Treasury Presentation to TBAC

Office of Debt Management

Fiscal Year 2018 Q4 Report

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Section I:
Executive Summary

Highlights of Treasury's November 2018 Quarterly Refunding Presentation to the Treasury Borrowing Advisory Committee (TBAC)

Receipts and Outlays

- During FY 2018, receipts totaled $3,329 billion (16.1% of GDP). Non-withheld income and SECA taxes were up $89 billion (15%) in FY 2018, most of which occurred during April, when strong final payments were made for the 2017 (pre-tax cut) liability. Withheld income and FICA taxes were up $23 billion (1%) in FY 2018, reflecting growth in both employment and wages. Since February, when use of lower tax withholding rates was required, withheld income and FICA taxes have either declined or shown small increases. Mostly offsetting the increases, gross corporate taxes were $76 billion (22%) lower than last year, largely due to the corporate tax rate reduction and the expanded ability to immediately deduct the full value of equipment purchases. Corporate refunds were up $17 billion (39%) compared with last year.

- During FY 2018, outlays totaled $4,108 billion (19.9% of GDP). After calendar adjustments, FY 2018 outlays were $183 billion (5%) higher than last year. Treasury outlays were $83 billion (15%) higher due primarily to increased interest on the public debt of $65 billion (14%) and lower overall receipts from the GSEs. Homeland Security outlays were $18 billion (35%) higher due to increased payments for disaster relief. Education outlays were $48 billion (43%) lower due to differences in subsidy re-estimates during the year. Social Security Administration outlays were $43 billion (4%) higher due to increases in enrollment and the average benefit. Health and Human Services outlays were $41 billion (4%) higher due to increases in Medicare. Defense expenditures were up $36 billion (6%) due to increased spending for military personnel, operations, maintenance, and procurement.

Projected Net Marketable Borrowing (FY 2019)

- Based on the quarterly borrowing estimate, Treasury's Office of Fiscal Projections (OFP) currently estimates a net privately-held marketable borrowing need of $425 billion for Q1 FY 2019, with an end-of-December cash balance of $410 billion. For Q2 FY 2019, the net privately-held marketable borrowing need is projected to be $356 billion, with an end-of-March cash balance of $320 billion. Privately-held marketable borrowing excludes rollovers (auction "add-ons") of Treasury securities held in the Federal Reserve's System Open Market Account (SOMA), but includes financing required due to SOMA redemptions.

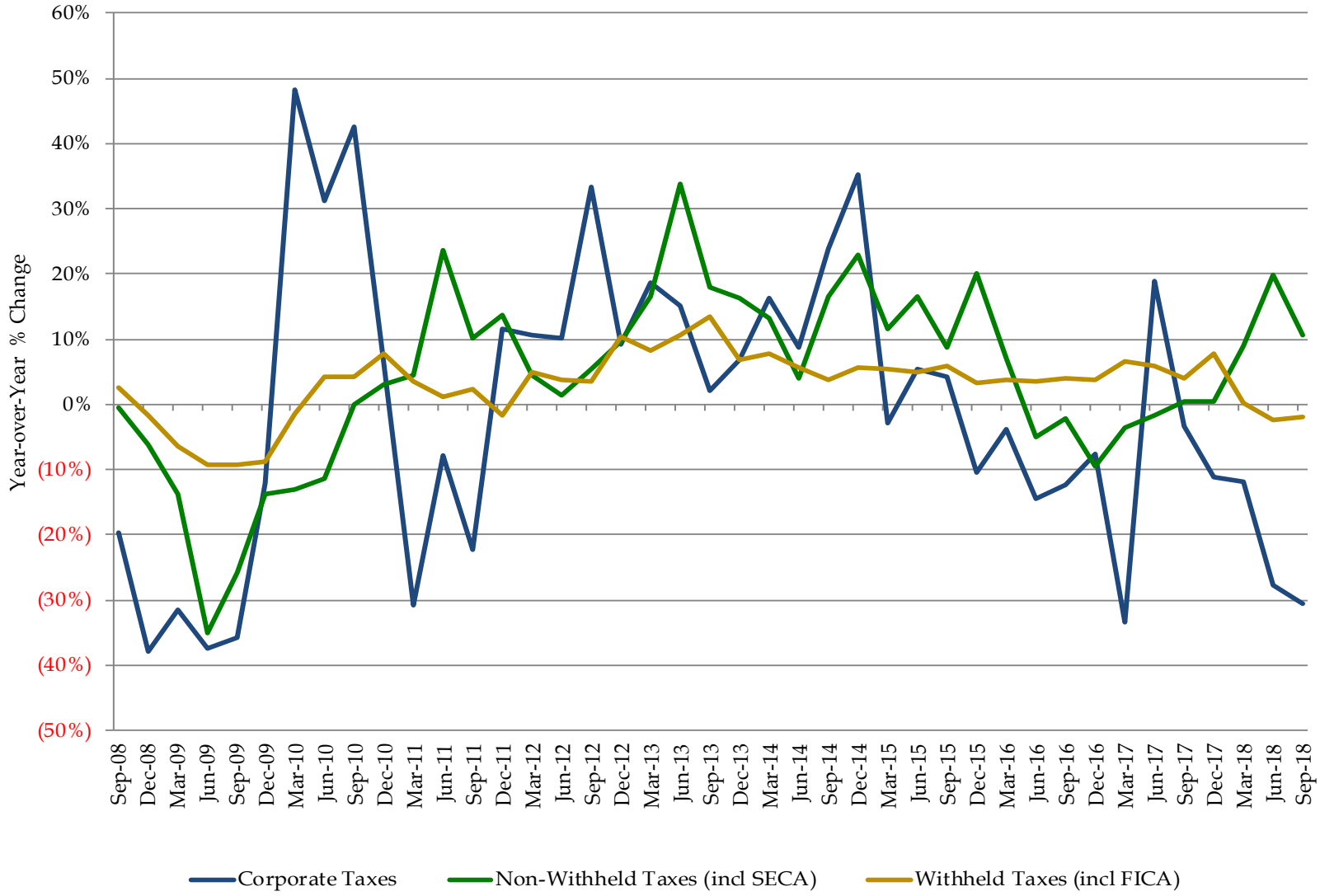
- Recent deficit estimates contained in OMB's "Mid-Session-Review, Fiscal Year 2019" (July 2018) in conjunction with SOMA redemptions suggest that Treasury auction sizes will need to rise over the next few years. CBO's updated budget projections are not yet available.

Demand for Treasury Securities

- Bid-to-cover ratios for all securities were largely stable over the last quarter.
- Foreign demand remained steady.

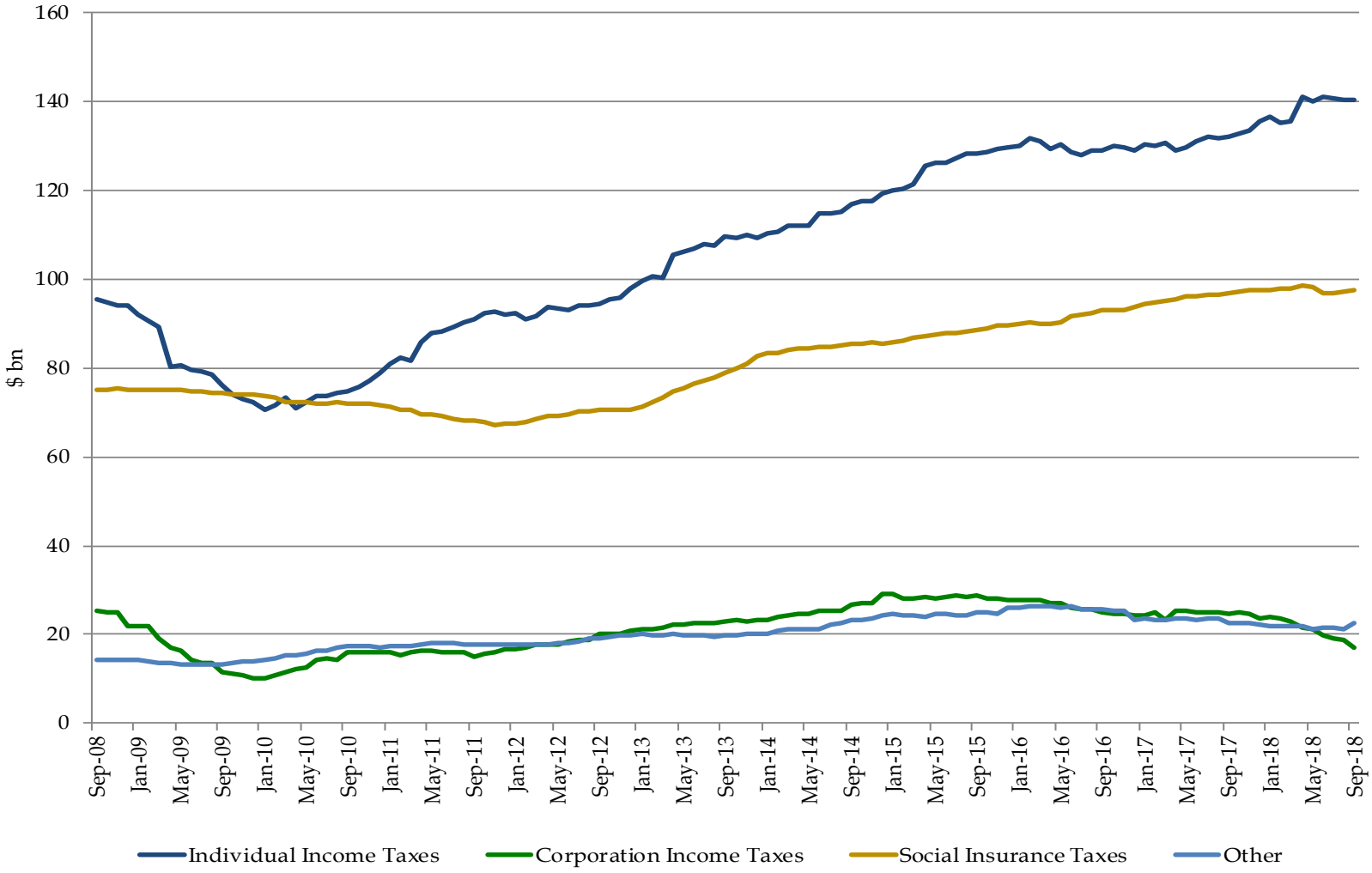
Section II: Fiscal

Quarterly Tax Receipts



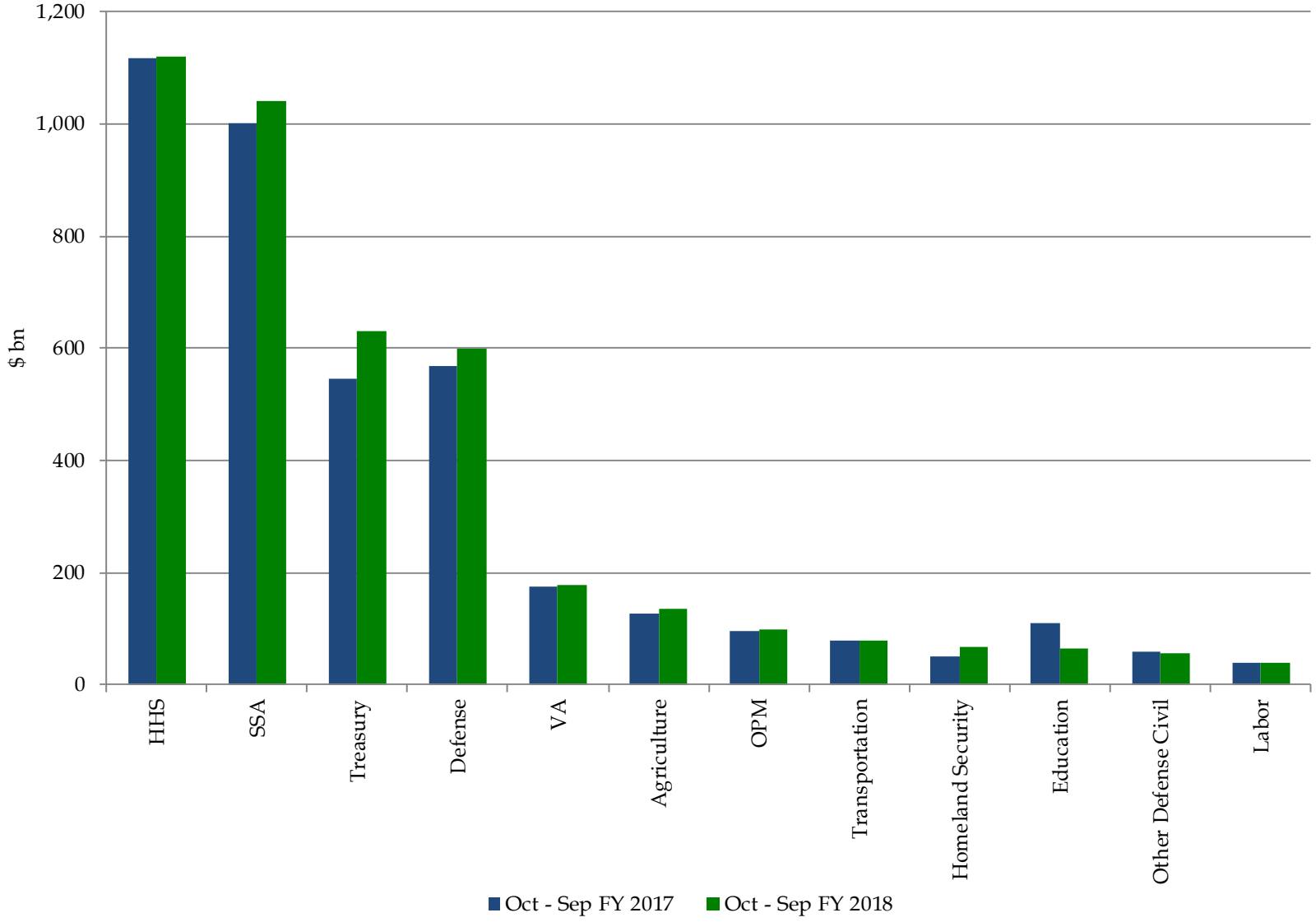
Source: United States Department of the Treasury

Monthly Receipt Levels
(12-Month Moving Average)



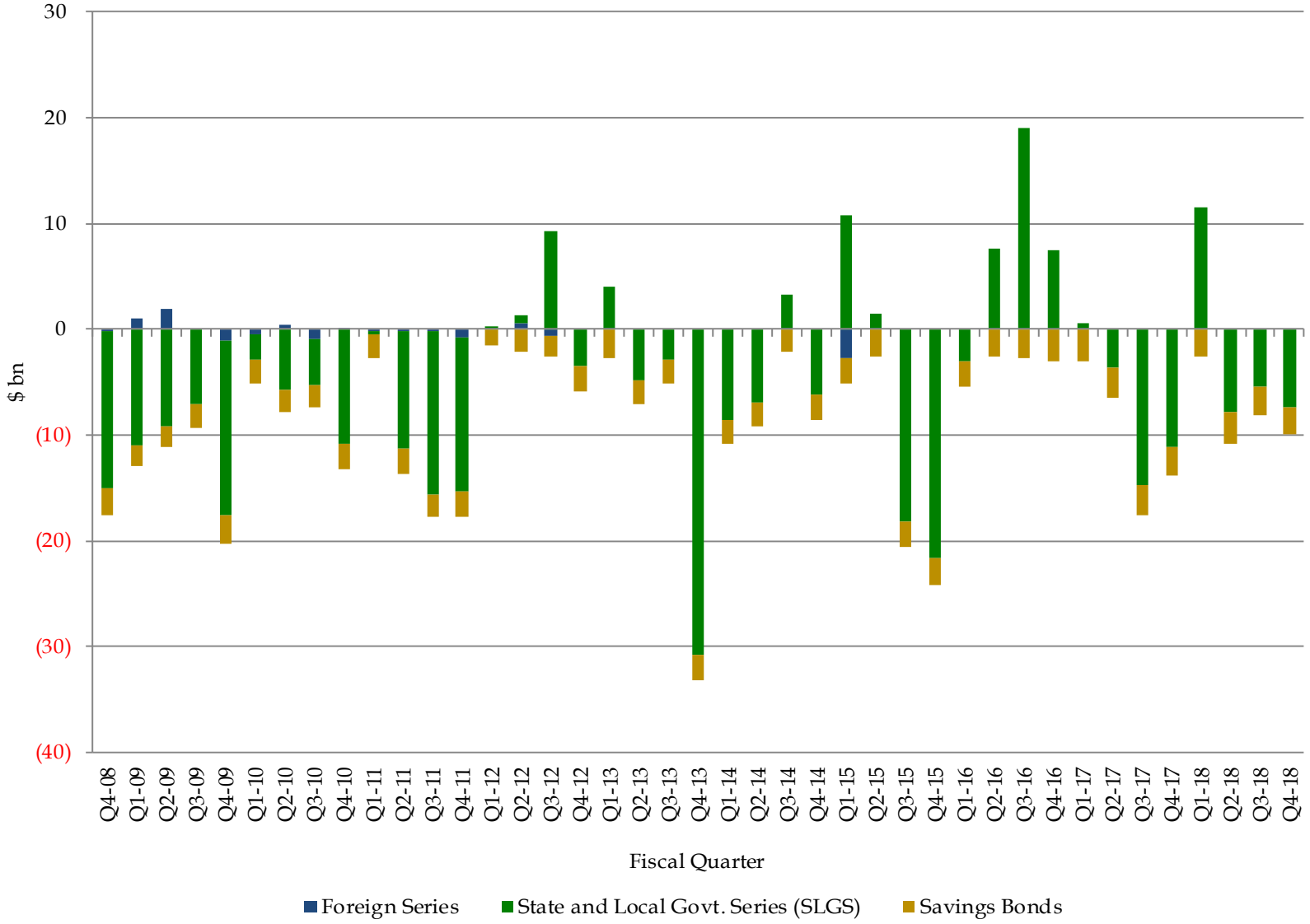
Individual Income Taxes include withheld and non-withheld. Social Insurance Taxes include FICA, SECA, RRTA, UTF deposits, FUTA and RUIA. Other includes excise taxes, estate and gift taxes, customs duties and miscellaneous receipts.
Source: United States Department of the Treasury

Largest Outlays



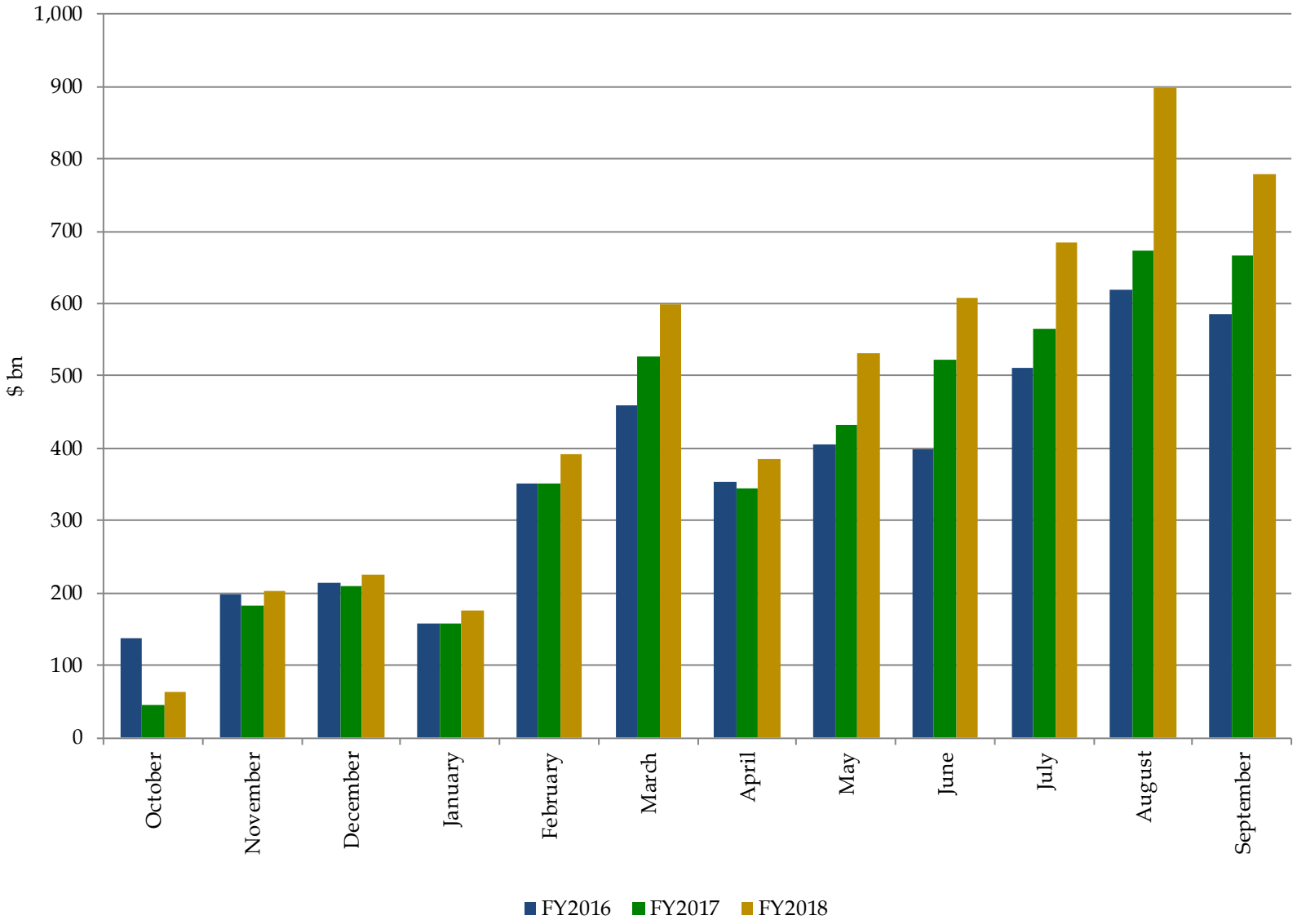
Source: United States Department of the Treasury

Treasury Net Nonmarketable Borrowing



Source: United States Department of the Treasury

Cumulative Budget Deficits by Fiscal Year



Source: United States Department of the Treasury

FY 2019-2021 Deficits and Net Marketable Borrowing Estimates*, in $ billions

	Primary Dealers[1]	OMB[2]	CBO[3]	CBO[4]
FY 2019 Deficit Estimate	1,000	1,086	955	981
FY 2020 Deficit Estimate	1,100	1,076	866	1,008
FY 2021 Deficit Estimate	1,200	1,010	945	1,123
FY 2019 Deficit Range	825-1,135			
FY 2020 Deficit Range	1,000-1,250			
FY 2021 Deficit Range	1,000-1,365			
FY 2019 Privately-Held Net Marketable Borrowing Estimate	1,300			
FY 2020 Privately-Held Net Marketable Borrowing Estimate	1,200			
FY 2021 Privately-Held Net Marketable Borrowing Estimate	1,273			
FY 2019 Privately-Held Net Marketable Borrowing Range	1,036-1,460			
FY 2020 Privately-Held Net Marketable Borrowing Range	900-1,500			
FY 2021 Privately-Held Net Marketable Borrowing Range	895-1,465			
FY 2019 SOMA Redemption Estimate	286			
FY 2020 SOMA Redemption Estimate	120			
FY 2021 SOMA Redemption Estimate	0			
FY 2019 Net Marketable Borrowing Estimate	1,014	1,186	1,049	1,074
FY 2020 Net Marketable Borrowing Estimate	1,080	1,164	924	1,065
FY 2021 Net Marketable Borrowing Estimate	1,273	1,097	993	1,171
Estimates as of:	Oct-18	Jul-18	May-18	Apr-18

1Based on primary dealer feedback in October 2018. Estimates above are medians.

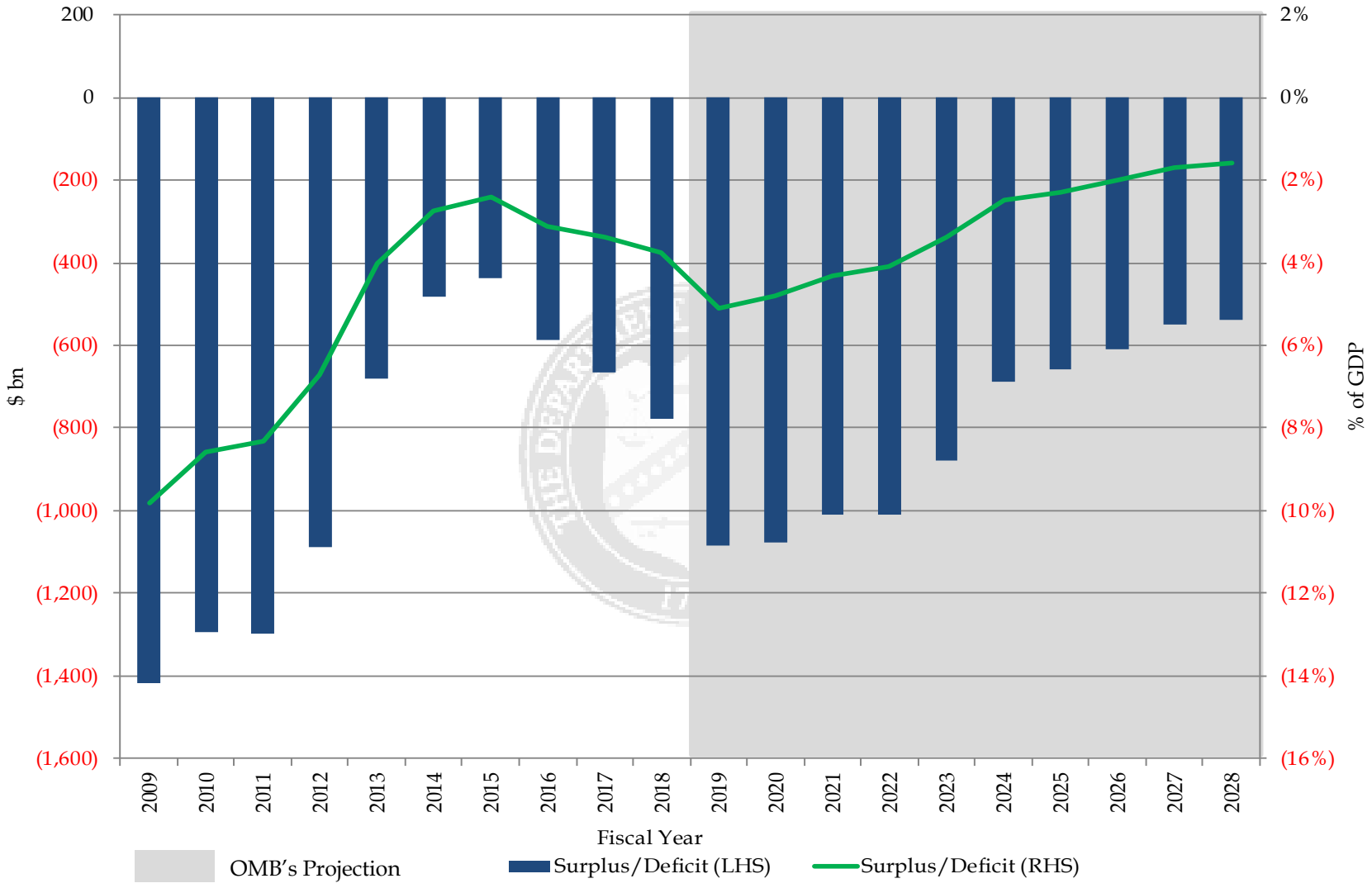
2Table S-11 of OMB's "Mid-Session Review, Fiscal Year 2019," July 2018.

3Table 2 of CBO's "An Analysis of the President's 2019 Budget," May 2018.

4Table 4-4 of CBO's "The Budget and Economic Outlook: 2018 to 2028," April 2018 (current law).

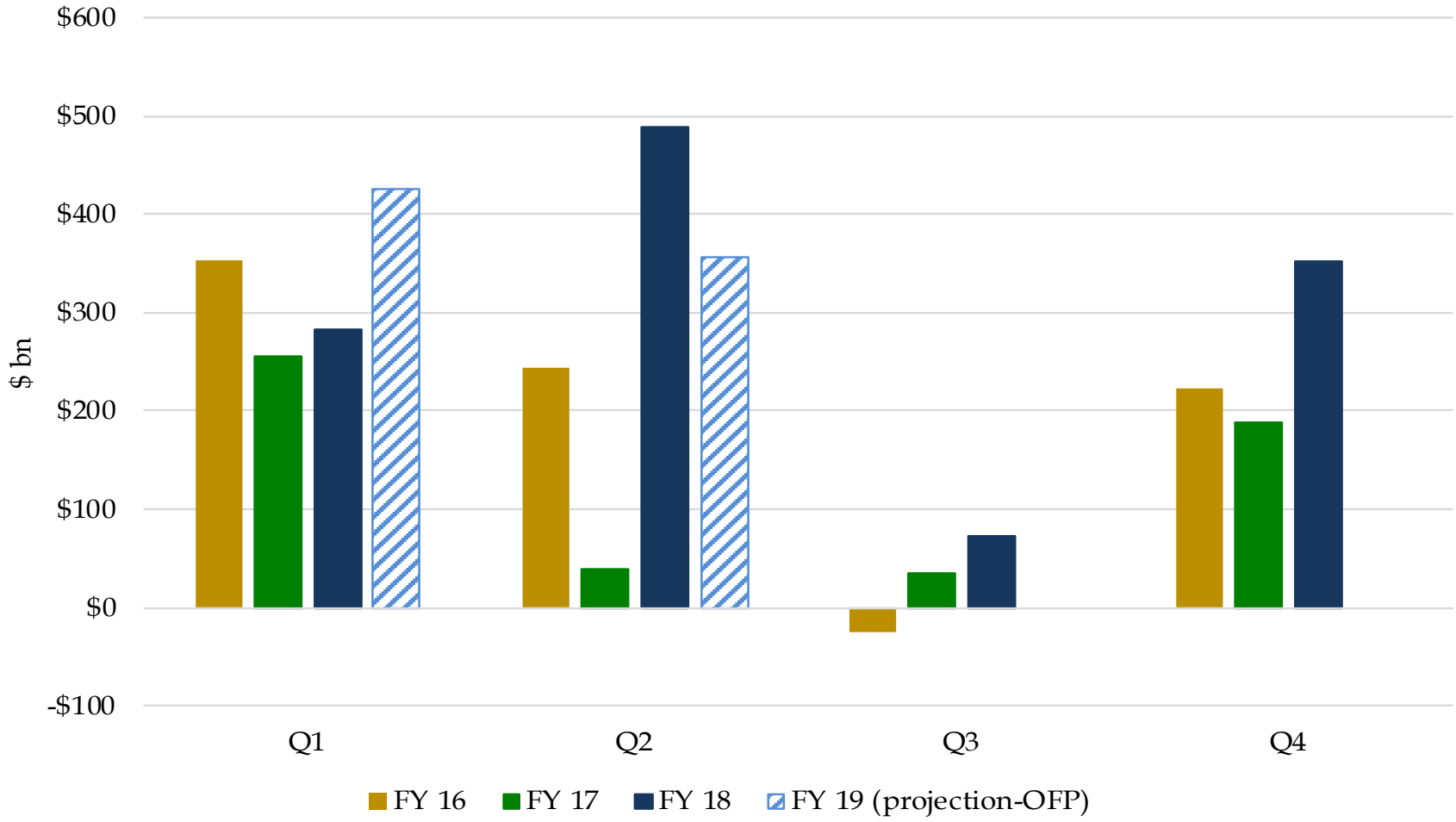
*Privately-held marketable borrowing excludes rollovers (auction "add-ons") of Treasury securities held in the Federal Reserve's System Open Market Account (SOMA), but includes financing required due to SOMA redemptions.

Budget Surplus/Deficit



Projections are from OMB's Table S-11 of "Mid-Session Review, Fiscal Year 2019," July 2018.

Privately-Held Net Marketable Borrowing Outlook*



*Privately-held marketable borrowing excludes rollovers (auction "add-ons") of Treasury securities held in the Federal Reserve's System Open Market Account (SOMA), but includes financing required due to SOMA redemptions.

Section III: Financing

Assumptions for Financing Section (pages 16 to 21)

- Portfolio and SOMA holdings as of 9/30/2018.
- Estimates assume an end date for SOMA capped redemptions at the end of CY2020. The assumption is based on the median case from "Statement Regarding the Annual Report on Open Market Operations during 2017," Federal Reserve Bank of New York, April 2018.
- Estimates assume announced issuance sizes and patterns remain constant for nominal coupons, TIPS, and FRNs given changes made at the August 2018 refunding, while using a total of ~$2.24 trillion of bills outstanding.
- The principal on the TIPS securities was accreted to each projection date based on market ZCIS levels as of 9/30/2018.
- No attempt was made to account for future financing needs.

Sources of Privately-Held Financing in FY18 Q4*

July - September 2018	
Net Bill Issuance	82
Net Coupon Issuance	271
Subtotal: Net Marketable Borrowing	353
Ending Cash Balance	385
Beginning Cash Balance	333
Subtotal: Change in Cash Balance	52
Net Implied Funding for FY18 Q4**	301

Security	July - September 2018 Bill Issuance			Fiscal Year-to-Date Bill Issuance		
	Gross	Maturing	Net	Gross	Maturing	Net
4-Week	690	650	40	2,460	2,405	55
13-Week	645	624	21	2,466	2,334	132
26-Week	567	564	3	2,154	1,905	249
52-Week	78	60	18	302	260	42
CMBs	0	0	0	139	179	(40)
Bill Subtotal	1,980	1,898	82	7,521	7,083	438

Security	July - September 2018 Coupon Issuance			Fiscal Year-to-Date Coupon Issuance		
	Gross	Maturing	Net	Gross	Maturing	Net
2-Year FRN	52	41	11	187	164	23
2-Year	105	78	27	358	234	124
3-Year	102	72	30	345	294	51
5-Year	109	53	56	420	398	22
7-Year	91	69	22	348	224	124
10-Year	71	14	57	267	66	201
30-Year	47	0	47	171	3	168
5-Year TIPS	14	0	14	44	53	(9)
10-Year TIPS	24	16	8	70	33	37
30-Year TIPS	0	0	0	17	0	17
Coupon Subtotal	615	344	271	2,227	1,469	758

Total	2,595	2,242	353	9,748	8,552	1,196

*Privately-held marketable borrowing excludes rollovers (auction "add-ons") of Treasury securities held in the Federal Reserve's System Open Market Account (SOMA), but includes financing required due to SOMA redemptions.
**An end-of-September 2018 cash balance of $385 billion versus a beginning-of-July 2018 cash balance of $333 billion. By keeping the cash balance constant, Treasury arrives at the net implied funding number.

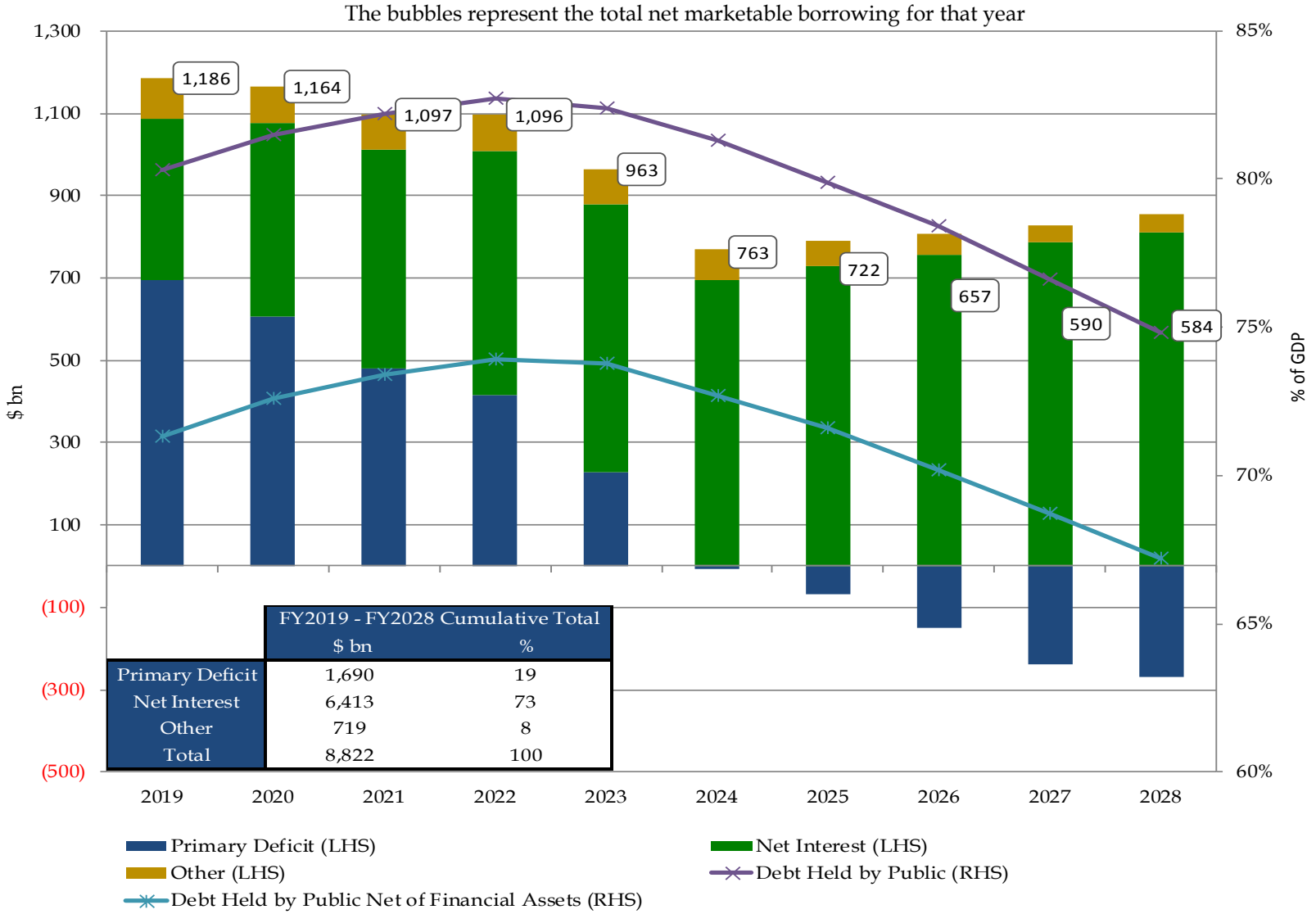
Sources of Privately-Held Financing in FY19 Q1*

October - December 2018	
Assuming Constant Coupon Issuance Sizes**	
Treasury Announced Net Marketable Borrowing***	425
Net Coupon Issuance	309
Implied Change in Bills	116

Security	October - December 2018 Coupon Issuance			Fiscal Year-to-Date Coupon Issuance		
	Gross	Maturing	Net	Gross	Maturing	Net
2-Year FRN	53	41	12	53	41	12
2-Year	151	104	47	151	104	47
3-Year	108	72	36	108	72	36
5-Year	155	94	61	155	94	61
7-Year	124	91	33	124	91	33
10-Year	72	27	45	72	27	45
30-Year	48	3	45	48	3	45
5-Year TIPS	14	0	14	14	0	14
10-Year TIPS	11	0	11	11	0	11
30-Year TIPS	5	0	5	5	0	5
Coupon Subtotal	741	432	309	741	432	309

*Privately-held marketable borrowing excludes rollovers (auction "add-ons") of Treasury securities held in the Federal Reserve's System Open Market Account (SOMA), but includes financing required due to SOMA redemptions.
**Keeping announced issuance sizes and patterns constant for nominal coupons, TIPS, and FRNs based on changes made at the August 2018 refunding.
***Assumes an end-of-December 2018 cash balance of $410 billion versus a beginning-of-October 2018 cash balance of $385 billion.
Financing Estimates released by the Treasury can be found here: http://www.treasury.gov/resource-center/data-chart-center/quarterly-refunding/Pages/Latest.aspx

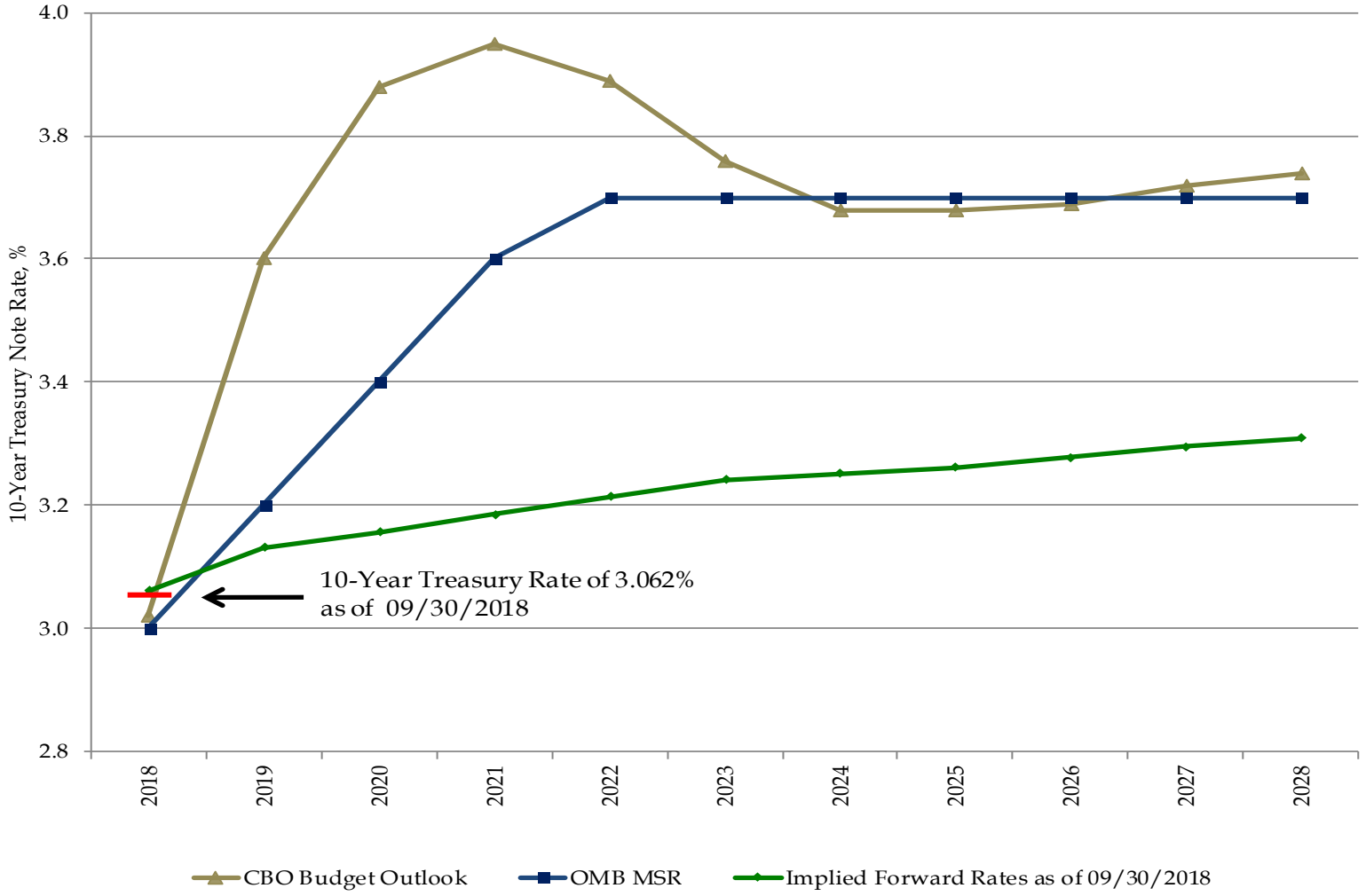
OMB's Projection of Borrowing from the Public



	FY2019 - FY2028 Cumulative Total	
	$ bn	%
Primary Deficit	1,690	19
Net Interest	6,413	73
Other	719	8
Total	8,822	100

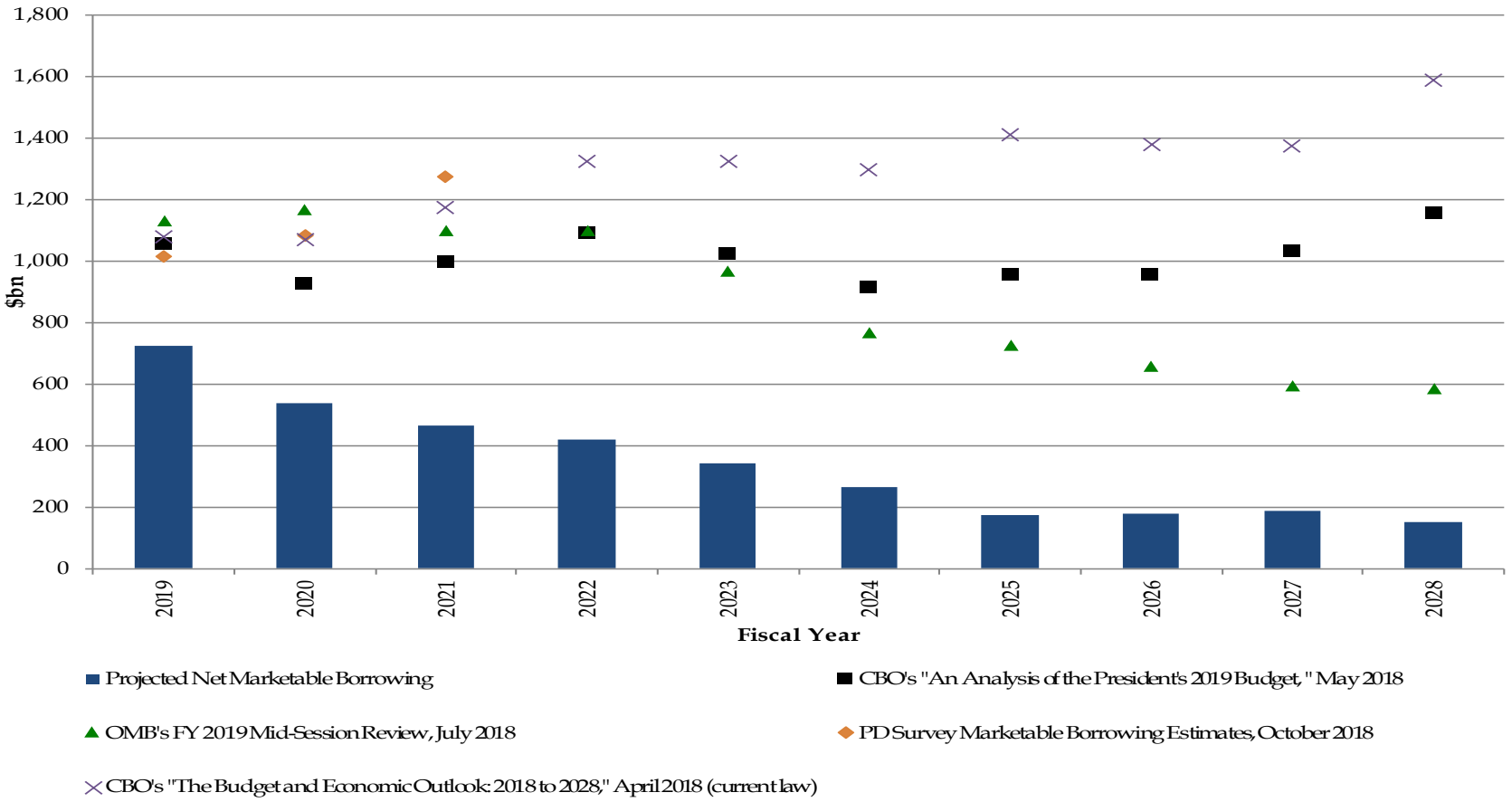
OMB's projections of the change in debt held by the public (borrowing) are from Table S-11 of "Mid-Session Review, Fiscal Year 2019," July 2018. "Other" represents borrowing from the public to provide direct and guaranteed loans.

Interest Rate Assumptions: 10-Year Treasury Note



OMB's economic assumption of the 10-Year Treasury Note rates are from Table 2 of OMB's "Mid-Session Review, Fiscal Year 2019," July 2018. CBO's economic assumption of the 10-Year Treasury Note rates are from Table D-1 of CBO's "The Budget and Economic Outlook: 2018 to 2028," April 2018. The forward rates are the implied 10-Year Treasury Note rates on September 30, 2018.

Projected Net Marketable Borrowing
Assuming Future Issuance Remains Constant*



Treasury's October 2018 primary dealer survey estimates can be found on page 11. OMB's projections of the change in debt held by the public are from Table S-11 of "Mid-Session Review, Fiscal Year 2019," July 2018. CBO's baseline budget projections of the change in debt held by the public are from Table 2 of "An Analysis of the President's 2019 Budget," May 2018. CBO's current law budget projections of the change in debt held by the public are from Summary Table2 of "The Budget and Economic Outlook:2018 to 2028," April 2018. See table at the end of this section for details.

*Projections reflect capped SOMA Treasury redemptions up until the end of CY 2020.

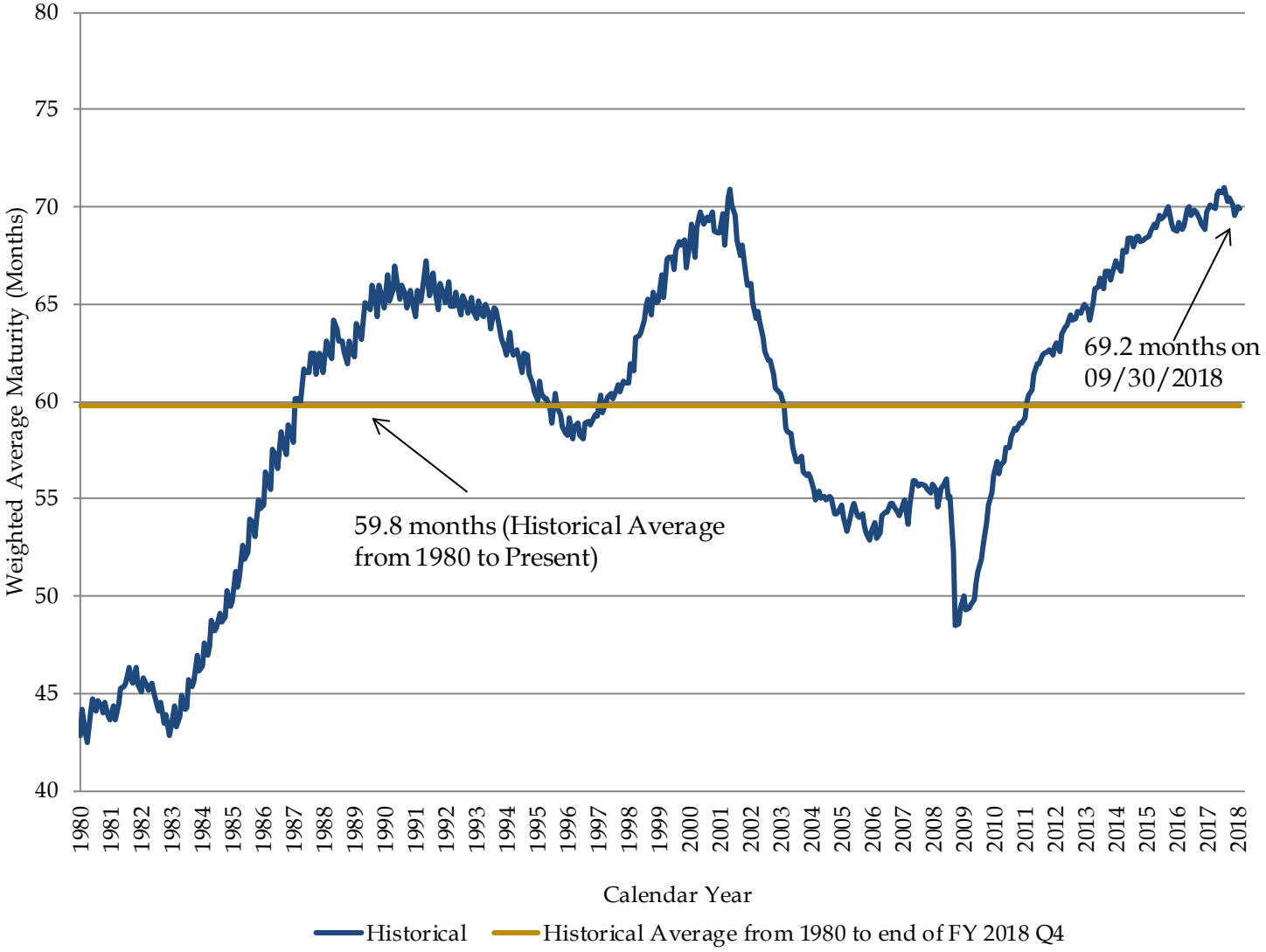
Historical Net Marketable Borrowing and Projected Net Borrowing Assuming Future Issuance Remains Constant, $ billions

Fiscal Year	Bills	2/3/5	7/10/30	TIPS	FRN	Historical/Projected Net Borrowing Capacity	OMB's FY 2019 Mid-Session Review	CBO's "An Analysis of the President's 2019 Budget "	Primary Dealer Survey
2014	(119)	(92)	669	88	123	669			
2015	(53)	(282)	641	88	164	558			
2016	289	(82)	477	64	47	795			
2017	155	9	292	55	9	519			
2018	438	209	316	51	26	1,040			
2019	(0)	431	205	44	42	723	1,186	1,049	1,014
2020	0	263	241	14	15	535	1,164	924	1,080
2021	0	169	298	(2)	(0)	465	1,097	993	1,273
2022	0	106	323	(13)	3	418	1,096	1,085	
2023	0	148	199	(10)	5	342	963	1,018	
2024	0	(5)	282	(13)	1	265	763	911	
2025	0	(31)	261	(55)	(2)	173	722	951	
2026	0	(29)	257	(47)	(2)	180	657	952	
2027	0	(5)	233	(36)	(3)	189	590	1,027	
2028	0	(13)	223	(64)	3	149	584	1,149	

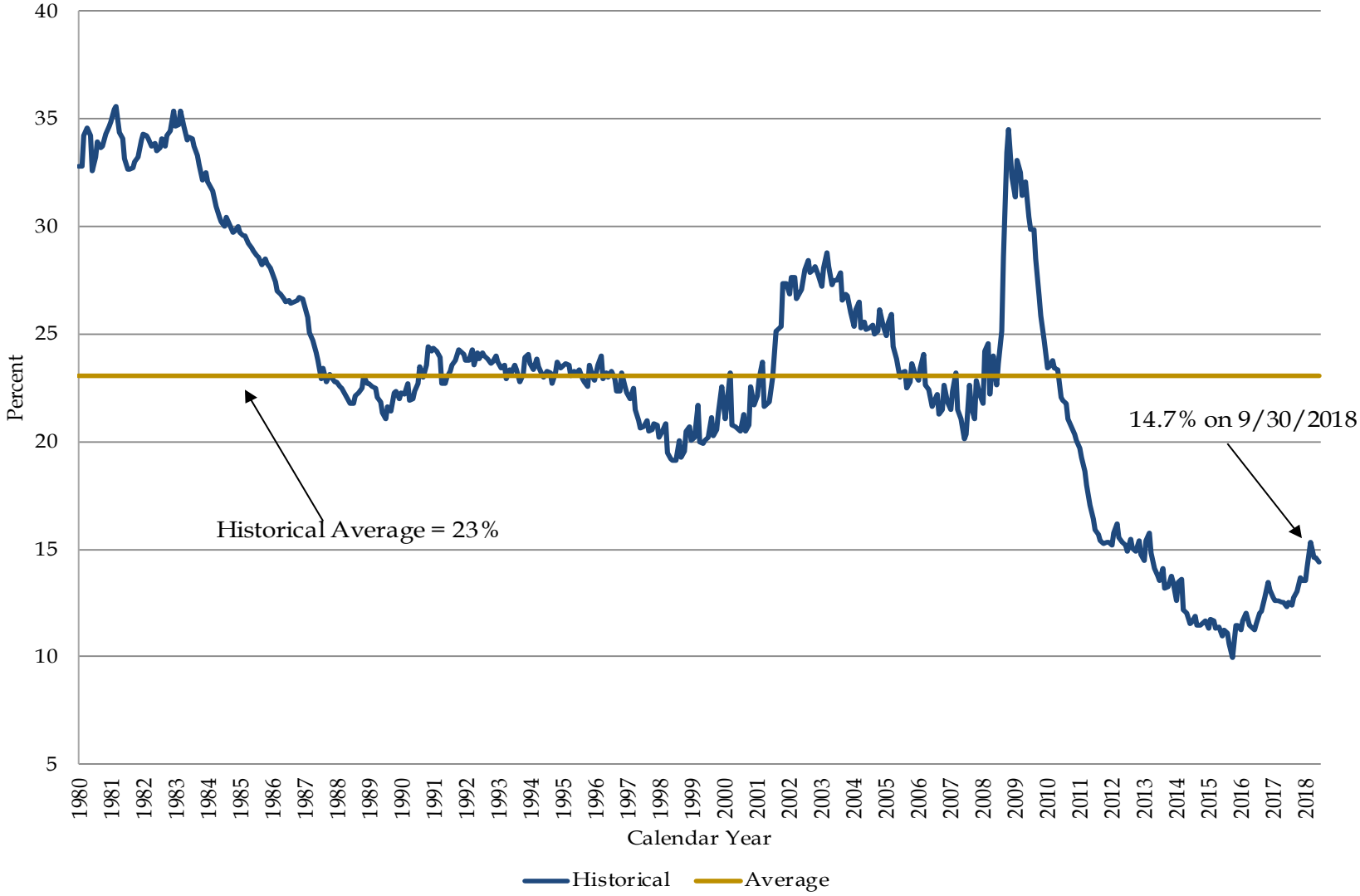
Net borrowing capacity reflects capped SOMA redemptions up until the end of CY 2020.
Treasury's October 2018 primary dealer survey estimates can be found on page 11. OMB's projections of the change in debt held by the public are from Table S-11 of "Mid-Session Review, Fiscal Year 2019," July 2018. CBO's baseline budget projections of the change in debt held by the public are from Table 2 of CBO's "An Analysis of the President's Budget," May 2018.

Section IV:
Portfolio Metrics

Historical Weighted Average Maturity of Marketable Debt Outstanding



Bills Outstanding as a Percent of Portfolio



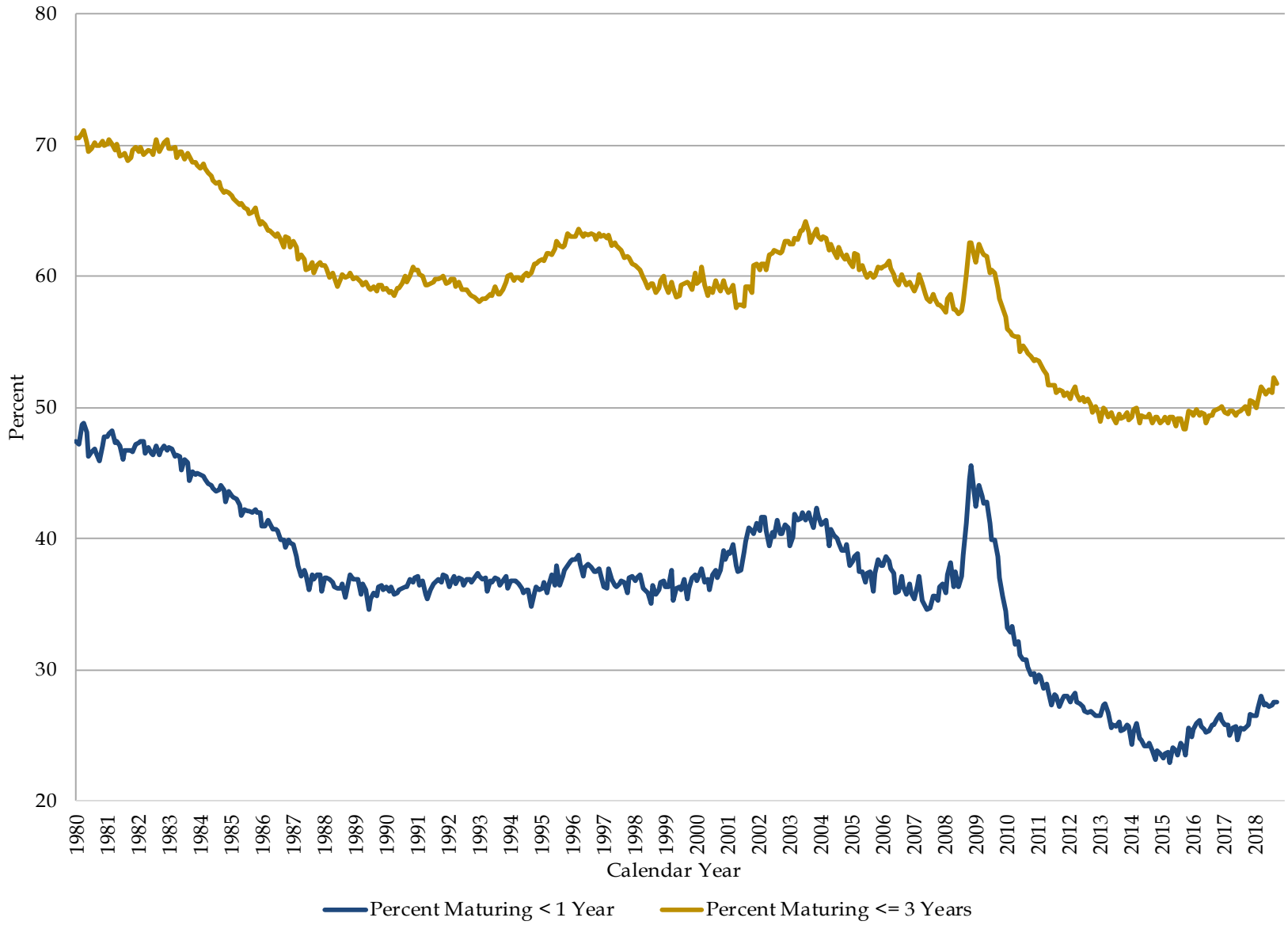
Recent Maturity Profile, $ billions

Date	(0,1]	(1,2]	(2,3]	(3,5]	(5,7]	(7,10]	(10,30]	Total	(0,5]
Sep-11	2,620	1,334	980	1,541	1,070	1,053	1,017	9,616	6,476
Sep-12	2,951	1,373	1,104	1,811	1,214	1,108	1,181	10,742	7,239
Sep-13	2,939	1,523	1,242	1,965	1,454	1,136	1,331	11,590	7,669
Sep-14	2,935	1,739	1,319	2,207	1,440	1,113	1,528	12,281	8,199
Sep-15	3,097	1,775	1,335	2,382	1,478	1,121	1,654	12,841	8,589
Sep-16	3,423	1,828	1,538	2,406	1,501	1,151	1,800	13,648	9,195
Sep-17	3,631	2,027	1,504	2,433	1,466	1,180	1,946	14,188	9,596
Sep-18	4,299	2,076	1,603	2,472	1,531	1,209	2,077	15,268	10,450

Recent Maturity Profile, percent

Date	(0,1]	(1,2]	(2,3]	(3,5]	(5,7]	(7,10]	(10,30]	(0,3]	(0,5]
Sep-11	27.2	13.9	10.2	16.0	11.1	10.9	10.6	51.3	67.3
Sep-12	27.5	12.8	10.3	16.9	11.3	10.3	11.0	50.5	67.4
Sep-13	25.4	13.1	10.7	17.0	12.5	9.8	11.5	49.2	66.2
Sep-14	23.9	14.2	10.7	18.0	11.7	9.1	12.4	48.8	66.8
Sep-15	24.1	13.8	10.4	18.5	11.5	8.7	12.9	48.3	66.9
Sep-16	25.1	13.4	11.3	17.6	11.0	8.4	13.2	49.7	67.4
Sep-17	25.6	14.3	10.6	17.1	10.3	8.3	13.7	50.5	67.6
Sep-18	28.2	13.6	10.5	16.2	10.0	7.9	13.6	52.3	68.4

Treasury Maturity Profile History



Section V: Demand

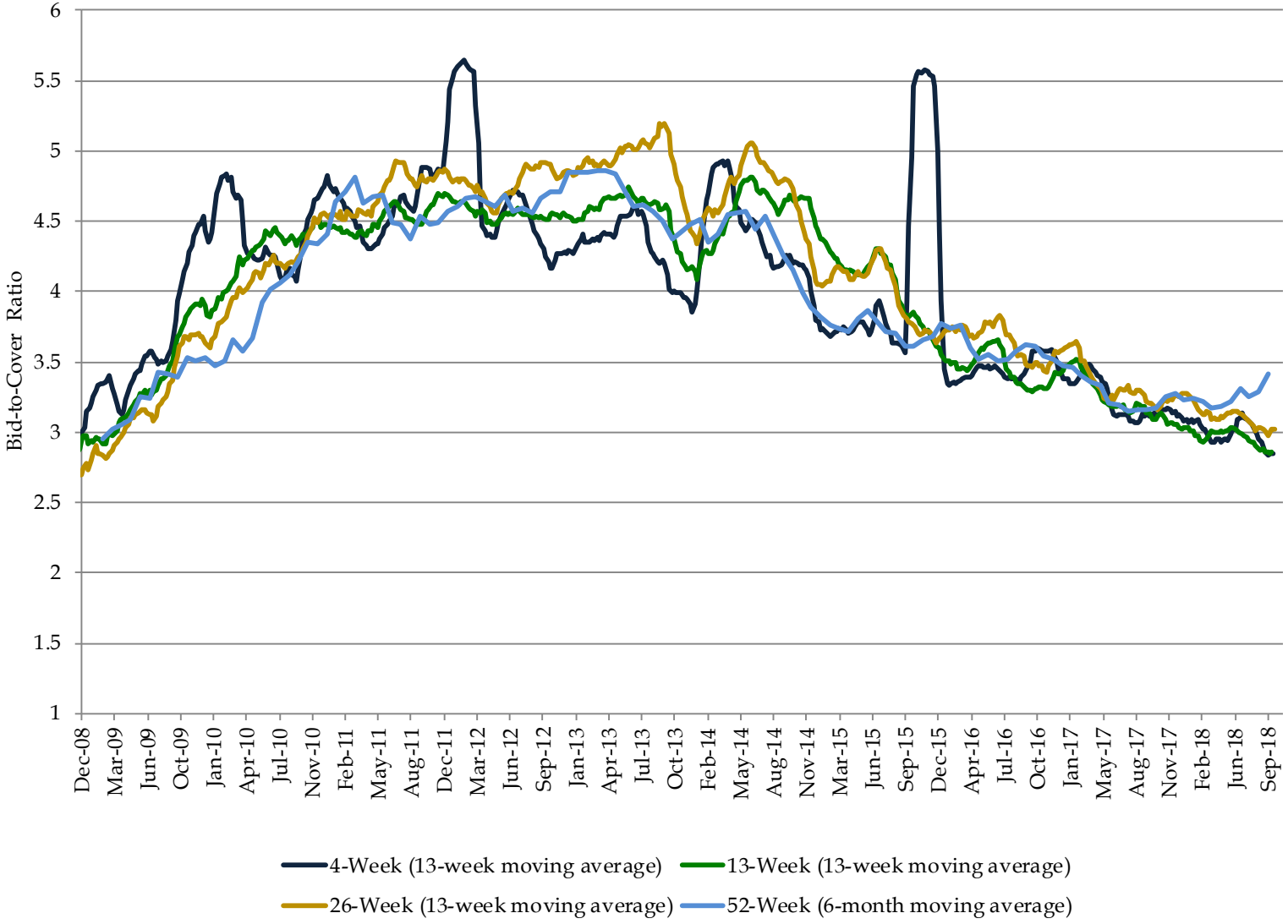
Summary Statistics for Fiscal Year 2018 Q4 Auctions

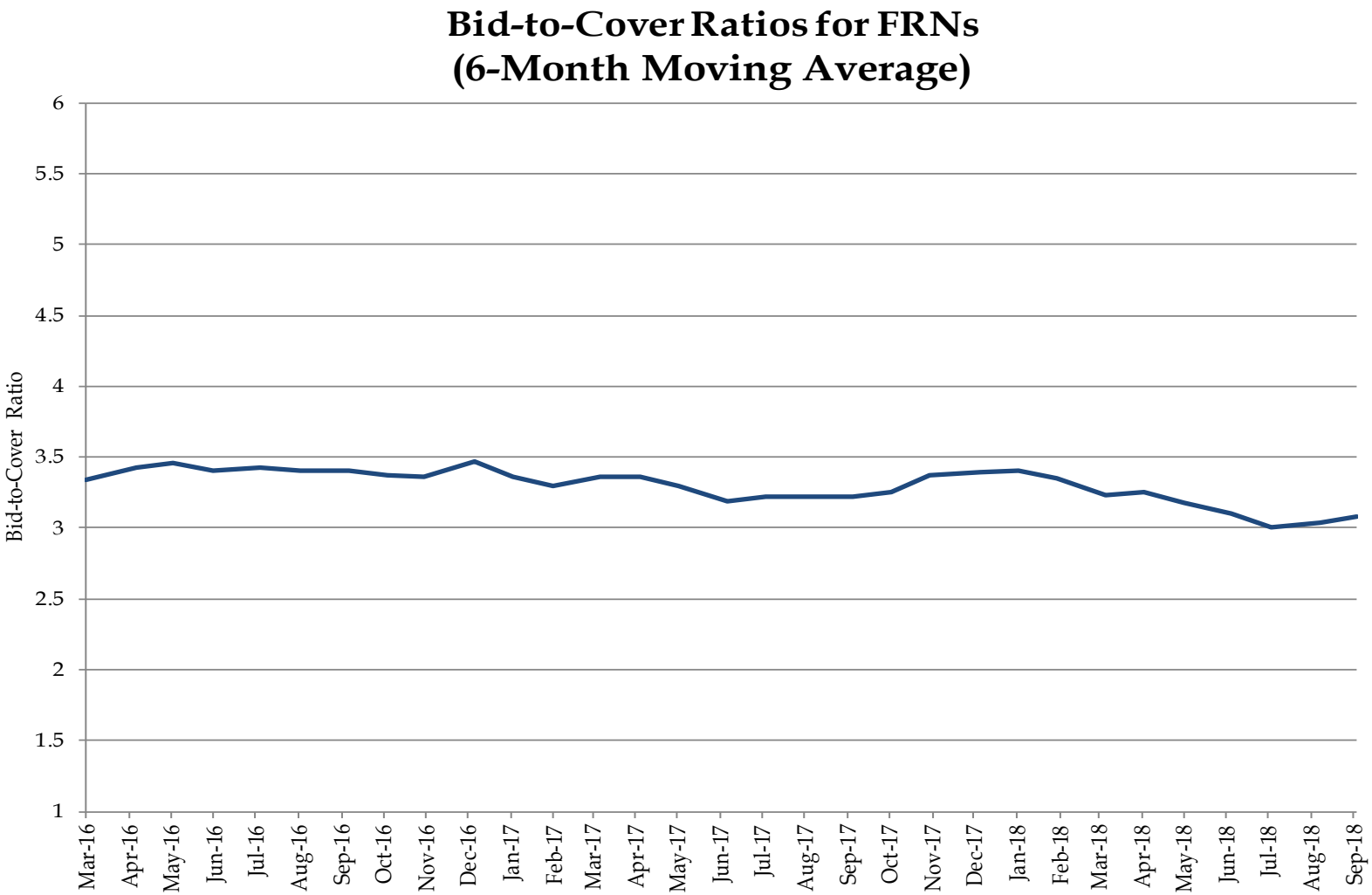
Security Type	Term	Stop Out Rate (%)*	Bid-to-Cover Ratio*	Competitive Awards ($bn)	% Primary Dealer*	% Direct*	% Indirect*	Non-Competitive Awards ($bn)	SOMA "Add-Ons" ($bn)	10-Year Equivalent ($bn)**
Bill	4-Week	1.926	2.8	676.8	54.4	9.2	36.4	13.2	0.0	6.1
Bill	13-Week	2.037	2.9	627.6	50.5	7.2	42.3	17.4	0.0	18.7
Bill	26-Week	2.191	3.0	550.0	45.4	4.6	50.0	17.0	0.0	32.8
Bill	52-Week	2.388	3.3	76.1	43.8	10.0	46.1	1.9	0.0	9.1
Coupon	2-Year	2.715	2.7	106.5	43.3	13.8	42.9	1.5	4.4	25.5
Coupon	3-Year	2.758	2.6	101.4	46.4	10.7	42.9	0.6	4.7	36.0
Coupon	5-Year	2.861	2.5	110.9	27.3	9.0	63.7	0.1	4.6	62.9
Coupon	7-Year	2.936	2.5	92.0	23.4	14.6	62.0	0.0	3.8	70.8
Coupon	10-Year	2.928	2.6	70.9	25.0	11.7	63.3	0.1	3.6	75.3
Coupon	30-Year	3.050	2.3	47.0	28.3	9.8	62.0	0.0	2.5	113.9
TIPS	5-Year	0.724	2.8	14.0	19.2	13.5	67.3	0.0	1.0	7.9
TIPS	10-Year	0.830	2.4	24.0	22.2	12.4	65.5	0.0	0.7	27.6
FRN	2-Year	0.047	2.9	51.9	42.9	7.6	49.5	0.1	2.2	0.0

Total Bills	2.056	2.9	1,930.5	50.1	7.3	42.6	49.5	0.0	66.7
Total Coupons	2.851	2.6	528.7	33.3	11.7	55.0	2.3	23.6	384.5
Total TIPS	0.791	2.5	37.9	21.1	12.8	66.1	0.1	1.7	35.5
Total FRN	0.047	2.9	51.9	42.9	7.6	49.5	0.1	2.2	0.0

*Weighted averages of Competitive Awards. FRNs are reported on discount margin basis.
**Approximated using prices at settlement and includes both Competitive and Non-Competitive Awards. For TIPS 10-year equivalent, a constant auction BEI is used as the inflation assumption.

Bid-to-Cover Ratios for Treasury Bills




Bid-to-Cover Ratios for FRNs
(6-Month Moving Average)
Bid-to-Cover Ratio
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
Mar-16
Apr-16
May-16
Jun-16
Jul-16
Aug-16
Sep-16
Oct-16
Nov-16
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
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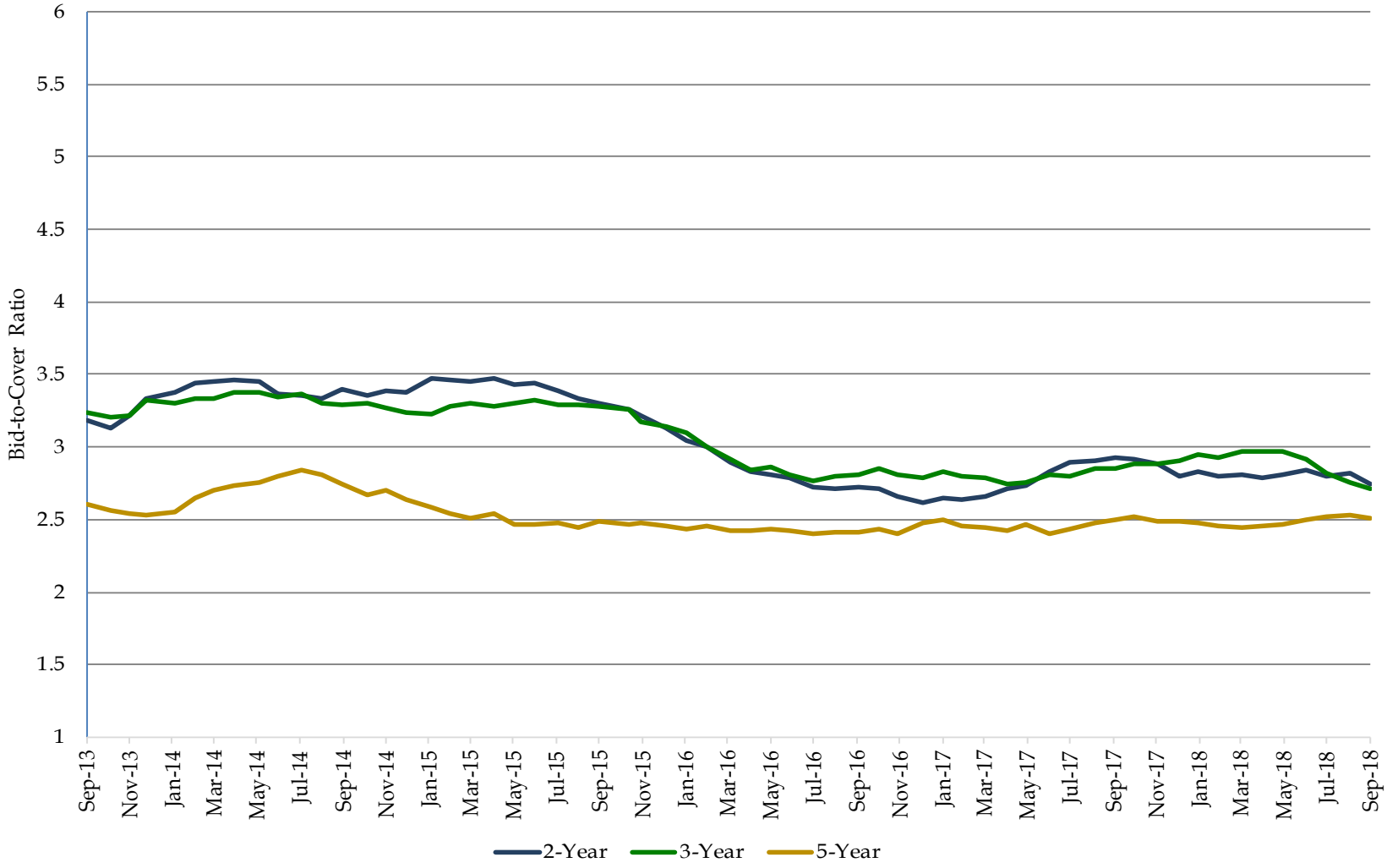
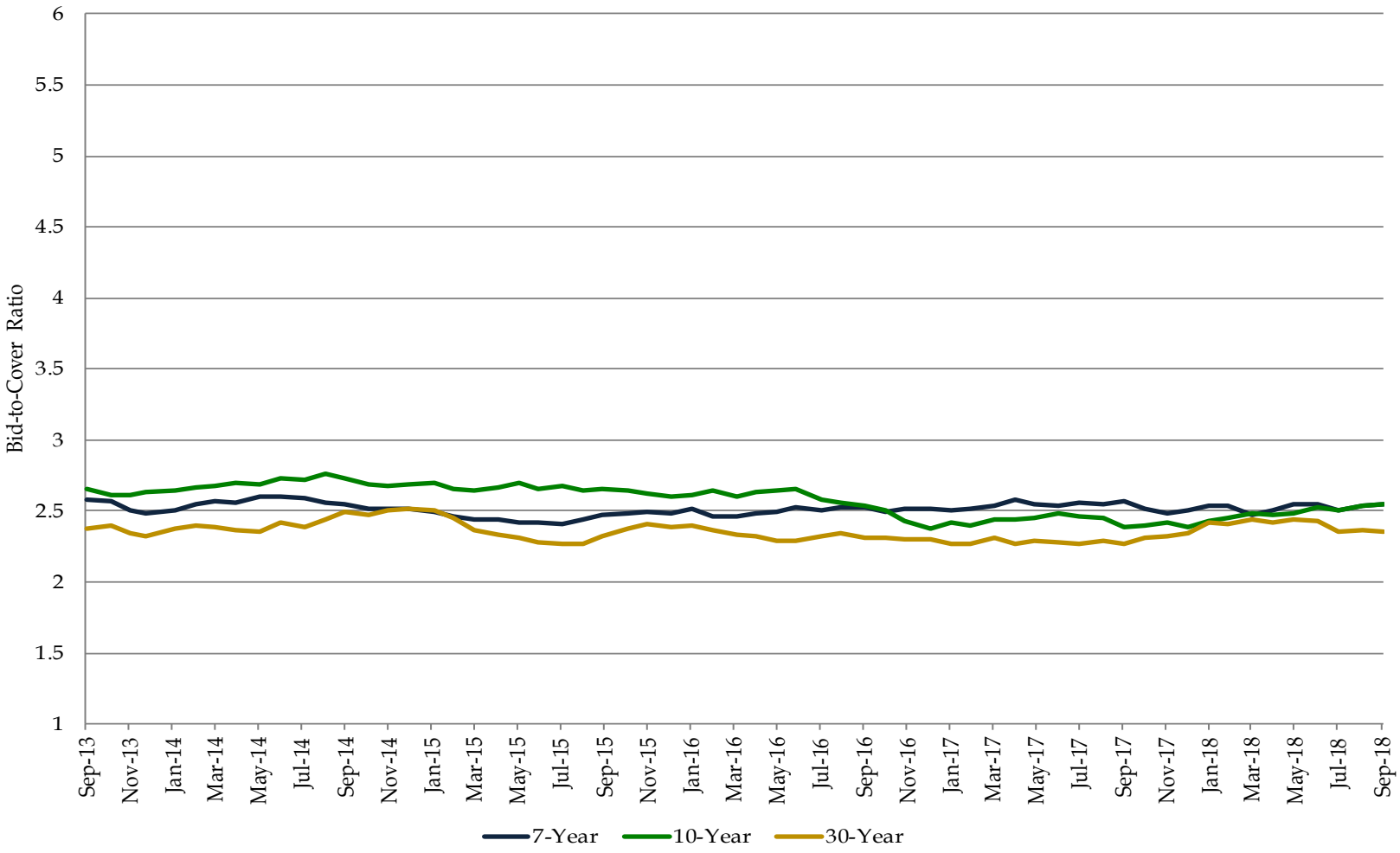
Jun-18
Jul-18
Aug-18
Sep-18

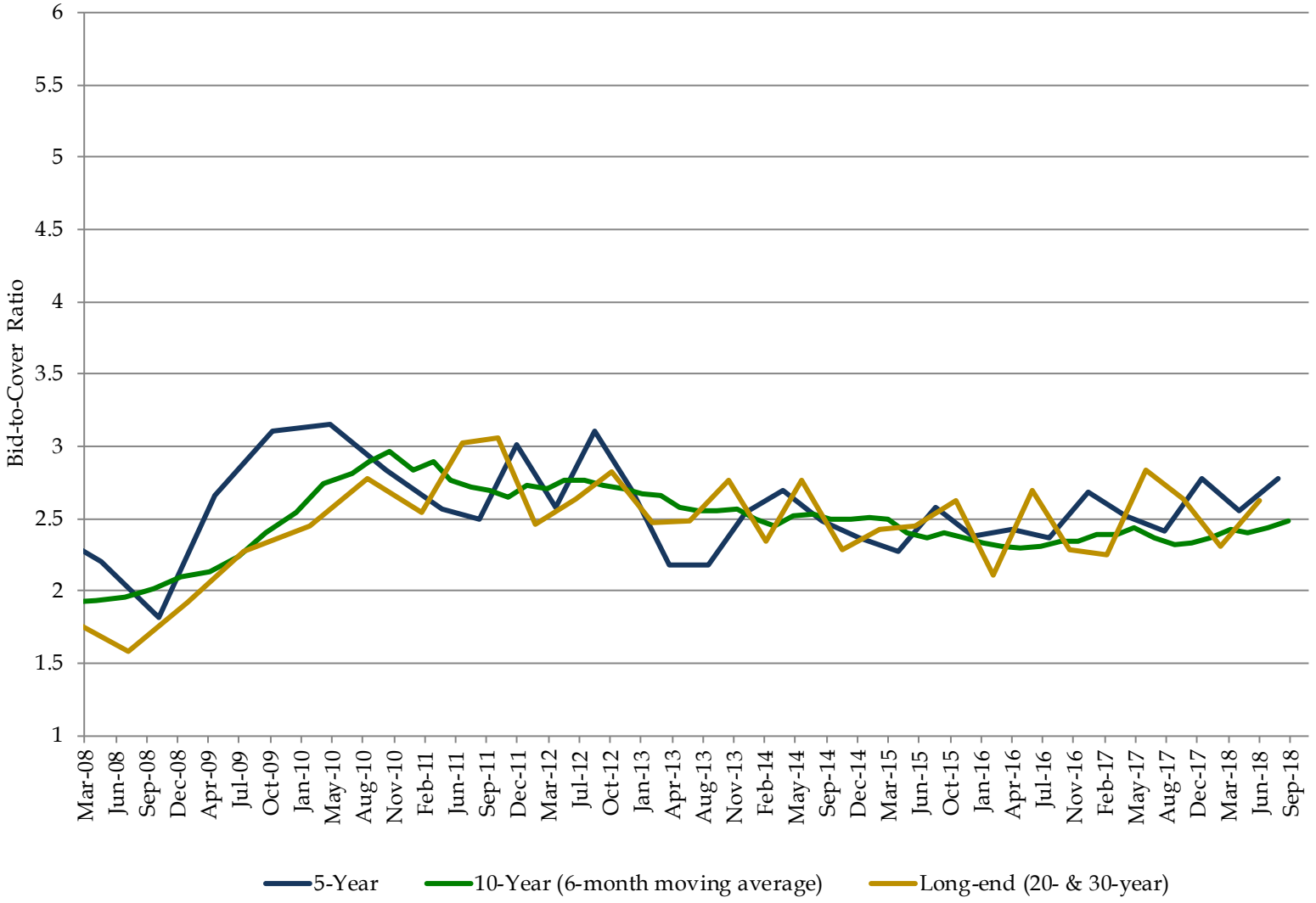
Bid-to-Cover Ratios for 2-, 3-, and 5-Year Nominal Securities (6-Month Moving Average)

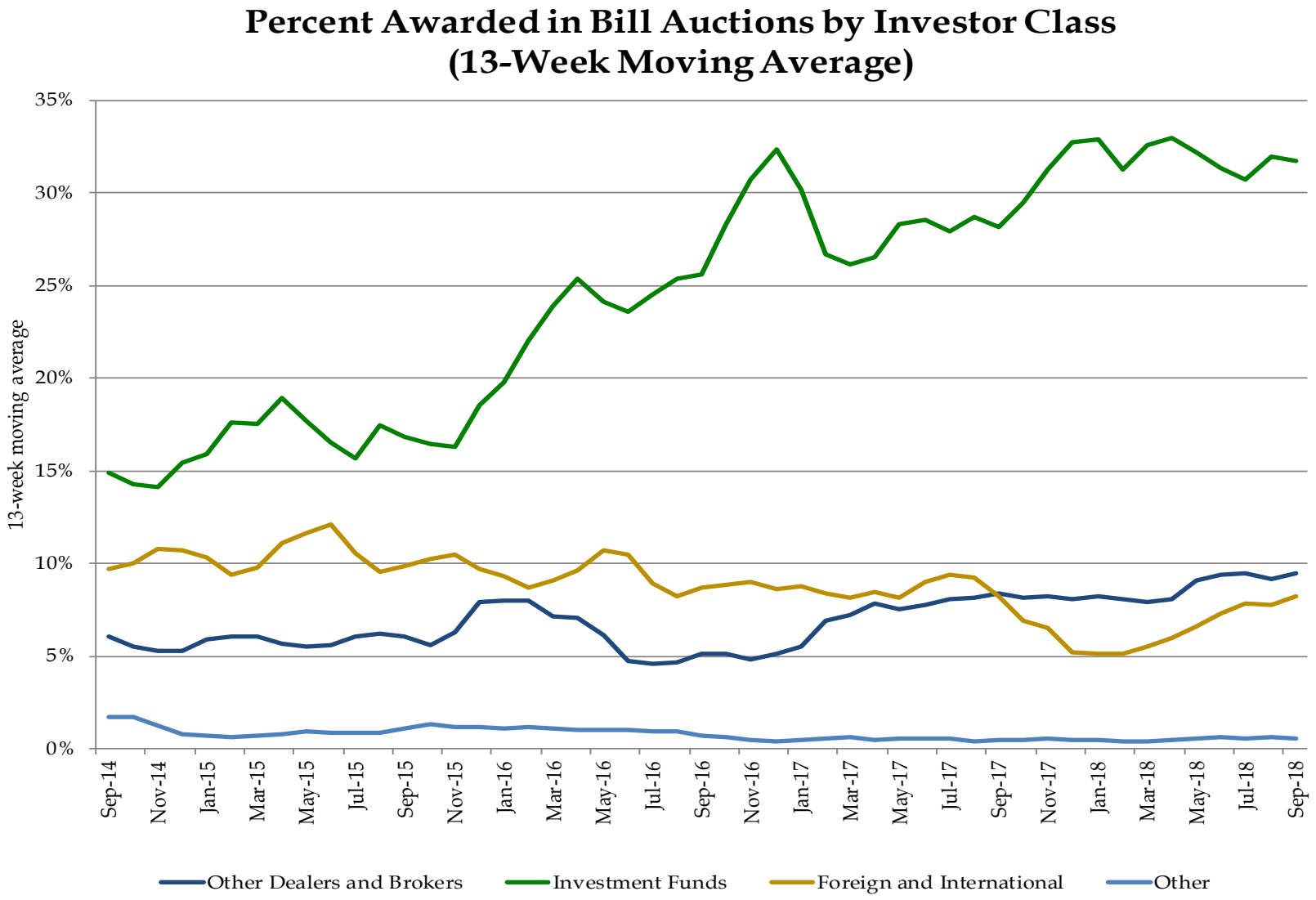


Bid-to-Cover Ratios for 7-, 10-, and 30-Year Nominal Securities (6-Month Moving Average)



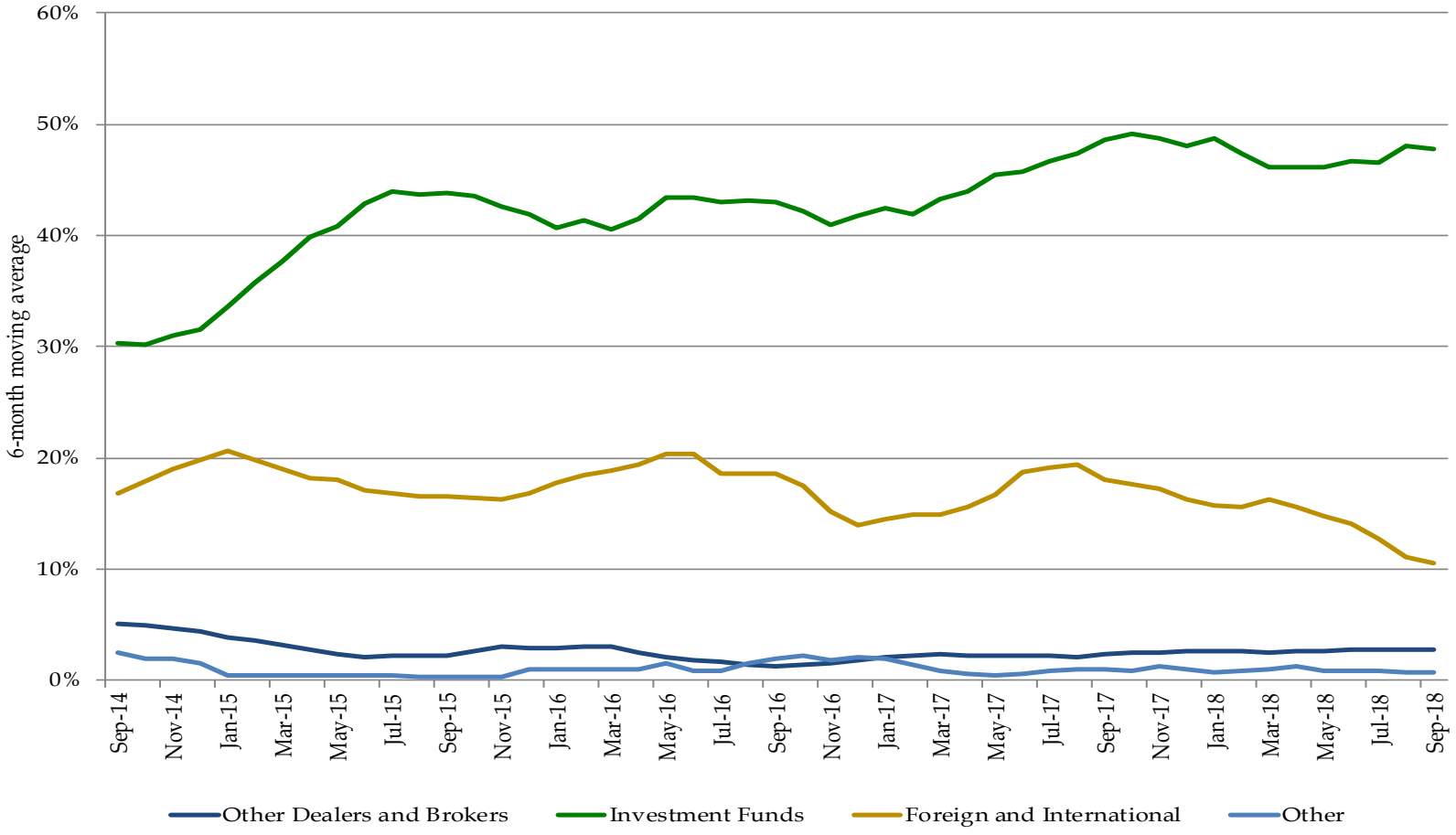
Bid-to-Cover Ratios for TIPS





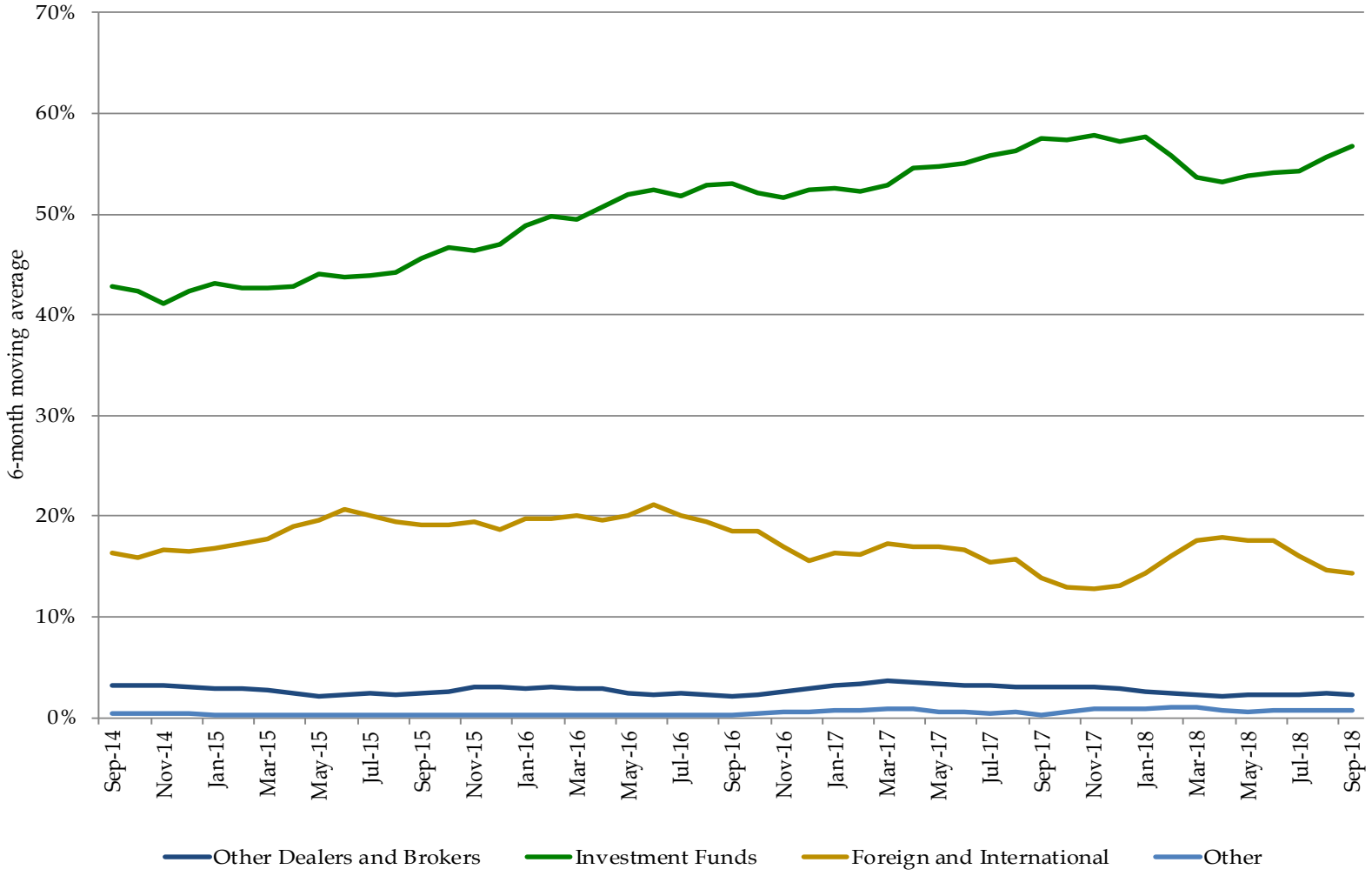
Excludes SOMA add-ons. The "Other" category includes categories that are each less than 5%, which include Depository Institutions, Individuals, Pension and Insurance.

Percent Awarded in 2-, 3-, and 5-Year Nominal Security Auctions by Investor Class (6-Month Moving Average)



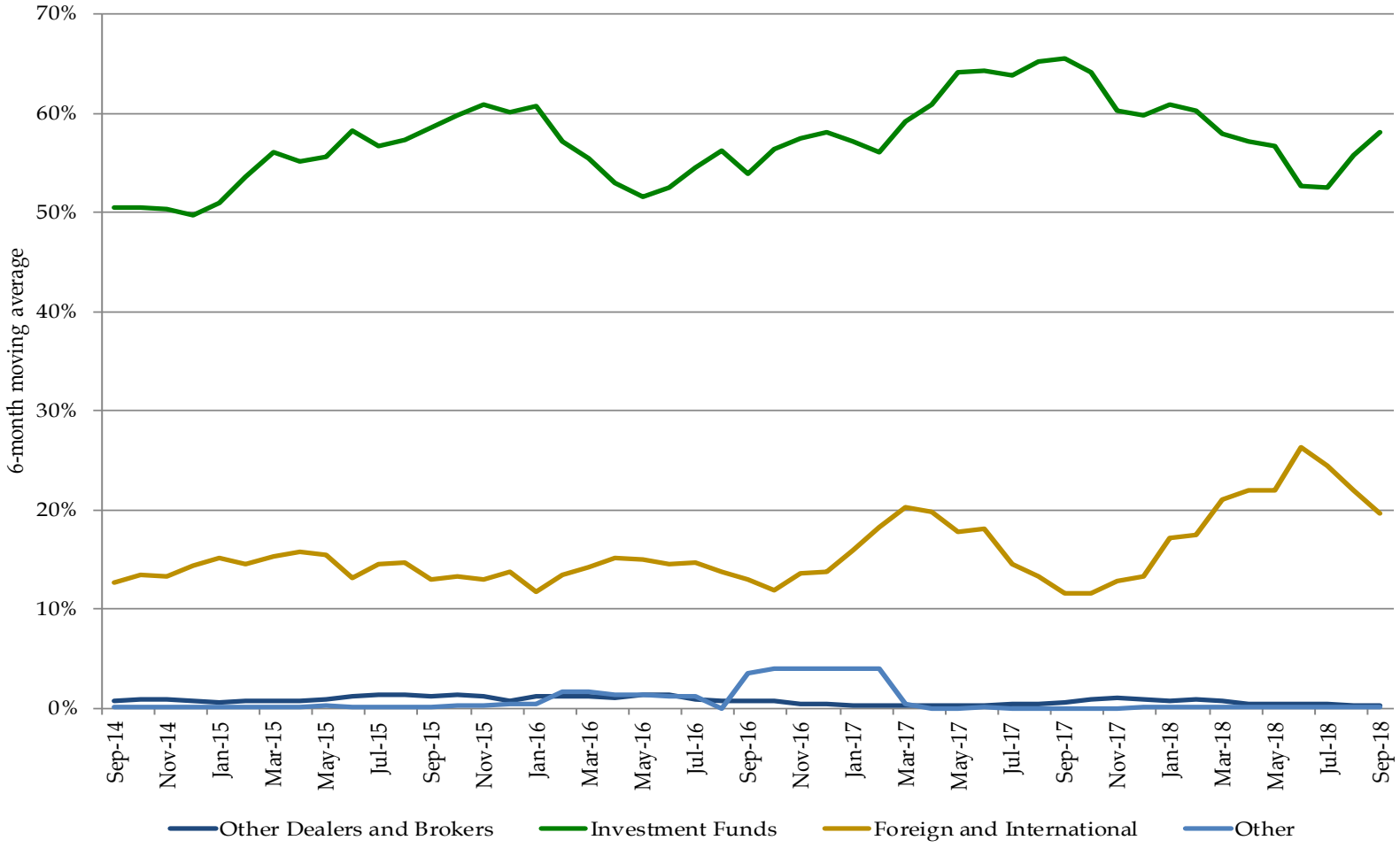
Excludes SOMA add-ons. The "Other" category includes categories that are each less than 5%, which include Depository Institutions, Individuals, Pension and Insurance.

Percent Awarded in 7-, 10-, 30-Year Nominal Security Auctions by Investor Class (6-Month Moving Average)



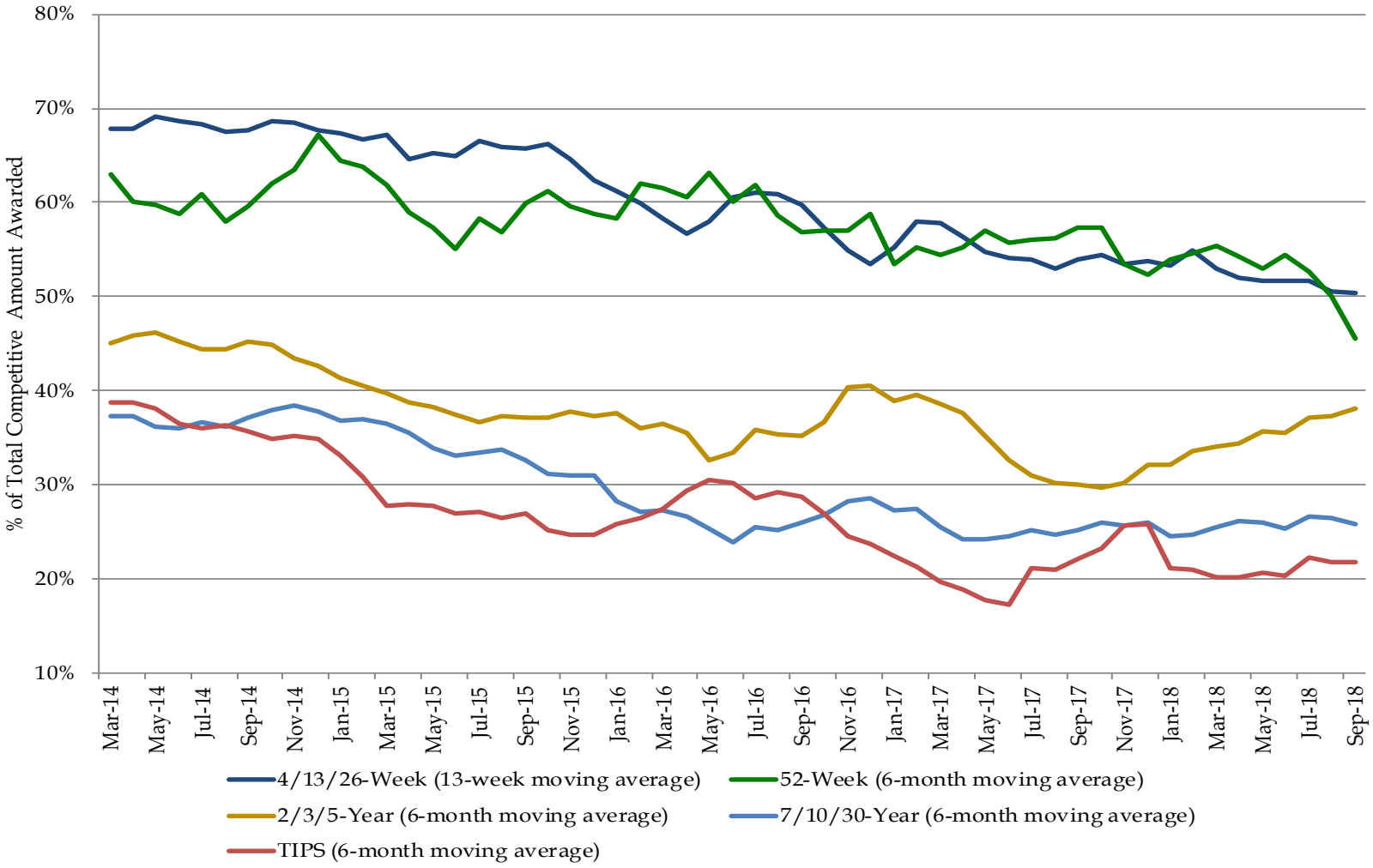
Excludes SOMA add-ons. The "Other" category includes categories that are each less than 5%, which include Depository Institutions, Individuals, Pension and Insurance.

Percent Awarded in TIPS Auctions by Investor Class (6-Month Moving Average)



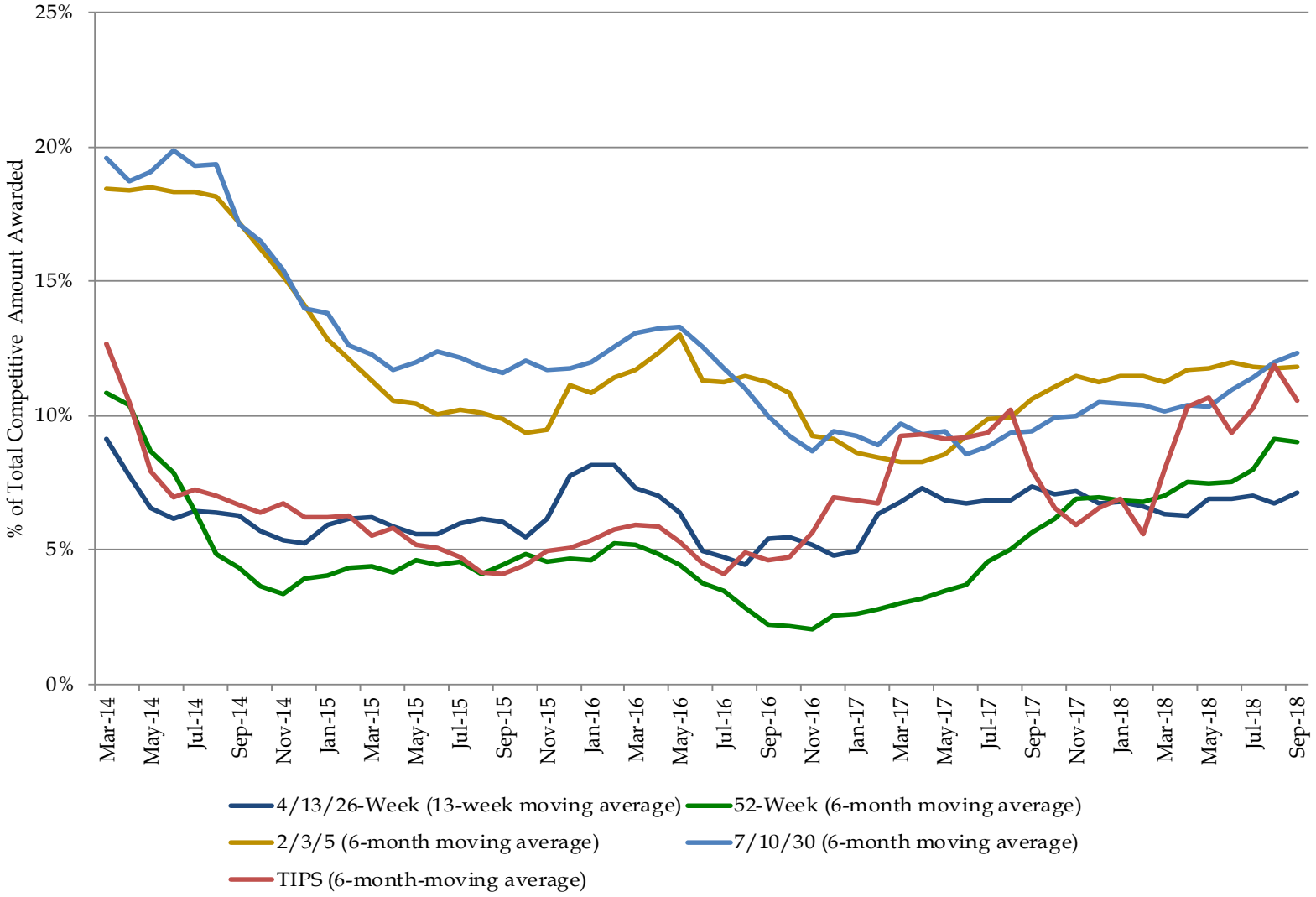
Excludes SOMA add-ons. The "Other" category includes categories that are each less than 5%, which include Depository Institutions, Individuals, Pension and Insurance.

Primary Dealer Awards at Auction



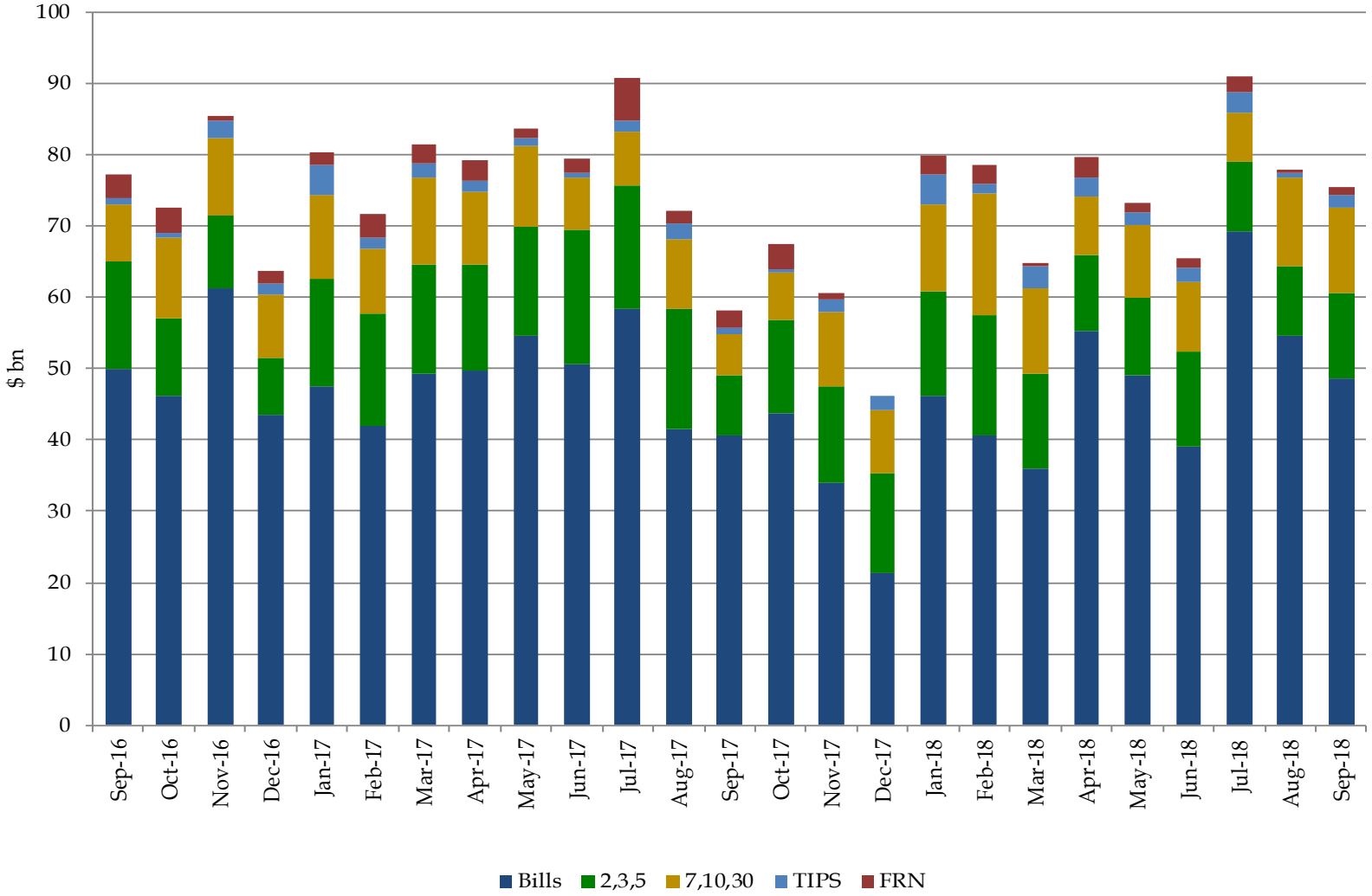
Excludes SOMA add-ons.

Direct Bidder Awards at Auction



Excludes SOMA add-ons.

Total Foreign Awards of Treasuries at Auction, $ billions



Foreign includes both private sector and official institutions.

Appendix

Bills										
Issue	Settle Date	Stop Out Rate (%)*	Bid-to-Cover Ratio*	Competitive Awards ($bn)	% Primary Dealer*	% Direct*	% Indirect*	Non-Competitive Awards ($bn)	SOMA "Add Ons" ($bn)	10-Year Equivalent ($bn)*
4-Week	7/5/2018	1.860	2.45	34.2	75.4	6.5	18.1	0.8	0.0	0.3
4-Week	7/12/2018	1.850	3.16	34.1	58.6	8.8	32.5	0.9	0.0	0.3
4-Week	7/19/2018	1.880	2.91	44.2	59.7	10.5	29.8	0.8	0.0	0.4
4-Week	7/26/2018	1.880	2.84	54.2	45.6	12.6	41.8	0.8	0.0	0.5
4-Week	8/2/2018	1.910	2.70	64.1	55.3	7.6	37.1	0.9	0.0	0.6
4-Week	8/9/2018	1.905	2.65	69.1	47.8	10.2	42.0	0.9	0.0	0.6
4-Week	8/16/2018	1.910	2.66	69.1	55.4	8.4	36.2	0.9	0.0	0.6
4-Week	8/23/2018	1.910	2.80	69.1	51.2	7.3	41.5	0.9	0.0	0.6
4-Week	8/30/2018	1.930	2.77	64.0	59.7	10.2	30.1	1.0	0.0	0.6
4-Week	9/6/2018	1.970	2.68	53.8	57.4	6.4	36.3	1.2	0.0	0.5
4-Week	9/13/2018	1.975	2.97	43.9	49.0	11.5	39.5	1.1	0.0	0.4
4-Week	9/20/2018	2.020	3.38	38.8	39.2	8.6	52.2	1.2	0.0	0.4
4-Week	9/27/2018	2.080	3.05	38.1	60.9	12.0	27.1	1.9	0.0	0.4
13-Week	7/5/2018	1.940	2.62	47.1	52.1	4.1	43.9	0.9	0.0	1.4
13-Week	7/12/2018	1.945	2.85	47.1	47.8	7.3	44.9	0.9	0.0	1.4
13-Week	7/19/2018	1.980	2.76	49.6	42.8	10.5	46.7	1.4	0.0	1.5
13-Week	7/26/2018	1.970	2.92	49.1	42.6	11.8	45.6	1.9	0.0	1.5
13-Week	8/2/2018	2.000	2.87	49.6	57.6	6.6	35.8	1.4	0.0	1.5
13-Week	8/9/2018	2.010	2.54	49.7	51.8	9.7	38.5	1.3	0.0	1.5
13-Week	8/16/2018	2.030	2.83	49.6	52.5	6.6	40.9	1.4	0.0	1.5
13-Week	8/23/2018	2.035	2.96	49.8	50.6	5.7	43.7	1.2	0.0	1.5
13-Week	8/30/2018	2.080	2.90	49.0	53.3	5.6	41.1	2.0	0.0	1.5
13-Week	9/6/2018	2.095	2.88	47.0	50.8	4.9	44.2	1.0	0.0	1.4
13-Week	9/13/2018	2.110	3.02	47.0	56.8	5.6	37.7	1.0	0.0	1.4
13-Week	9/20/2018	2.125	2.94	46.7	49.4	4.4	46.2	1.3	0.0	1.4
13-Week	9/27/2018	2.180	3.01	46.1	48.4	10.6	41.0	1.9	0.0	1.4
26-Week	7/5/2018	2.085	2.83	40.8	47.6	3.9	48.5	1.2	0.0	2.4
26-Week	7/12/2018	2.100	2.78	40.7	53.3	4.1	42.6	1.3	0.0	2.4
26-Week	7/19/2018	2.140	2.98	43.7	44.7	3.2	52.2	1.3	0.0	2.6
26-Week	7/26/2018	2.140	2.90	43.2	46.6	12.0	41.4	1.8	0.0	2.6
26-Week	8/2/2018	2.160	3.14	43.9	45.8	4.8	49.4	1.1	0.0	2.6
26-Week	8/9/2018	2.180	2.66	43.7	42.2	4.4	53.4	1.3	0.0	2.6
26-Week	8/16/2018	2.180	3.25	43.7	32.3	3.7	64.1	1.3	0.0	2.6
26-Week	8/23/2018	2.185	3.11	43.9	45.1	3.3	51.5	1.1	0.0	2.6
26-Week	8/30/2018	2.210	3.06	43.3	49.4	3.8	46.8	1.7	0.0	2.6
26-Week	9/6/2018	2.240	3.03	41.0	47.9	3.2	48.9	1.0	0.0	2.4
26-Week	9/13/2018	2.265	3.14	41.0	46.3	4.0	49.7	1.0	0.0	2.4
26-Week	9/20/2018	2.290	3.09	40.9	51.9	3.0	45.1	1.1	0.0	2.4
26-Week	9/27/2018	2.320	3.28	40.3	37.8	6.0	56.2	1.7	0.0	2.5
52-Week	7/19/2018	2.335	3.03	25.4	47.8	10.0	42.2	0.6	0.0	3.0
52-Week	8/16/2018	2.365	3.21	25.3	50.7	12.7	36.6	0.7	0.0	3.1
52-Week	9/13/2018	2.465	3.76	25.4	33.0	7.4	59.6	0.6	0.0	3.0

*Weighted averages of competitive awards.
**Approximated using prices at settlement and includes both competitive and non-competitive awards.

Nominal Coupons										
Issue	Settle Date	Stop Out Rate (%)*	Bid-to-Cover Ratio*	Competitive Awards ($bn)	% Primary Dealer*	% Direct*	% Indirect*	Non-Competitive Awards ($bn)	SOMA "Add Ons" ($bn)	10-Year Equivalent ($bn)*
2-Year	7/31/2018	2.657	2.92	34.5	40.7	14.3	45.0	0.5	1.9	8.5
2-Year	8/31/2018	2.655	2.89	35.5	42.5	13.7	43.8	0.5	2.5	8.7
2-Year	10/1/2018	2.829	2.44	36.5	46.6	13.4	40.0	0.5	0.0	8.4
3-Year	7/16/2018	2.685	2.51	32.8	51.3	9.1	39.6	0.2	0.1	11.2
3-Year	8/15/2018	2.765	2.65	33.8	45.2	12.1	42.7	0.2	4.6	13.1
3-Year	9/17/2018	2.821	2.68	34.8	43.0	10.7	46.3	0.2	0.0	11.7
5-Year	7/31/2018	2.815	2.61	36.0	24.1	8.7	67.2	0.0	2.0	20.9
5-Year	8/31/2018	2.765	2.49	36.9	24.7	9.0	66.2	0.1	2.6	21.4
5-Year	10/1/2018	2.997	2.39	38.0	32.9	9.2	57.9	0.0	0.0	20.6
7-Year	7/31/2018	2.930	2.49	30.0	23.4	12.0	64.6	0.0	1.6	23.6
7-Year	8/31/2018	2.844	2.65	31.0	21.5	19.0	59.5	0.0	2.2	24.4
7-Year	10/1/2018	3.034	2.45	31.0	25.3	12.8	62.0	0.0	0.0	22.8
10-Year	7/16/2018	2.859	2.57	22.0	24.5	10.5	65.0	0.0	0.1	22.0
10-Year	8/15/2018	2.960	2.55	26.0	27.5	11.3	61.3	0.0	3.5	30.3
10-Year	9/17/2018	2.957	2.58	23.0	22.6	13.4	63.9	0.0	0.0	23.0
30-Year	7/16/2018	2.958	2.34	14.0	27.8	10.3	61.9	0.0	0.1	32.2
30-Year	8/15/2018	3.090	2.27	18.0	29.7	8.0	62.2	0.0	2.4	47.6
30-Year	9/17/2018	3.088	2.34	15.0	27.0	11.3	61.7	0.0	0.0	34.2
2-Year FRN	7/31/2018	0.043	2.79	18.0	42.3	6.3	51.4	0.0	1.0	0.0
2-Year FRN	8/31/2018	0.047	2.94	17.0	51.9	8.5	39.5	0.0	1.2	0.0
2-Year FRN	9/28/2018	0.050	3.06	17.0	34.4	8.0	57.5	0.0	0.0	0.0

TIPS										
Issue	Settle Date	Stop Out Rate (%)*	Bid-to-Cover Ratio*	Competitive Awards ($bn)	% Primary Dealer*	% Direct*	% Indirect*	Non-Competitive Awards ($bn)	SOMA "Add Ons" ($bn)	10-Year Equivalent ($bn)*
5-Year TIPS	8/31/2018	0.724	2.78	14.0	19.2	13.5	67.3	0.0	1.0	7.9
10-Year TIPS	7/31/2018	0.762	2.22	13.0	22.6	15.3	62.1	0.0	0.7	15.5
10-Year TIPS	9/28/2018	0.910	2.57	11.0	21.7	8.9	69.5	0.0	0.0	12.1

*Weighted averages of competitive awards. FRNs are reported on discount margin basis.
**Approximated using prices at settlement and includes both competitive and non-competitive awards. For TIPS' 10-Year equivalent, a constant auction BEI is used as the inflation assumption.

TBAC Charge: An Update on the TBAC Issuance Model – Incorporating TIPS

Please provide an update on efforts the Committee is making with regard to the development of issuance models, including any updated analysis or results and any revisions to or extensions of the modeling work that was presented in October 2017, particularly the incorporation of TIPS into the model. Comment on the degree to which the updated modeling efforts can be used by Treasury as one input to help to inform potential its decisions regarding nominal coupon and TIPS issuance.

Executive Summary

- This presentation extends the debt management model of Belton et al.[1] to assess the optimal mix and maturity structure of nominal and inflation linked debt. While model outputs should not be (and are not being) used prescriptively, they do provide a number of insights on how TIPS contribute to U.S. debt costs and risks.
- Under the model's structure, the debt service costs for TIPS issuance are generally lower than that of equivalent maturity nominal issuance because the risk premium required by investors as compensation for inflation risk exceeds what is required to compensate for liquidity risk.
  - Five year TIPS seem to offer the greatest cost advantage; however, ten year TIPS offer an attractive cost / risk trade off. Minimum issuance sizes in the thirty year point are useful in maintaining a long-dated benchmark.
  - Currently, the relative risk premium of nominal versus TIPS issuance appears lower than the longer run average. However, the dynamic optimal response function does not react sensitively to time varying inflation risk premium.
- TIPS issuance can reduce risk to the Treasury if kept to amounts that leave TIPS allocations as a moderate proportion of the debt stock.
  - TIPS principal accretion flows through interest expense and introduces significant debt service volatility in any given period, even though this accretion does not represent an actual funding need in that period.
  - Nevertheless, the negative correlation between CPI-U and U.S. primary deficits creates a significant diversification benefit for Treasury debt stock allocations containing TIPS. Assuming historical correlations hold going forward, total deficit volatility is reduced for TIPS allocations up to 13% of the debt stock.
- In summary, when accounting for their relative cost and capacity for risk reduction, the model suggests that the level of TIPS outstanding could range from just a few percent of the outstanding debt stock (for a debt manager less averse to risk) to as much as 14% of the outstanding debt stock (for a more risk averse debt manager). Currently, TIPS make up 9% of the debt stock.

[1]Belton, Dawsey, Greenlaw, Li, Ramaswamy, and Sack, "Optimizing the maturity structure of U.S. Treasury debt: A model-based framework", The Hutchings Center on Fiscal and Monetary Policy, Brookings Institution (October 10, 2018). https://www.brookings.edu/research/optimizing-the-maturity-structure-of-u-s-treasury-debt/

Review of Current Model and Extension

- The existing debt optimization model (which does not contemplate TIPS) contains:
  - A simulation module consisting of:
    - A macroeconomic model for the unemployment gap, core PCE inflation, the Fed Funds target rate, the rate of change of real GDP, the potential rate of change of real GDP, and the equilibrium real rate of interest
    - A model for the Treasury yield curve using expected Fed policy and term premium
    - A fiscal model for the primary budget deficit
  - A debt dynamics module that evolves current and future debt issuance
  - An optimization module that identifies low cost strategies given risk appetite and constraints and can generate:
    - Static optimizations (issuance fractions never change)
    - Dynamic optimizations (issuance fractions depend on macro variables)

- In order for the original model to be extended, it needed to be re-implemented, and outputs cross-referenced with the original.

- In order to include TIPS, the re-implemented model had to be extended to include:
  - Headline CPI in the macroeconomic model
  - A model for the TIPS yield curve consistent with the existing model implementation, which involves a decomposition of term premium into inflation, real rate, and liquidity components
  - The addition of TIPS to the debt dynamics module
  - The inclusion of TIPS in the optimization module (both static and dynamic)

- By including TIPS, we aim to assess the optimal issuance allocation across nominal and inflation linked securities as well as optimal issuance points for each.

Term Premium Decomposition

We decompose TIPS breakevens by extending the model of AACM[1] to include 30Y yield curves[2]

- TIPS investors need to be paid a risk premium for real rate risk (RRP), while investors in nominal Treasuries must be paid an extra risk premium for taking inflation risk (IRP). The sum of the IRP + RRP is the nominal term premium (TP), which was modeled by Belton et al.

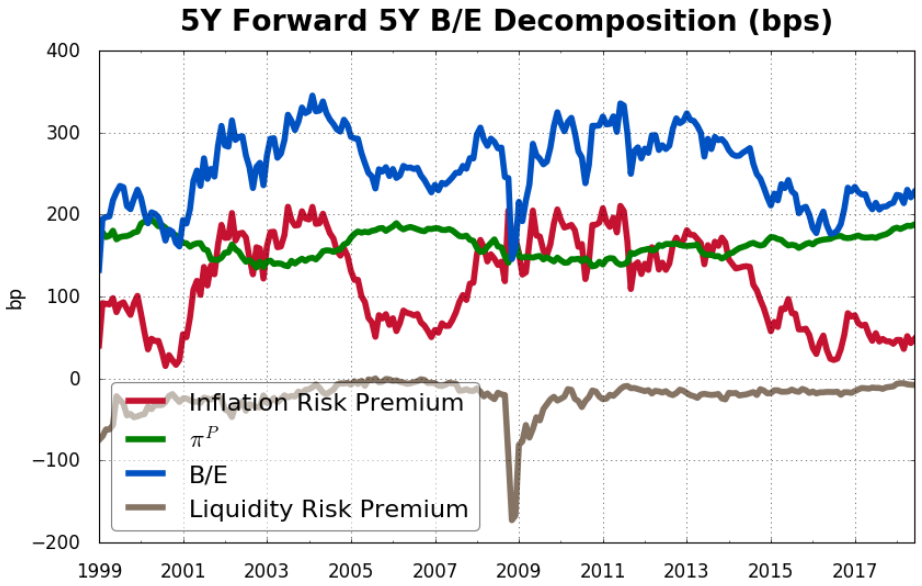
$$\text{Nominal yield} = \text{expected inflation} + \text{expected real yield} + \text{IRP} + \text{RRP}$$

- In addition, a liquidity risk premium (LRP) for TIPS is necessary in order to provide a sensible yield decomposition of nominal and inflation-linked Treasuries into expected inflation, expected real yield, inflation risk premium, and real rate risk premium.

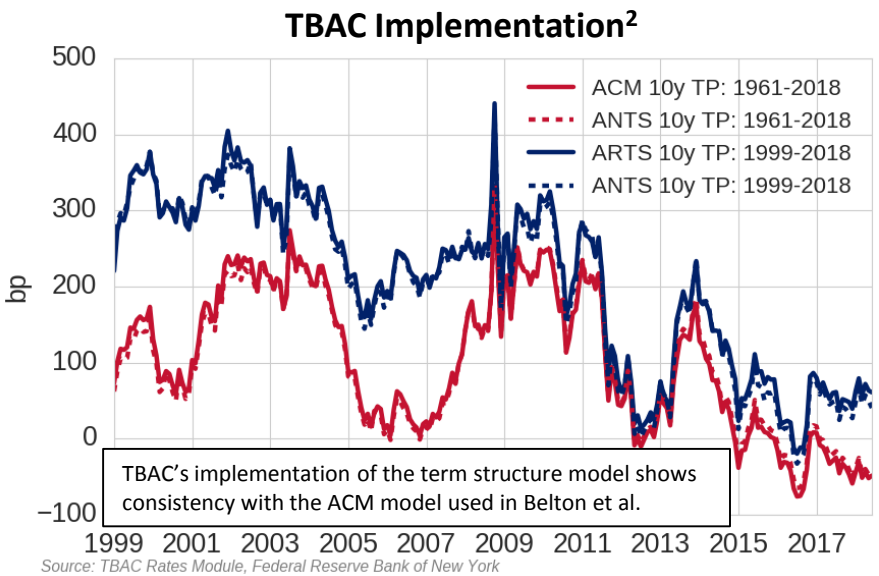
$$\text{TIPS yield} = \text{expected real yield} + \text{RRP} + \text{LRP}$$

- Market-implied breakeven inflation, which is the difference between equal maturity Treasury and TIPS yields, leads to counter-intuitive results during periods of low market liquidity unless it is adjusted for LRP.

$$\text{Breakeven Inflation} = \text{Nominal yield} - \text{TIPS yield} = \text{expected inflation} + \text{IRP} - \text{LRP}$$



Source: TBAC ARTS



Source: TBAC Rates Module, Federal Reserve Bank of New York

[1] Abrahams, Michael, Adrian, Tobias, Crump, Richard K., and Moench Emanuel, "Decomposing Real and Nominal Yield Curves", Federal Reserve Bank of New York Stat Reports (February 2015). https://www.newyorkfed.org/medialibrary/media/research/staff_reports/sr570.pdf

[2] In what follows, we refer to TBAC's implementation of the AACM model as ARTS (Affine Real Term Structure) when including TIPS and ANTS (Affine Nominal Term Structure)when using only nominal Treasuries.

Inflation and Real Rate Risk Premiums

Inflation risk premium is modeled to vary with monetary policy; steady state behavior is based on recent averages

- The term premium is the sum of inflation risk premium and real rate risk premium.

- (A) Output of the ARTS model shows more of the variation in TP can be explained with RRP. IRP is more steady.

- In our simulation module, we model IRP directly, and derive RRP as the difference between TP and IRP.

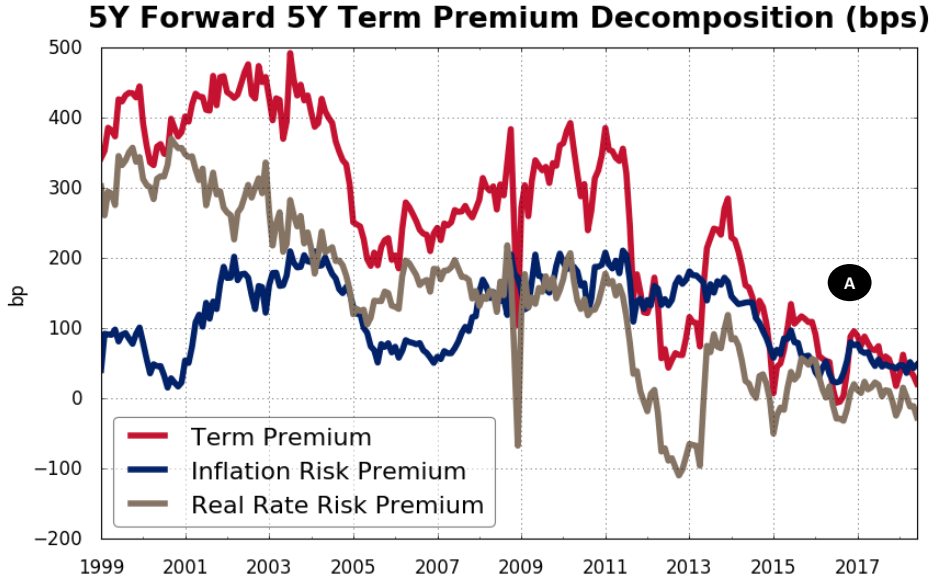
- The model for TP in our simulation module remains the same as in Belton et al.

- In the simulation module, we model expected real rates $r^P_{t,\tau}$ as the difference between expected nominal rates and expected inflation.

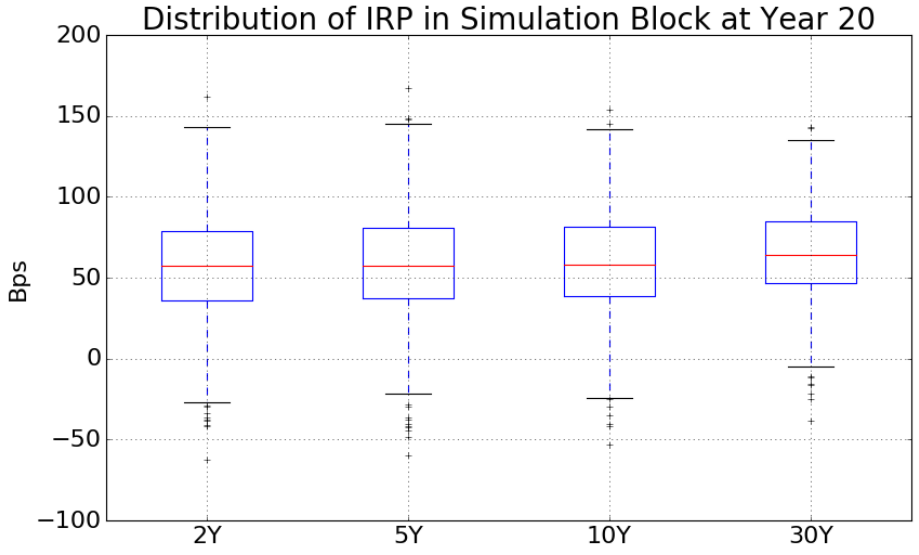
- We then write 5y and 10y IRP as affine functions of $r^P_{t,\tau}$ - r^*_t.

- Slope coefficients are estimated from regressions of ARTS model outputs onto the above variables, and the constant term is chosen to set the long-term expected level of IRP.

- IRP for other maturities is obtained from IRP5 and IRP10 using historical regression of ARTS model outputs.



Source: TBAC ARTS



Source: TBAC Simulation Module

Liquidity Risk Premium

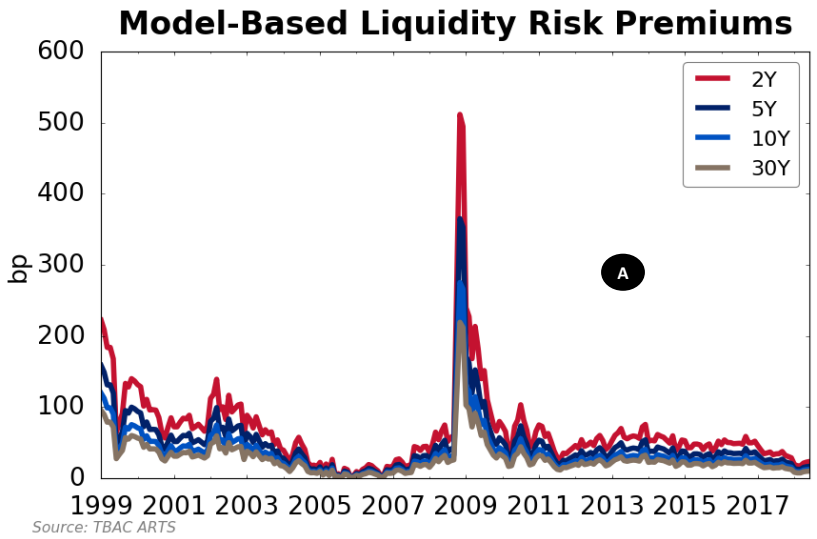
Model based estimates and market observables can be used to approximate TIPS liquidity risk premiums

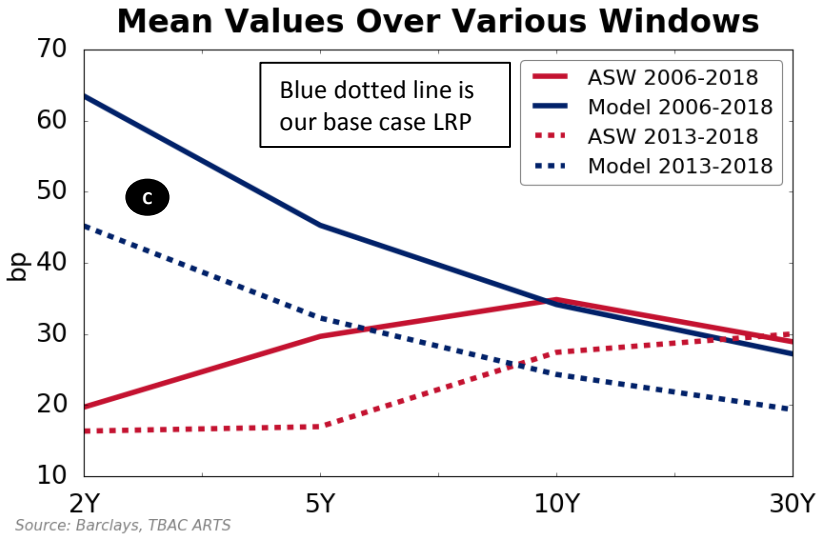
- **A** The ARTS model uses TIPS yield curve fit errors and trade volume data to generate liquidity risk premiums for TIPS over the entire calibration window (1999-present).

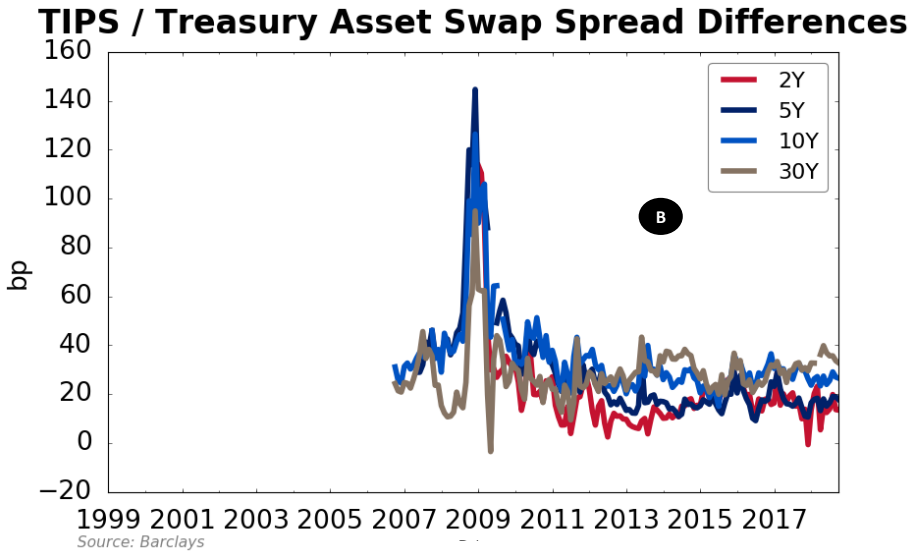
- **B** In the period for which there exists data on asset swap levels, the model based estimates are broadly similar (and in particular pick up the massive illiquidity during the financial crisis), but there are differences.

- **C** Comparing the term structures, we see that the model tends to generate larger liquidity premiums for shorter dated TIPS than is observed in the asset swap market.

- We use model liquidity premiums as our base case for TIPS but also show results using asset swap levels instead (the differences are marginal).







Single Security Issuance Results for TIPS

Results show average debt service cost in year 20 vs two different measures of variance across the path population

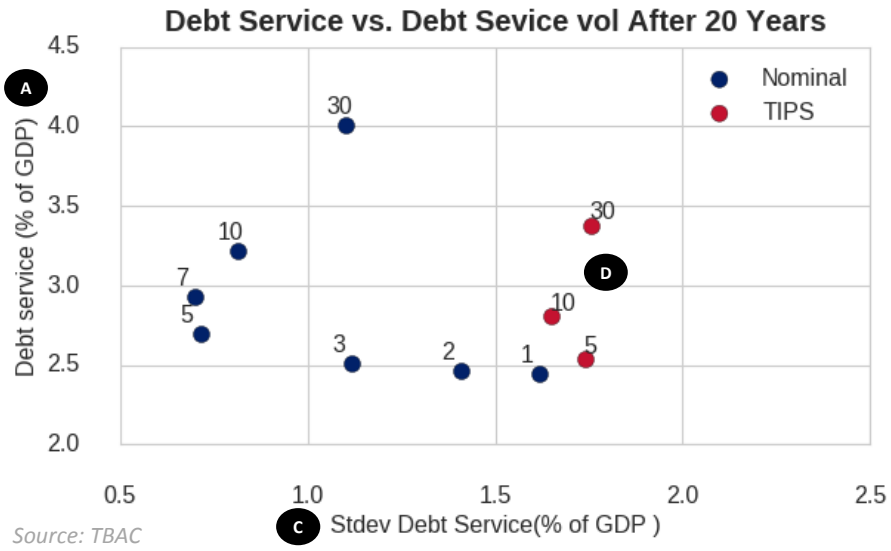
- The scatterplots below introduce metrics for the cost vs. risk visualization and optimization we will be using throughout this work.
- In these simulations, cash needs are met every quarter entirely by issuance of a single security whose stock would, in the steady-state, finance the entire debt.

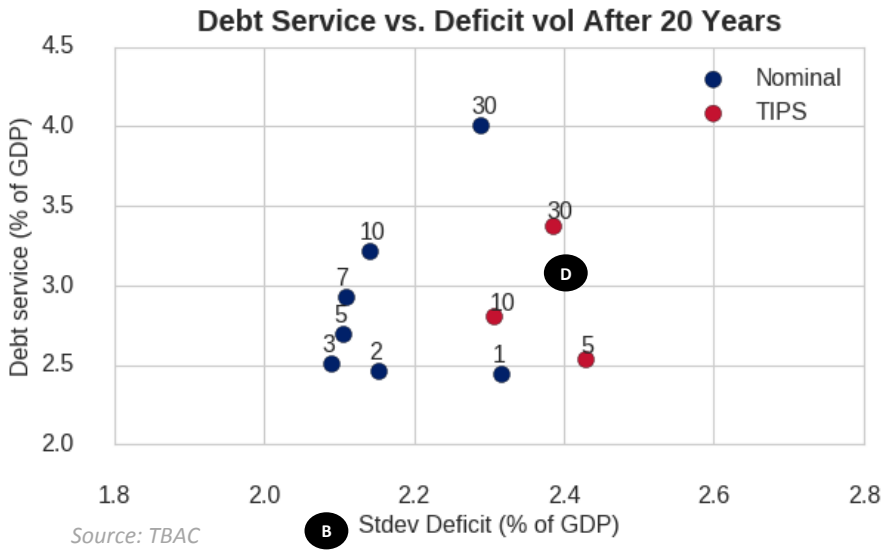
A The cost we look to minimize, on the vertical axis, is the average debt service cost (across all 2000 paths) at year 20 of our simulation.

B The risk on the right graph is the standard deviation (across all 2000 paths) of the total deficit (primary deficit + funding cost), which we continue to use throughout what follows.

C However, on the left we also show standard deviation (across all 2000 paths) of the debt service cost, as a touchpoint back to Belton et al. The blue dots show results for nominals, in close agreement with previous work.

D We are adding the red dots (TIPS), which for like tenor, are more volatile (shifted right), but also have lower cost (shifted lower), as holders of nominals must be compensated for the inflation risk premium.





Single Security Issuance Results for TIPS

Results show additional cost and risk summary statistics for single-security strategies

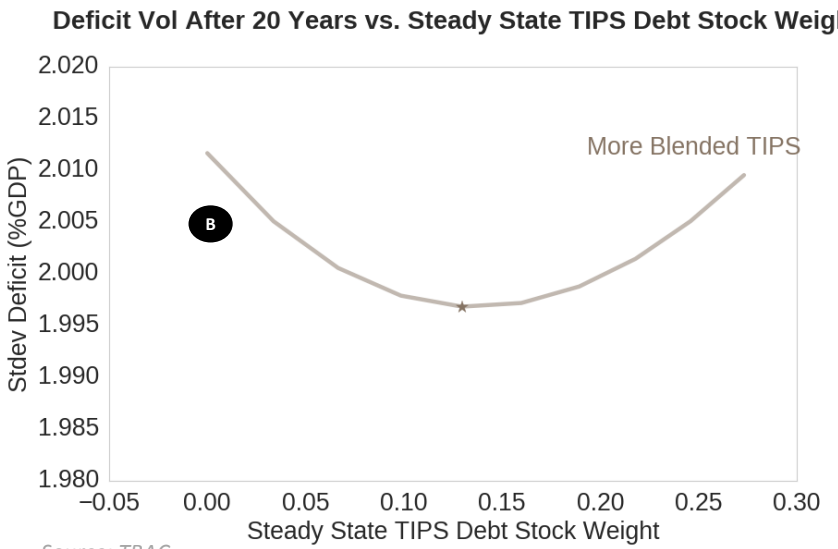
	1yN	2yN	3yN	5yN	7yN	10yN	30yN	2yT	5yT	10yT	30yT
Average issuance rate	2.99	2.96	2.99	3.10	3.25	3.44	4.01	1.18	1.04	1.21	1.63
Average debt service / GDP	2.44	2.46	2.51	2.69	2.93	3.21	4.00	2.71	2.53	2.80	3.37
Standard deviation debt service/GDP	1.62	1.41	1.12	0.72	0.70	0.82	1.11	2.27	1.74	1.65	1.76
Standard deviation total deficit (%GDP)	2.32	2.15	2.09	2.11	2.11	2.14	2.29	2.67	2.43	2.31	2.38
Correlation funding cost, primary deficit (%GDP)	(0.14)	(0.18)	(0.11)	0.12	0.14	0.11	0.10	(0.19)	(0.11)	(0.16)	(0.15)

A

C

C

Source: TBAC



Source: TBAC

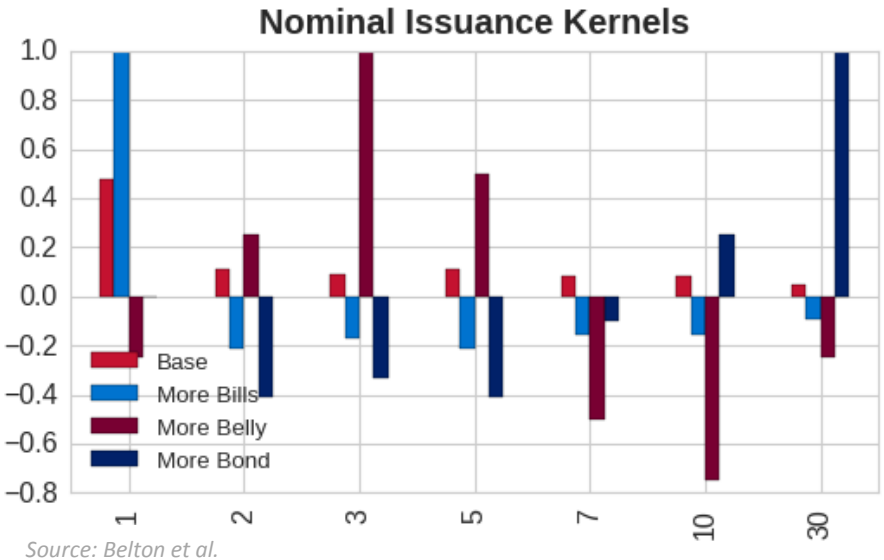
A While TIPS are more volatile, they also have desirable correlation properties.

B Since our primary risk metric is deficit volatility, where deficit = (funding cost + primary deficit), negative correlation between these two therefore lowers the volatility of the sum.

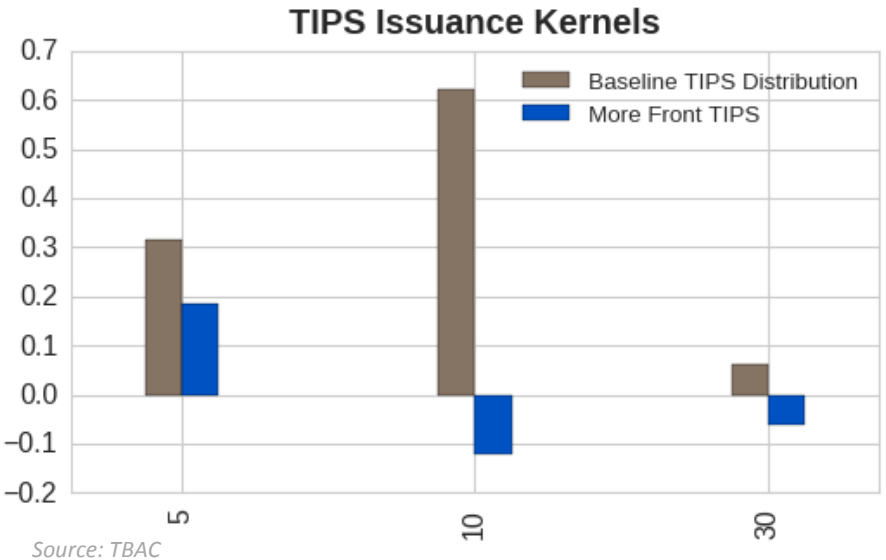
C We see in the last row of the table that, for example, 5y TIPS show modest negative funding cost/ primary deficit correlation, while 5y nominals show small positive correlation.

Issuance Kernels for Nominals and TIPS

Reduce the issuance profile to a base-case which meets funding needs and several kernels



Source: Belton et al.



Source: TBAC

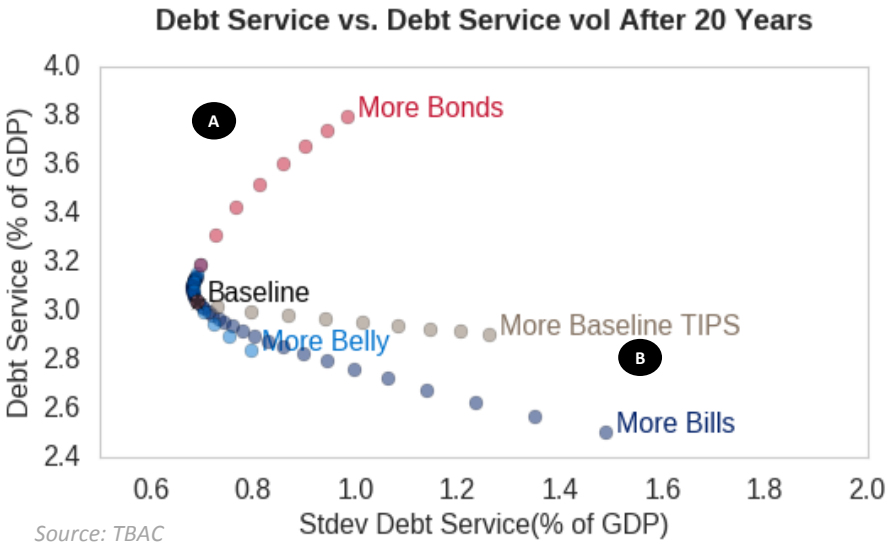
- One must be careful in specifying issuance kernels in terms of issuance, in order to take into account the implications for the steady-state debt distribution (see Appendix slides 21 and 22 for additional detail).

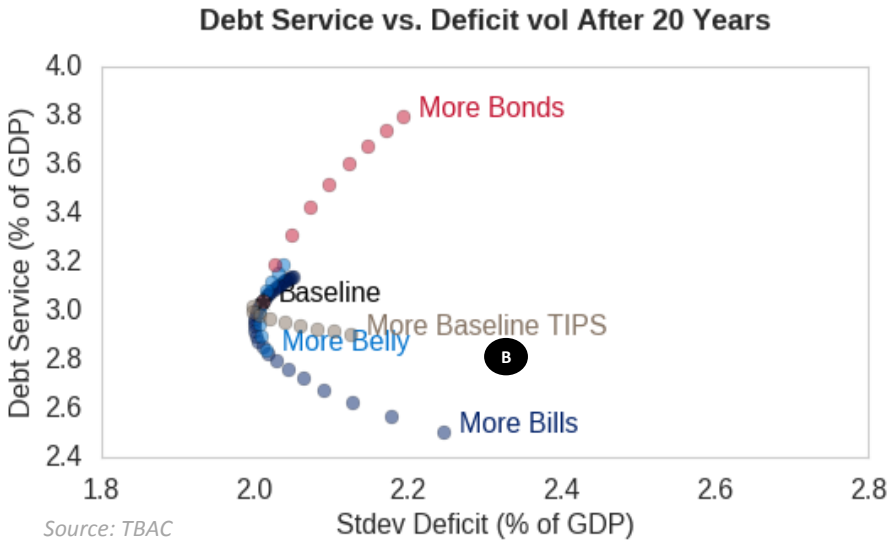
- Long-term issuance will pile up. For example, the baseline issuance kernel in Belton et al. would leave a large stock of original-issue 30y bonds after 20 years of issuance (5% of the quarterly issuance leads to 34% of the debt stock).

- The baseline TIPS kernel above is intended to replicate the current maturity distribution of TIPS after 20 years.

Issuance Kernels for Nominals and TIPS

Frontier plots allow us to see the risk / cost contribution of each kernel





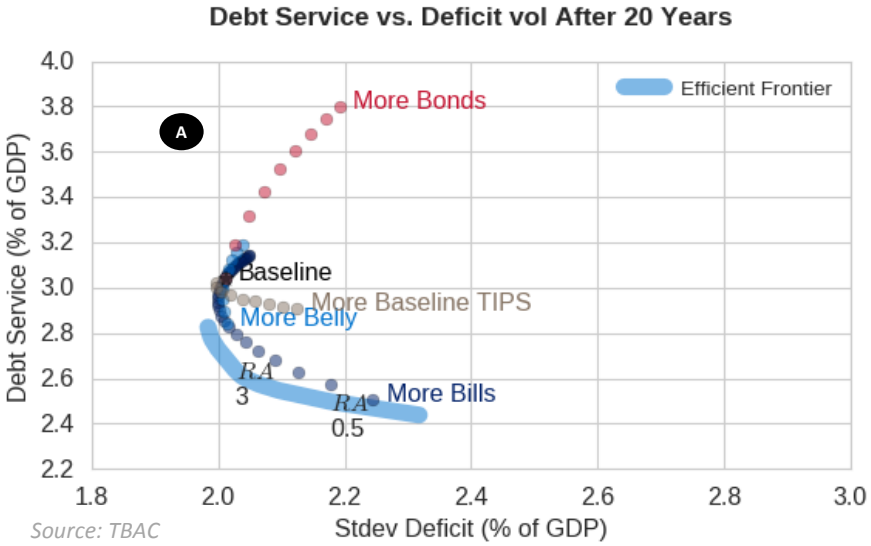
- In the plots above we display the effect of adding progressively more of each kernel to the baseline issuance (defined as one unit of nominal base kernel).

A The results of the “More Bills”, “More Belly”, and “More Bonds” kernels closely correspond with the results of the previous model.

B Adding more Baseline TIPS decreases cost.

Static Optimization of Kernels

Optimizing over kernel weights produces more realistic issuance strategies

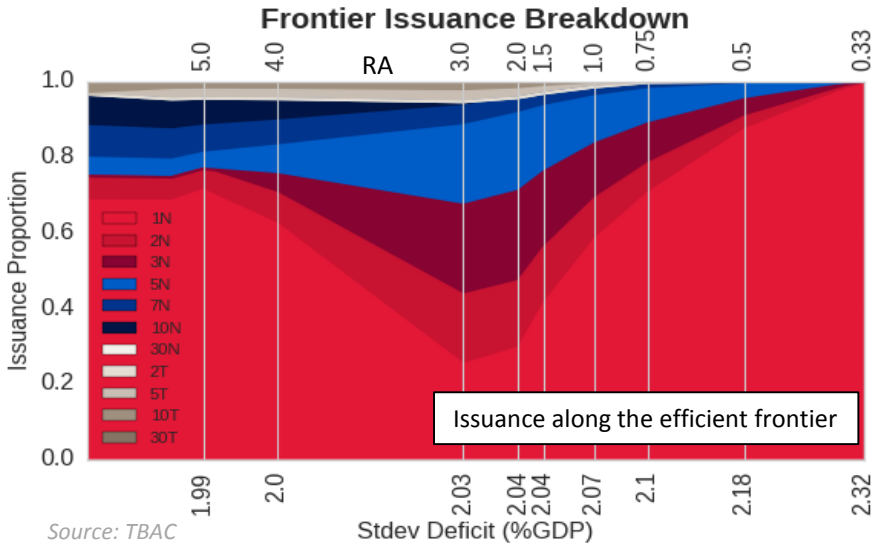


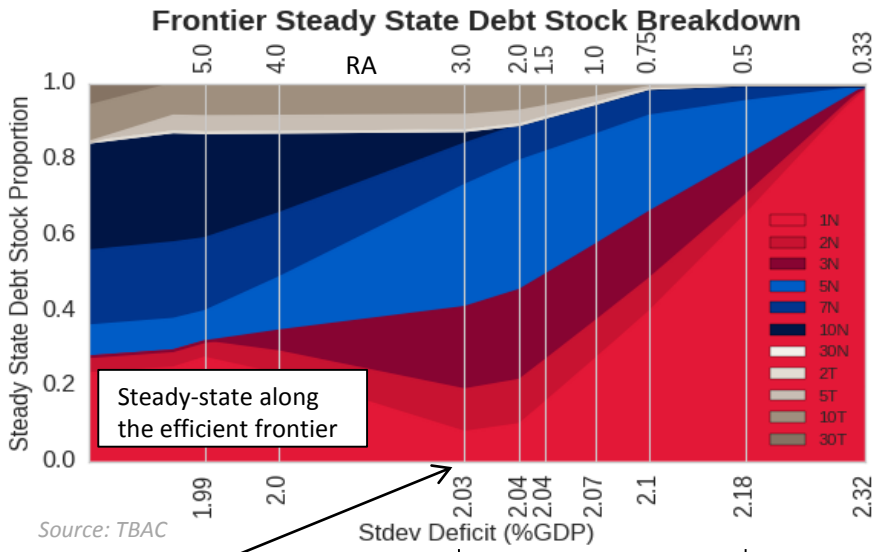
A At top left, the efficient frontier comes from minimizing the objective:

$$cost + RA \times risk$$

for different levels of risk aversion (RA).

- The risk aversion coefficient tells the optimizer what the relative importance of cost and risk are to Treasury.
- The two extremes are $RA = \infty$ and $RA = 0$. When RA is large the optimizer focuses almost exclusively on risk reduction and if RA is small the optimizer puts more emphasis on cost reduction.
- The optimizer solves for kernel weights constrained so that issuance proportions are non-negative.
- Gross issuance is zero for all but the base kernel.



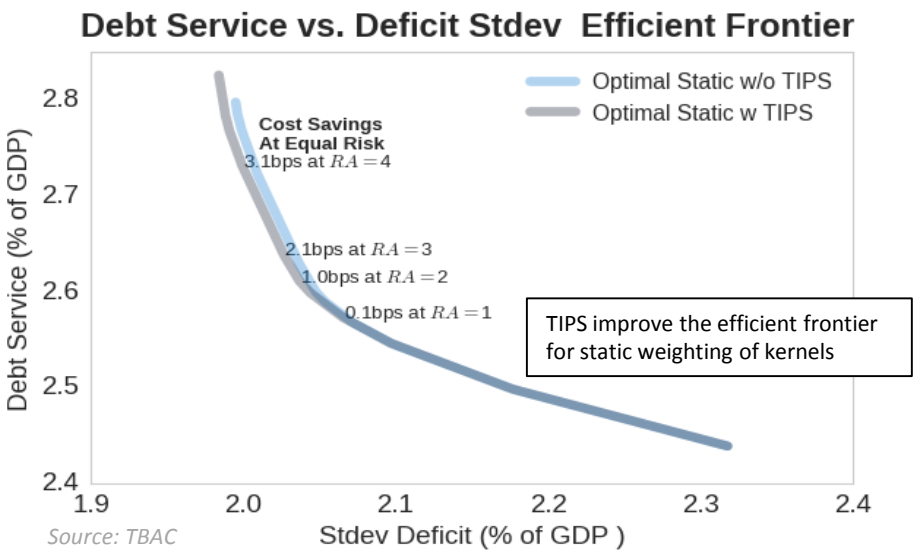


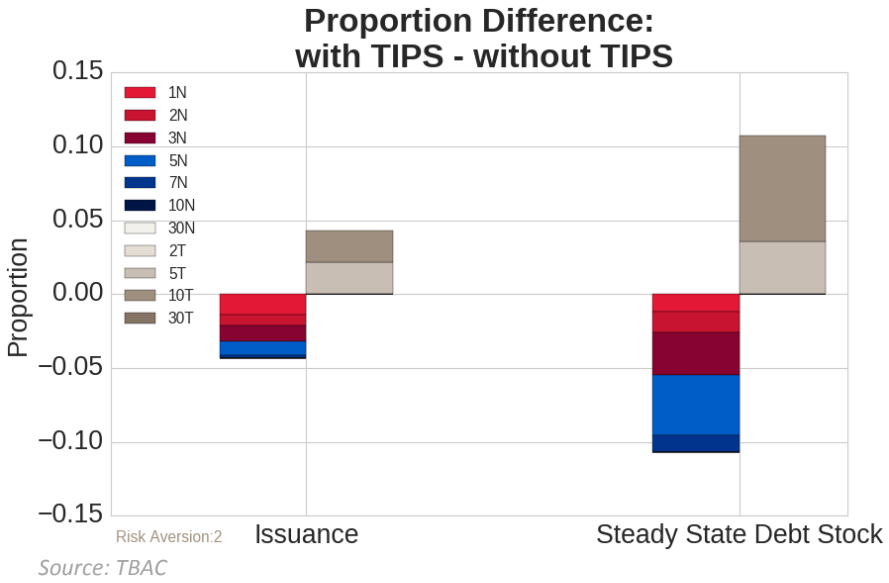
TIPS proportion is 12.5% at lower risk end of plausible range.

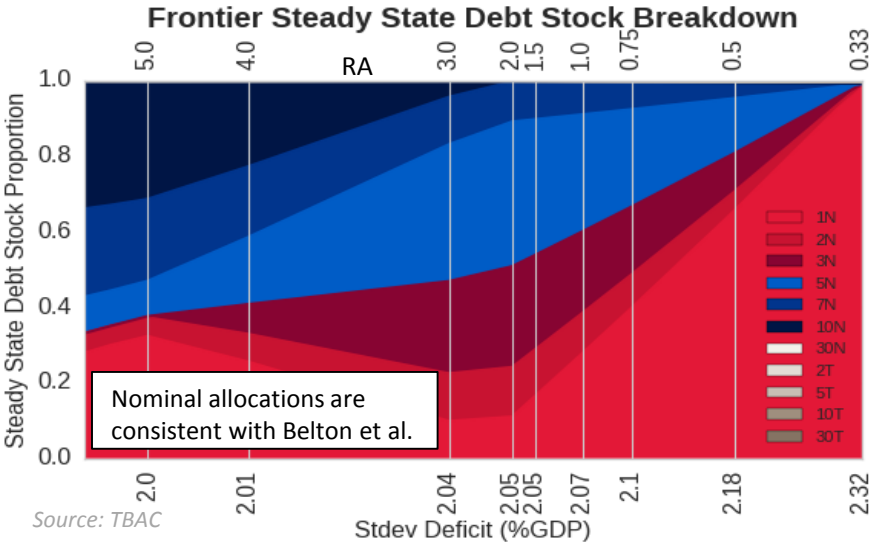
Plausible Range

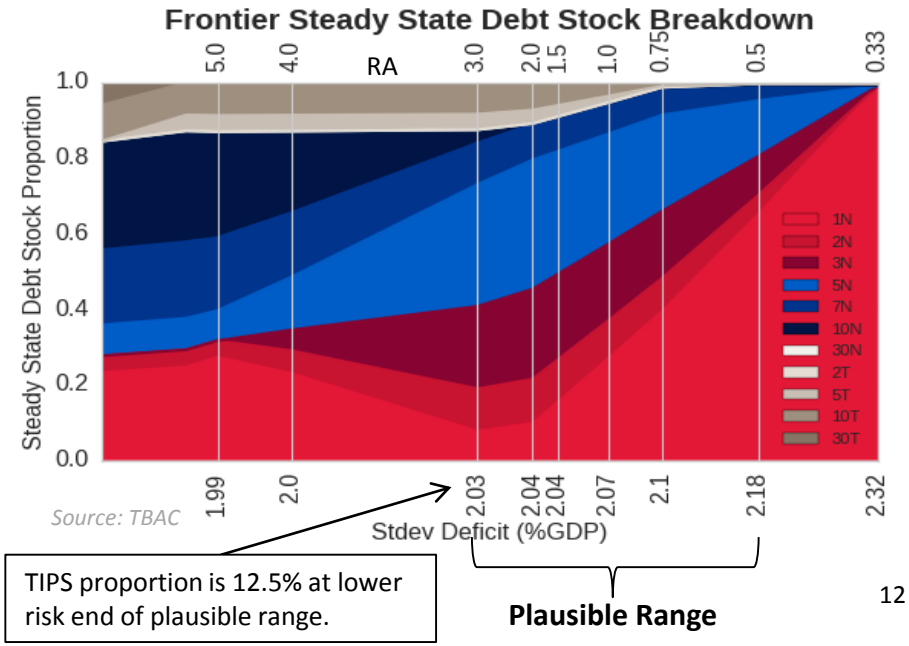
Cost Benefit From Issuing TIPS

Optimal allocations include TIPS for a wide range of risk preferences



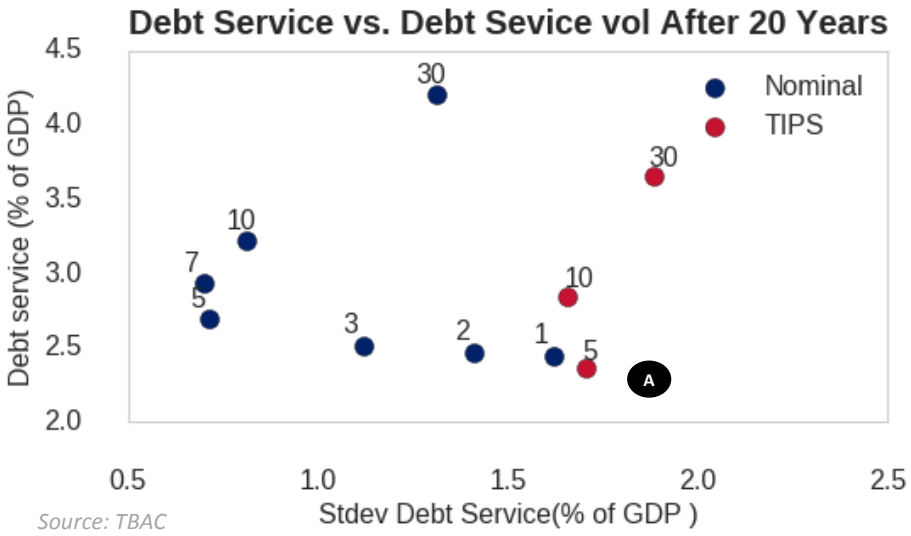




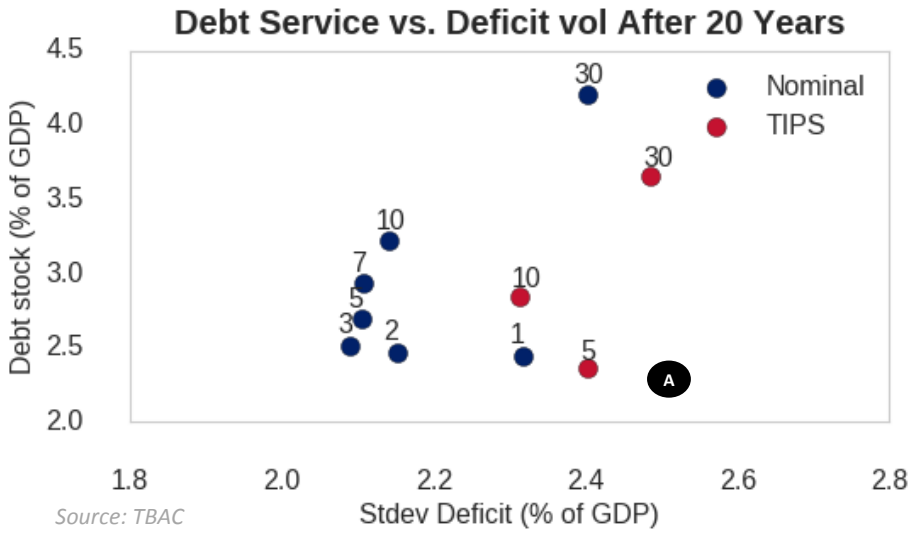


Reassessing 5 Year TIPS Using Alternative LRP

5y TIPS look more attractive if the asset swap market is used to estimate the LRP instead of the ARTS model

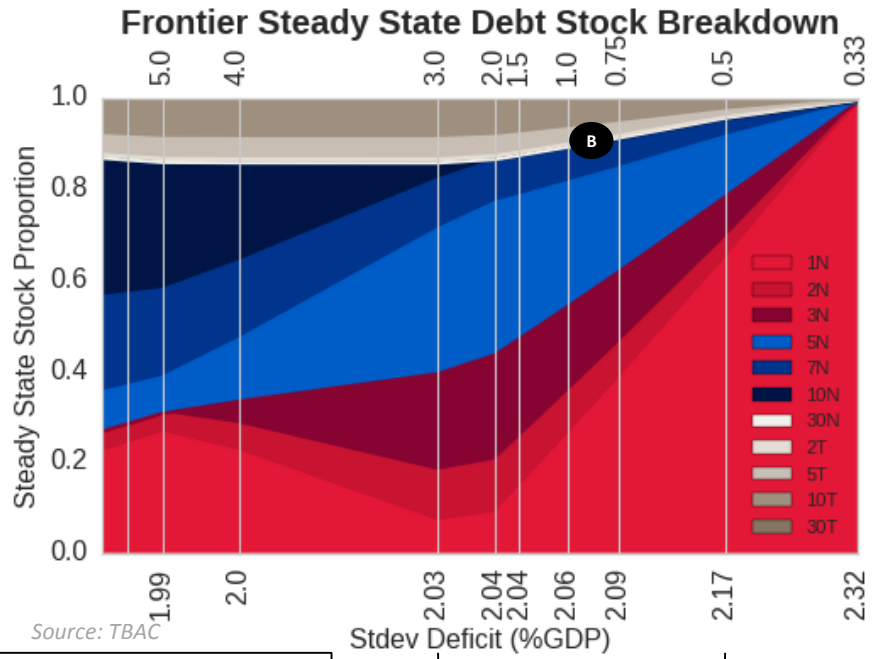


Source: TBAC



Source: TBAC

- **A** Lowering the liquidity premium for shorter dated TIPS makes them more attractive.
- **B** Static kernel-based optimization shows a larger allocation to 5y and 10y TIPS in the range of plausible risk preferences, particularly for higher risk tolerances.
- The relative attractiveness of TIPS versus nominal Treasuries can be similarly shifted by changing assumptions for the long term average level of inflation risk premium.



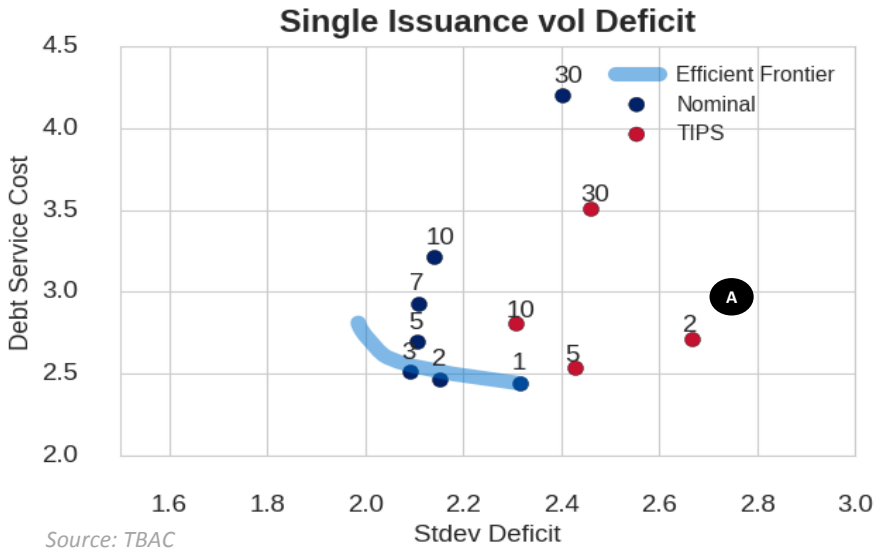
Source: TBAC

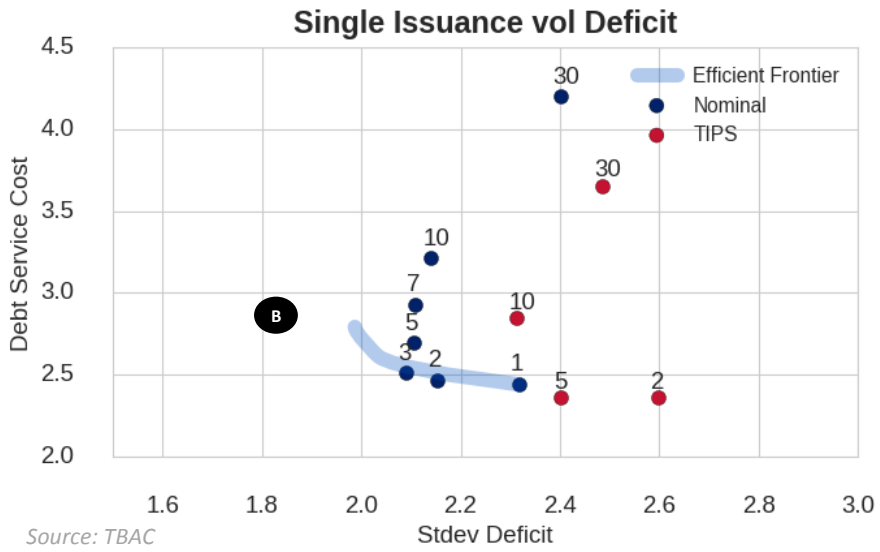
TIPS proportion ranges from 2.5% to 14.25% over the plausible range.

Plausible Range

Assessing 2 Year TIPS in the Model

Treasury doesn't currently issue 2y TIPS; however, the model would provided ASW spreads are used for LRP





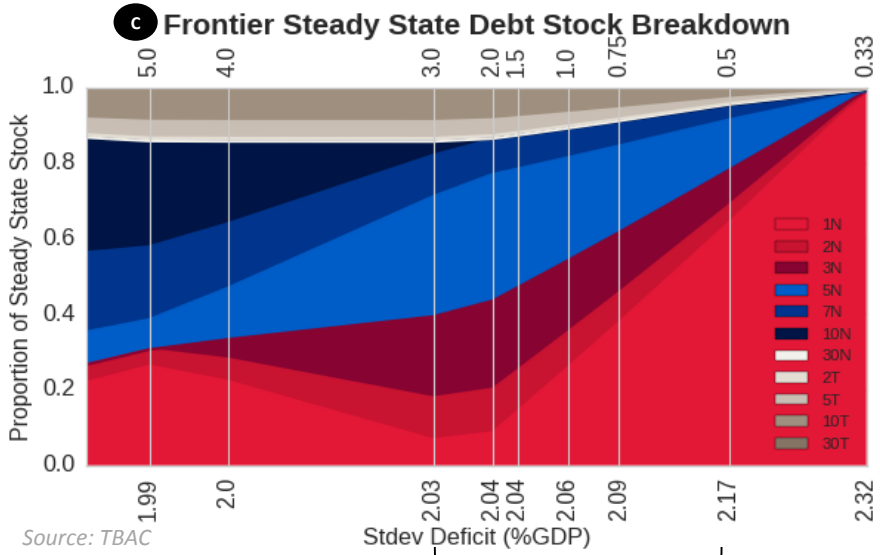
- While Treasury does not currently issue 2y TIPS, we explore their attractiveness in the model.

A Currently, 2y TIPS have a higher cost than 5y TIPS, and they are also significantly more volatile.

B Taking our LRPs from asset swaps (ASW) drops and flattens the 2y-5y LRP (page 6, dotted red line), lowering the cost for those two assets.

C We add 2y TIPS to our More Front TIPS kernel as 20% of issuance and run our model using ASW LRPs.

- Front TIPS issuance becomes optimal at lower levels of risk aversion when using ASW spreads for LRP, due to lower cost of the front-end TIPS.
- A small change in IRP term structure would be equivalent to a relative change in LRP.



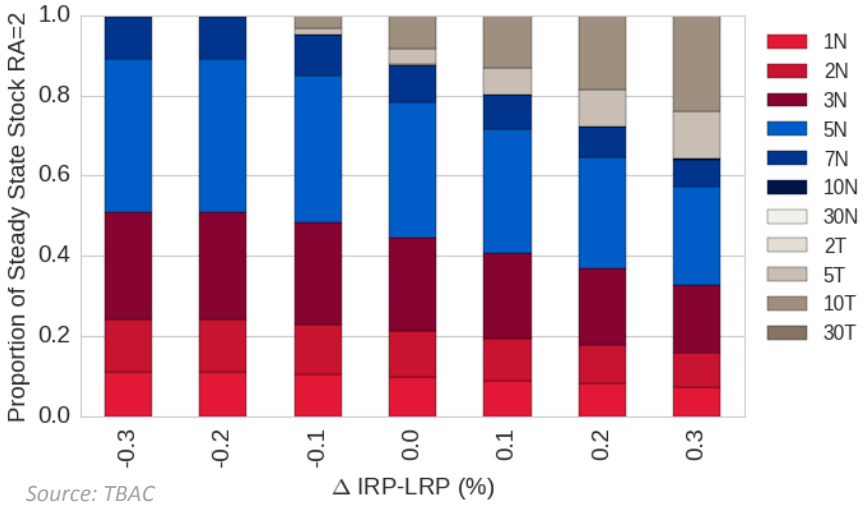
TIPS proportion ranges from 4.5% to 14.33% over the plausible range.

Plausible Range

Examining Effects of IRP, CPI, Correlation

We vary the key drivers of relative cost and risk between TIPS and nominals

A IRP-LRP spread is a key driver of relative cost[1]



Source: TBAC

[1] 0.3% change in IRP is roughly the 25/75 percentile range in our simulations (page 5)

- In the cost vs. risk tradeoff of our objective, each component has one key variable which drives the relative attractiveness of TIPS compared to nominals.

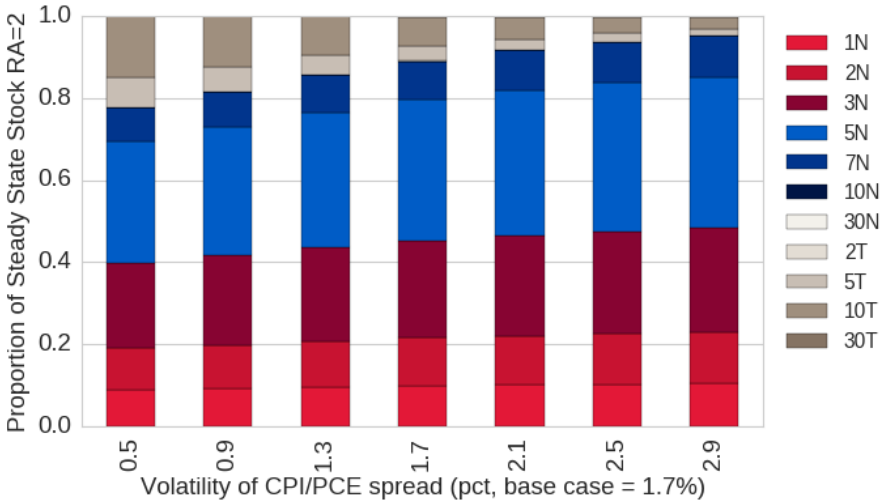
A The TIPS cost advantage for the issuer comes from the IRP-LRP spread. At top left, we show the effect of shifting the IRP-LRP spread in parallel across all tenors.

- On the risk side, the TIPS disadvantage is driven by the volatility of CPI, which we model as a spread to PCE.

B The spread volatility is 1.7% and PCE vol is 0.79%, and the two are uncorrelated. At bottom left, we vary the spread vol.

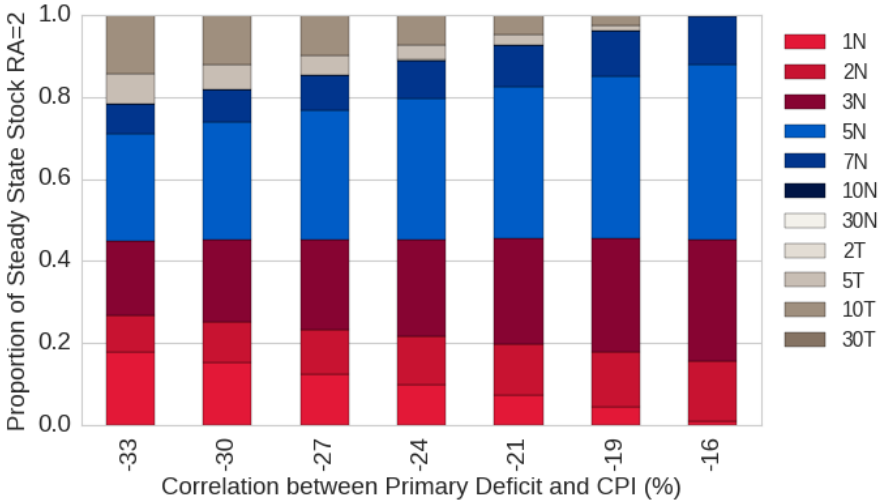
C TIPS inflation indexation helps to lower total deficit vol, because inflation and primary deficit are negatively correlated.

B CPI vol is the main driver of extra TIPS volatility



Source: TBAC

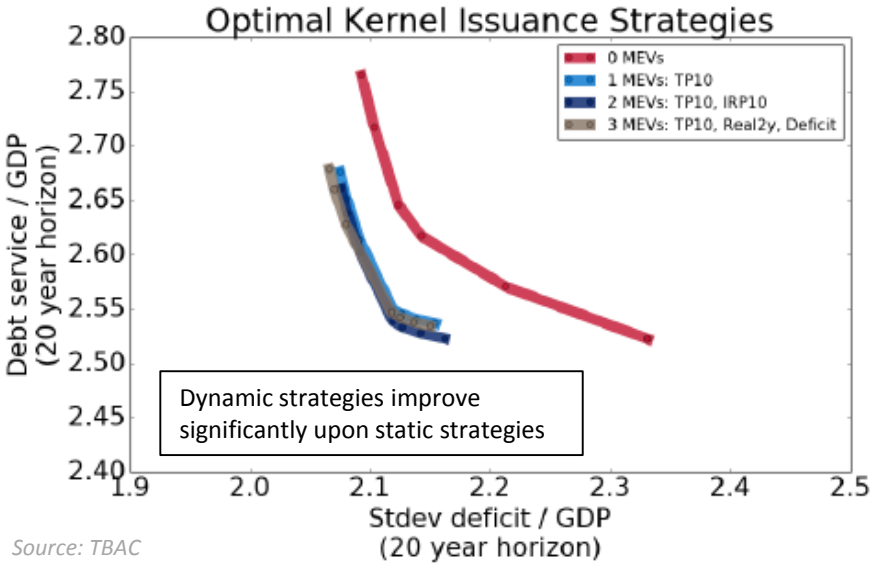
C Less negative correlation makes TIPS less attractive



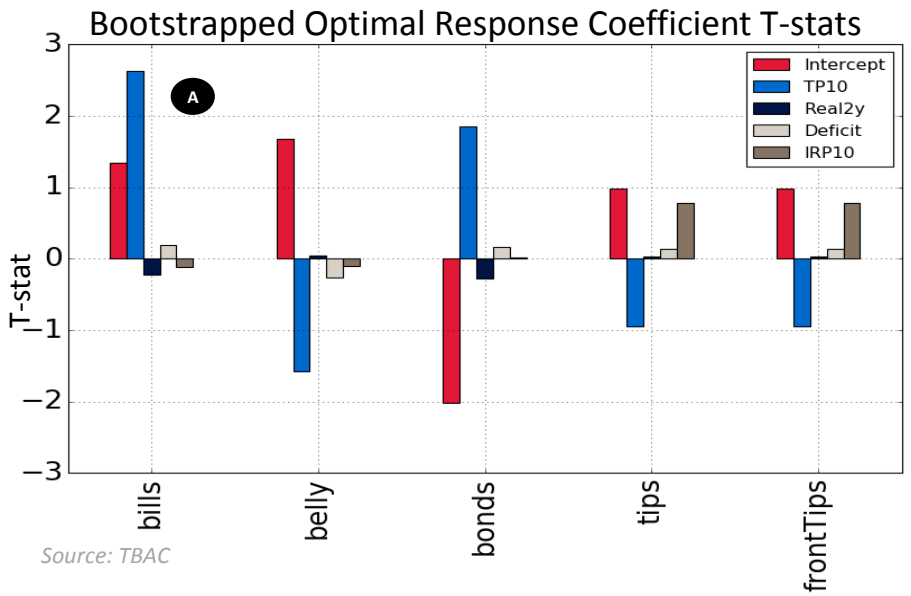
Source: TBAC

Dynamic Strategy Results

Bootstrap results suggest a sparse set of macro economic variables (MEV) consisting of just IRP10 and TP10



Source: TBAC



Source: TBAC

- We computed bootstrap t-stats for the optimal response function coefficients:
  - We generated 100 independent simulations, each consisting of 50 paths.
  - For each simulation we estimated the matrix of optimal response coefficients for a risk aversion parameter of 1.
  - For each coefficient we computed the average and standard deviation across the 100 simulations.
  - Finally we set the t-stat of each coefficient to be the ratio between its average and its standard deviation.

A T-stat results suggest that Deficit and Real2y might not be significant; however, TP10 and IRP10 appear significant.

  - Similar to Belton et al., we find that the model rotates out of the belly and into bills as TP10 increases.
  - Additionally, as IRP increases, the model rotates out of bills and into the belly and TIPS.

Bootstrapped Optimal Response Coefficients					
	intercept	**TP10**	**Real2y**	**Deficit**	**IRP10**
bills	7.7%	10.1%	-2.3%	1.1%	-3.4%
belly	8.0%	-1.8%	0.4%	-0.2%	0.6%
bonds	-2.1%	0.5%	-0.1%	0.0%	-0.1%
tips	4.3%	-0.6%	0.0%	-0.3%	0.9%
frontTips	4.3%	-0.6%	0.0%	-0.3%	0.9%

Bootstrapped Optimal Response T-stats					
	intercept	**TP10**	**Real2y**	**Deficit**	**IRP10**
bills	1.38	2.59	-0.23	0.16	-0.09
belly	1.72	-1.55	0.05	-0.23	-0.13
bonds	-2.09	1.80	-0.29	0.13	0.04
tips	0.98	-0.93	0.02	0.13	0.79
frontTips	0.98	-0.93	0.02	0.13	0.79

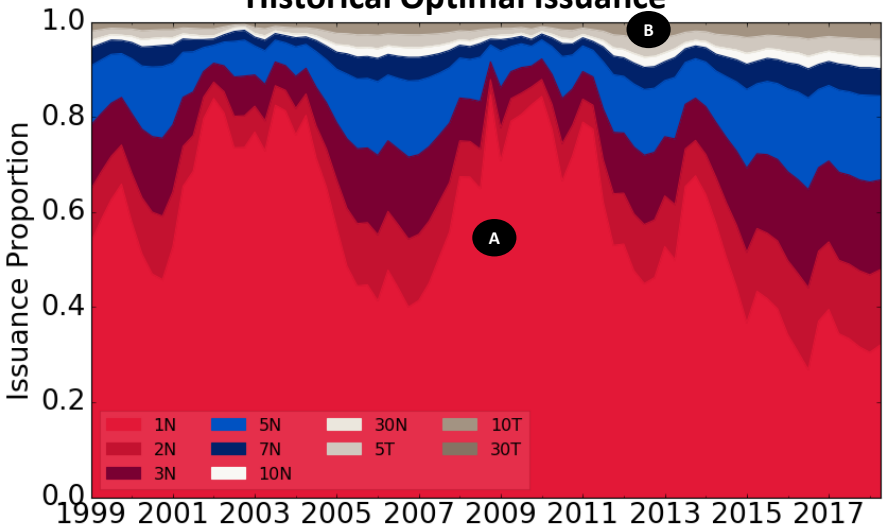
Source: TBAC

The reaction function is fit to standardized MEVs; therefore, each column of coefficients above represents the effect of a one-sigma move in the corresponding MEV.

Dynamic Strategy Results[1]

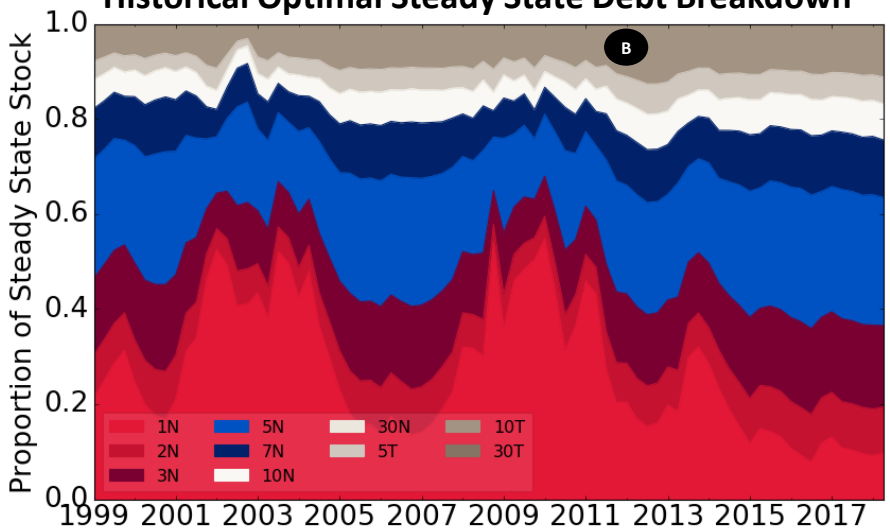
Most of the variation in issuance patterns is caused by fluctuations in TP10

Historical Optimal Issuance



Source: TBAC

Historical Optimal Steady State Debt Breakdown



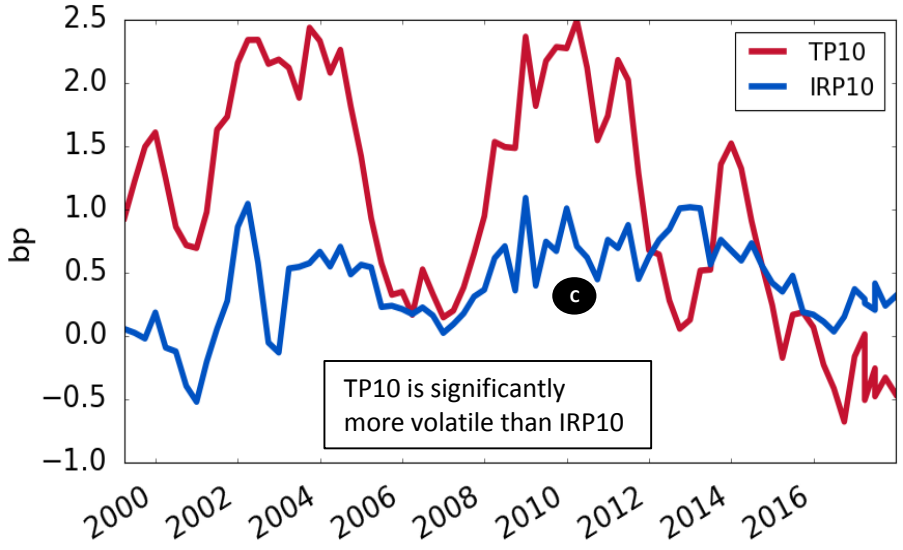
Source: TBAC

A Consistent with the results of Belton et al., most of the fluctuation in issuance comes via bills and belly kernels.

B TIPS issuance ranges from 1% to 7%, with an average of 4%. The steady state proportions range from 5% to 19%, with an average of 13%.

C TP10 is equal to RRP10 + IRP10. Most of the variation in TP10 is coming from fluctuations in RRP10.

History of MEVs

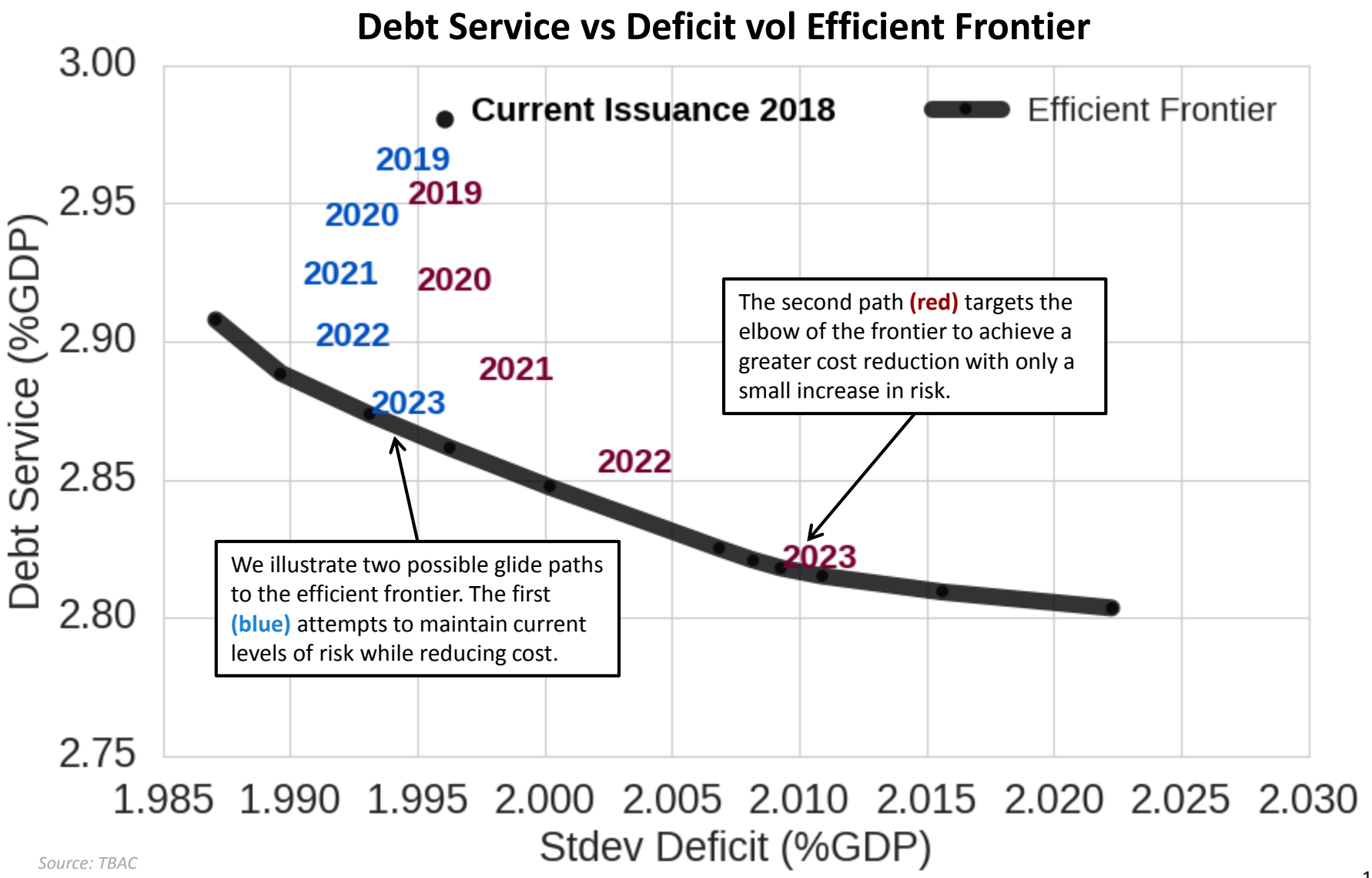


Source: TBAC

[1]Back test uses a risk aversion parameter of 2 and imposes 0% lower bounds on issuance sizes.

Case Study: Optimizing 2019 Issuance

We use the model to build an efficient frontier for issuance while maintaining minimum issuance sizes. We also study glide paths from 2018 issuance weights to the frontier.



Source: TBAC

Case Study: Two Glide Paths Toward Lower Cost Issuance

- **A** The **blue** glide path of issuance presented on the previous slide decreases cost while maintaining or reducing the level of risk associated with current issuance patterns. This path toward the frontier steadily increases allocations to bills and TIPS at the expense of the all other issues.

- **B** The **red** glide path of issuance aims toward the elbow of the efficient frontier (a point with a good cost to risk tradeoff). With each step along the path, allocations to the belly and TIPS expand, while allocations to bills and the long end shrink.

- A blend of these two allocations could be used to move closer to the efficient frontier with relatively small absolute changes in issuance sizes.

Issuance glide path: blue

Issuance Proportion Through Time (%)						
	2018	2019	2020	2021	2022	2023
Debt Service	2.980	2.962	2.942	2.921	2.898	2.874
Stdev Deficit	1.996	1.993	1.991	1.990	1.991	1.993
Stdev Debt Service	0.734	0.751	0.771	0.795	0.824	0.858
Bills + FRN (A)	53.7	56.5	59.2	62.0	64.8	67.6
2y Nominal	8.7	8.2	7.6	7.1	6.6	6.1
3y Nominal	8.2	7.5	6.8	6.1	5.4	4.7
5y Nominal	9.2	8.6	7.9	7.3	6.6	6.0
7y Nominal	7.7	7.1	6.4	5.8	5.1	4.5
10y Nominal	5.9	5.6	5.3	4.9	4.6	4.3
30y Nominal	3.9	3.5	3.1	2.8	2.4	2.0
TIPS	2.8	3.2	3.6	4.0	4.5	4.9

Source: TBAC

Issuance glide path: red

Issuance Proportion Through Time (%)						
	2018	2019	2020	2021	2022	2023
Debt Service	2.980	2.950	2.919	2.886	2.853	2.818
Stdev Deficit	1.996	1.995	1.995	1.997	2.002	2.009
Stdev Debt Service	0.734	0.758	0.787	0.821	0.860	0.904
Bills + FRN (B)	53.7	53.1	52.6	52.0	51.4	50.9
2y Nominal	8.7	9.1	9.4	9.8	10.2	10.6
3y Nominal	8.2	9.4	10.7	11.9	13.2	14.4
5y Nominal	9.2	9.9	10.5	11.1	11.7	12.4
7y Nominal	7.7	6.7	5.7	4.7	3.7	2.8
10y Nominal	5.9	4.9	3.9	3.0	2.0	1.0
30y Nominal	3.9	3.6	3.3	3.0	2.7	2.4
TIPS	2.8	3.4	3.9	4.5	5.1	5.6

Source: TBAC

Limitations

Modeling Considerations

- This work represents one model with results that depend critically on model assumptions. TBAC does not drive recommendations off of one model, but instead takes into account a wide range of inputs on investor demand and market pricing.
- Results depend critically on the choice of risk measure (standard deviation of deficit versus debt service), and correlation between primary deficits and inflation.
- Results depend heavily on the ex-ante assessment of term premium and its decomposition into inflation, liquidity, and real risk premia.
- Results depend heavily on debt manager risk aversion.

Investor Demand Considerations

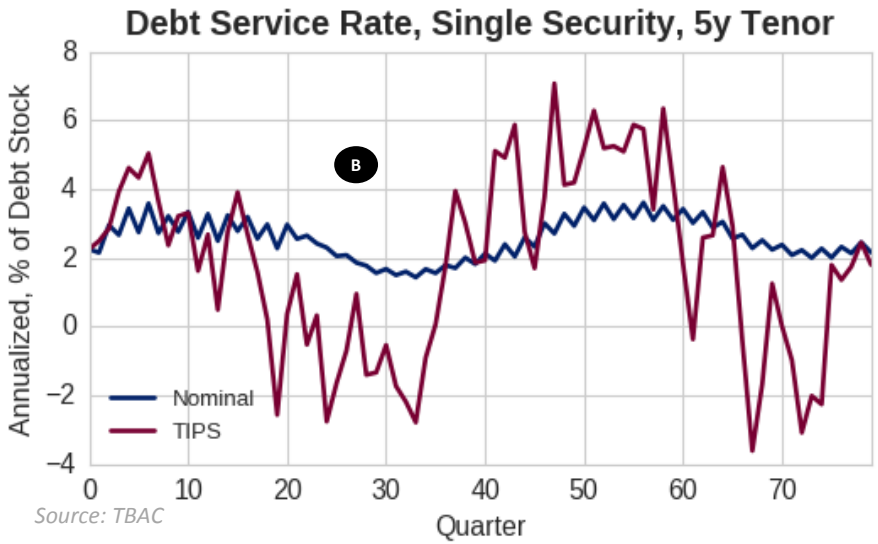
- TIPS trading volumes and turnover suggest that they are less liquid than nominal Treasuries and Conventional MBS. This may be due to the lack of an active derivatives / futures market.
- TIPS are more complex than nominal Treasuries.
- For tax purposes, TIPS are treated as original issue discount (OID) bonds, which means that increases in TIPS principal are taxable for the year in which they occur, rather than at maturity.

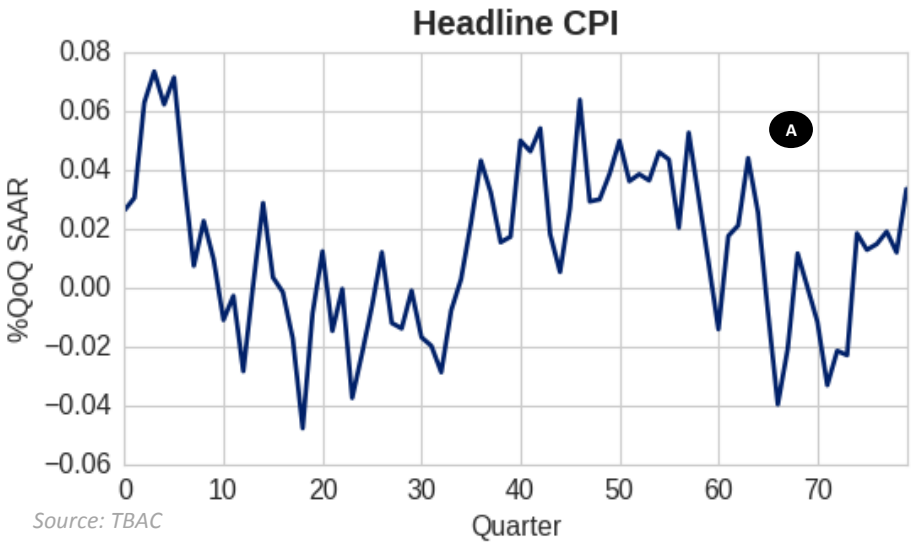
Conclusions and Recommendations

- The extension of the model of Belton et al. to incorporate TIPS demonstrates a cost and risk reduction for the issuance of TIPS in addition to nominals.
    - Assuming historical correlations hold, total deficit volatility is reduced for TIPS allocations up to 13% of the debt stock (currently TIPS make up 9% of the debt stock).
- The optimal amount of TIPS to issue varies based on choice of risk metric, assessment of market risk premiums, and Treasury's overall risk appetite.
- Given the diversification / correlation benefits, as well as the benefits of having benchmark issuance across the entire curve, continued issuance across the existing benchmark tenors (5y, 10y, 30y) is appropriate.
    - The analysis of potential issuance of 2y TIPS illustrates that benefits here may be more limited, but further study is needed.
- The model finds that TIPS dependence on CPI causes them to behave like floating rate notes, and thus have many of the same risk characteristics as bills (both are relatively lower cost and higher volatility), but further study is needed.
- Overall, though further work is still needed, the model does correspond well with market intuition and provides a useful framework for future analysis of the tradeoffs involved in achieving a more optimal issuance allocation.

Appendix

TIPS Interest Expense Accounting





INTEREST EXPENSE ON PUBLIC ISSUES (C)	
ACCRUED INTEREST EXPENSE	
Treasury Notes	$11,131,125,626.39
Treasury Bonds	$5,881,996,867.71
Inflation Protected Securities (TIPS)	$892,576,159.49
Int. Expense Inflation Compensation (TIPS)	(D) ($5,635,577,715.66)
Treasury Floating Rate Notes (FRN)	$11,030,196.93
Domestic Series - C/I's & Demand Deposits	$0.00
Foreign Series - C/I, Notes & Bonds	$0.00
REA Series	$0.00
State & Local Government-C/I's, Notes & Bonds	$87,837,116.27
Matured Debt	$0.00
TOTAL ACCRUED INTEREST EXPENSE	$12,368,988,251.13

(A) Treasury records the principal accrual of TIPS as an interest expense (or interest income) according to moves up (down) in CPURNSA

(B) We follow this treatment in our simulation block, resulting in the behavior shown above

(C) Treasury reporting for month of February 2015
- Uses CPURNSA change from mid-Nov to mid-Dec 2014
  - 2014 Refs: mid Nov 236.792, mid Dec 235.4815
  - Change – 0.5534%

(D) Treasury interest credit of $5.636Bn
- Implies outstanding TIPS notional of $5.636Bn/0.5534%
  - Implies $1.02Tn TIPS outstanding in Feb2015
  - Bloomberg DEBPINNT Index: $1.07Tn TIPS outstanding

See, for example, https://www.treasurydirect.gov/govt/reports/ir/IntExp022015.xls

Maturity Weighted Issuance

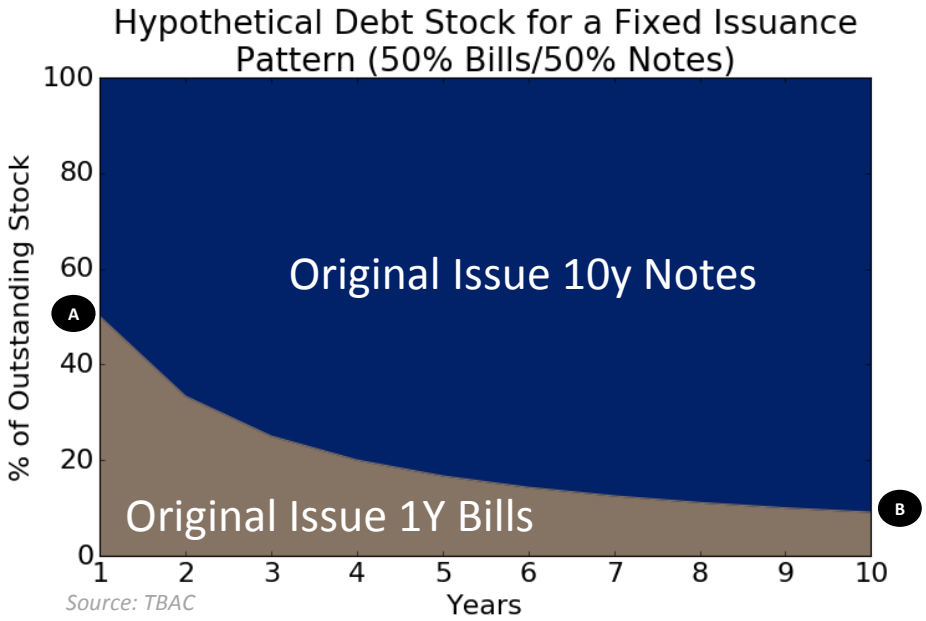
We focus on maturity weighted issuance because it more closely aligns with steady state portfolio metrics

A Consider a hypothetical issuance split 50% : 50% between 1y Bills and 10y Notes.

- In steady state, 100% of the outstanding stock of Bills turns over every year, but only 10% of the stock of 10y Notes would be redeemed.

B The 50% : 50% issuance split leads to a 9% : 91% Bills / Notes steady state distribution.

- The weighted average maturity of the steady state debt distribution is 4.6 years, which is more than ½ the WAM of a 1Y + the WAM of a 10y (2.75 years).



- Suppose Treasury can issue securities with maturities $\{\tau_1, \ldots, \tau_M\}$. Denote by w_m the fraction of each years debt issued in the m-th maturity with $\sum_{m=1}^{M} w_m = 1$.
- Assume that quarterly issuance is a constant one unit, and that the issuance fractions never change. Then after a long time, the total amount of outstanding debt which is an original-issue τ_m- maturity security is simply $\tau_m w_m$, because it takes τ_m years for each w_m of debt issued to mature. The total stock of debt is simply $D = \sum_{m=1}^{M} \tau_m w_m$.
- We can define the *steady-state debt stock fractions*

$$\bar{w}_m = \frac{\tau_m w_m}{\sum_{n=1}^{M} \tau_n w_n},$$

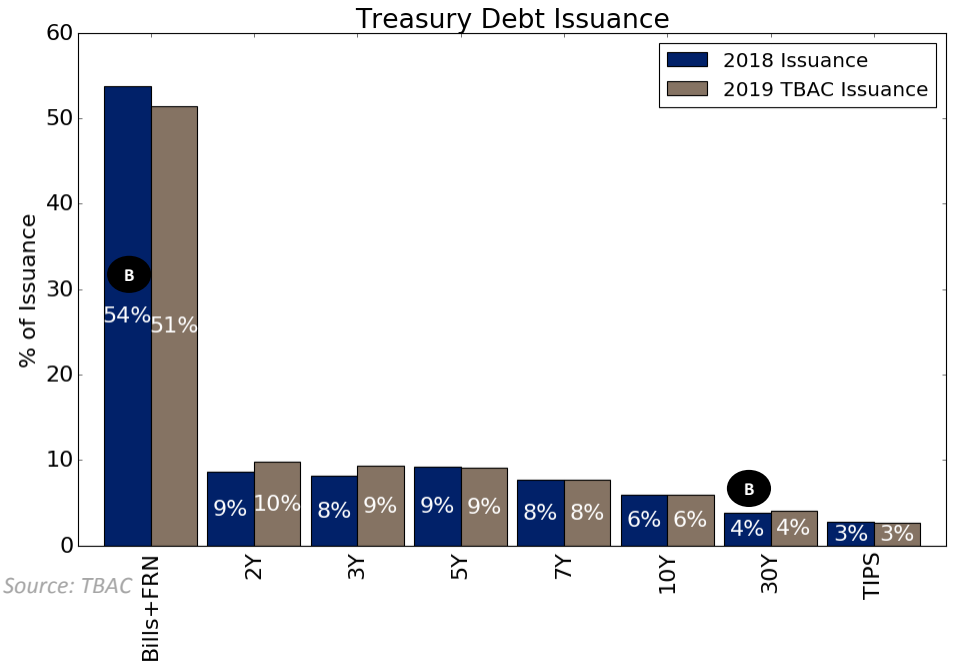
which also sum to 1. The weighted average maturity of the debt stock can be computed as $W = \frac{1}{2}\sum_{m=1}^{M} \bar{w}_m \tau_m$.

- The relationship can also be inverted, so that if one has a desired set of steady state debt stock fractions, one can find the required yearly issuance fractions as

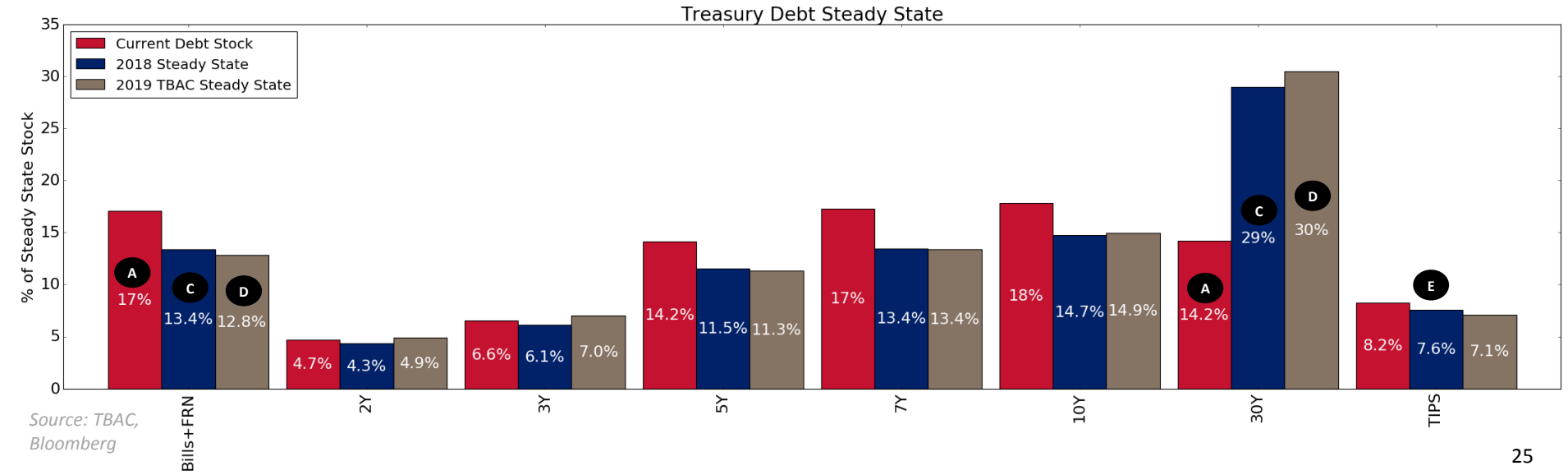
$$w_m = \frac{(\bar{w}_m/\tau_m)}{\sum_{n=1}^{M}(\bar{w}/\tau_n)}.$$

Steady State Based on Current/Projected Issuance

- **A** As a point of reference, the current debt stock has approximately the same allocation of original issue bills and 30s (17% and 14% respectively).
- **B** In terms of 2018 issuance, bills far outweigh bonds (54% and 4% respectively).
- **C** If 2018 issuance percentages are held constant, the steady state allocations will converge to 29% for bonds and 13.4% for bills.
- **D** With increasing percentages of 30y issuance projected for 2019, the steady state stock of 30y will be even higher (30%) and the bills slightly lower (12.8%).
- **E** Based on 2018 maturity issuance in TIPS, the stock will fall through time, from the current level of 8.2% to 7.6%.



Source: TBAC



Source: TBAC, Bloomberg

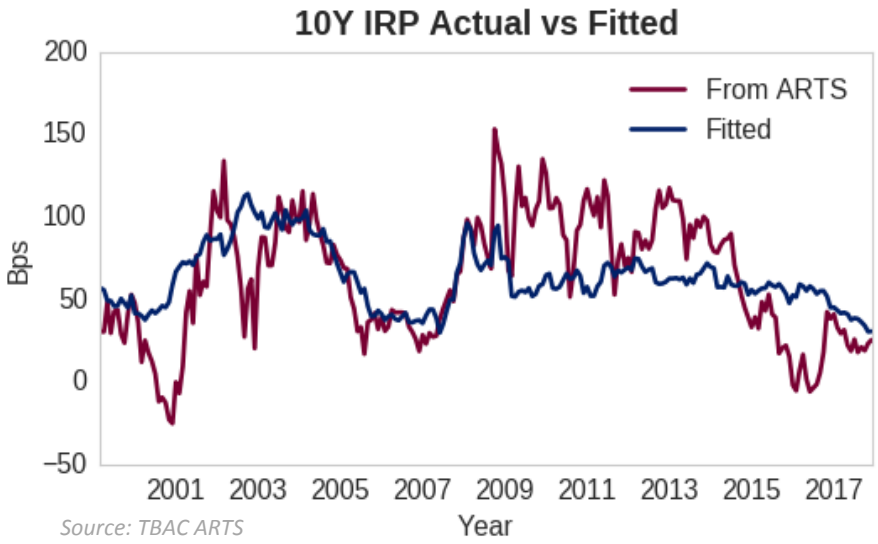
Inflation Risk Premium Regression Details

We fit historical inflation risk premia from our implementation of the AACM model (ARTS) to the historical expected level of monetary policy accommodation:

$$IRP_{t,\tau} = \alpha_\tau + \beta_\tau\left(r^P_{t,\tau} - r^*_t\right) + \epsilon_{t,\tau}$$

where

- $IRP_{t,\tau}$ is the τ year inflation risk premium from our model
- $r^P_{t,\tau}$ (expected real rate) is the τ year nominal yield less the τ year ACM TP less expected inflation[1]
- r^*_t is the neutral real rate of interest
- t is time through history



- In our simulation block we model 5y and 10y IRP as an affine function of $r^P_{t,\tau}$ - r^*_t, where both rates are in the block.
- We take the betas from the historical regression.
- We choose intercepts to match steady-state levels to their five-year averages in the ARTS model.
- Residual AR1 processes come from the historical regression

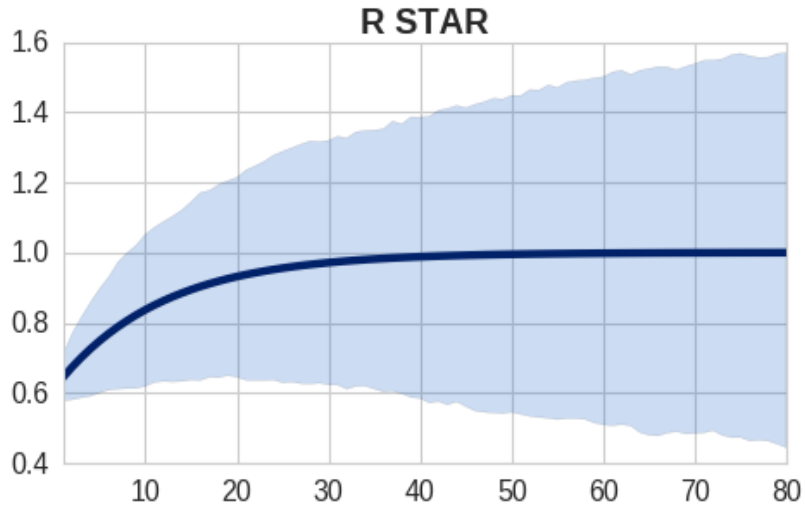
$$IRP_{t,5} = 0.61 \; - 0.145\left(r^P_{t,5} - r^*_t\right) + \epsilon_{t,5}$$

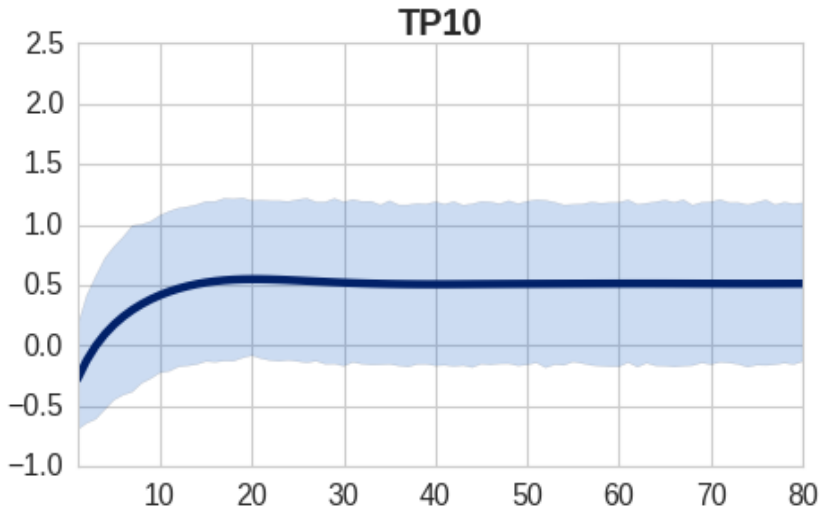
$$IRP_{t,10} = 0.61 \; - 0.245\left(r^P_{t,10} - r^*_t\right) + \epsilon_{t,10}$$

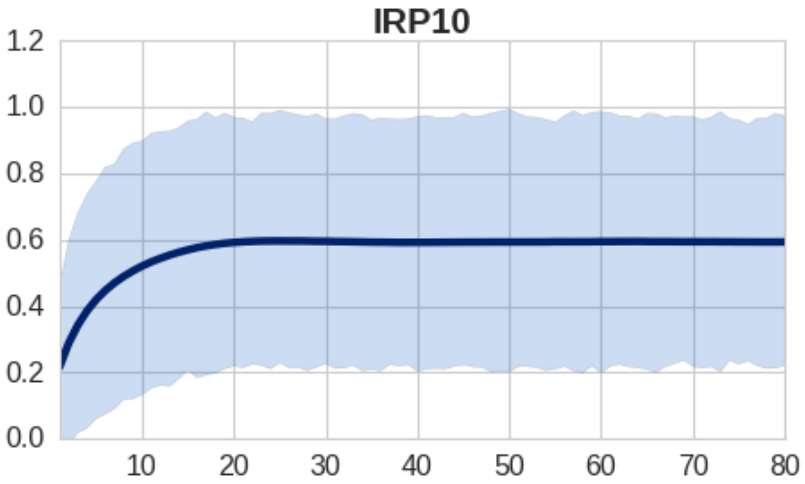
where t is now the forward time of our simulation

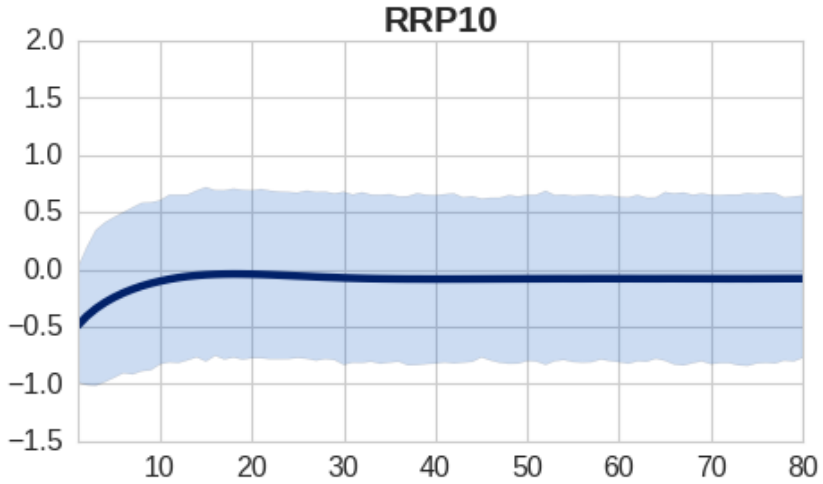
[1]We calculated the historical time series of expected inflation using the method described in Belton et al.

Simulation Module Outputs









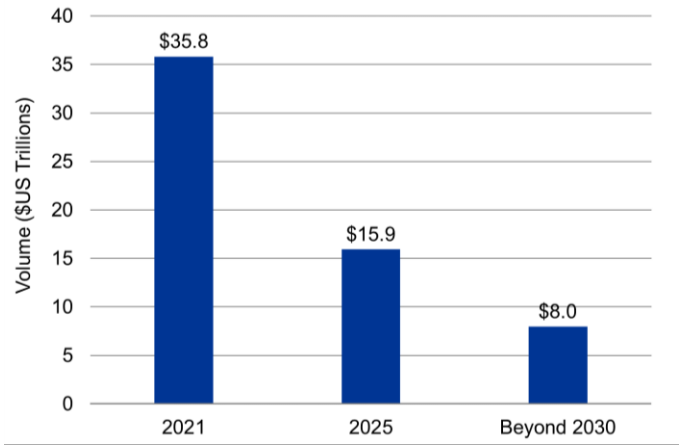
TBAC Charge

Please comment on developments regarding the transition away from LIBOR and toward the Secured Overnight Financing Rate (SOFR). How should market participants evaluate the risks of continued use of financial instruments linked to LIBOR? Summarize developments in SOFR derivative markets, the introduction of SOFR-linked issuance, and your expectations going forward.

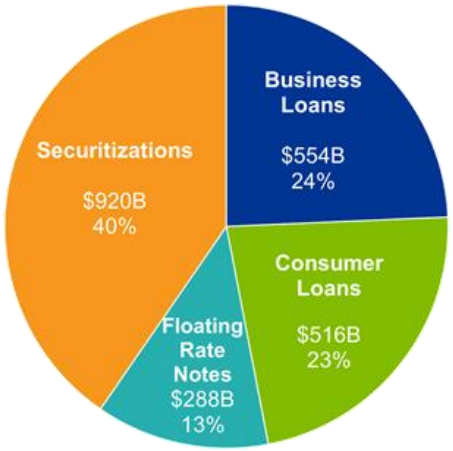
LIBOR Exposure

- In July 2017 Andrew Bailey, the Chief Executive of the Financial Conduct Authority (FCA), announced a plan to no longer sustain LIBOR through the current mechanism, by which the FCA persuades or obliges panel banks to submit contributions to the benchmark, beyond the end of 2021
- The Alternative Reference Rates Committee (ARRC) chose SOFR to the be the standard overnight financing rate
  - Following Andrew Bailey's timeline the ARRC broadened its goals to help facilitate the transition of end-user cash products such as floating rate notes, CLOs, mortgages and consumer loads, etc
- ISDA has been leading an industry wide effort to implement robust fallbacks for derivative contracts referencing interbank offered rates (IBORs)
  - ISDA launched a market-wide consultation on technical issues regarding the new benchmark fallbacks for derivative contracts that reference interbank offered rates (IBORs)

USD LIBOR-Related Notional Outstanding: 2021 and Beyond



Breakdown of USD LIBOR Notional Outstanding Not Maturing by 2022 (ex Derivs.)



Source: Member firm calculations, NYFRB, Second Report of The Alternative Reference Rates Committee, March 2018.

Taking Stock of LIBOR's Broad and Ongoing Usage

- Over $200T in financial instruments currently reference LIBOR
- An estimated $36T notional of LIBOR-linked instruments will remain outstanding after 2021 assuming there are no new transactions referencing LIBOR
  - Many new trades continue to reference LIBOR and the calculation does not consider replacement risk
  - After this date, the FCA will no longer compel banks to provide LIBOR submissions
- Interest rate derivatives represent the largest portion of the notional outstanding beyond 2021, but LIBOR has a much broader asset class reach
- LIBOR remains an important reference rate as evidenced by new issue markets
- LIBOR transition plans have not meaningfully altered issuance behavior – many deals continue to reference LIBOR

LIBOR footprint by asset class

		Volume (Trillions USD)	Share Maturing By: End 2021	End 2025	After 2030	After 2040
Over-the-Counter Derivatives	Interest rate swaps	81	66%	88%	7%	5%
	Forward rate agreements	34	100%	100%	0%	0%
	Interest rate options	12	65%	68%	5%	5%
	Cross currency swaps	18	88%	93%	2%	0%
Exchange Traded Derivatives	Interest rate options	34	99%	100%	0%	0%
	Interest rate futures	11	99%	100%	0%	0%
Business Loans[2]	Syndicated loans	1.5	83%	100%	0%	0%
	Nonsyndicated business loans	0.8	86%	97%	1%	0%
	Nonsyndicated CRE/Commercial mortgages	1.1	83%	94%	4%	2%
Consumer Loans	Retail mortgages[3]	1.2	57%	82%	7%	1%
	Other Consumer loans	0.1	---	---	---	---
Bonds	Floating/Variable Rate Notes	1.8	84%	93%	6%	3%
Securitizations	Mortgage -backed Securites (incl. CMOs)	1.0	57%	81%	7%	1%
	Collateralized loan obligations	0.4	26%	72%	5%	0%
	Asset-backed securities	0.2	55%	78%	10%	2%
	Collateralized debt obligations	0.2	48%	73%	10%	2%
Total USD LIBOR Exposure:		**199**	**82%**	**92%**	**4%**	**2%**

Source: ARRC

Critical Steps Towards LIBOR Transition Are Already Underway

Alternative Reference Rates

- **Smooth functioning markets must exist for Alternative Reference Rates**
  - In the US, the NYFRB began publishing Secured Overnight Financing Rate (SOFR) in April 2018
  - CME launched trading in SOFR Futures (1-month and 3-month) on May 7, 2018 and clearing for OTC SOFR Swaps on October 1, 2018; LCH started clearing OTC SOFR swaps on July 16, 2018
  - SOFR-linked issuance began in July 2018
  - Increased SOFR-linked issuance will be another key driver towards building SOFR derivative liquidity
  - There is a need for collaboration across jurisdictions

Alternative Reference Rates by Jurisdiction

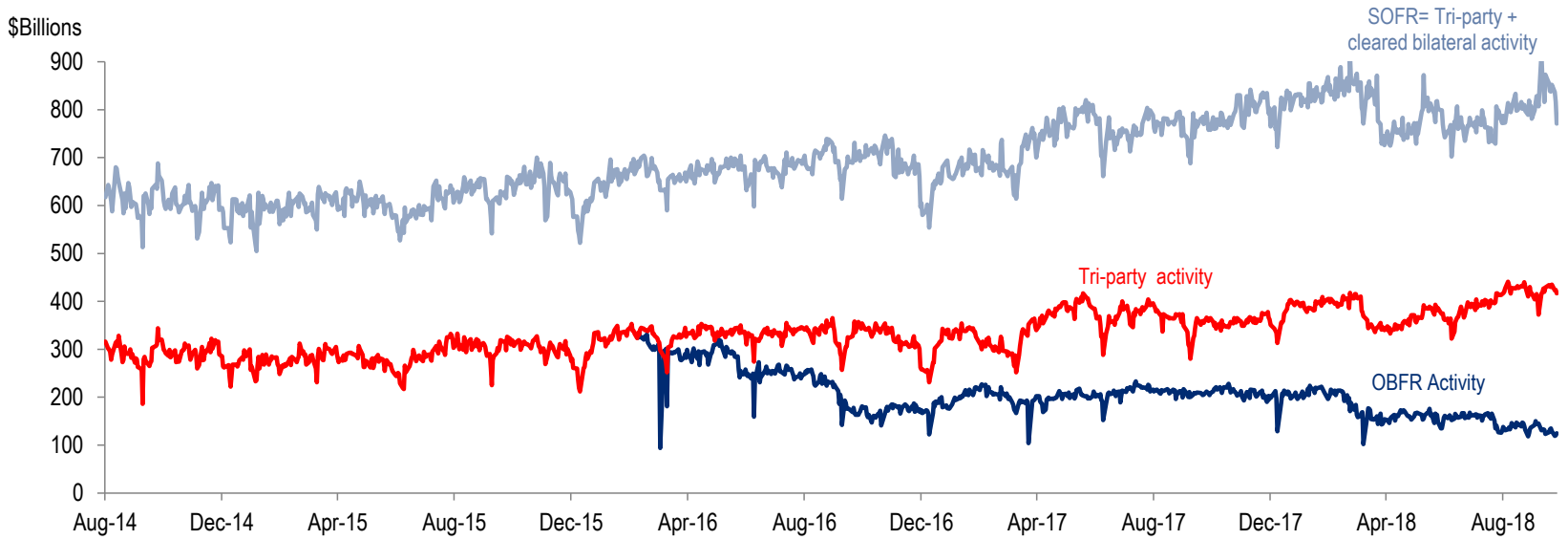
Jurisdiction	Working Group	Public Sector	Alternative RFR	Rate Administrator	Secured vs. Unsecured	Tenor	Expected Launch Date
	Alternative Reference Rates Committee	Federal Reserve	**SOFR** *Secured Overnight Financing Rate*	Federal Reserve Bank of New York	Secured	Overnight	Currently published
	Working Group on a RFR Rate for the Euro Area	European Central Bank	**ESTER** *Euro Short-Term Rate*	European Central Bank	Unsecured	Overnight	October 2019
	Study Group on Risk-Free Reference Rates	Bank of Japan	**TONA** *Tokyo Overnight Average Rate*	Bank of Japan	Unsecured	Overnight	Currently published
	National Working Group on Swiss Franc Reference Rates	Swiss National Bank	**SARON** *Swiss Average Rate Overnight*	SIX Swiss Exchange	Secured	Overnight	Currently published
	Working Group on Sterling Risk-free Rates	Bank of England	**SONIA** *Sterling Overnight Index Average*	Bank of England	Unsecured	Overnight	Currently published

Source: ISDA.

What is SOFR?

- The Alternative Reference Rate Committee (ARRC) identified the Secured Overnight Financing Rate (SOFR) as its preferred rate
- SOFR is a transaction based rate, calculated from a broad universe of o/n UST repo activity. SOFR is based on three different repo segments:
  - Tri-party US Treasury general collateral (GC) repo, cleared and settled by Bank of New York Mellon, excluding transactions with the Federal Reserve
  - Tri-party US Treasury GC repo within the FICC GCF repo framework, where FICC acts as a central counterparty
  - Bilateral Treasury repo transactions cleared through the FICC Delivery-versus-Payment (DVP) service

Aggregate Volumes underlying select MMF rates



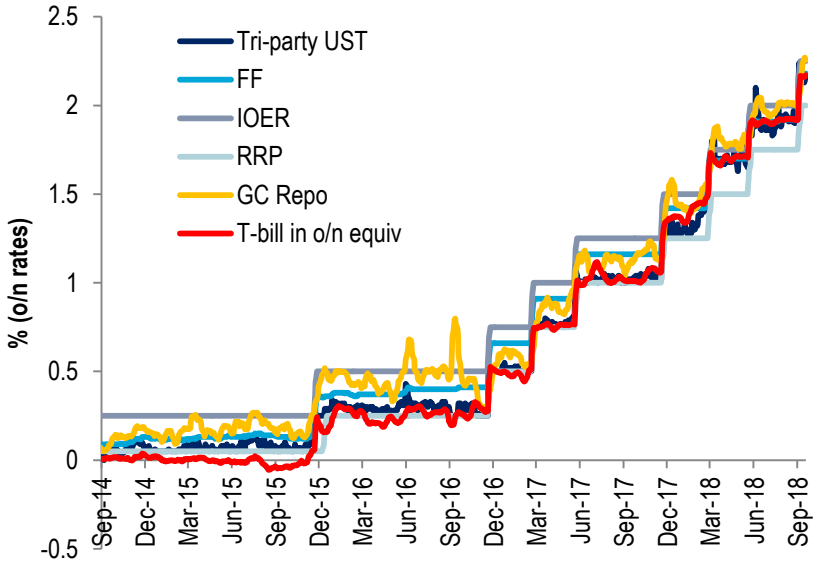
Source: ARRC, New York Fed

What drives SOFR?

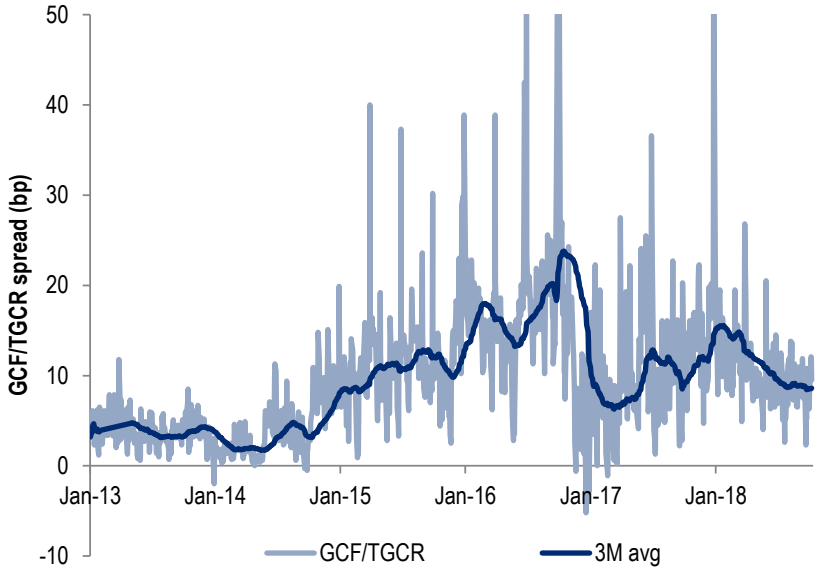
- **SOFR moves with T-bill yields:**
  Higher T-bill issuance brought all o/n rates higher, including tri-party repo rates, as a competing asset for US MMFs

- **SOFR moves with dealer B/S cost of repo:**
  Bilateral/GCF and BNYM Tri-party repo rates are linked as a bid-ask for dealers to intermediate repo between MMF and end-users (e.g. hedge funds). We have seen repo spreads widening from 2014-2016 as LCR / SLR phased-in. Since then, we saw it tightening with more competitive repo intermediation post the US MMF reform

Cheapening of T-bill brought all o/n rates higher…



GCF/Tri-party repo spreads tend to reflect bid-ask of repo from dealer's perspective

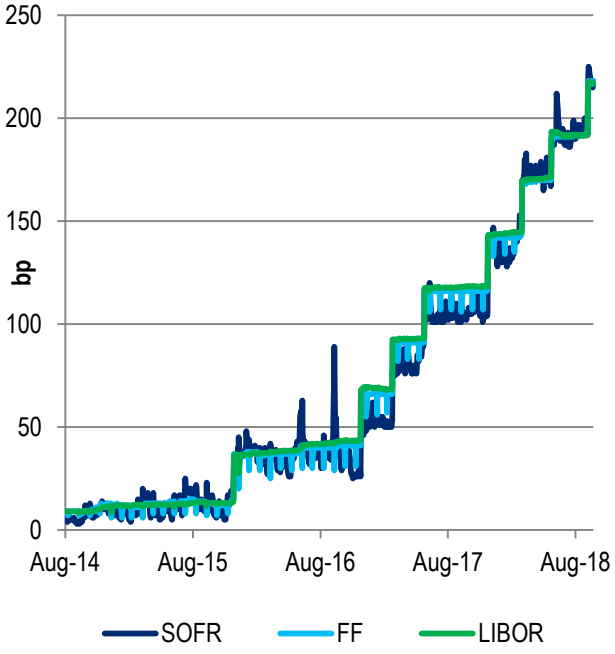


Source: Bloomberg, NYFed
Note: T-bill in o/n equivalents are calculated as 1M T-bill yield – (1M FF OIS – O/N FF)

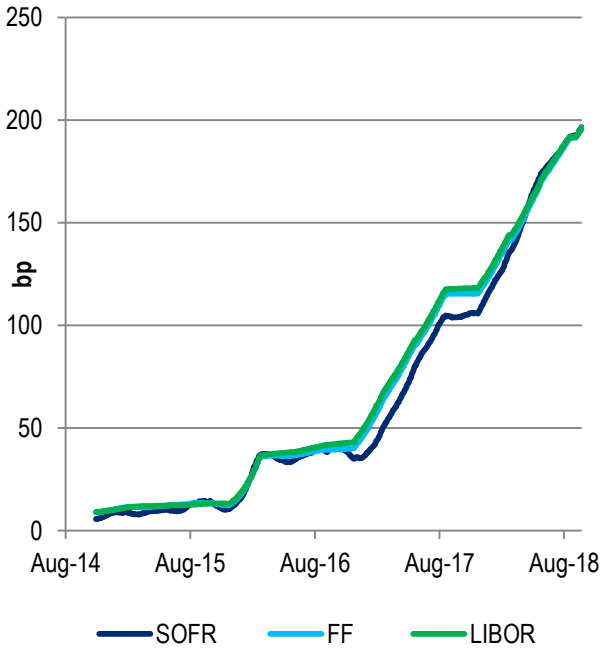
How do SOFR and LIBOR differ?

- 3M LIBOR and o/n SOFR differ in two aspects:
  - SOFR is secured and LIBOR is unsecured. LIBOR is inherently bank-credit sensitive, pro-cyclical asset whereas SOFR is collateralized and largely cleared, hence a counter-cyclical asset
  - 3M LIBOR is a term rate vs SOFR is an overnight rate. We find this difference to be more salient, as noted by volatility in 3M LIBOR / 3M FF OIS basis
- 3M LIBOR/OIS tend to widen on funding "stress" scenarios. This is not the case for SOFR

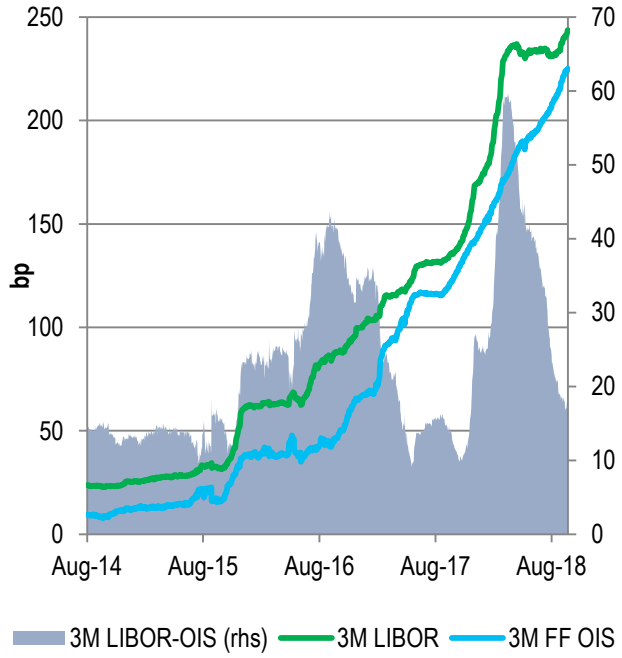
Overnight MMF rates tend to behave similarly on o/n basis …



As well as in longer frames (3m rolling geometric average)…



However, behavior of OIS vs term rate such as 3M LIBOR can be quite different…

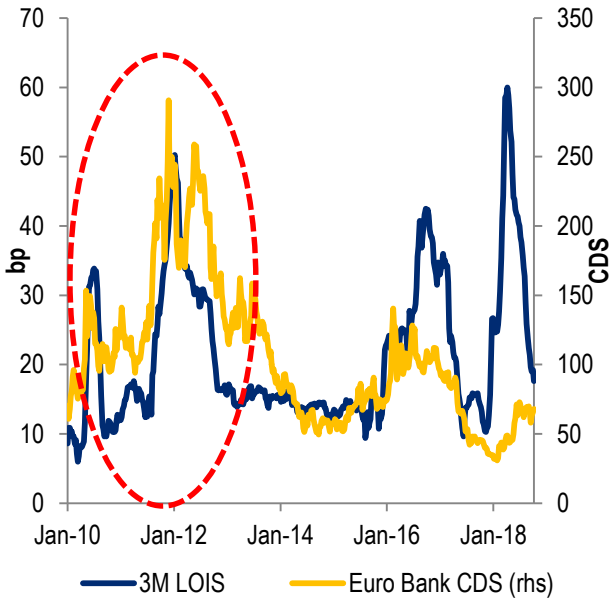


Source: Bloomberg

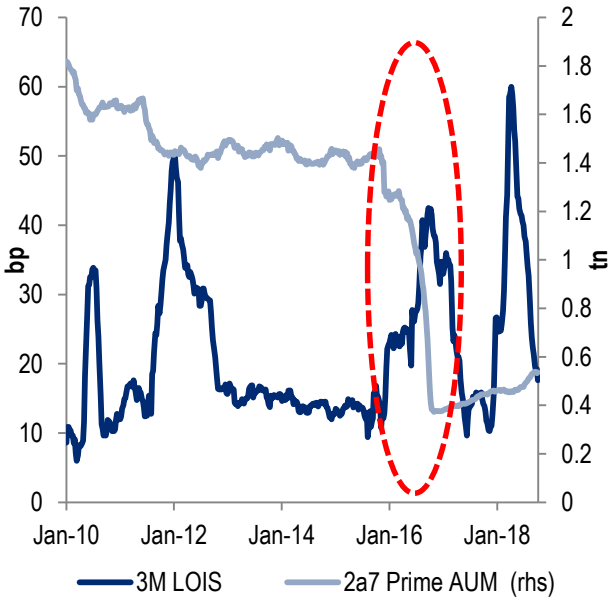
LIBOR/OIS tend to widen on funding shock episodes

- Since the crisis, LIBOR/OIS basis has experienced 4 widening episodes
  - **In 2010 and 2011/2012**, European debt crisis intensified to put bank's creditworthiness in question
  - **In 4Q2016**, the basis widened on US MMF reform – which caused a pullback on 2a7 Prime funds to cause a demand shock in funding markets
  - **In 1Q2018**, rapid T-bill issuance and shortening of WAM of repatriated cash after the tax reform led LOIS wider

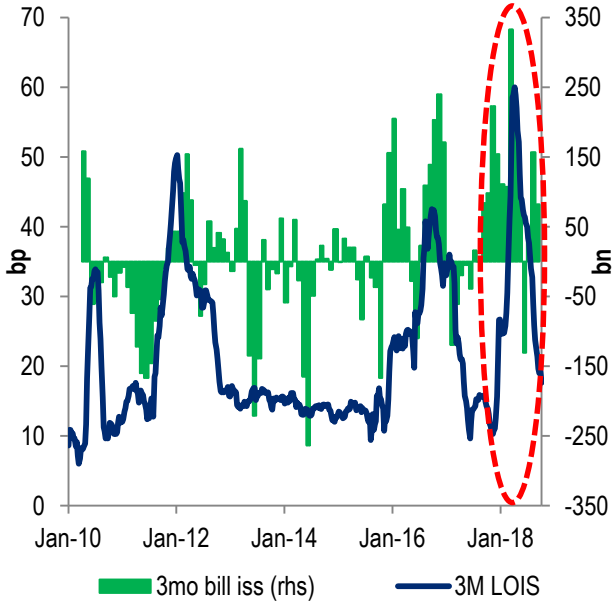
Credit "shock" caused LOIS widening in prior years…



MMF reform "shock" caused LOIS widening in 2H2016…



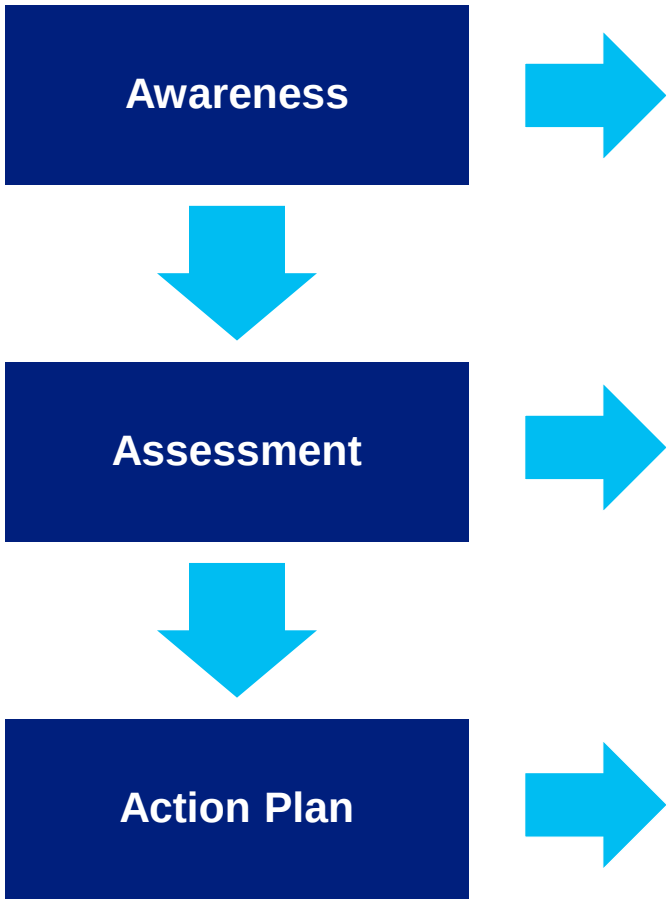
Bill issuance & repatriation "shock" caused LOIS widening in 1H2018…



Source: Bloomberg

Preparing for LIBOR Transition

Preparation is key and requires engagement across multiple stakeholders within every firm



Education is Critical -- from Main Street to Wall Street

- Households:
  - Need to understand impact on mortgages, consumer loans, student loans
- Industry:
  - Collaboration is underway - Alternative Reference Rate Committee (ARRC) includes representation across industry groups
  - Trade associations are promoting global coordination

Evaluate existing exposures to LIBOR

- Compress existing positions to simplify exposures where possible

Carefully review fallback methodologies:

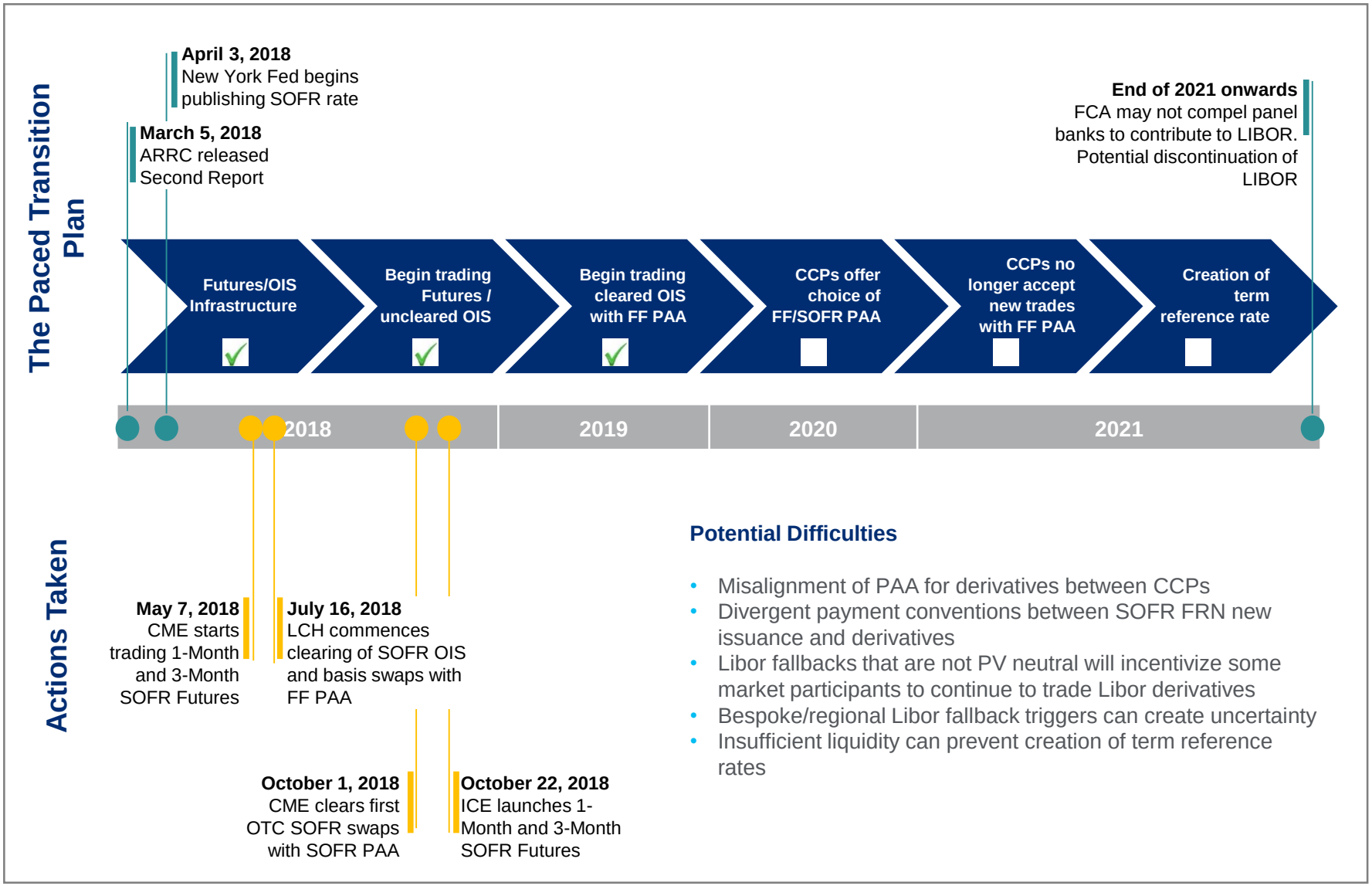
- Assess inconsistencies or lack of sufficient fallbacks within existing agreements
- Require stronger fallback language be incorporated into new LIBOR-referenced instruments
  - ISDA consultation underway for derivatives
  - ARRC consultation for cash products
- Facilitate growth of SOFR markets and LIBOR/SOFR basis through more concrete fallback methodologies

Analyze Systems Readiness

The ARRC published a "Paced Transition Plan", but all investors and market participants will need to make the appropriate preparations

Markets are highly interconnected - there will be implications both cross-asset and cross-currency

Paced Transition Milestones



Potential Difficulties

- Misalignment of PAA for derivatives between CCPs
- Divergent payment conventions between SOFR FRN new issuance and derivatives
- Libor fallbacks that are not PV neutral will incentivize some market participants to continue to trade Libor derivatives
- Bespoke/regional Libor fallback triggers can create uncertainty
- Insufficient liquidity can prevent creation of term reference rates

Libor- vs SOFR-linked Liabilities – Banks' Perspective (i)

Suitability for Financial Institutions and Other Borrowers

- Likely suitable for majority of floating rate borrowers seeking exposure to secured funding rate
- Potential operational/system challenges, particularly for smaller institutions and if compounding becomes standard

Risks

- Persistent limited liquidity in cash and derivatives markets
  - Inadequate investor pool for new issuances and secondary trading
  - Restricted ability to perform dynamic ALM
  - Long-dated callable issuances may require references to illiquid/long-end parts of the SOFR curve
- May not match performance of Libor-based assets
- Limited ability to hedge general bank funding risk due to secured nature of SOFR

Benefits

- SOFR issuances may provide greater transparency for investors (clearer delineation of credit risk)
- Can closely match performance of certain secured investments
- Potentially represents new balance sheet management tool in combination with Libor instruments
- Certain investors may see additional utility in SOFR-based investments – potentially offsetting premium demanded by other investors

Libor- vs SOFR-linked Liabilities – Banks' Perspective (ii)

Considerations following the Crisis of 2007 and Outlook

- Banks generally responded to increased regulation and improved liquidity risk management with the extension of maturity profiles of unsecured borrowings
- Post-crisis shifts towards deposit funding (commercial/demand deposits) increased the relative size of certain short- to medium- duration liabilities

  ➡ Overall the exposure to funding spread resets of liabilities arguably has been reduced

- However banks still have to manage funding spread risks due to spread duration gaps between assets with longer re-pricing cycles and shorter-dated liabilities – exposing banks to a sudden widening of sector credit spreads

  ➡ There is still a need for ALM instruments whose performance is linked to unsecured bank credit spread such as Libor

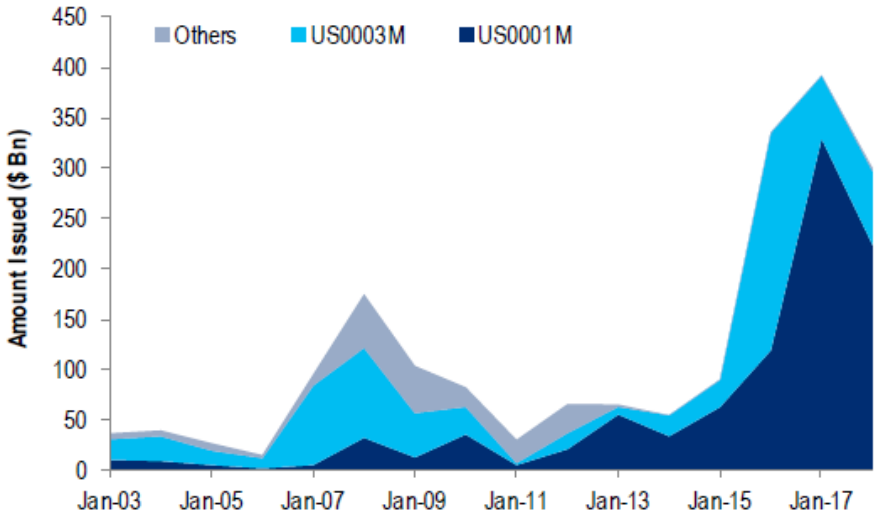
- On the other hand unsecured inter-bank lending volumes have collapsed since the crisis resulting in Libor being less representative of actual bank funding costs

  ➡ Will the banking industry require new hedging instruments based on unsecured benchmarks?

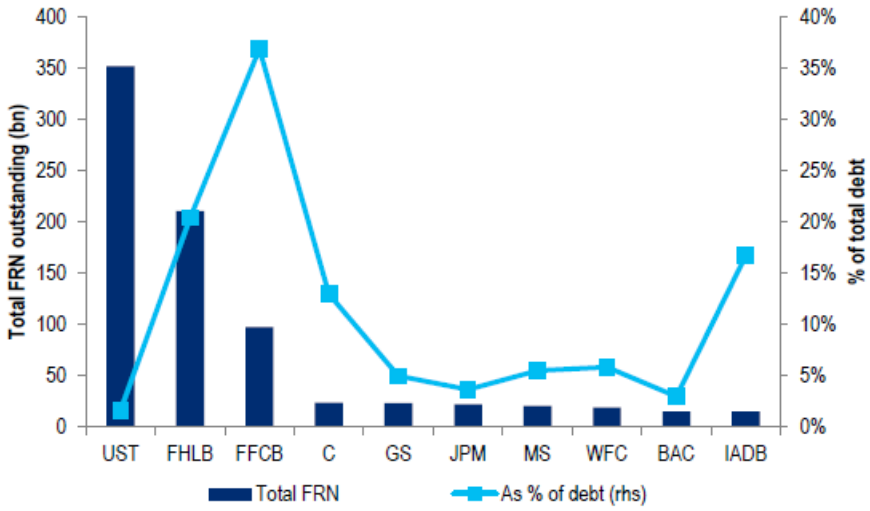
SOFR can allow GSE Issuers to diversify out of LIBOR

- FHLBs are the second largest issuer of USD FRNs as of end of Q3 2018, after the US Treasury. SOFR floaters would allow FHLBs to diversify their LIBOR exposure upon the cessation/fallback risk
  - FHLBs may have been issuing more floaters over the years as (1) increase in Government-only fund AUM post the US MMF reform increased demand for GSE papers and (2) hiking cycle made floaters more attractive to fixed from the investors without derivative access
- SOFR FRN issuance by GSEs is the natural starting place to test and develop the demand base for cash SOFR products, as end-users often won't require derivative markets
  - Fannie Mae have issued the most SOFR FRNs so far ($11bn)
  - The survey notes that investors are likely to be more receptive to SOFR FRNs issued by GSEs

FHLBs have increased LIBOR FRN issuance after the US money market reform



FHLBs are the second largest issuer of USD FRNs (as the end of Q32018)



Source: Bloomberg

Managing LIBOR Risk

Risks of existing Libor contracts without fallbacks

- Inadequate legacy fallback language increases risk of litigation
- Partial adoption of new fallbacks

Risks of Libor references with fallbacks

- SOFR market not sufficiently developed at time of cessation could lead to market disruption
- Fallback rate calculation causes valuation impact upon cessation
- Accounting/Tax/Margin/Clearing impact from Libor cessation and fallback adoption could lead to litigation risk and liquidity risk
- Regional or product specific trigger events lead to partial cessation increasing market fragmentation

Risks of new SOFR contracts

- Sluggish adoption of SOFR as new standard
- Insufficient liquidity in longer tenors

- Market participants establish risk metrics for active management of net exposure to Libor
- Active banking and public sector outreach to amend existing contracts
- ISDA protocol amendment approach with limited optionality
- Dealers and FMUs support development of liquid SOFR derivative term markets
- ISDA/ARRC may recommend market-neutral fallback language in derivative and cash markets
- ARRC regulatory advocacy for no action relief and exemptions
- Bank-wide “Libor offices” contribute to global and cross-product coordination to align trigger language; exposure management by product
- Industry coordination with CCPs to align market conventions and cessation triggers

Critical Steps Towards LIBOR Transition Are Already Underway

Fallback Methodologies

An appropriate "fallback methodology" must be established

Permanent cessation of LIBOR is generally not consistently contemplated in documentation

Contract language is not standardized across corporates, mortgages, FRNs, and loans, raising risk of fragmentation

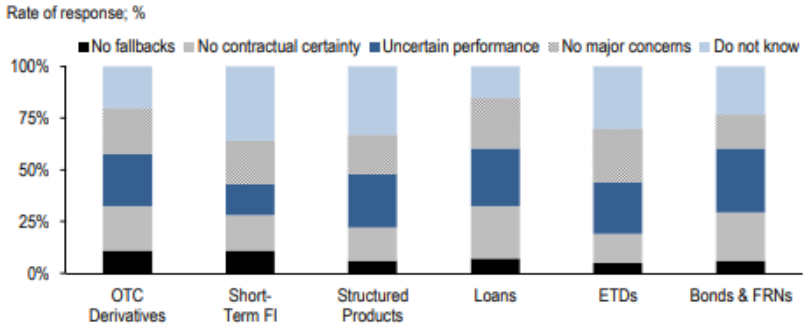
- For example: "in the event of LIBOR cessation…"

  "…the security can change to a fixed rate based off the last setting"

  "…the security converts to a fixed instrument based on the first setting"

  "…the issuer, in its sole discretion, can name a successor rate"
- In some cases there is no fallback mentioned at all

Recent ISDA survey highlights fallback provisions as a key concern in the event LIBOR is permanently discontinued



Note: Full response options are: (1) There are no fallback provisions, (2) Fallback provisions will not provide contractual certainty, (3) Fallback provisions will provide contractual certainty but the trade/position will not continue to function as originally intended, (4) Fallback provisions will provide contractual certainty and the trade/position will continue to function as originally intended, and (5) Do not know. For details, see *IBOR Global Benchmark Transition Report*, June 2018.

Source: ISDA

A "fallback methodology" should:

- Define what constitutes LIBOR cessation event
- Outline a methodology to capture the spread between LIBOR and SOFR
- Methodologies should be consistent across asset classes to mitigate market disruption and fragmentation

ISDA and ARRC are undertaking industry-wide consultations with numerous methodologies being considered for various products

- Upon update of ISDA definitions, new LIBOR derivatives would reflect the final fallback methodology
- New fallback language will not necessarily apply to legacy products, but ISDA contemplates a protocol approach to amend legacy derivatives
- ARRC Guiding Principles for More Robust LIBOR Fallback Contract Language in Cash Products:

Shift from discretion to specificity; Consistency between asset classes; Feasibility and fairness of implementation; Rate, spread and term structure adoption

Ultimately, clarity on the selected methodology will create a path forward and introduce potential for more active trading of basis swaps between these markets

Market disruption is a risk if LIBOR prematurely ceases publication

Defining major risks and market implications

Market participants are working to define major risks

- Inconsistent legal interpretations could lead to contract frustration
- Inconsistent fallback language and calculation methodology could drive market fragmentation and asset hedge misalignments
- Breadth of jurisdictional oversight, if not aligned, could drive market fragmentation
- Inconsistent accounting / tax implications could factor into fallback adoption
- Market participants could use economic impact from fallback to drive protocol adoption decisions

Potential market implications of a LIBOR cessation

- Rotation from LIBOR based derivatives to OIS, or SOFR and a move from IRS instruments to Treasury futures
- Reduction of the CCP delta mismatch could shift the CME/LCH basis
- Market pricing of LIBOR forwards will also be a function of the selected fallback approach

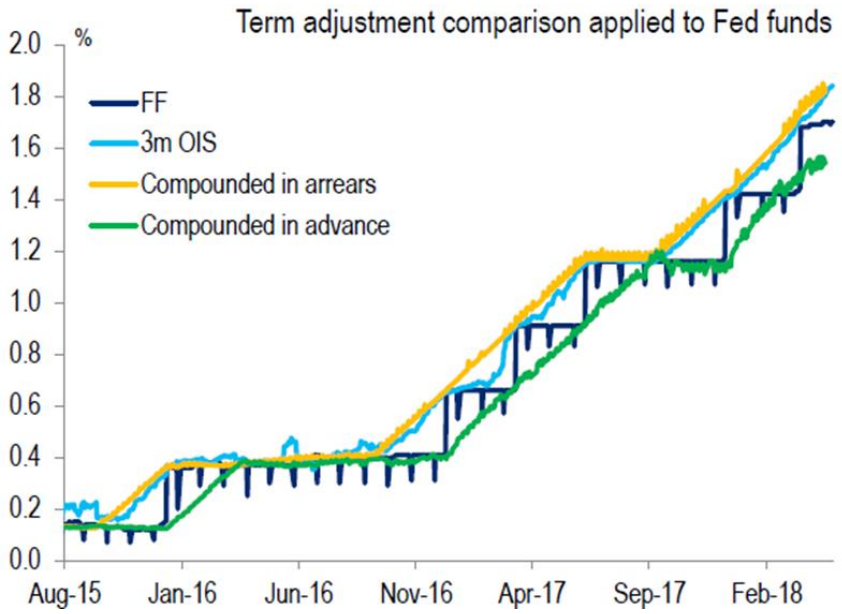
How firms can quantify LIBOR cessation risk

- For derivatives: firms can estimate their exposure by quantifying their LIBOR projection risk, in dv01 terms, under different fallback scenarios
- For cash products: the notional amount for instruments referencing LIBOR can be analyzed under different fallback scenarios

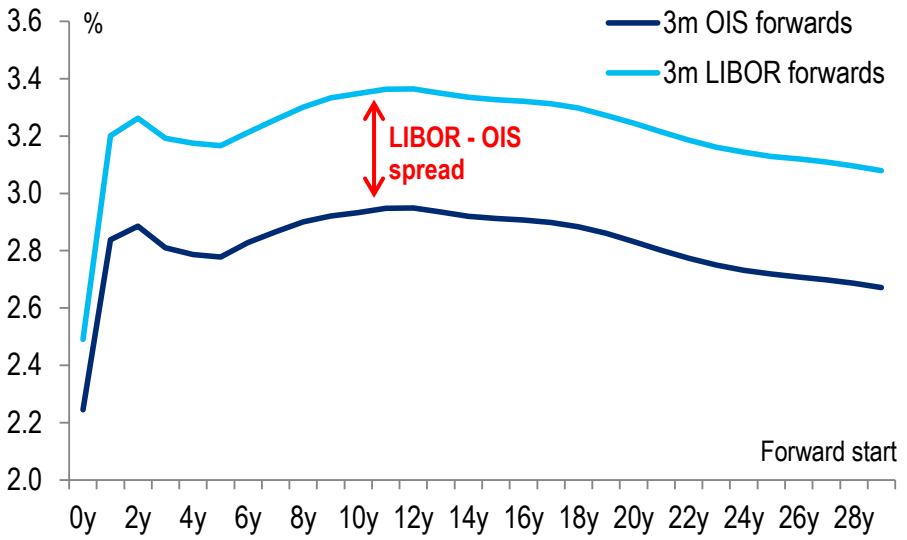
LIBOR fallback process

- Two step process to apply SOFR as LIBOR replacement:
  - Term adjustment: Transform SOFR, which is an o/n rate, to a term rate
  - Spread/Credit adjustment: Apply a spread on top of the SOFR rate to take into account LIBOR's credit premium component
- Potential term adjustment methodologies: Spot o/n SOFR, Convexity adjusted o/n SOFR, Compounded in arrears, and Compounded in advance
- Potential spread adjustment methodologies: Forward curve, Historical mean/median, Spot spread

We benchmark term adjustment methodologies to 3m OIS forwards



Spread adjustment captures the basis between LIBOR and the risk free rate

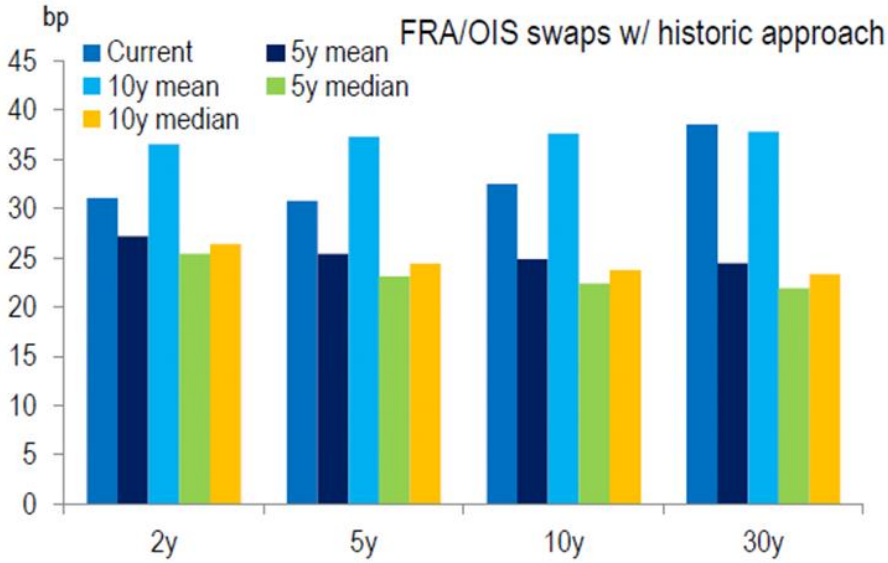


Source: Bloomberg

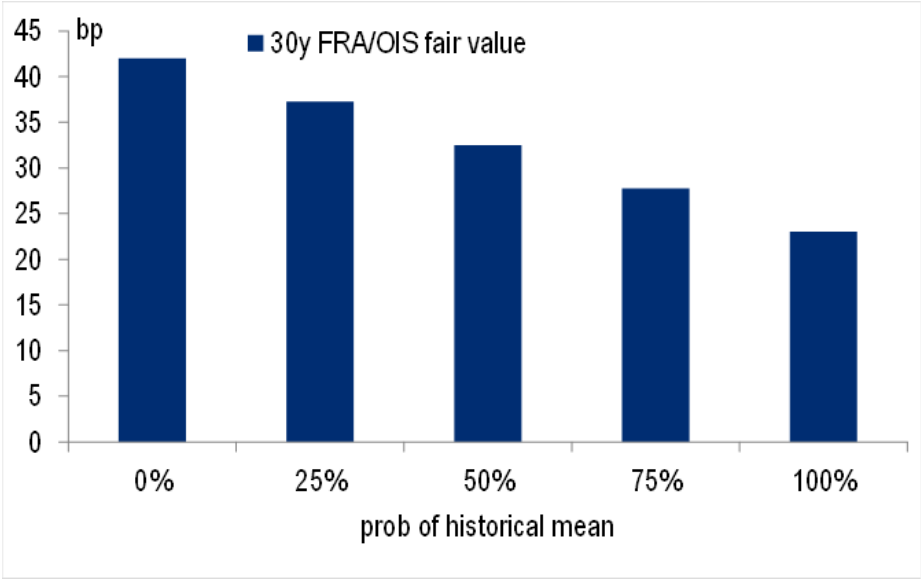
Market implications from LIBOR fallback

- Choosing the historical mean approach as fallback would likely flatten the LIBOR-OIS basis swap curve
  - This is especially true for 5s30s and 10s30s
- The probability that the historical mean approach will be implemented, on a cessation of LIBOR, can be implied from 30y FRA/OIS spreads
- We can approximate the fair value of 30y FRA/OIS to be ~23bp assuming:
  - Historical mean approach is used in the fallback process with a 10y window
  - A 20% chance of LIBOR discontinuation each year from 2021-2025

FRA/OIS will likely flatten with the historic approach



LIBOR cessation estimates can be derived from current 30y FRA/OIS levels



Source: Bloomberg

SOFR Adoption

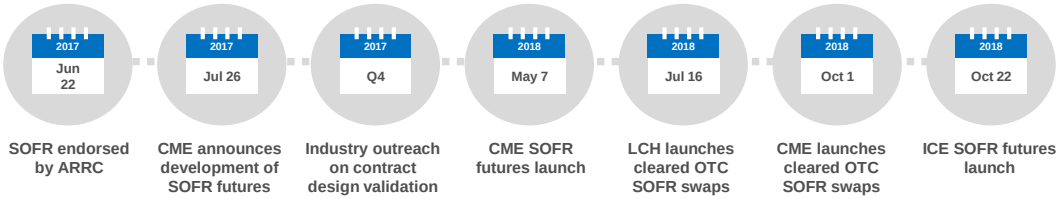
Trading Begins

CCPs Launch Futures and Swaps

Fannie Mae issues first SOFR-linked debt deal

Broader adoption of SOFR-linked issuance is gaining momentum

SOFR Product Development Timeline



Maturities	Amount	Pricing
6-month	$2.5B	SOFR + 8 bps
12-month	$2.0B	SOFR + 12 bps
18-month	$1.5B	SOFR + 16 bps
Total	**$6.0B**	

Source: Fannie Mae

Issue Date	Issuer	Notional ($M)	Tenor (years)
07/30/18	Fannie Mae	$6,000	1.5, 0.5, 1.0
08/21/18	World Bank	$1,000	2.0
08/21/18	Credit Suisse AG/NY	$100	0.5
08/28/18	Barclays	$525	0.25
09/07/18	MetLife	$1,000	2.0
09/20/18	Triborough Bridge & Tunnel	$107.28	13.5
09/21/18	Wells Fargo	$1,000	1.5
09/25/18	Wells Fargo	$125	1.0
10/05/18	Credit Suisse	$1,056	0.5, 1.0
10/19/18	JP Morgan	$800	2.0
10/24/18	Toyota	$500	0.25
10/30/18	Fannie Mae	$5,000	0.5, 1.0, 1.5
10/31/18	L-Bank (SSA in Germany)	$12	1
	Total	**$17,225**	

- **Fannie Mae successfully issued a three-tranche, $6B SOFR debt transaction on July 26, 2018**
- **The deal was met by demand from a broad and diverse investor base**
- **Over $10 billion in SOFR floaters have been issued**
- **Investors should read the fine print:**
  - **Compounding differences can occur between deals**
  - **LIBOR and SOFR can be expected to behave differently in different market environments**

SOFR Adoption

Going Forward

We have identified several areas of further development that we expect would help build activity and liquidity

Official Sector Guidance	
Regulators	• Could provide relief on central clearing mandate for legacy LIBOR positions • Could assess ways to encourage banks to move away from using LIBOR • Consideration of effects across jurisdictions given global nature of the swaps market
LIBOR Oversight	• Guidance on conditions under which LIBOR will no longer be representative (or produced at all)

Market Structure Developments	
Yield Curve	• Build liquidity beyond 2 years • Build out of the long-dated SOFR curve - this will require issuer / derivative market participation
CCPs	• SOFR-based PAA
Options/ Swaptions	• Developed options market on SOFR futures • Eventual growth of SOFR swaptions
Bilateral agreements	• Thoughts on other ways bilateral counterparties can choose to incorporate SOFR discounting
Issuers	• Treasury should evaluate issuing FRNs off SOFR

SOFR Survey to Short-end investors

- We performed a front-end survey around SOFR FRN issuance in September 2018
  - 100 respondents covered 2a7 funds (government and prime), non-2a7 money market funds such as offshore, security lenders and corporate treasurers

- Key results:
  - **LIBOR cessation risk**:
    50% chance of cessation beyond 2021*(25% of the respondents)*
  - **SOFR FRNs would be considered over LIBOR:**
    for cheaper levels *(27%)*, and for diversification of floating benchmarks *(24%)*
  - **LIBOR FRNs are still attractive over SOFR :**
    given the better liquidity in cash markets *(18%)* and derivative markets *(16%)* and volatility of the underlying rate *(16%)*
  - **Preferred issuers of SOFR FRNs:**
    GSEs *(25%),* Financials *(22%)* and US Treasury *(15%)* would be more receptive
  - **SOFR FRNs would take up significant portion (more than a quarter) of their FRN portfolio:**
    beyond 2021 *(38%)*

Source: Bloomberg