	$3.7	$2.3	$2.2	$12.6	$8.0
2017	$5.7	$13.2	$5.5	$6.8	$10.8	$2.3	$6.6	$2.8	$3.1	$15.9	$3.4	$6.1
2016												$7.0
SITFO Mean	$5.0	$7.5	$5.7	$5.7	$8.8	$4.9	$8.8	$2.4	$5.1	$8.6	$9.1	$6.2

SITLA Breakout

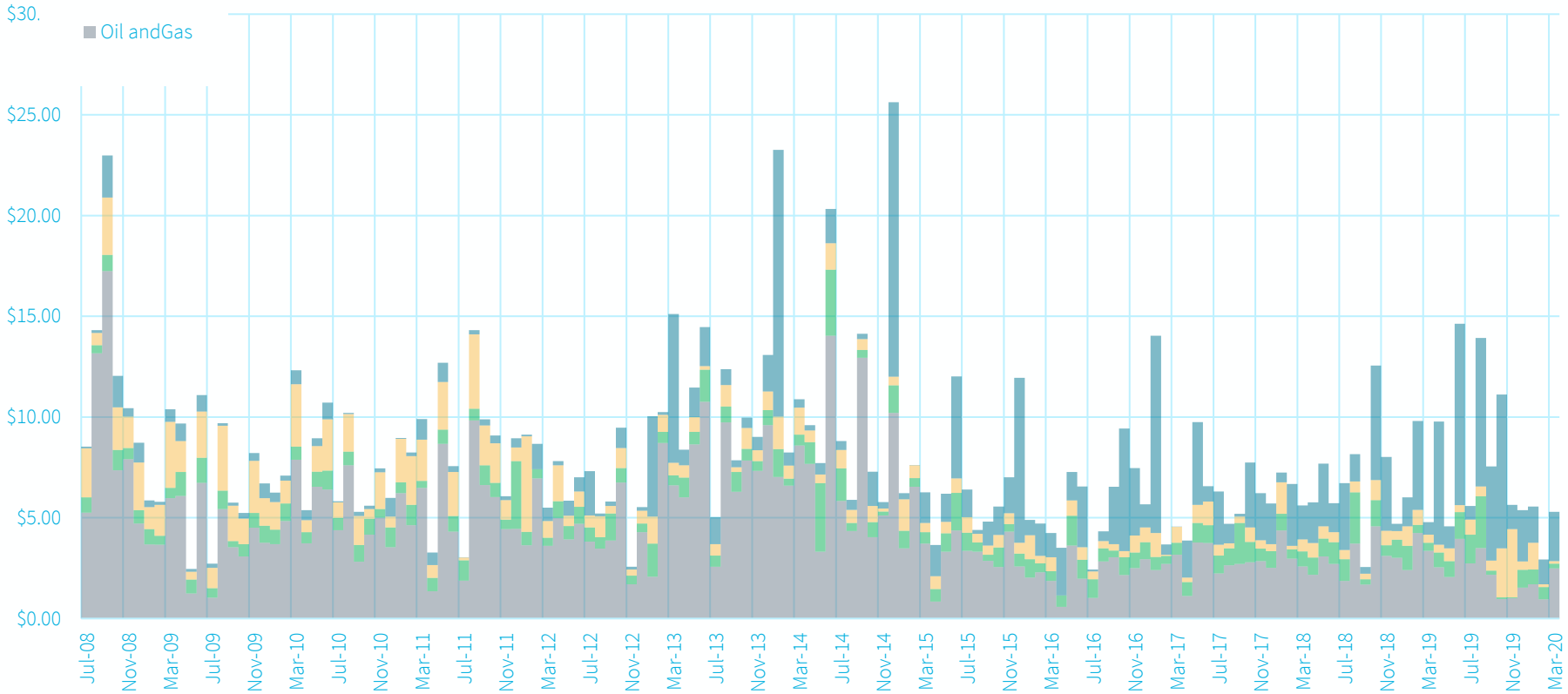
SITLA Gross Historical Revenue



Average annual SITLA contribution to SITFO across 2017-2019 is $80MM

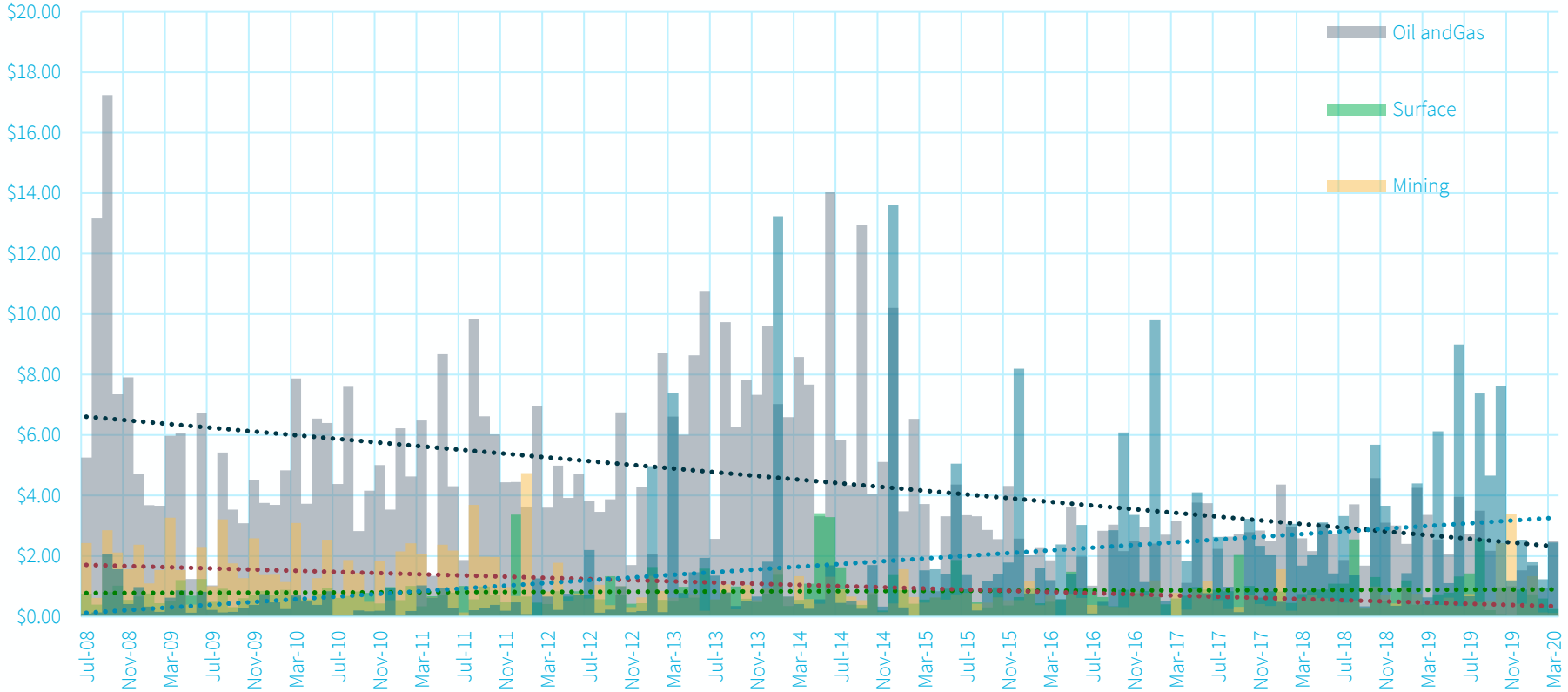
SITLA Breakout

SITLA Historical Data



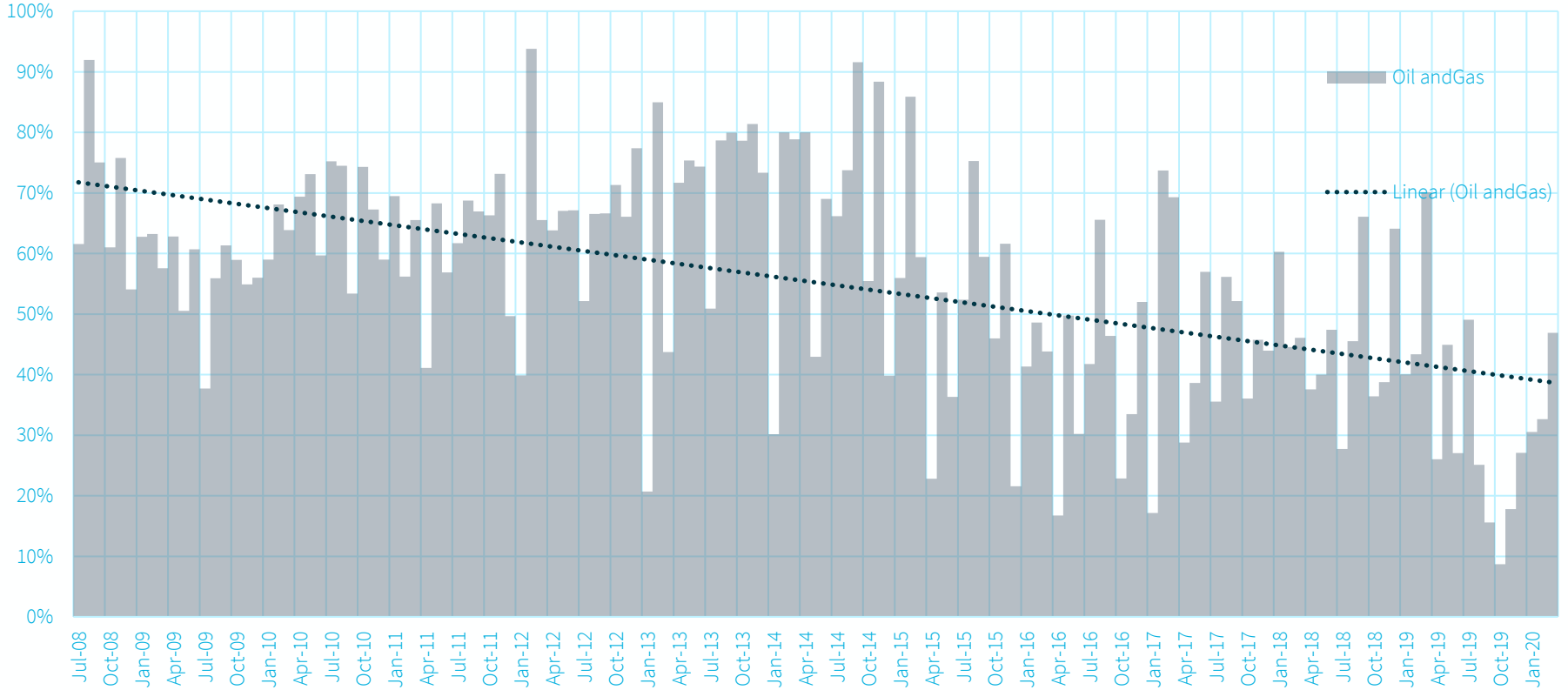
SITLA Breakout

SITLA Historical Data



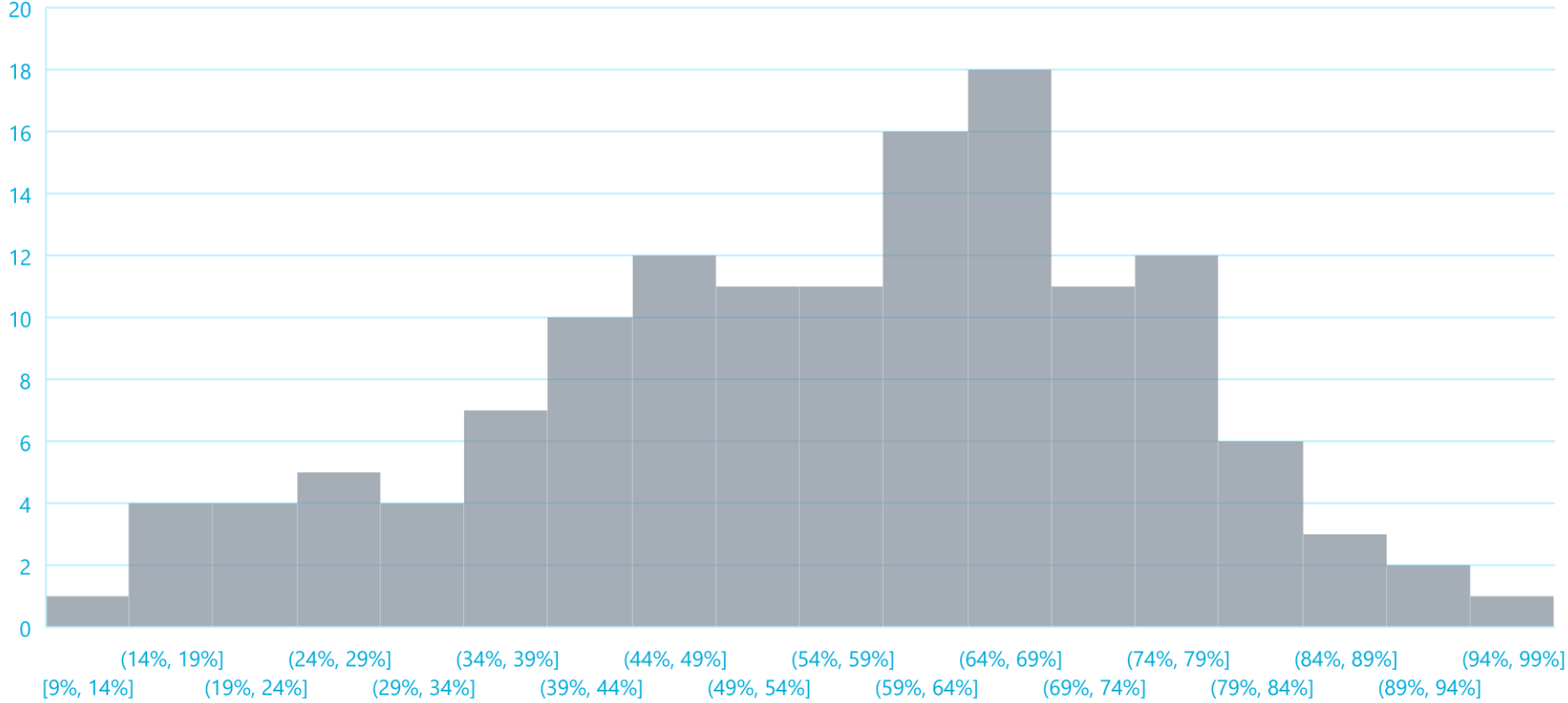
SITLA Breakout: Oil & Gas

Percentage Contribution



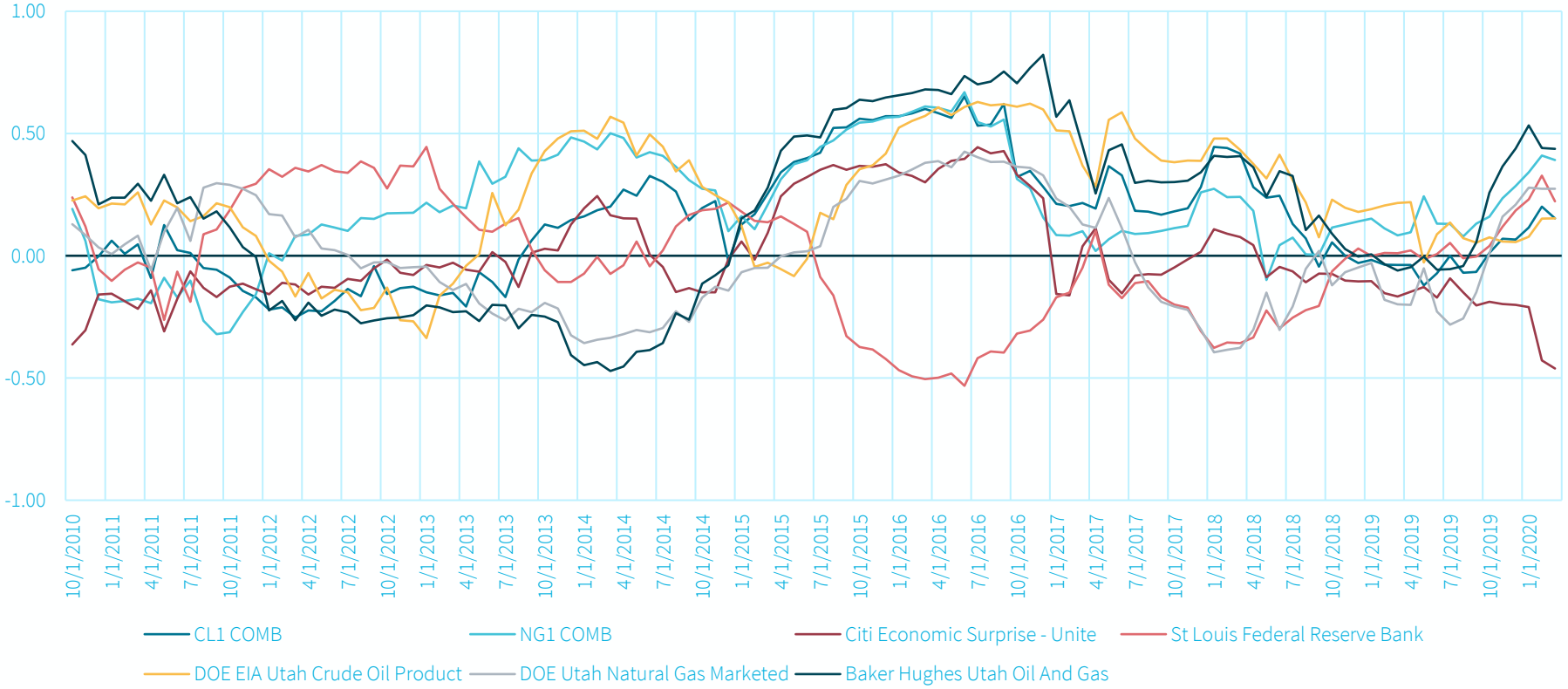
SITLA Breakout: Oil & Gas

Percentage Contribution

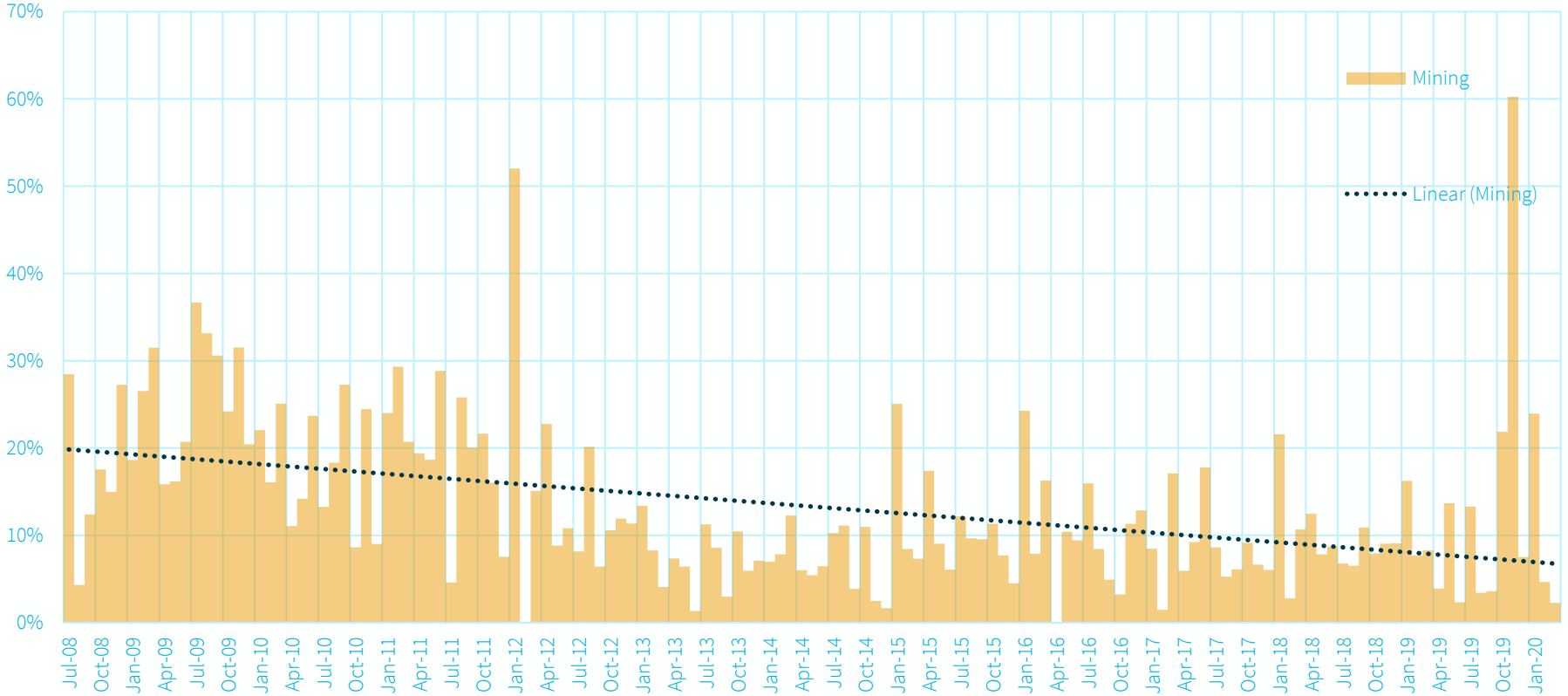


SITLA Breakout: Oil & Gas

Correlation (Rolling 30-Month)

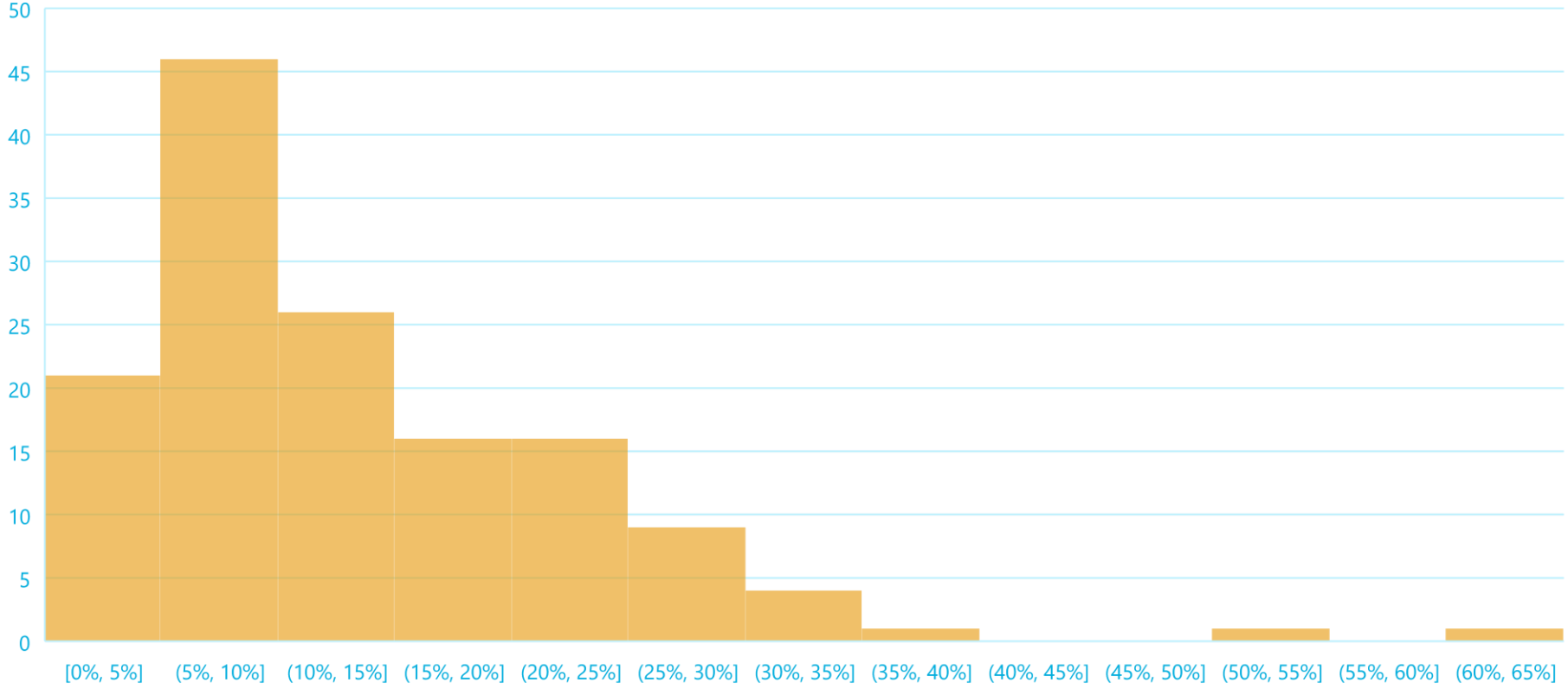


SITLA Breakout: Mining
Percentage Contribution

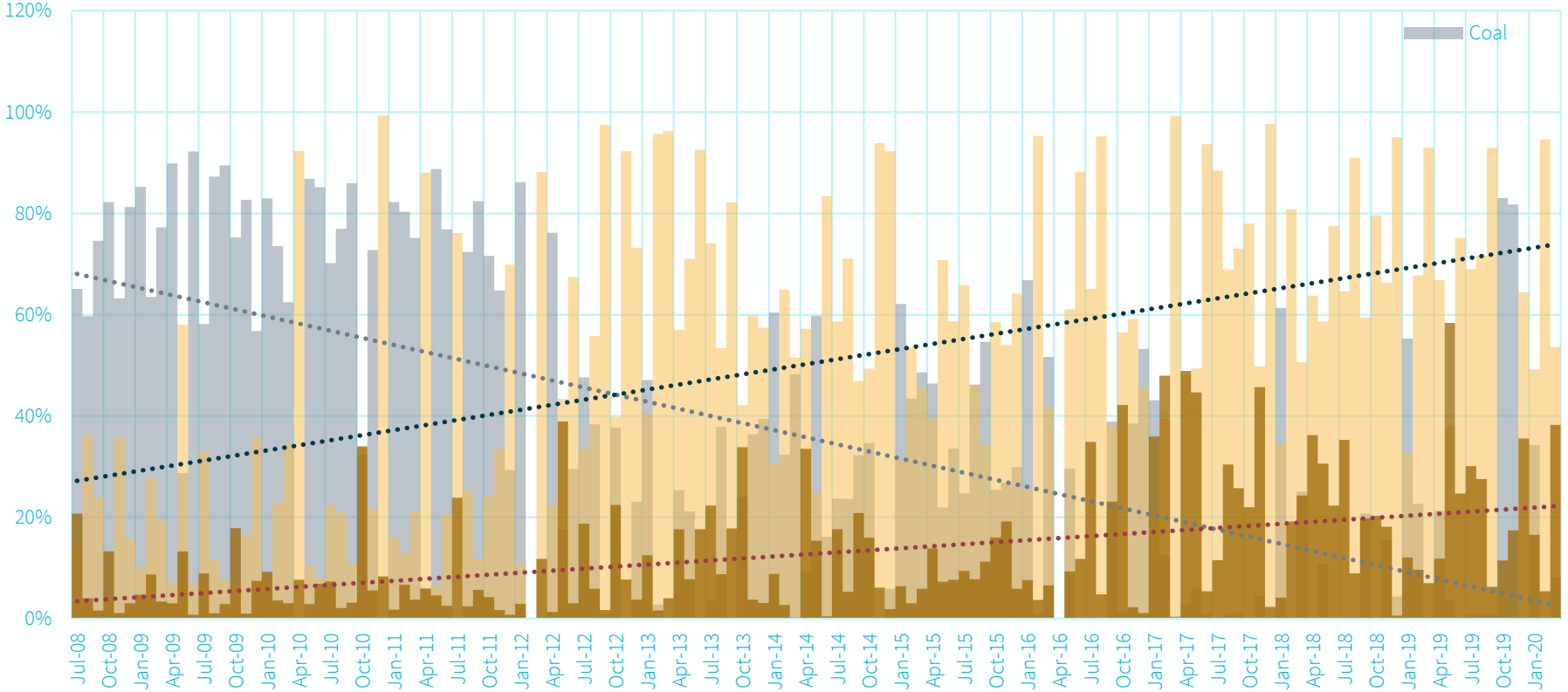


SITLA Breakout: Mining

Percentage Contribution

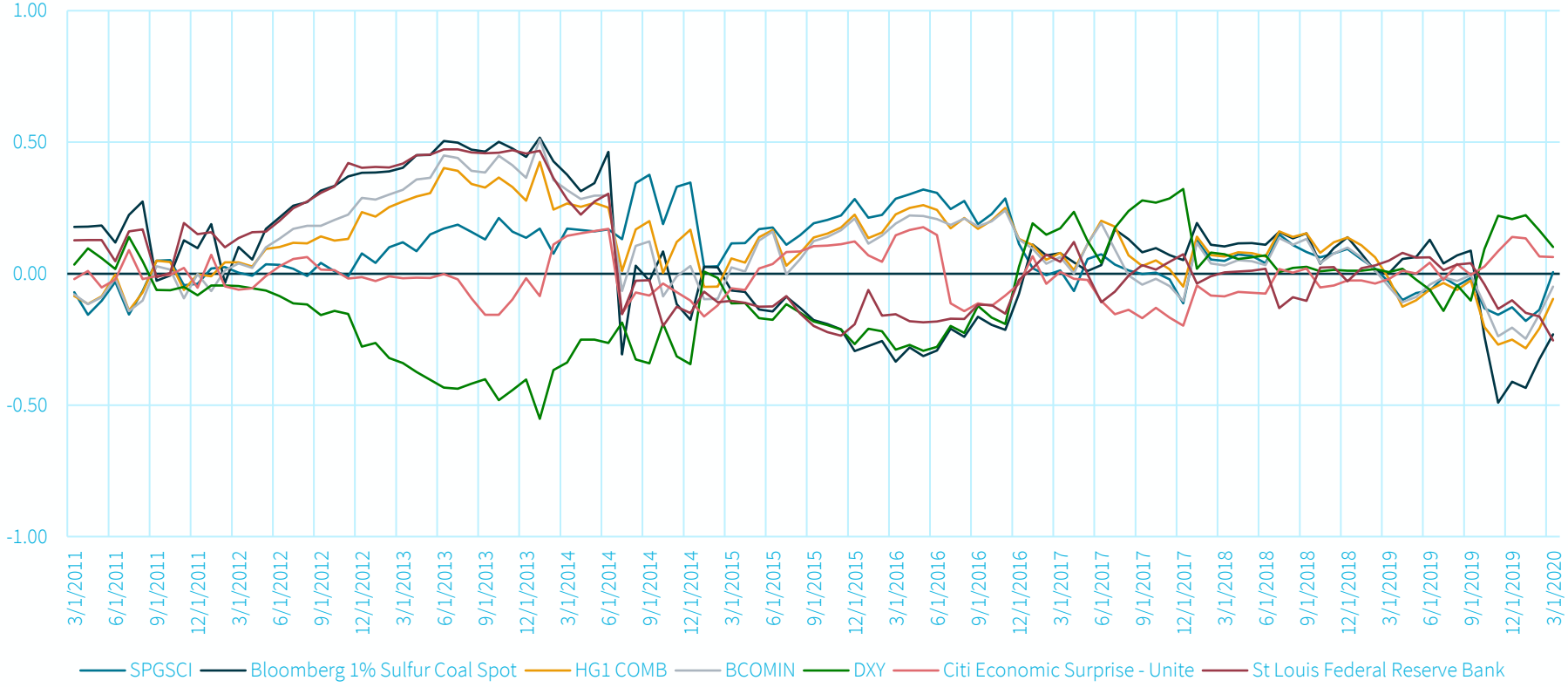


SITLA Breakout: Mining
Percentage Contribution



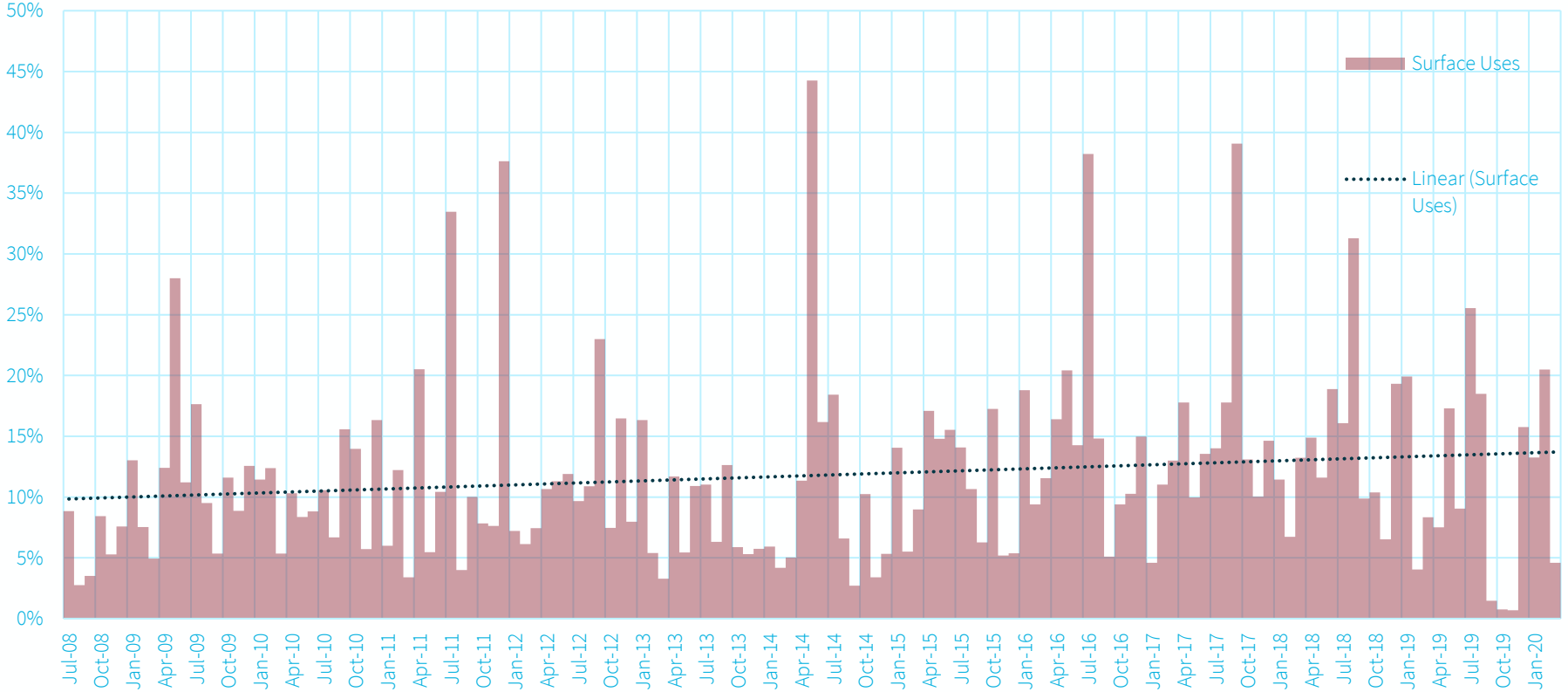
SITLA Breakout: Mining

Correlation (Rolling 30-Month)



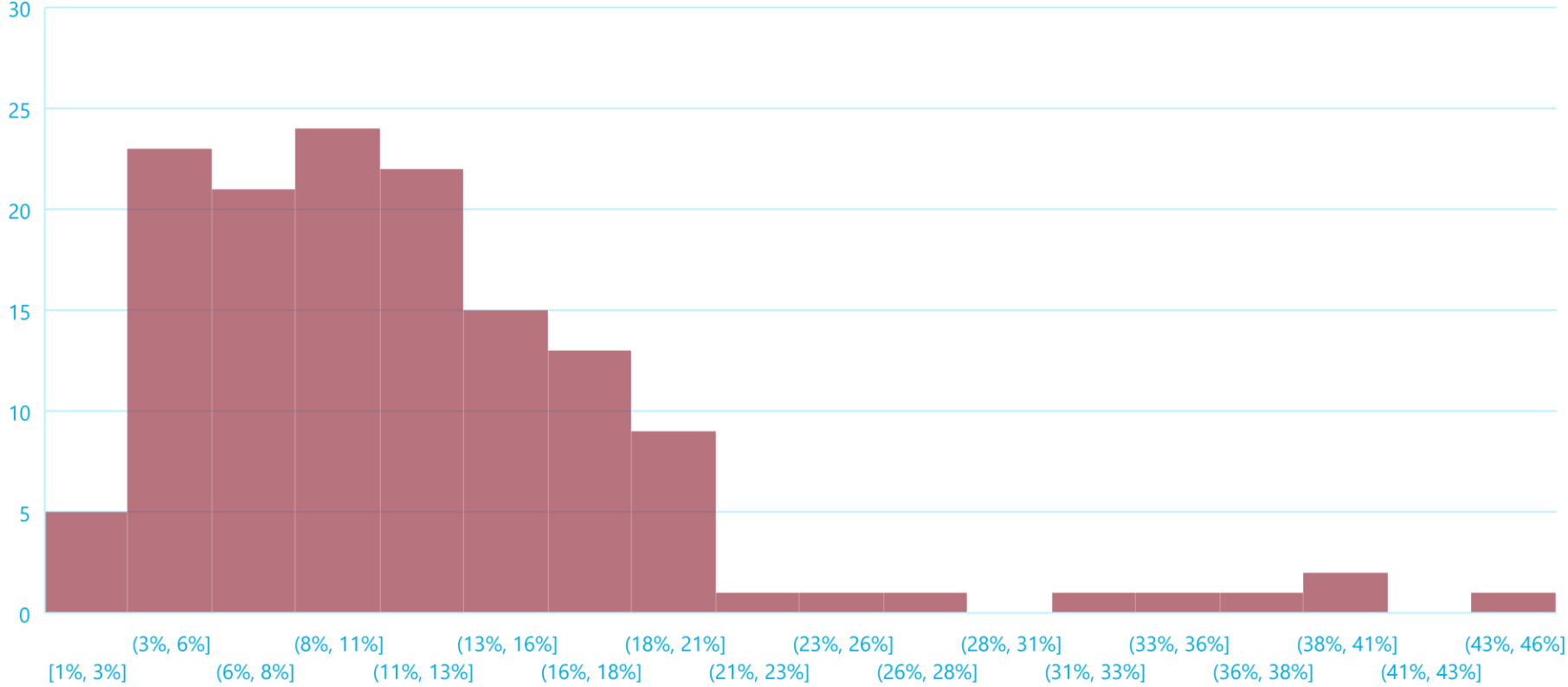
SITLA Breakout: Surface Uses

Percentage Contribution



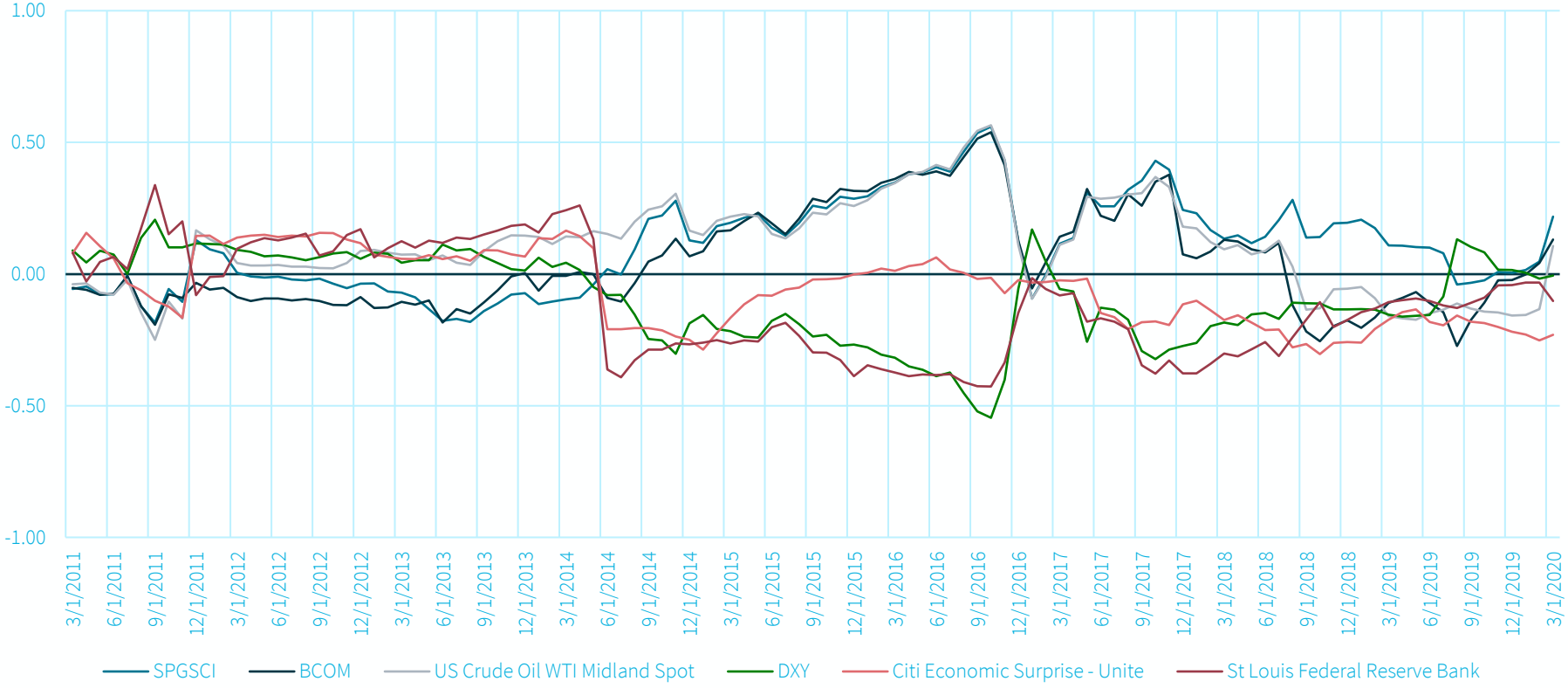
SITLA Breakout: Surface Uses

Percentage Contribution



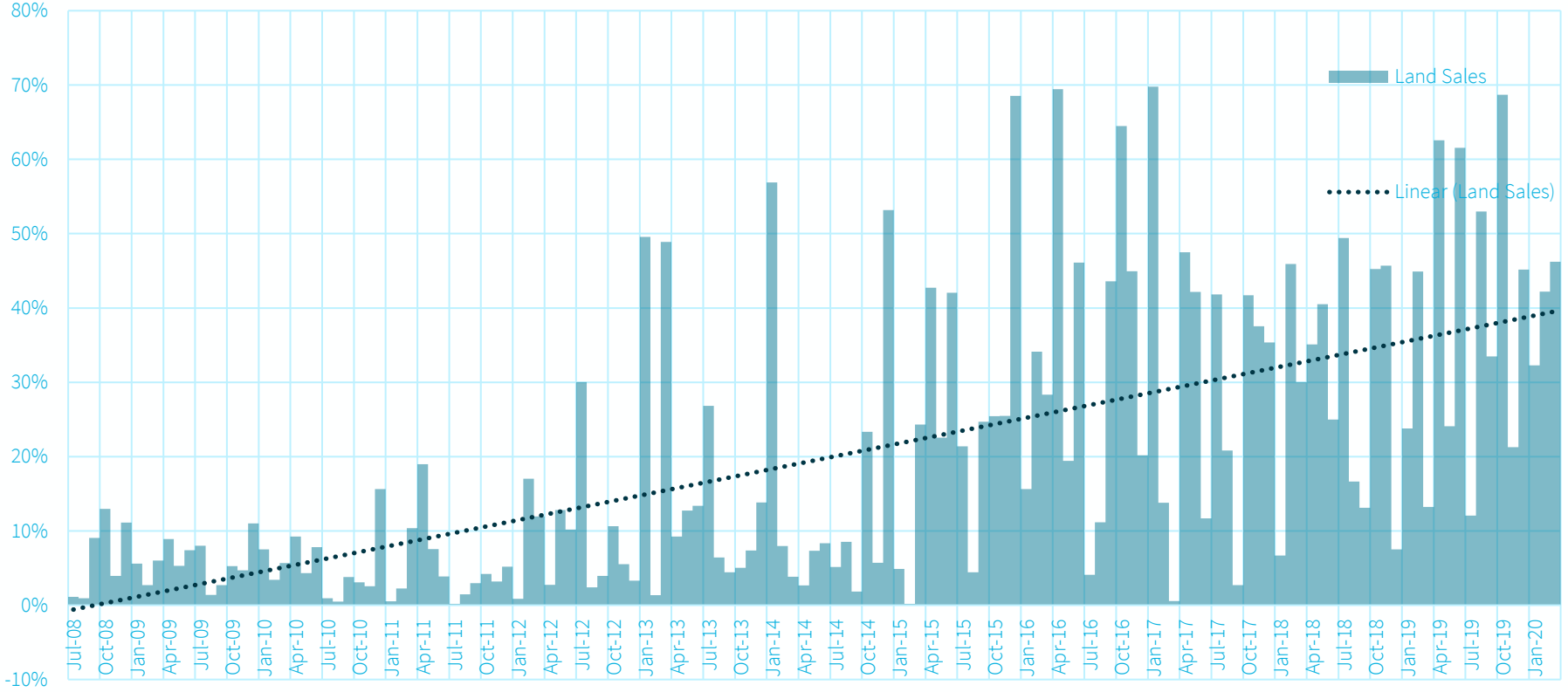
SITLA Breakout: Surface Uses

Correlation (Rolling 30-Month)



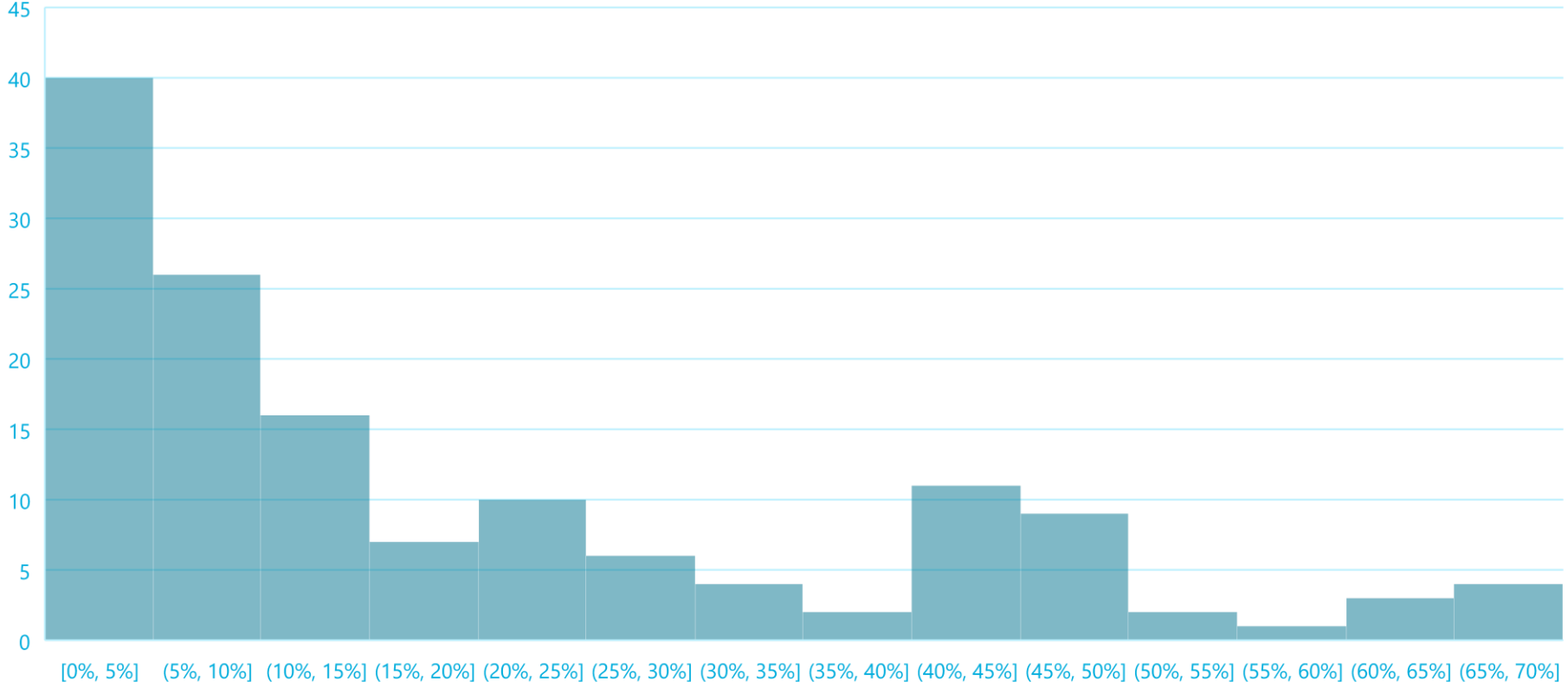
SITLA Breakout: Land Sales

Percentage Contribution



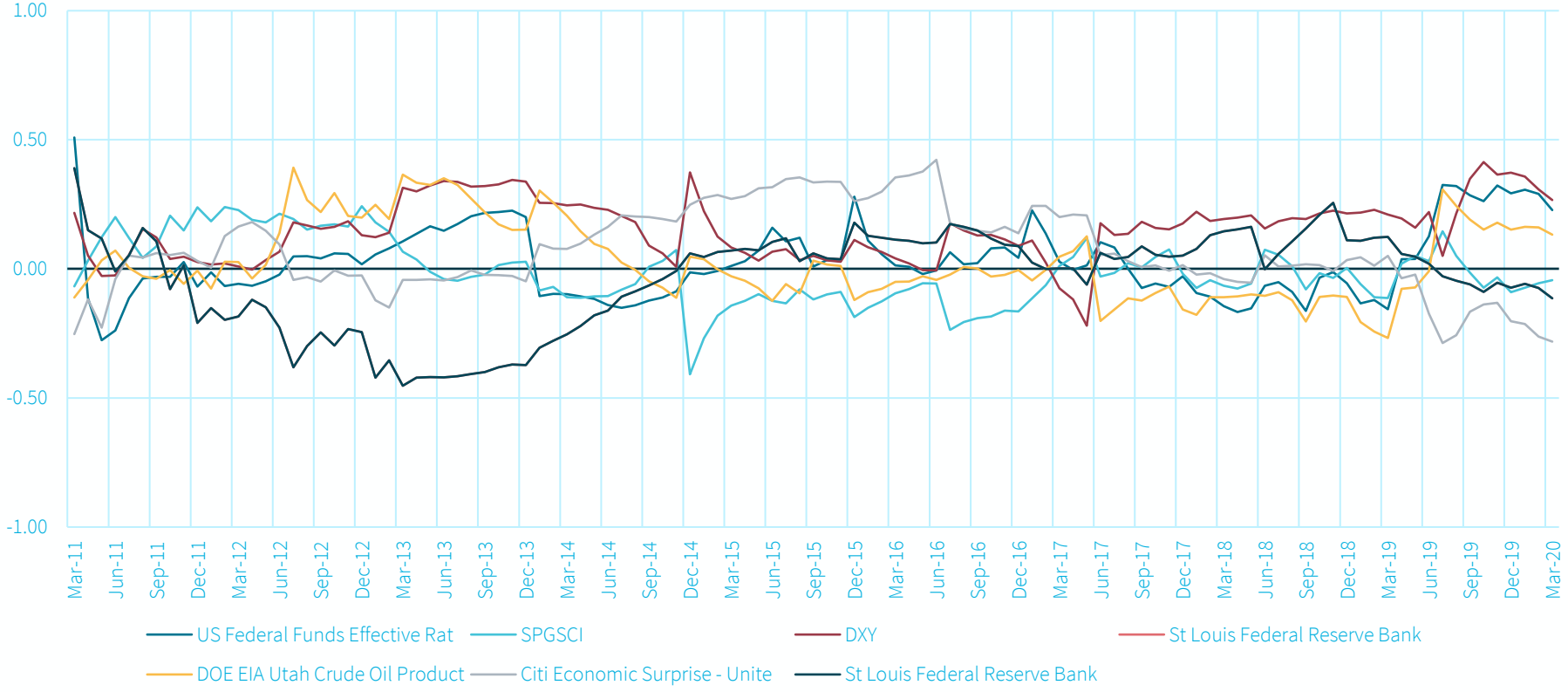
SITLA Breakout: Land Sales

Percentage Contribution



SITLA Breakout: Land Sales

Correlation (Rolling 30-Month)



Stressed SITLA Effects

Procedure

- Stress SITLA contributions across return environments

- SITLA stress scenarios are:
  - Flat contributions year-over-year
  - 75% contribution of previous year
  - 50% contribution of previous year
  - No contributions after the first timestep

- Based on current market value, distribution rate, and evolving corpus figures determine:
  - How long distributions could continue until corpus is reached and distributions are eliminated (we will also compute time to an arbitrary market value in this case $1B)
  - Compute the independent and conditional probabilities of this happening across negative return regimes

Inputs	
Portfolio Value	$2.6B
Distribution Rate	4%
Annual SITLA	$80MM
Corpus	$1.7B

Path to Corpus

- $PV_{t+1} = PV_t * (1+\text{return stress}) + SITLA_t - 4\% * PV_t$
- Begin with current portfolio value at time t
- Subject market value to return stress
- Add stressed SITLA amount to portfolio value
- Add stressed SITLA amount to corpus
- Subtract portfolio value * 4% distribution
- Sum is t+1 beginning portfolio value
- Each time step is one year, compute 500 years
- Note years until portfolio value is less than corpus i.e. distribution is suspended
- Note years until portfolio value has decreased to some level of severity (in this case $1B)

Distribution and Probabilities

- Attempt to build a distribution of possible market experiences by collecting monthly returns of equity, bonds, commodities, and crypto currency
- This broad inclusion is conservative in nature because it dramatically increases the probability of extreme events
- Monthly return windows are annualized by trailing, chronological 12-month windows (total annual return outcomes = 5,690)
- Approach return observations as a uniform distribution i.e. all outcomes are equally likely
- Two important assumptions:
  - Serial correlation may exist across annual returns
  - Since annual return observations could be dependent we use both conditional probability and multiplication rule for independent events

Selected Indexes
Dow Jones Industrial Average
S&P 500 Index
NASDAQ Composite Index
Russell 3000 Index
Bloomberg Barclays U.S. Agg
Bloomberg Barclays Long Term UST
Bloomberg Commodity Index
Generic 1st 'CL' Future (WTI Crude)
Bitcoin/U.S. DOLLAR

Distribution and Probabilities

- If two random variables are independent then their covariance zero. Since the converse is not true, zero covariance can only really push research one direction or another. The table to the left shows two quick covariance calculations. Save for crypto, most time series indicate non-zero covariance. We can't definitively say all annual return observations are independent, but small nonzero covariance suggests return observations could be sort-a dependent but mostly independent.

- We can formally test for serial correlation with the Durbin-Watson statistic. Where we lag a time series, run OLS regression analysis, and test the residuals. This too is somewhat abbreviated because we're only testing one-period lags. However the results do not rule out dependence across return periods.

HO: Serial Correlation <= 0 (there is no serial correlation)

Ha: Serial Correlation > 0 (there is positive serial correlation)

	n*	Covar**	Covar***	dL, a = 0.05	dU, a = 0.05	DW**** Statistic	Results
Dow Jones Industrial Average	1,424	0.04	0.03	1.71	1.83	1.77	Inconclusive
S&P 500 Index	1,089	0.04	0.03	1.71	1.83	1.64	Reject H0: Ser Corr ~= 0
NASDAQ Composite Index	571	0.05	0.04	1.71	1.83	1.74	Inconclusive
Russell 3000 Index	477	0.02	0.02	1.71	1.83	1.80	Inconclusive
Bloomberg Barclays US Agg Tota	512	0.00	0.00	1.71	1.83	1.73	Inconclusive
Bloomberg Barclays Long Term U	380	0.01	0.01	1.71	1.83	1.71	Inconclusive
Bloomberg Commodity Index	704	0.05	0.03	1.71	1.83	1.82	Inconclusive
Generic 1st 'CL' Future	426	0.10	0.08	1.71	1.83	1.77	Inconclusive
Bitcoin/US DOLLAR	98	492.70	849.91	1.55	1.80	1.58	Inconclusive

Critical DW range for DW test statistic

Reject H0	< dL	Inconclusive		< dU	Cannot Reject H0

* Each row is annualized return of 12-month rolling windows

**Covariance of entire n-length time series and one-period lag

***Arithmetic mean of 30-day trailing time series and one-period lag

**** Residuals obtained from regression analysis on entire n-length time series and one-period lag

Distribution and Probabilities

- [1] Shows Bayes formula for multiple conditions (e.g., “the probability of return range Y after three consecutive years Y_1, Y_2, Y_3 of the same return range”). Here we also use the multiplication rule to obtain probabilities but “without replacement.”

- [2] Assumes independence for the same question. To obtain the probability of an event happening n times we can just raise the probability of the event happening once to the power of n.

[1] $$P(Y\,|Y_1, Y_2, Y_3) = \frac{P(\,Y_1, Y_2, Y_3|Y)P(Y)}{P(\,Y_1, Y_2, Y_3|Y)P(Y) + \,P(\,Y_1, Y_2, Y_3|Y')P(Y')}$$

[2] $$\forall\, independent\ Y_i, since\ P(Y|Y_1) = P(Y)P(Y), then\ P(Y_1, Y_2, Y_3, Y_4) = P(Y)^4$$

Drawdowns Across SITLA/Return Stress

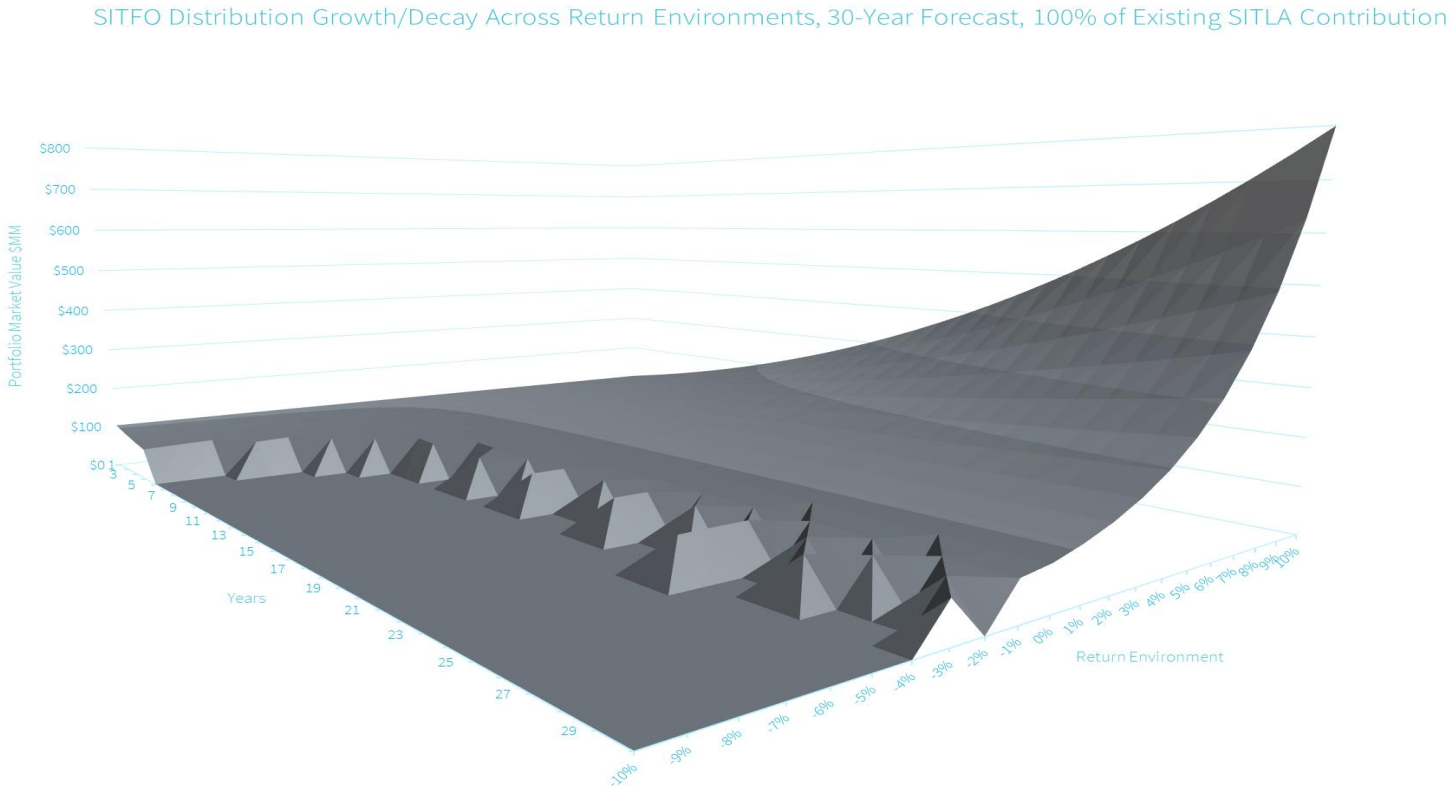
		-10%	-9%	-8%	-7%	-6%	-5%	-4%	-3%	-2%	-1%	0%
SITLA Growth/Decay Stressed 100%	Years Until MV = $1B	19	26	396	500	500	500	500	500	500	500	500
	Years Until MV = Corpus	4	4	4	5	6	6	31	149	268	388	500
SITLA Growth/Decay Stressed 75%	Years Until MV = $1B	10	10	12	13	15	18	21	28	39	70	500
	Years Until MV = Corpus	3	4	4	4	5	5	6	6	7	9	10
SITLA Growth/Decay Stressed 50%	Years Until MV = $1B	9	10	10	12	14	16	20	25	38	71	500
	Years Until MV = Corpus	3	3	4	4	4	5	5	6	6	7	9
SITLA Growth/Decay Stressed 0%	Years Until MV = $1B	8	9	11	11	13	16	19	25	36	68	500
	Years Until MV = Corpus	3	3	3	4	4	4	5	5	6	7	8

		0%	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
SITLA Growth/Decay Stressed 100%	Years Until MV = $1B	500	500	500	500	500	500	500	500	500	500	500
	Years Until MV = Corpus	500	500	500	500	500	500	500	500	500	500	500
SITLA Growth/Decay Stressed 75%	Years Until MV = $1B	500	500	500	500	500	500	500	500	500	500	500
	Years Until MV = Corpus	10	133	258	383	500	500	500	500	500	500	500
SITLA Growth/Decay Stressed 50%	Years Until MV = $1B	500	500	500	500	500	500	500	500	500	500	500
	Years Until MV = Corpus	9	132	256	381	500	500	500	500	500	500	500
SITLA Growth/Decay Stressed 0%	Years Until MV = $1B	500	500	500	500	500	500	500	500	500	500	500
	Years Until MV = Corpus	8	131	255	381	500	500	500	500	500	500	500

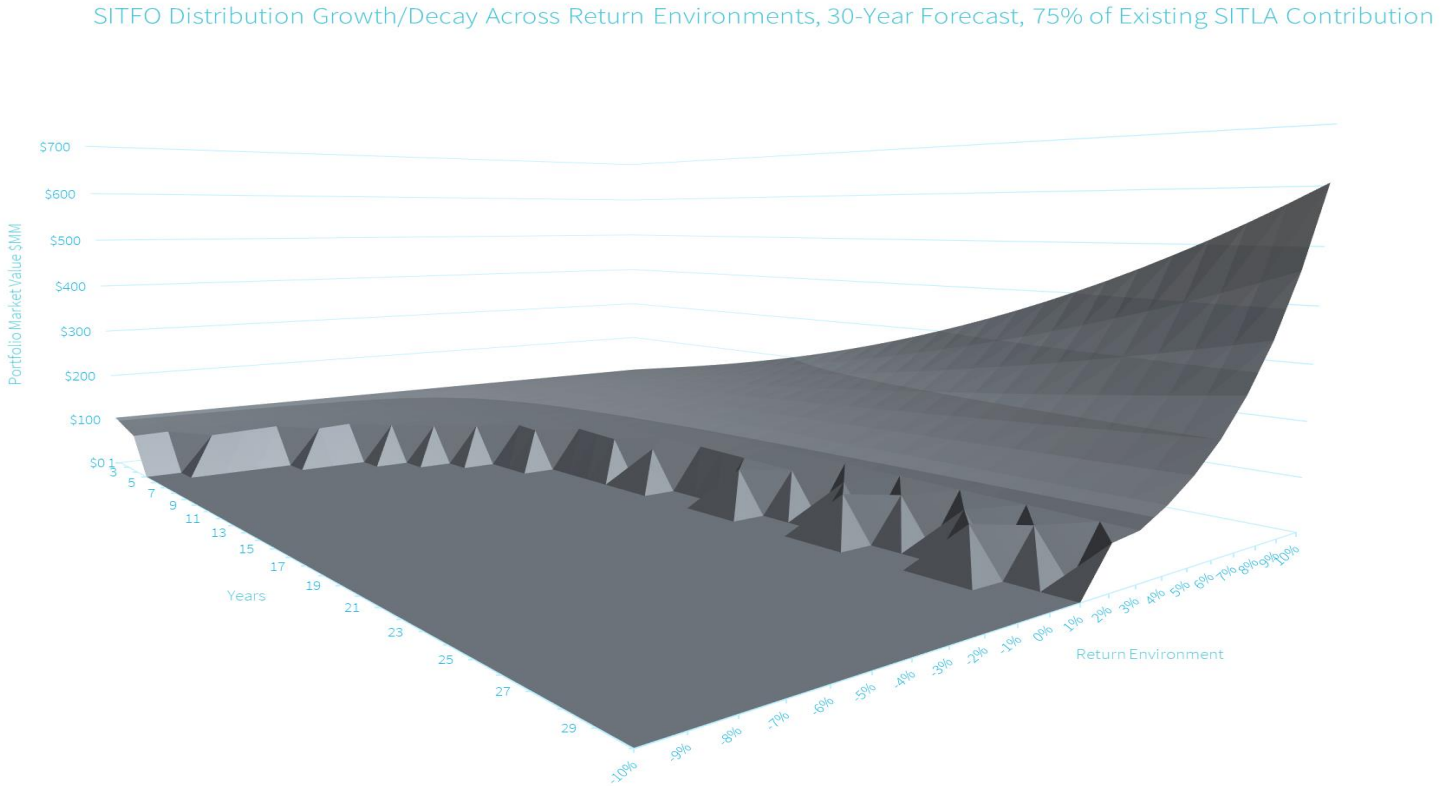
Drawdown Probabilities

		≤ -10%	-9% ≤ x ≤ -6%	-6% ≤ x ≤ -3%	-3% ≤ x ≤ 0%
	P(one year of return)	15.3%	3.3%	4.2%	5.0%
SITLA Growth/Decay Stressed 100%	Years Until MV = $1B	19	26	500	500
	Years Until MV = Corpus	4	4	6	149
	P(drawdown to corpus)	1.0124%	0.0039%	0.0007%	0.0000%
	Drawdown odds in years	99	25,959	141,739	Undef
	P(drawdown to corpus)	0.0552%	0.0001%	0.0000%	0.0000%
	Drawdown odds in years	1,813	821,489	1.87E+08	5.49E+193
SITLA Growth/Decay Stressed 75%	Years Until MV = $1B	10	10	15	28
	Years Until MV = Corpus	3	4	5	6
	P(drawdown to corpus)	1.0124%	0.0039%	0.0007%	0.0000%
	Drawdown odds in years	99	25,959	141,739	Undef
	P(drawdown to corpus)	0.3599%	0.0001%	0.0000%	0.0000%
	Drawdown odds in years	278	821,489	7.81E+06	6.33E+07
SITLA Growth/Decay Stressed 50%	Years Until MV = $1B	9	10	14	25
	Years Until MV = Corpus	3	3	4	6
	P(drawdown to corpus)	1.0124%	0.0039%	0.0007%	0.0000%
	Drawdown odds in years	99	25,959	141,739	Undef
	P(drawdown to corpus)	0.3599%	0.0037%	0.0003%	0.0000%
	Drawdown odds in years	278	27,287	3.27E+05	6.33E+07
SITLA Growth/Decay Stressed 0%	Years Until MV = $1B	8	9	13	25
	Years Until MV = Corpus	3	3	4	5
	P(drawdown to corpus)	1.0124%	0.0039%	0.0007%	0.0000%
	Drawdown odds in years	99	25,959	141,739	Undef
	P(drawdown to corpus)	0.3599%	0.0037%	0.0003%	0.0000%
	Drawdown odds in years	278	27,287	3.27E+05	3.17E+06

Forecast Surface 1



Forecast Surface 2



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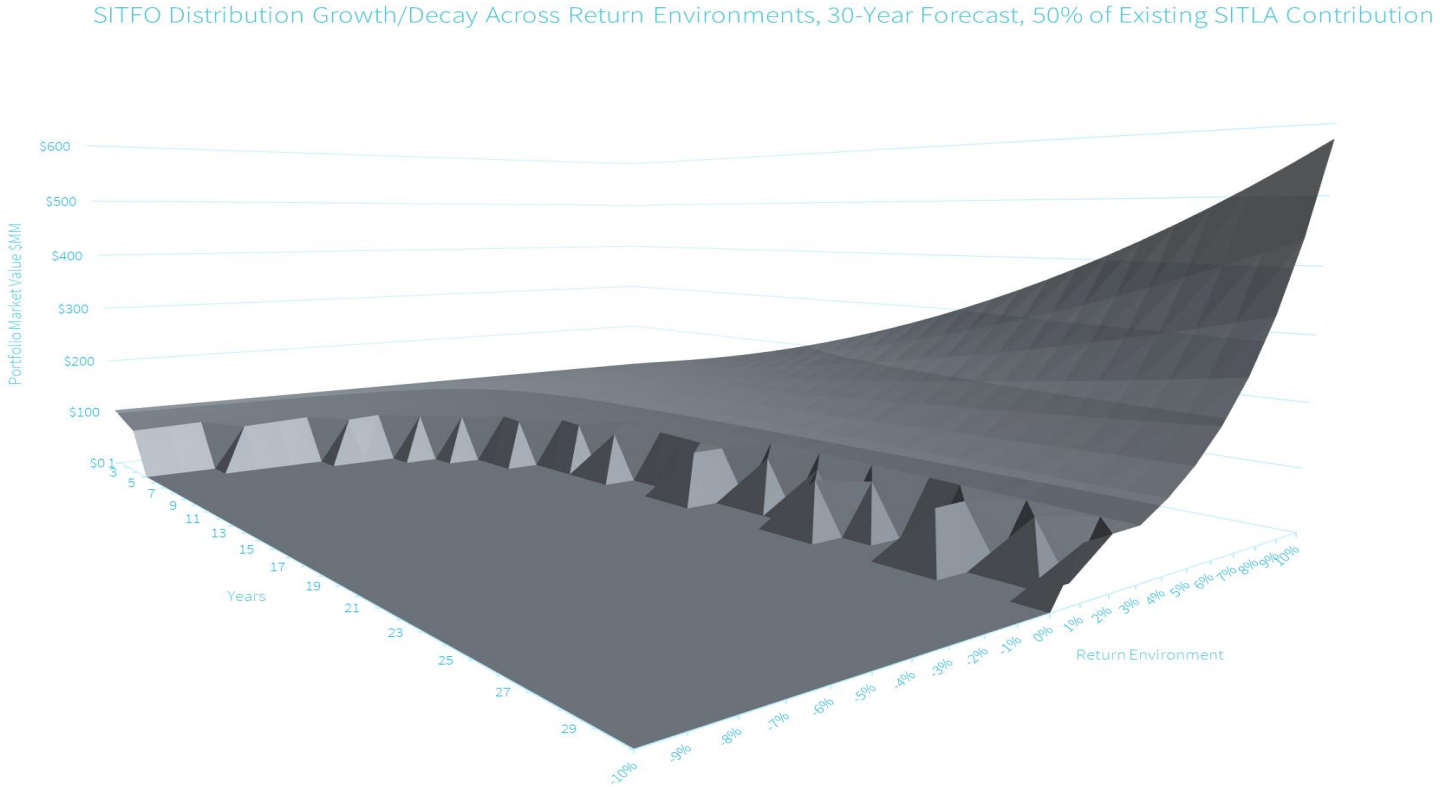
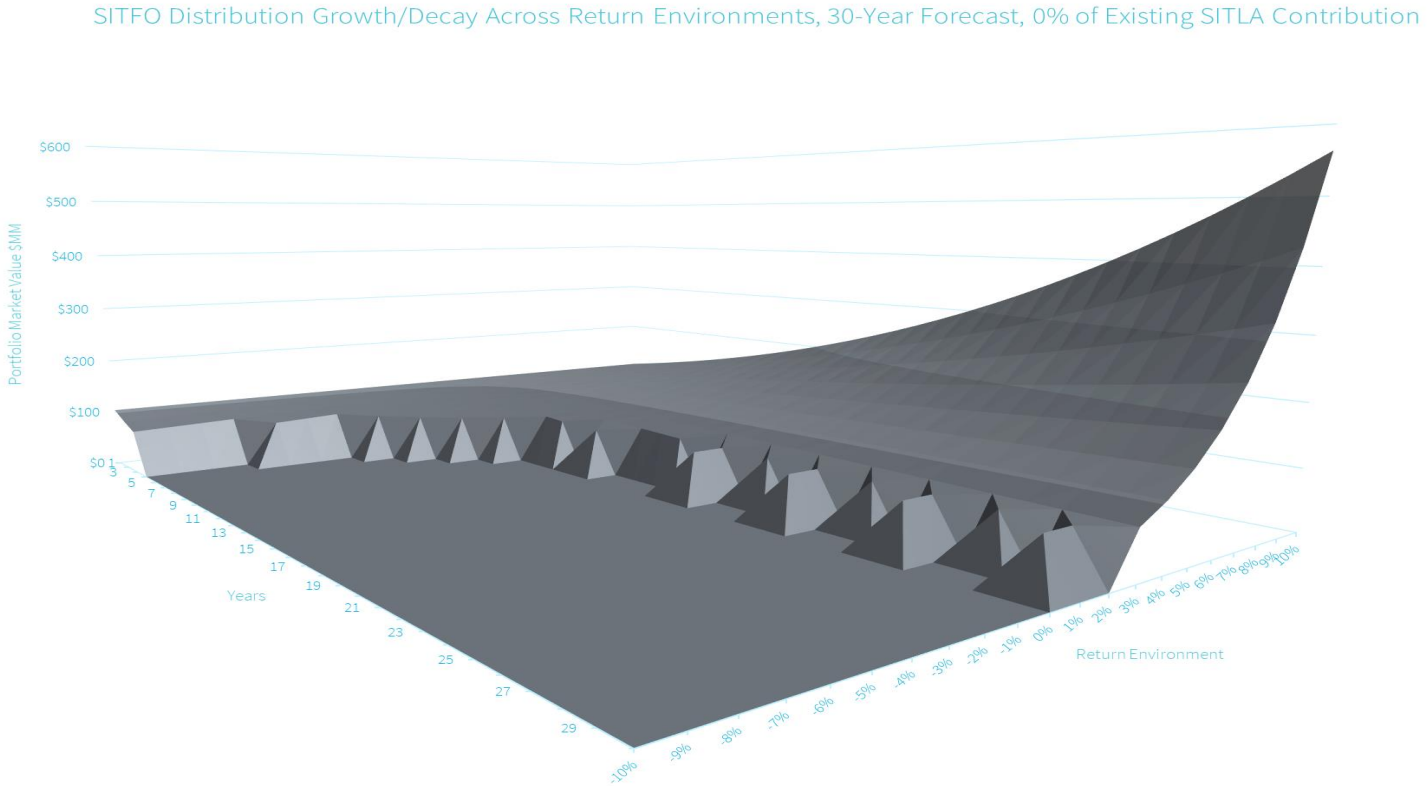


Forecast Surface 4



End