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Agency Prepayment Modeling and Outlook
Release of Model Version 21.5 on The Yield Book

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Highlights of Major Model Updates from v21.4 to v21.5

- **P/S Spread Model Enhancements**
  - **Wide WAC spreads assumed to drive below-normal current values**
    - P/S spread widens about 20 bps in next couple of years as WAC spread assumed to contract
  - **Baseline value versus CMM102 is no longer constant**
    - Assumed tighter at times of excess capacity and when flat curve reduces durations
  - **GNMA/FNMA swap adjusted before computing GNMA primary rate**
    - FN – GN Primary rate modeled 20 bps below FN – GN CMM102 on high FN WAC spreads
    - Reduction phased out over next couple of years as WAC spread assumed to contract

- **Cash-Out Model Enhancements**
  - **"Perfect storm" of cash-outs in 2018 considered temporary (thru 2019) in v21.4**
    - Baseline considered to be 2017 levels
    - 2018 drivers – tax cut, housing shortage, excess capacity, Fed rate hikes, underwriting
  - **Excess capacity and Fed hikes (driving HELOC rates) modeled explicitly in v21.5**
  - **More cash-outs assumed on out-of-the-money loans in v21.5**
  - **More cash-out differentiation by servicer (faster non-bank, slower bank) in v21.5**
  - **Assume final VA cash-out NTB rule stricter than interim rule & FHA NTB to follow**

- **Recalibrated Refi Response – Seasoning Ramp, PIW, Burnout, Spec Category Review**
  - **Conventional/GNMA refi ramps recalibrated based on major/multi pool response**
    - Capture faster conventional TBA delivered collateral speeds relative to seasoned/specs
    - PIW effect refined – PIW assumed to partially drive much sharper conventional refi ramp
    - GNMA peak ramp speeds less sensitive to rates, more sensitive to servicer
  - **Flatter S-curve overall; stronger burnout on seasoned GNMAs; pre-HARP slowed**
  - **Specs slowed to slightly above actuals; some catch-up likely if rates remain low**

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Final Rollout of Model Version 21.5

- **August 29, 2019** – First release of a new agency RMBS experimental model (v99). This first release is now in version 98.

- **September 26** – Second release of v99; adjustments made to the first release based on August prepayments, user feedback, and further review of various sectors.

- **October 3** -- The updated agency RMBS prepayment model has been frozen and exposed as v21.5 on The Yield Book. Changes from the second release of v99 were very modest and include only the following:

  - Slightly stronger burnout on premium VA collateral, resulting in about 1-2 bp OAS increase and 0-0.1 year duration extension on GNMA II TBAs versus the second release of v99

- **November 17** -- Model v21.5 becomes the default production agency RMBS prepayment model on The Yield Book

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Mortgage Index Comparisons: v21.5 vs. v21.4

10/2/2018	1-YEAR CPR			Long-Term CPR			OAS			EFF DUR			EFF CONV		
	v21.5	v21.4	Diff	v21.5	v21.4	Diff	v21.5	v21.4	Diff	v21.5	v21.4	Diff	v21.5	v21.4	Diff
Total	22.5	22.9	-0.4	16.7	17.8	-1.1	56.8	46.7	10.1	2.5	2.2	0.4	-1.4	-1.3	-0.1
GNMA	26.9	28.8	-1.9	19.0	20.7	-1.7	50.2	35.1	15.1	2.4	1.9	0.5	-1.3	-1.1	-0.1
FHLM	21.0	20.9	0.1	15.9	16.7	-0.8	59.0	50.8	8.2	2.6	2.3	0.3	-1.5	-1.3	-0.2
FNMA	20.5	20.4	0.1	15.6	16.5	-0.8	60.2	51.9	8.3	2.7	2.3	0.3	-1.4	-1.3	-0.1
30 Year	23.3	23.8	-0.5	16.9	18.2	-1.3	58.3	47.2	11.1	2.6	2.2	0.4	-1.5	-1.3	-0.2
GNMA 30 Yr	26.9	28.8	-1.9	19.0	20.7	-1.7	50.2	35.1	15.1	2.4	1.9	0.5	-1.3	-1.1	-0.1
FNMA 30 Yr	21.3	21.3	0.0	15.8	16.8	-1.1	62.6	53.2	9.4	2.7	2.3	0.3	-1.6	-1.4	-0.2
FHLM 30 Yr	21.9	21.9	0.0	16.1	17.1	-1.1	61.4	52.0	9.4	2.6	2.3	0.3	-1.6	-1.4	-0.2
15 Year	15.6	14.7	0.9	14.7	14.2	0.5	44.1	42.9	1.2	2.5	2.4	0.1	-0.6	-0.6	0.0
FHLM 15 Yr	15.6	14.6	1.0	14.7	14.1	0.6	44.3	43.5	0.8	2.5	2.5	0.0	-0.6	-0.6	0.0
FNMA 15 Yr	15.4	14.4	1.0	14.6	14.1	0.5	44.6	43.6	1.0	2.5	2.5	0.0	-0.6	-0.6	0.0

- The updated model projects lower base case speeds on a flatter long-term S-curve and stronger impairment adjustments on certain attributes (low loan balance, low FICO, investor, etc.), partially offset by much faster refi ramps on new TBA collateral, higher cash-outs from inclusion of HELOC rates in the cash-out model, and lower near-term primary-secondary spreads.

- Conventional durations are generally longer and convexity is slightly less negative on the overall universe as a result of the above changes; but the reverse is true on new TBA collateral, driven by the much faster refi ramps and higher peak speeds.

- GNMA speeds are down more than conventionals on stronger burnout for both FHA and VA collateral (both of which tend to prepay very slowly if they have faced many years of refinancing opportunities and heavy solicitation), lower peak speeds on cuspy coupons, and reduced impact of the GNMA/FNMA CMM102 swap on GNMA primary mortgage rates in the near term.

- For 15-year collateral, the faster ramps on new collateral and stronger cash-outs from consideration of HELOC rates outweigh the impact of the flatter S-curve.

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TBA/Spec Comparisons: v21.5 vs. v21.4

Agency	Coupon	level	Age	Wac	1 Yr Proj Old	New	Diff	LT Proj Old	New	Diff	OAS Old	New	Diff	Eff Duration Old	New	Diff	Eff Convexity Old	New	Diff
v21.5 vs v21.4			10/2/2019																
FNMA TBA	3.0	101.7	4	4.01	21.1	25.1	4.0	17.2	17.0	-0.2	40	41	0	2.7	2.4	-0.2	-2.5	-3.2	-0.6
	3.5	102.7	7	4.41	28.3	33.9	5.5	22.8	22.2	-0.6	59	59	0	1.9	1.7	-0.2	-1.8	-2.2	-0.3
	4.0	103.9	7	4.91	32.6	39.0	6.4	28.0	27.6	-0.5	62	57	-5	1.3	0.9	-0.4	-0.9	-1.3	-0.4
	4.5	105.4	7	5.38	33.0	38.9	5.9	30.0	29.9	-0.1	64	53	-11	1.4	0.8	-0.6	-0.1	-0.5	-0.4
	5.0	107.1	13	5.75	34.7	36.2	1.5	31.0	29.6	-1.4	48	51	3	1.5	1.2	-0.3	0.3	-0.2	-0.5
	5.5	108.3	14	6.30	33.2	35.3	2.1	29.5	29.5	0.1	69	62	-7	2.0	1.5	-0.4	0.4	0.1	-0.3
	6.0	110.7	140	6.54	18.6	15.1	-3.6	17.5	14.1	-3.5	153	187	33	3.4	3.8	0.4	0.2	0.0	-0.1
GNMAII TBA	2.5	101.3	28	3.02	12.6	13.2	0.6	11.5	11.9	0.4	22	31	9	3.5	3.9	0.4	-2.1	-1.9	0.2
	3.0	102.8	4	3.55	22.5	19.4	-3.1	17.6	16.2	-1.4	16	26	10	1.8	2.2	0.4	-2.6	-2.9	-0.3
	3.5	103.6	8	4.01	37.6	36.8	-0.8	24.8	23.4	-1.4	22	34	12	0.9	1.2	0.3	-1.1	-1.8	-0.6
	4.0	104.0	8	4.51	43.3	44.2	0.9	30.6	28.1	-2.5	36	49	13	0.6	0.8	0.1	-0.5	-1.2	-0.7
	4.5	104.6	8	4.99	44.4	44.2	-0.2	35.5	31.1	-4.4	45	65	20	0.7	0.7	0.0	-0.1	-1.0	-0.9
	5.0	105.4	8	5.54	52.1	49.1	-3.0	42.7	36.1	-6.6	5	45	41	0.3	0.2	-0.1	0.6	-1.0	-1.5
	5.5	106.4	135	5.94	17.8	15.9	-1.9	15.3	13.6	-1.7	219	233	13	3.2	3.6	0.4	-0.3	-0.3	0.1
	6.0	106.8	135	6.46	17.7	15.9	-1.8	15.3	13.7	-1.5	259	272	13	3.2	3.6	0.4	-0.2	-0.2	0.1
3.5's of 19	GEN	102.7	4	4.43	29.2	34.7	5.5	22.6	22.3	-0.4	60	60	0	2.0	1.8	-0.2	-1.7	-2.1	-0.4
	LLB	105.9	3	4.20	7.4	6.8	-0.5	10.2	9.9	-0.3	67	75	8	4.4	4.8	0.4	-1.4	-1.3	0.1
	MLB	105.6	3	4.27	9.1	8.7	-0.4	11.4	11.0	-0.4	57	66	9	3.5	4.0	0.4	-1.8	-1.9	-0.1
	HLB	104.9	3	4.30	12.2	11.6	-0.6	13.1	12.5	-0.6	53	61	9	2.9	3.2	0.3	-2.0	-2.3	-0.3
	HHLB	104.5	3	4.36	15.0	14.6	-0.4	14.7	14.1	-0.7	50	56	6	2.5	2.6	0.1	-2.0	-2.4	-0.4
	200K	104.1	4	4.38	16.9	16.9	0.0	15.8	15.0	-0.8	52	58	6	2.3	2.4	0.0	-2.0	-2.4	-0.5
	NY	105.0	4	4.27	14.0	12.1	-1.9	12.8	11.4	-1.4	43	59	16	2.4	3.3	0.8	-2.4	-2.8	-0.4
	New	103.0	1	4.40	27.8	33.1	5.2	23.6	23.2	-0.4	46	40	-6	1.6	1.2	-0.5	-1.7	-2.2	-0.5
4's of 19	GEN	103.9	5	4.86	30.2	35.8	5.6	24.4	23.9	-0.5	76	76	-1	1.7	1.5	-0.2	-1.1	-1.4	-0.3
	LLB	108.3	4	4.58	9.3	8.9	-0.4	11.5	11.1	-0.5	68	77	8	3.8	4.1	0.4	-1.3	-1.3	0.0
	MLB	107.7	4	4.63	12.4	11.3	-1.1	13.4	12.4	-1.0	56	68	11	2.8	3.2	0.4	-1.6	-1.9	-0.2
	HLB	106.5	5	4.71	16.8	16.0	-0.8	15.8	14.7	-1.1	60	69	9	2.2	2.4	0.2	-1.5	-1.9	-0.4
	HHLB	106.0	5	4.81	21.1	20.8	-0.4	18.5	17.1	-1.4	51	58	7	1.7	1.7	0.0	-1.3	-1.8	-0.6
	200K	105.7	5	4.80	23.6	24.7	1.1	20.0	18.7	-1.3	49	53	4	1.5	1.4	-0.1	-1.2	-1.7	-0.6
	NY	107.3	5	4.67	20.5	18.5	-2.0	16.4	14.0	-2.4	36	58	22	1.5	2.4	0.9	-1.4	-2.1	-0.6
	New	104.4	1	4.90	29.1	35.0	5.9	27.7	27.7	0.0	56	42	-14	1.6	0.9	-0.7	-0.7	-1.1	-0.4
4.5's of 18	GEN	105.4	14	5.12	30.9	32.5	1.6	24.5	23.1	-1.5	88	93	5	1.6	1.6	0.0	-0.6	-1.0	-0.4
	LLB	110.5	14	5.02	13.6	12.5	-1.0	13.2	12.5	-0.7	66	76	10	3.3	3.7	0.4	-1.1	-1.1	-0.1
	MLB	109.3	14	5.00	16.9	14.9	-1.9	15.2	14.0	-1.2	61	75	14	2.3	2.8	0.5	-1.2	-1.5	-0.2
	HLB	108.1	14	5.01	21.9	19.6	-2.3	17.9	16.3	-1.6	59	73	14	1.7	2.1	0.4	-1.0	-1.5	-0.5
	HHLB	107.4	14	5.07	25.8	23.4	-2.4	20.9	18.9	-2.0	56	68	12	1.4	1.6	0.2	-0.7	-1.3	-0.6
	200K	107.0	14	5.09	27.8	25.9	-2.0	22.5	20.1	-2.3	56	68	11	1.3	1.4	0.2	-0.6	-1.2	-0.7
	NY	108.9	13	4.99	24.2	20.4	-3.8	18.7	15.3	-3.4	41	72	31	1.2	2.3	1.1	-0.7	-1.4	-0.7
	New	105.8	1	4.90	29.1	35.0	5.9	27.7	27.7	0.0	13	-3	-16	1.1	0.3	-0.8	-0.3	-0.8	-0.5

Source: The YieldBook, Citi

Mortgage Index Comparisons: v21.5 vs. v98

10/2/2018	1-YEAR CPR			Long-Term CPR			OAS			EFF DUR			EFF CONV		
	v21.5	v98	Diff	v21.5	v98	Diff	v21.5	v98	Diff	v21.5	v98	Diff	v21.5	v98	Diff
Total	22.5	22.6	-0.1	16.7	16.4	0.3	56.8	58.3	-1.5	2.5	2.6	-0.1	-1.4	-1.4	0.0
GNMA	26.9	26.9	0.0	19.0	19.0	0.0	50.2	48.4	1.8	2.4	2.3	0.1	-1.3	-1.4	0.1
FHLM	21.0	21.2	-0.2	15.9	15.5	0.4	59.0	61.7	-2.7	2.6	2.7	-0.1	-1.5	-1.5	0.0
FNMA	20.5	20.7	-0.2	15.6	15.3	0.3	60.2	62.7	-2.5	2.7	2.8	-0.1	-1.4	-1.4	0.0
30 Year	23.3	23.4	-0.1	16.9	16.6	0.3	58.3	59.7	-1.4	2.6	2.6	-0.1	-1.5	-1.5	0.0
GNMA 30 Yr	26.9	26.9	0.0	19.0	19.0	0.0	50.2	48.4	1.8	2.4	2.3	0.1	-1.3	-1.4	0.1
FNMA 30 Yr	21.3	21.5	-0.2	15.8	15.4	0.4	62.6	65.3	-2.7	2.7	2.8	-0.1	-1.6	-1.6	0.0
FHLM 30 Yr	21.9	22.1	-0.2	16.1	15.7	0.4	61.4	64.3	-2.9	2.6	2.7	-0.1	-1.6	-1.6	0.0
15 Year	15.6	15.5	0.1	14.7	14.5	0.2	44.1	45.5	-1.4	2.5	2.6	-0.1	-0.6	-0.6	0.0
FHLM 15 Yr	15.6	15.5	0.1	14.7	14.5	0.2	44.3	45.6	-1.3	2.5	2.6	0.0	-0.6	-0.6	0.0
FNMA 15 Yr	15.4	15.3	0.1	14.6	14.4	0.2	44.6	45.9	-1.3	2.5	2.6	-0.1	-0.6	-0.6	0.0

- Model v21.5 projects faster long-term base case speeds than the initial experimental model (now v98) released in August. Slower-than-expected speeds on older vintages are now attributed more to capacity-driven lags and impairment when applicable, and less to general burnout. While the stronger burnout assumption brought TBA durations more in line with empiricals, it was nevertheless somewhat speculative and seemed inconsistent with recent developments that have tended to streamline the refinancing process.

- Conventional durations are generally shorter and convexity is slightly more negative on the overall universe, but particularly so on new TBA collateral, as a result of the revisions from v98 to v21.5.

- GNMA speeds are mixed, with generally faster speeds on lower coupons but slower speeds on higher coupons due to stronger impairment on the lowest credit scores and stronger burnout on FHA and VA collateral. FHA/VA borrowers that have had many years to refinance into a more favorable loan under heavy solicitation but have not done so tend to prepay very slowly. Neither model v21.4 nor v98 seemed to adequately capture this.

- Adjustments from v21.5 to v98 for 15-year collateral were similar to those for 30-year collateral.

Source: The YieldBook, Citi

TBA/Spec Comparisons: v21.5 vs. v98

| Agency	Coupon	level	Age	Wac	1 Yr Proj Old	New	Diff	LT Proj Old	New	Diff	OAS Old	New	Diff	Eff Duration Old	New	Diff	Eff Convexity Old	New	Diff
FNMA TBA	3.0	101.7	4	4.01	26.2	25.1	-1.1	16.4	17.0	0.6	46	41	-5	2.8	2.4	-0.4	-3.0	-3.2	-0.2
	3.5	102.7	7	4.41	32.9	33.9	1.0	20.6	22.2	1.6	66	59	-8	2.1	1.7	-0.4	-2.1	-2.2	0.0
	4.0	103.9	7	4.91	37.0	39.0	2.0	25.5	27.6	2.1	70	57	-13	1.4	0.9	-0.4	-1.4	-1.3	0.1
	4.5	105.4	7	5.38	37.3	38.9	1.5	28.2	29.9	1.7	66	53	-13	1.2	0.8	-0.3	-0.7	-0.5	0.1
	5.0	107.1	13	5.75	35.5	36.2	0.6	28.6	29.6	1.0	61	51	-10	1.3	1.2	-0.2	-0.2	-0.2	0.1
	5.5	108.3	14	6.30	34.4	35.3	0.9	28.5	29.5	1.0	73	62	-12	1.7	1.5	-0.2	0.0	0.1	0.0
	6.0	110.7	140	6.54	15.1	15.1	-0.1	14.1	14.1	0.0	187	187	0	3.8	3.8	0.0	0.0	0.0	0.0
GNMAII TBA	2.5	101.3	28	3.02	13.2	13.2	0.0	11.9	11.9	0.0	31	31	0	3.9	3.9	0.0	-1.9	-1.9	0.0
	3.0	102.8	4	3.55	20.6	19.4	-1.2	15.8	16.2	0.4	30	26	-4	2.4	2.2	-0.3	-2.8	-2.9	-0.1
	3.5	103.6	8	4.01	35.9	36.8	0.9	21.9	23.4	1.5	40	34	-6	1.5	1.2	-0.3	-1.9	-1.8	0.1
	4.0	104.0	8	4.51	43.0	44.2	1.2	27.3	28.1	0.8	53	49	-4	0.9	0.8	-0.1	-1.4	-1.2	0.1
	4.5	104.6	8	4.99	44.1	44.2	0.1	31.8	31.1	-0.8	62	65	3	0.6	0.7	0.1	-1.0	-1.0	0.0
	5.0	105.4	8	5.54	49.4	49.1	-0.3	37.9	36.1	-1.8	34	45	11	0.1	0.2	0.1	-0.8	-1.0	-0.1
	5.5	106.4	135	5.94	17.1	15.9	-1.2	14.6	13.6	-1.0	225	233	8	3.3	3.6	0.3	-0.4	-0.3	0.1
	6.0	106.8	135	6.46	16.9	15.9	-1.0	14.6	13.7	-0.9	264	272	8	3.4	3.6	0.2	-0.3	-0.2	0.1
3.5's of 19	GEN	102.7	4	4.43	34.0	34.7	0.7	20.6	22.3	1.6	68	60	-8	2.2	1.8	-0.4	-2.0	-2.1	0.0
	LLB	106.0	3	4.20	6.9	6.8	-0.1	9.9	9.9	0.0	74	74	0	4.9	4.8	-0.1	-1.2	-1.3	-0.1
	MLB	105.6	3	4.27	8.8	8.7	-0.1	11.0	11.0	0.0	66	65	-1	4.1	3.9	-0.2	-1.8	-1.9	-0.2
	HLB	105.0	3	4.30	11.8	11.6	-0.2	12.4	12.5	0.1	62	59	-3	3.4	3.2	-0.2	-2.1	-2.3	-0.2
	HHLB	104.6	3	4.36	14.7	14.6	-0.1	13.9	14.1	0.2	58	55	-3	2.8	2.6	-0.3	-2.2	-2.4	-0.2
	200K	104.1	4	4.38	16.8	16.9	0.1	14.7	15.0	0.3	61	56	-4	2.7	2.3	-0.3	-2.2	-2.4	-0.2
	NY	105.2	4	4.27	14.1	12.1	-2.0	11.4	11.4	0.0	59	57	-2	3.5	3.2	-0.2	-2.5	-2.8	-0.3
	New	103.0	1	4.40	32.6	33.1	0.4	21.7	23.2	1.5	49	40	-9	1.7	1.2	-0.5	-2.2	-2.2	0.0
4's of 19	GEN	103.9	5	4.86	34.6	35.8	1.2	22.1	23.9	1.8	86	76	-10	1.9	1.5	-0.4	-1.5	-1.4	0.0
	LLB	108.4	4	4.58	8.9	8.9	-0.1	11.0	11.1	0.0	75	74	-1	4.2	4.1	-0.1	-1.3	-1.3	-0.1
	MLB	107.8	4	4.63	11.4	11.3	-0.1	12.4	12.4	0.0	68	66	-2	3.3	3.2	-0.2	-1.7	-1.9	-0.1
	HLB	106.6	5	4.71	16.0	16.0	0.0	14.5	14.7	0.2	70	67	-3	2.6	2.4	-0.2	-1.8	-1.9	-0.1
	HHLB	106.1	5	4.81	20.6	20.8	0.2	16.8	17.1	0.4	62	57	-5	2.0	1.7	-0.3	-1.8	-1.8	-0.1
	200K	105.8	5	4.80	24.3	24.7	0.4	18.2	18.7	0.5	58	52	-6	1.7	1.4	-0.4	-1.7	-1.7	0.0
	NY	107.5	5	4.67	20.1	18.5	-1.5	13.8	14.0	0.2	56	53	-3	2.6	2.3	-0.3	-1.9	-2.1	-0.2
	New	104.3	1	4.90	33.8	35.0	1.2	26.1	27.7	1.6	55	44	-11	1.3	0.9	-0.4	-1.3	-1.1	0.1
4.5's of 18	GEN	105.4	14	5.12	32.0	32.5	0.6	21.8	23.1	1.3	102	93	-9	1.9	1.6	-0.2	-1.1	-1.0	0.1
	LLB	110.6	14	5.02	12.7	12.5	-0.2	12.5	12.5	0.0	74	74	0	3.7	3.7	0.0	-1.1	-1.1	0.0
	MLB	109.4	14	5.00	15.2	14.9	-0.3	14.0	14.0	0.0	73	73	-1	2.9	2.8	-0.1	-1.4	-1.5	0.0
	HLB	108.3	14	5.01	19.8	19.6	-0.2	16.2	16.3	0.2	72	70	-3	2.2	2.1	-0.1	-1.5	-1.5	0.0
	HHLB	107.5	14	5.07	23.6	23.4	-0.2	18.6	18.9	0.3	69	65	-4	1.8	1.6	-0.2	-1.3	-1.3	0.0
	200K	107.1	14	5.09	26.0	25.9	-0.1	19.8	20.1	0.4	69	65	-4	1.6	1.4	-0.2	-1.2	-1.2	0.0
	NY	109.0	13	4.99	21.6	20.4	-1.3	15.2	15.3	0.1	71	69	-2	2.4	2.3	-0.1	-1.4	-1.4	0.0
	New	105.8	1	4.90	33.8	35.0	1.2	26.1	27.7	1.6	10	-3	-13	0.8	0.3	-0.5	-1.0	-0.8	0.2

Source: The YieldBook, Citi

P/S SPREAD MODEL ENHANCEMENTS

P/S Spread Sub-Model Overhauled for Model v21.5

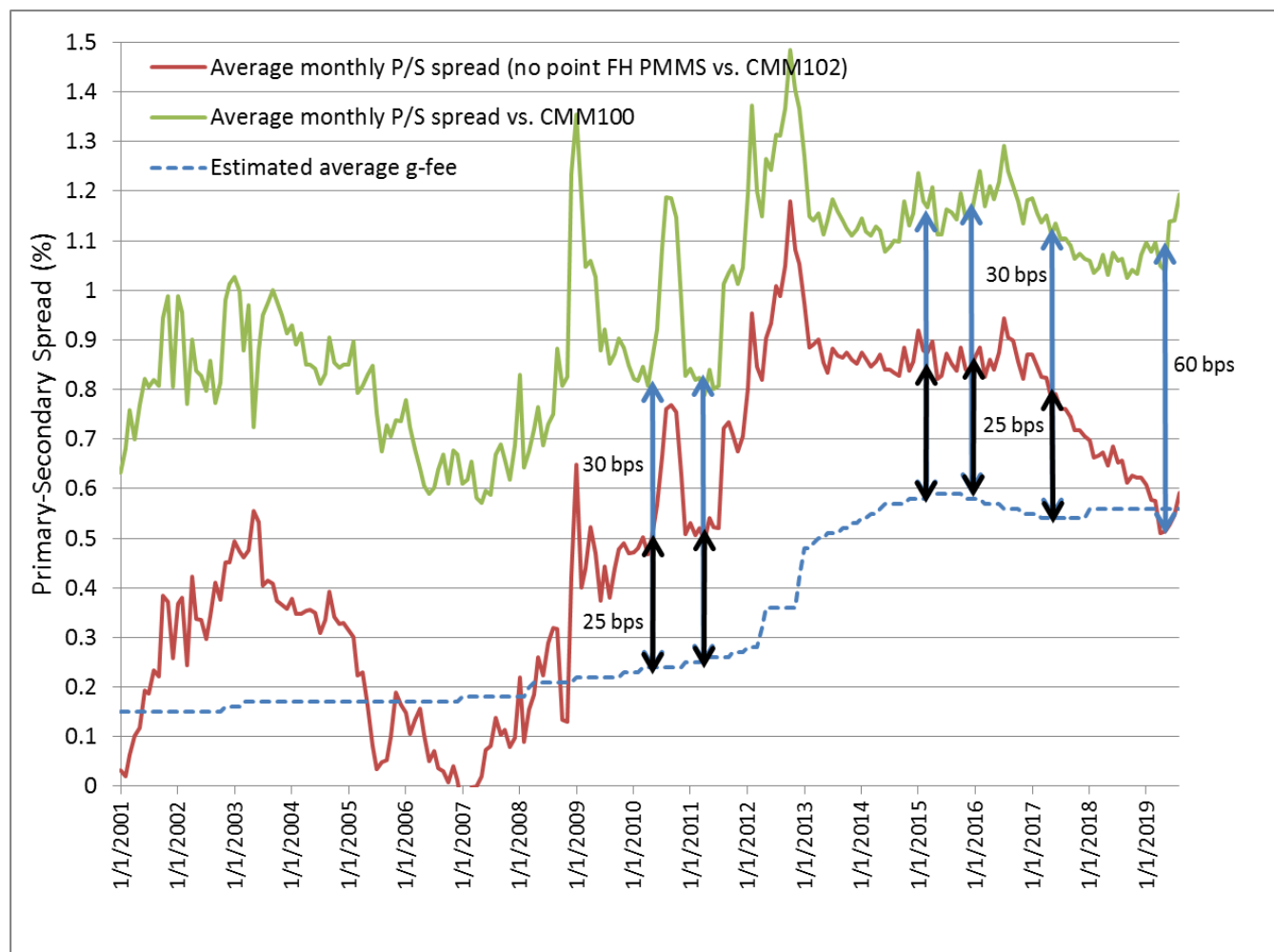**Model v21.4 P/S Spread Model Sep 19 Close**
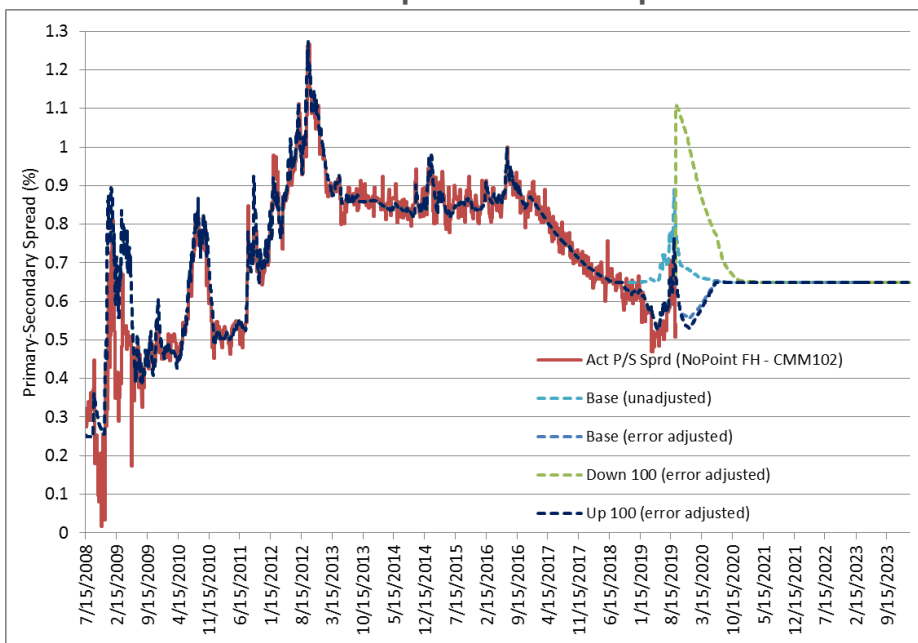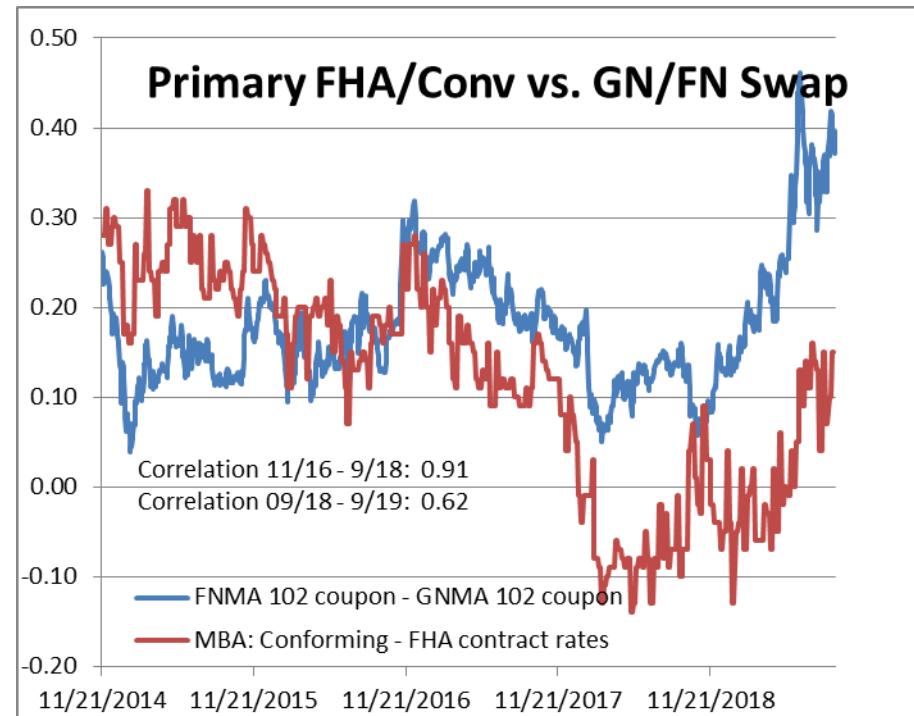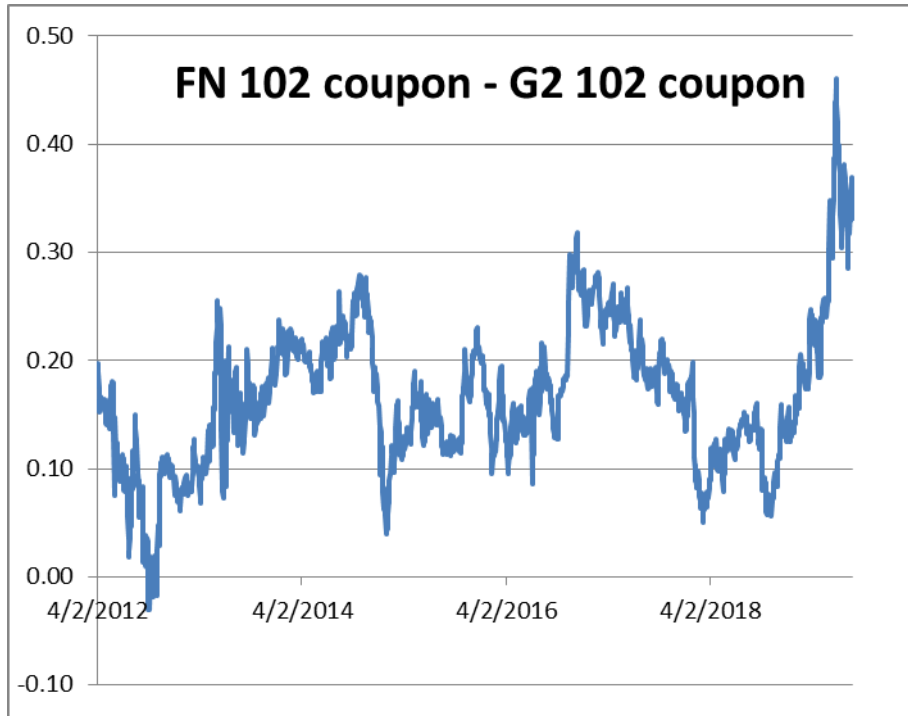

Model v21.5 P/S Spread Model Sep 19 Close
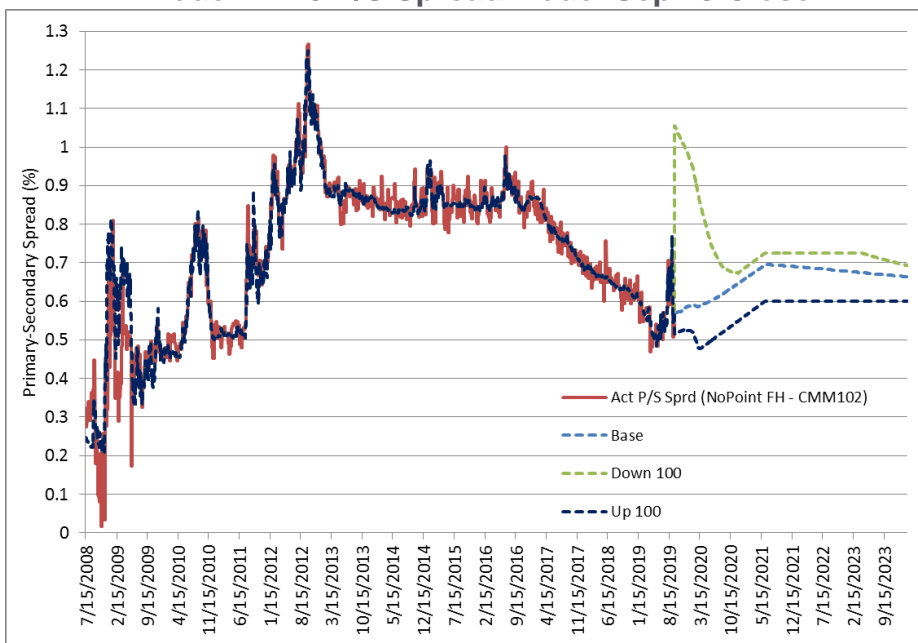
- The primary-secondary spread model in model v21.4 consists of a long-term baseline primarily driven by g-fees, with a short term adjustment based on the estimated refinancible universe and assumed capacity constraints.

- The baseline P/S spread level (relative to CMM102) fell well below the 21.4 baseline before the recent rally. We assume this was driven by intense originator competition and a more compressed TBA stack from high WAC spreads and a flat curve. We assume high WAC spreads account for about 20 bps of P/S spread tightening vs. CMM102.

- For model v21.5, the baseline level itself now depends on the estimated refinancible universe and the shape of the curve; the result tends to be tighter spreads at times of excess capacity, more widening in modest rallies, and a lower spread when the curve is flat.

- Both v21.4 and v21.5 add an error term to the model-estimated P/S spread, equal to the average difference between actual and model P/S spreads over the past 60 days, to obtain an "error-adjusted" value. The adjustment remains for three months and amortizes to zero over the subsequent six months (v21.4) or twelve months (v21.5).

Source: Freddie Mac

P/S Spread Tighter vs. CMM102 Recently, But Not CMM100

- Until fairly recently, g-fee-adjusted P/S spread using CMM102 has been ~25 bps, with a ~30 bps spread between CMM102 and CMM100

- The spread between CMM102 and CMM100 has widened to 60 bps on flatter curve and more negatively convex TBA deliverables (higher WAC spreads, higher loan size and worse servicer mix)

- Model version 21.5 reverses 20 bps of this widening on normalizing WAC spreads for TBA deliveries over the next couple of years, causing CMM102-based P/S spread to widen by the same amount.

- Uncertainty in future P/S spreads is driven by advances in digital underwriting, GSE reform, and the expiration in October 2021 of the legislated 10 bps g-fee pass-through from the GSEs to the U.S. Treasury.

Legend:
- Average monthly P/S spread (no point FH PMMS vs. CMM102)
- Average monthly P/S spread vs. CMM100
- Estimated average g-fee

Y-axis: Primary-Secondary Spread (%)

Annotations: 30 bps, 25 bps, 30 bps, 25 bps, 60 bps

Source: Freddie Mac, Fannie Mae, FHFA

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GN/FN Swap Less Indicative of GN/FN Primary Rates

FN 102 coupon - G2 102 coupon

Primary FHA/Conv vs. GN/FN Swap

Correlation 11/16 - 9/18: 0.91
Correlation 09/18 - 9/19: 0.62

FNMA 102 coupon - GNMA 102 coupon
MBA: Conforming - FHA contract rates

- **The GNMA primary rate is especially important for new WALA GNMAs refinancing into another FHA/VA/RHS loan. Model version 21.4 introduced the GNMA/FNMA swap as a driver for relative primary rates for FHA/VA and conventional loans, as seemed reasonable and was supported by recent historical correlation at that time.**

- **The GNMA primary rate is modeled in v21.4 as the FNMA primary rate minus the GNMA/FNMA swap, which is defined as CMM102 (FNMA) minus CMM102 computed equivalently using the GNMA II TBA coupon stack.**

- **Lower recent correlation may be explained in part by much higher WAC spreads on conventional TBA deliveries, which inflate FNMA CMM102, and in part by pricing for worsening credit metrics on FHA loans.**

- **To account for high WAC spreads on conventional TBA deliveries, model version v21.5 first subtracts 20 bps from the GNMA/FNMA swap; the modified value is then subtracted from the FNMA primary rate to obtain the GNMA primary rate. The 20 bps adjustment is phased out over the next few years as the WAC spread is assumed to normalize.**

11   Source: Freddie Mac, MBA

CASH-OUT MODEL ENHANCEMENTS

Cash-Out Activity Remains Strong on Relative Basis
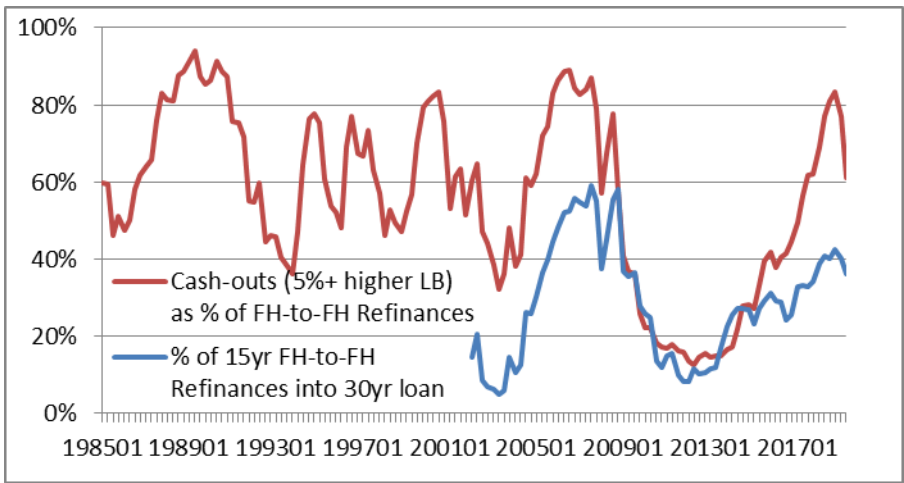
The cash-out fraction of refis and the fraction of 15-year loan refinances into 30-year loans (which are often done to facilitate a cash-out) continued to push higher in 2018, approaching all-time highs, and declining only modestly into the recent rally.

GNMA cash-outs have remained particularly strong throughout 2018 and into 2019 in spite of higher rates last year, supported by strong home price appreciation over many years.
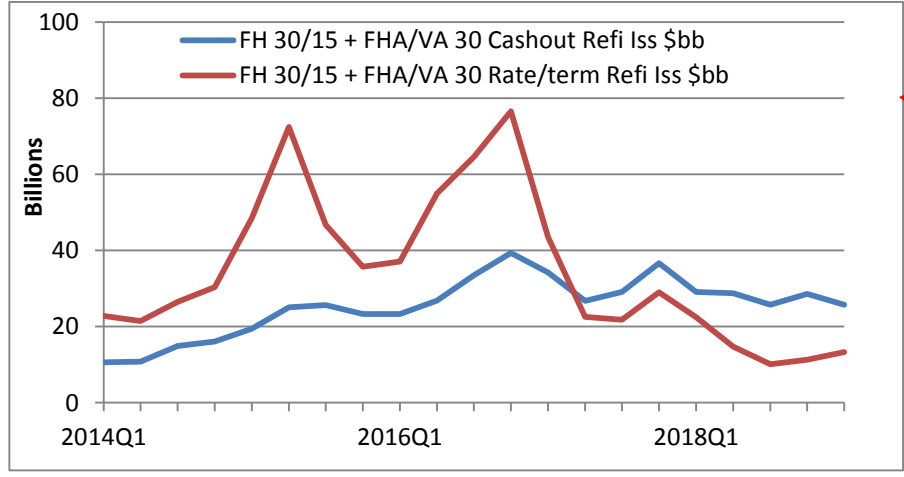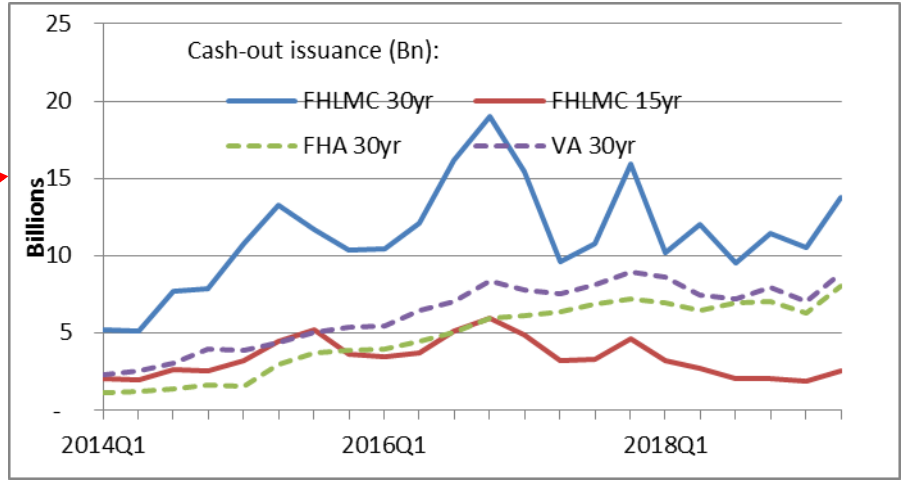
The absolute volume of agency cash-out issuance remained at almost three times 2014 levels in 2018, with rate/term refis falling substantially below 2014 levels following the backup in 2018 and pressure on early GNMA streamline refis. Rate-term refis have recovered somewhat during the 2019 rally, but cash-outs have kept up the pace; many borrowers are likely combining a rate and cash-out driven refinance.

Source: eMBS, Freddie Mac

Higher Rates on HELOCs Likely Driving Cash-Outs

	2014	2017-2018	Q1 2019
HELOC Share	70%	55%	50%
Mortgage Rate	4.5%	4% to 4.5%	4.25%
Prime Rate	3.25%	4% to 5%	5.5%

Source: Black Knight (see Feb 2019 and May 2018 Mortgage Monitor)

The share of home equity tapped via HELOC was about 70% in 2014 when fixed 30-year mortgage rates rose to the low-to-mid 4s and the bank prime rate was 3.25%.

When fixed mortgage rates reached similar levels again in early 2018, with prime approaching 5%, the HELOC share was in the mid-50s.

In Q1 2019, with prime at 5.5% and fixed rates generally in the mid 4s, the HELOC share fell to 50%.

The change in the bank prime rate relative to fixed mortgage rates is likely an important reason for a higher share of borrowers extracting equity using a cash-out refinance as opposed to a HELOC.
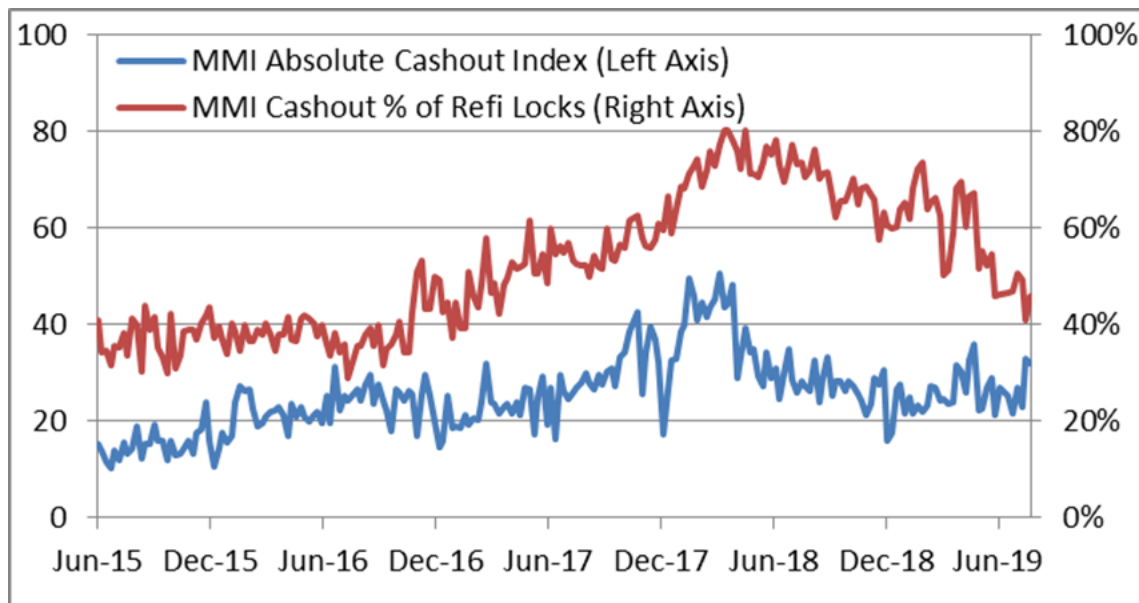
Source: OpenClose, MortgageDaily

Cash-out refinancing rate locks as recorded by the MMI cash-out refinancing index increased sharply as the Fed began to raise rates more aggressively. Other drivers at the time were looser underwriting on higher DTI loans from both FHA and the GSEs and the LLPA waiver from Fannie Mae for loans that meet student loan cash-out refinance requirements.

Cash-Out LTVs and DTIs Rising, Credit Scores Falling
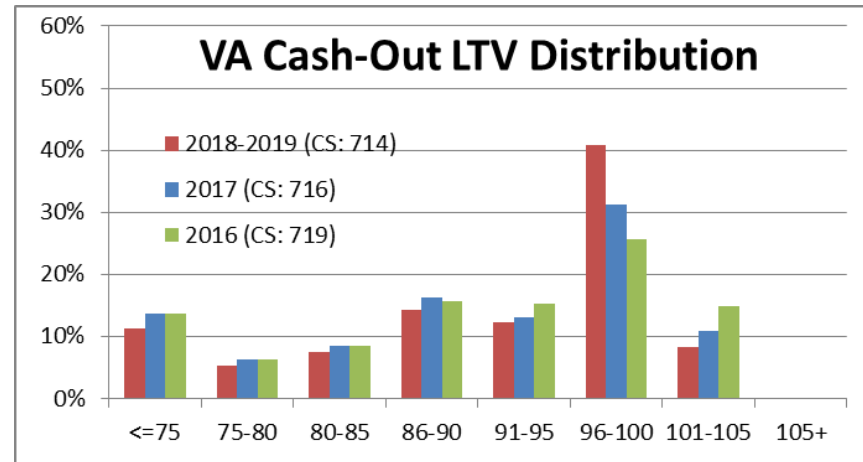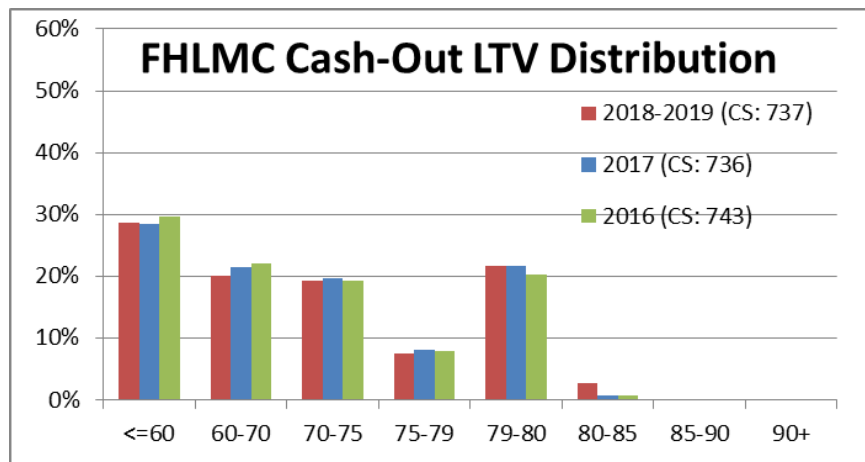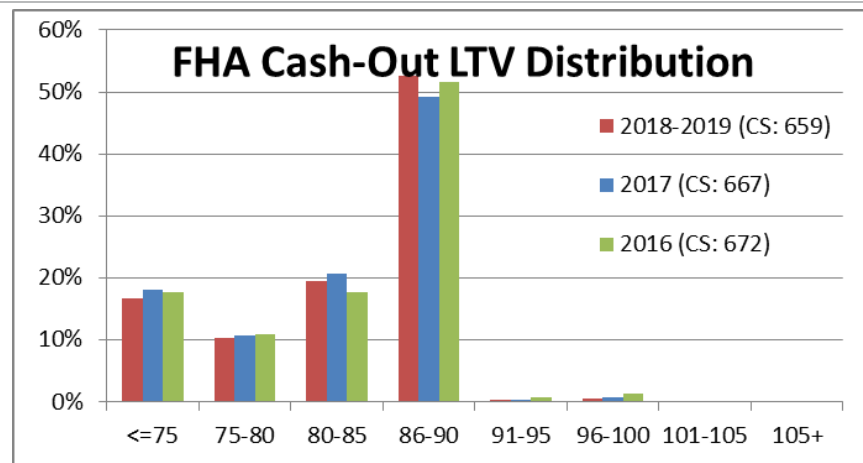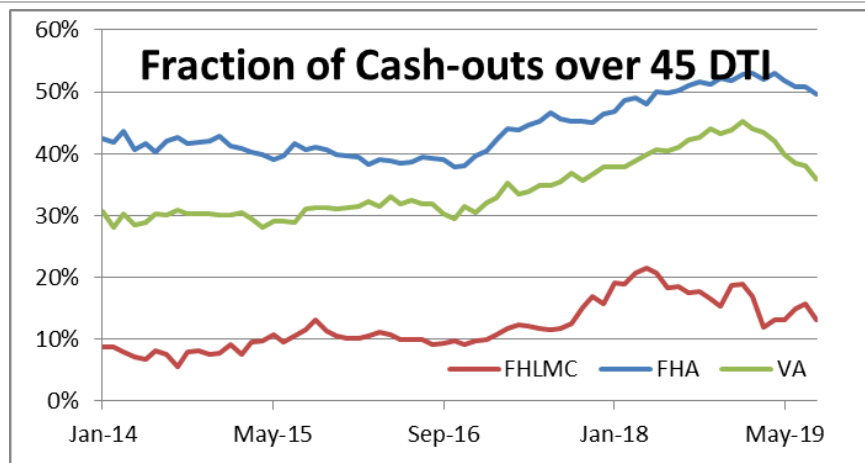
- **Higher-DTI cash-out loans began to increase as a fraction of cash-out refinances in 2016 and 2017, as rates increased and FHA and GSEs reduced obstacles to higher DTI loans.**

- **While new conventional cash-out loans are spread out across LTV buckets, a significant plurality of FHA and VA borrowers cash-out to the maximum LTV permitted.**

- **Overall, credit metrics have deteriorated on cash-out loans recently, with higher DTIs, worsening credit scores, and more borrowers cashing out to the maximum LTV. FHA, VA, GNMA and the GSEs have taken various steps to address this (e.g., cash reserve requirements, manual underwriting, lower LTV limits); further details below.**

Source: eMBS

Impact of Major Changes to v21.5 Cash-Out Model

FHLMC 3.5s of 16 Long Term Cashout S-Curve
- Model 21.4
- Model 21.5

High HELOC rates relative to fixed mortgage rates

Higher cash-outs on discount coupons and at times of excess capacity

FHLMC 3.5s of 2016 Cash-Out Projections
- Model v21.4
- Model v21.5 Prime=5.25%
- Model v21.5 Prime=3.75%
- Model v21.5 Prime=3.25%

30-yr primary rate ~3.75%
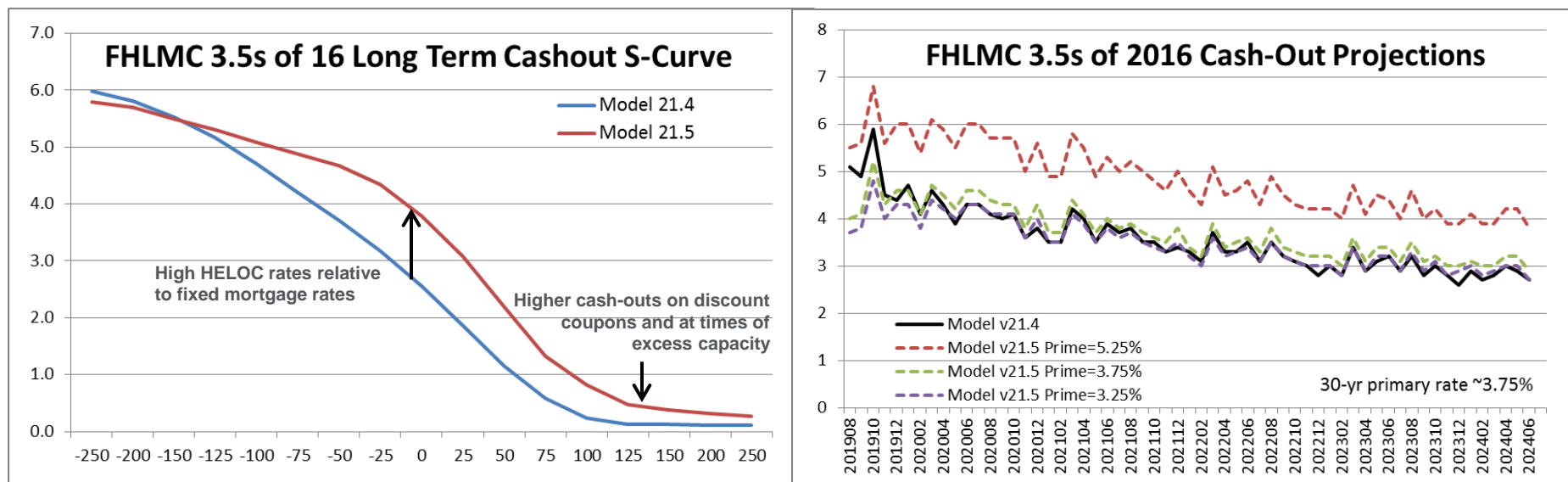
- **Model version 21.4 assumed that the apparent cash-out surge starting in late 2017-early 2018 was largely driven by temporary factors and would normalize by 2020.**

- **The most important of these factors in our view is the relative level of HELOC rates vs. fixed 30-year mortgage rates; this has been modeled explicitly in v21.5.**

- **Model v21.5 projections are similar to v21.4 longer-term when prime rates are at about the same level as fixed 30-year mortgage rates.**

- **Other important changes to the cash-out model are the elimination of severe lock-in at high disincentives if sufficient cash can be obtained, and to account for more aggressive cash-out solicitation at times of excess originator capacity.**

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Cash-Outs Are Material Even on Deep Discount Loans

Rate Scenario: 150 bps backup from Aug 23 close

Rate Scenario: 150 bps backup from Aug 23 close

FNMA 3s of 2013 Projected Cashout CPR — Model v21.5, Model v21.4

GNMA II 3s of 2013 Projected Cashout CPR — Model v21.5, Model v21.4
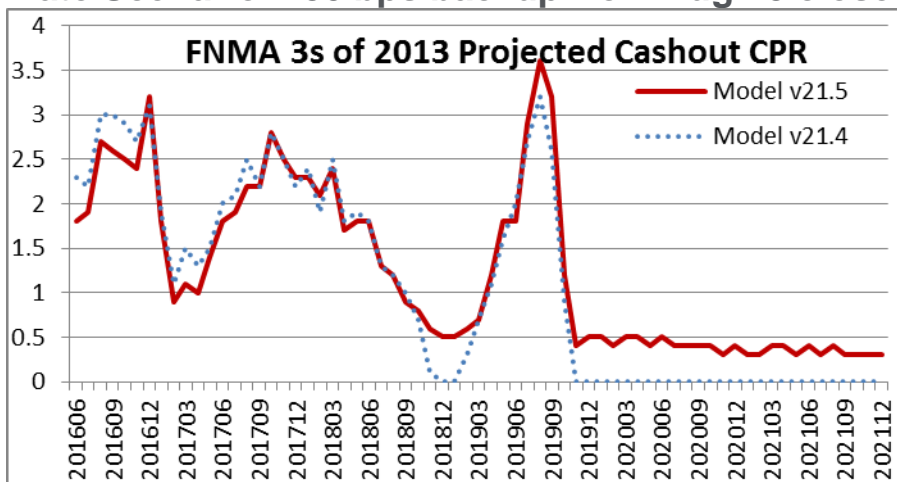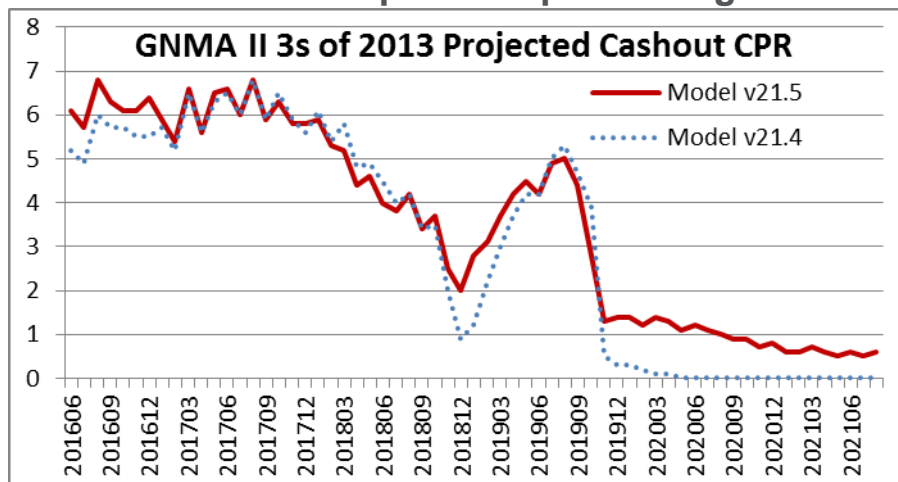
"*She said she is happy that the roughly $75,000 in cash will help her pay off a credit card and complete a home addition, even though she had to trade in a mortgage with a 3.625% rate for one with a 5.75% rate*" – The Wall Street Journal, "*Borrowers Are Tapping Their Homes for Cash, Even as Rates Rise,*" November 25, 2018, referring to a borrower who recently completed a cash-out refi

- **Black Knight indicated in its May 2018 and Feb 2019 Mortgage Monitors that in Q1 2018, 45% of borrowers took a higher rate on their cash-out than on their original loan, by an average of 70 bps; by Q4 2018, about two-thirds took a higher rate, the largest share ever recorded.**

- **Model v21.4 generally assumes that cash-outs are immaterial for disincentives exceeding 125-150 bps for conventionals (both due to assumed affordability issues and availability of HELOCs) and 150-200 bps for FHA/VA loans (largely due to assumed affordability issues).**

- **However, based on anecdotes like the above quote and actual speeds during the backups in 2017 and 2018, we believe the model should project at least modest cash-outs for high disincentives.**

Source: The Wall Street Journal, www.blackknightinc.com

More Model Cash-Out Adjustments by Servicer in v21.5

FNMA 3s of 2016 Generic CPR

GNMA II 3s of 2016 Generic CPR

FNMA 3s of 2013 Generic CPR

GNMA II 3s of 2013 Generic CPR

Legend for all charts:
- Major Bank/Credit Union
- Major Non Bank
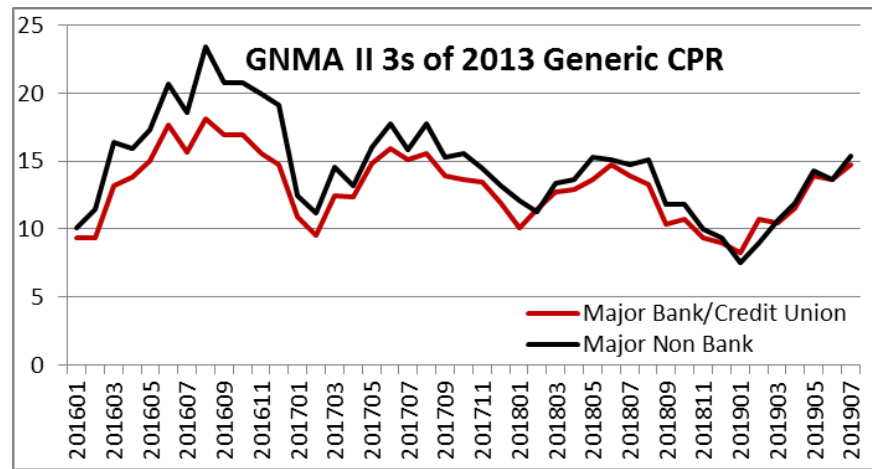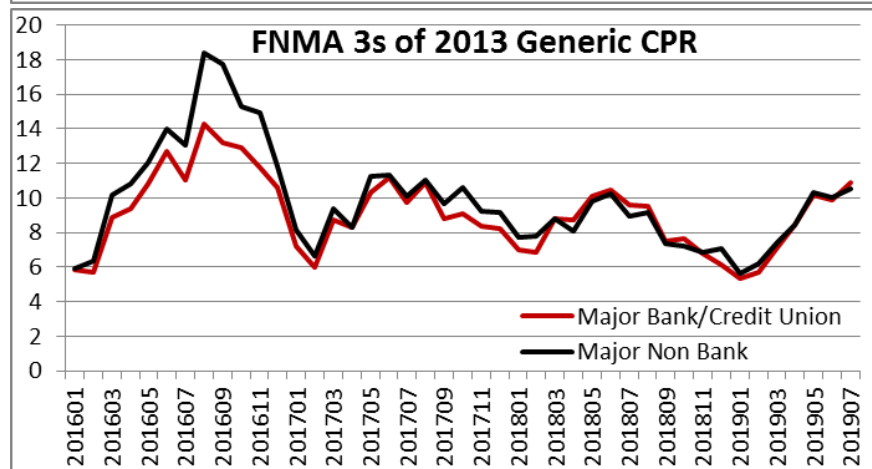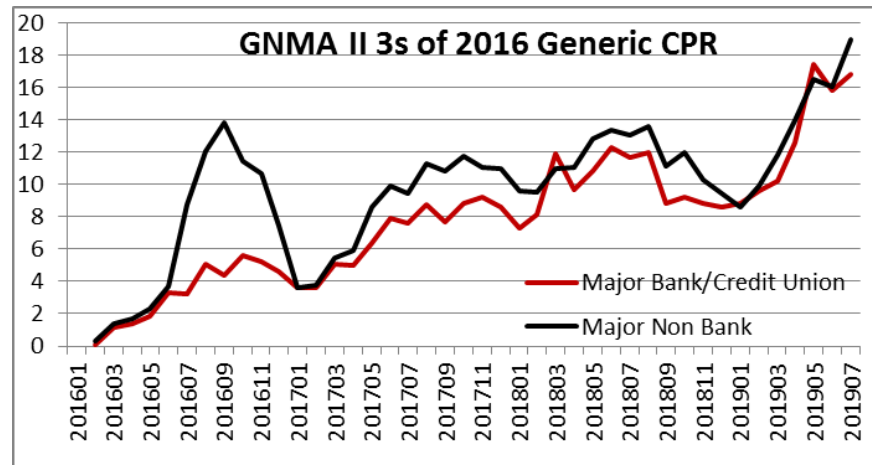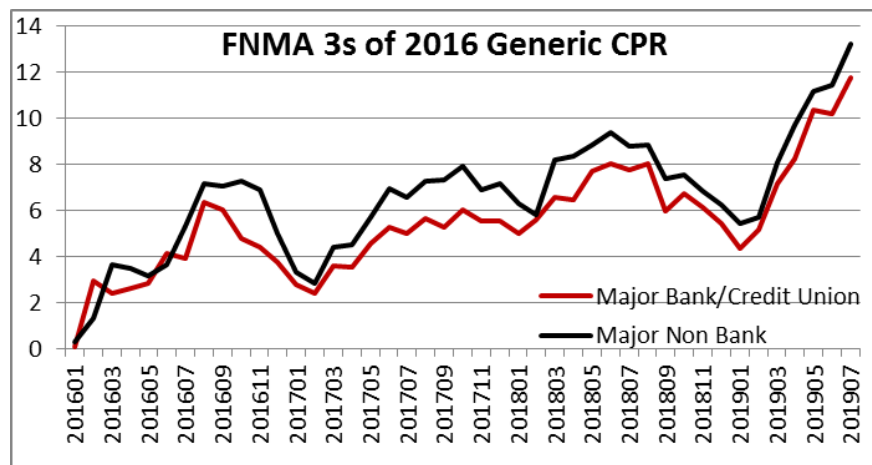
- Most model servicer adjustments apply to rate-and-term refinances only. Quicken is the only significant servicer with cash-out adjustments in the current production model (v21.4).

- There is clear evidence of differentiation in discount speeds by servicer, particularly on GNMA collateral, as shown by the actual speeds in the above charts.

- Cash-out adjustments have been made for several servicers in model version 21.5, as indicated on the page entitled "Servicer Refi Adjustment Changes" below.

Model Impact of New GNMA / FHA / VA / GSE Cash Out Regs
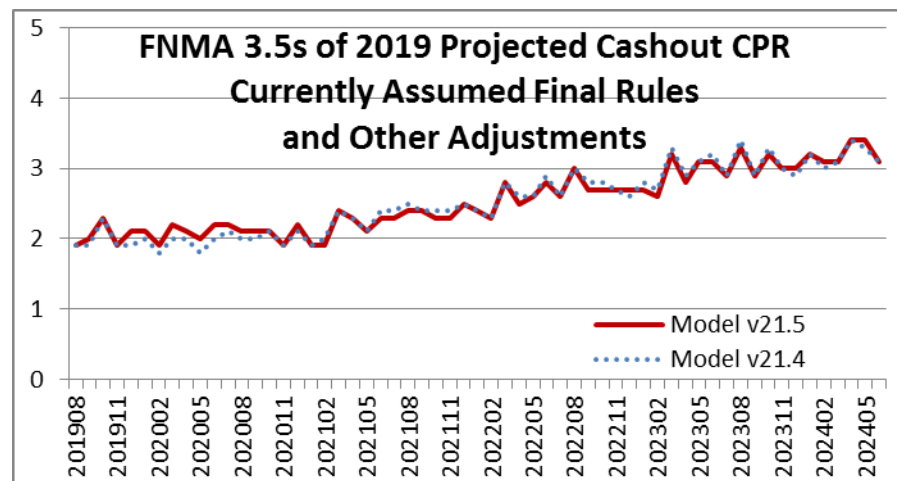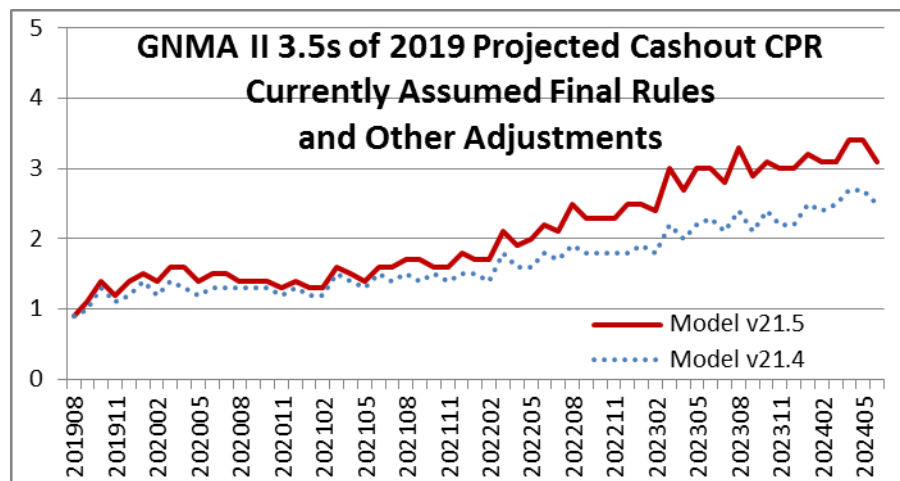
- Model version 21.4 assumes that the final VA cash-out NTB rule would be followed by a similar FHA rule, moving the GNMA cash-out S-curve closer to conventionals.

- The VA interim final cash-out NTB rule, which likely had minimal impact, remains in place. However, GNMA no longer permits cash-outs above 90 LTV in deliverable pools. Model v21.5 assumes rates offered to borrowers on such cash-outs will now be higher, since custom VA cash-out pools should trade at a material discount to TBAs.

- FHA has reduced its maximum LTV on cash-out loans from 85 to 80; accordingly, the model shifts the cash-out LTV multiplier by 5 LTV, but also assumes some pent-up demand at lower LTVs.

- Conventional cash-outs have been slowed in model v21.5 as well, particularly for higher LTVs and DTIs. FHA's action prevents conventional borrowers from taking advantage of a higher FHA maxImium LTV versus the GSEs. And in December 2018, FNMA began to require six months of cash reserves for cash-out loans above 45 DTI.

- At present it is not clear what additional steps, if any, will be taken to contain cash-out lending. While LTV limits are lower, there is still nothing to prevent non-economic cash-outs that may be aggressively marketed to cash-strapped borrowers. At this point, the model continues to assume that additional NTB requirements to contain cash-out lending, particularly to FHA and VA borrowers, will ultimately be implemented.

RECALIBRATION OF REFINANCING RESPONSE

Faster v21.5 Peak Speeds on FNMA Majors/FHLMC MLGs
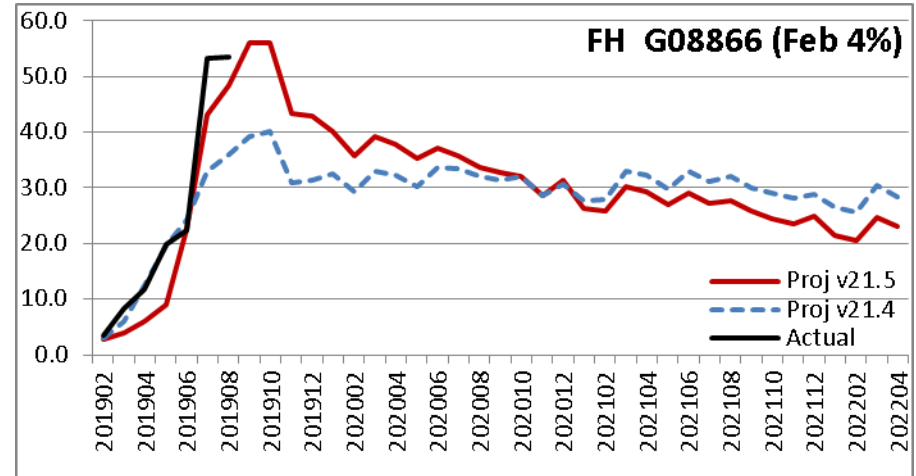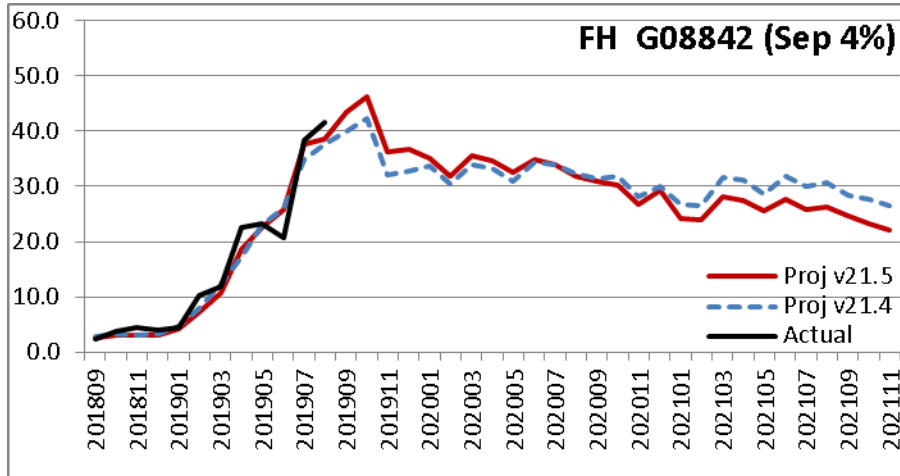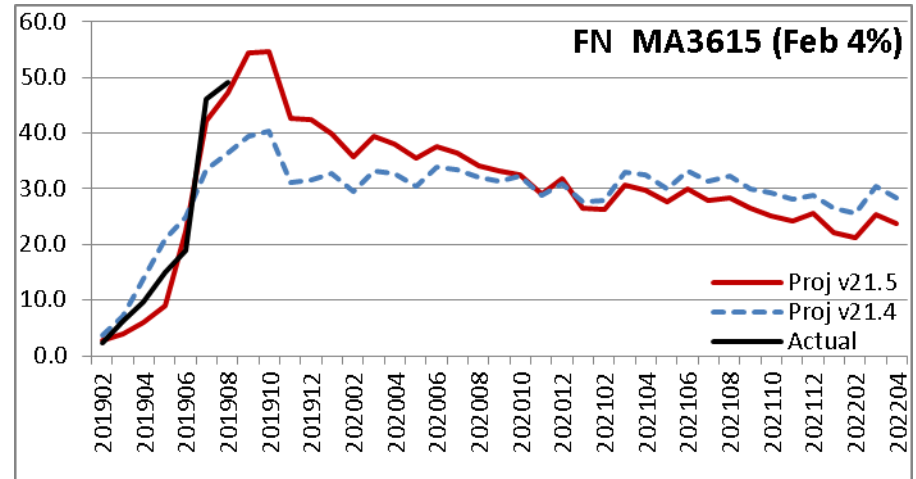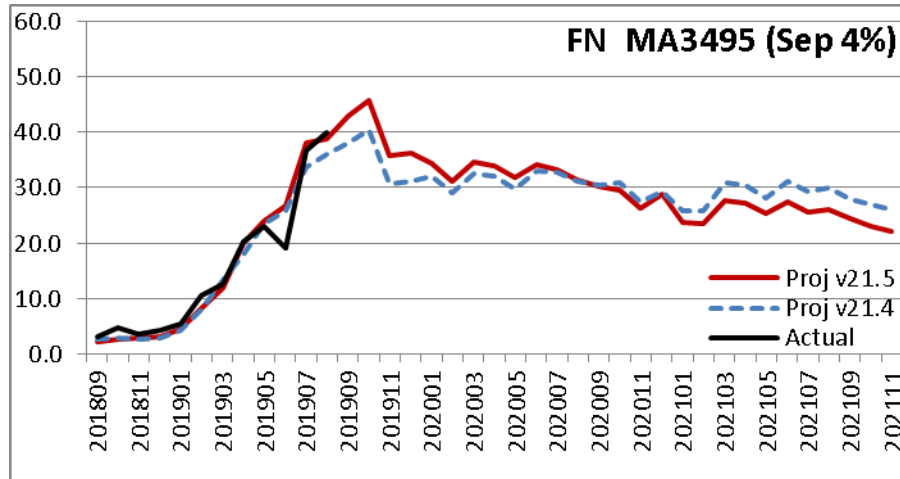
- **Model v21.5 assumes that automated underwriting efficiencies from Day One Certainty and LoanAdvisor, especially the availability of PIW for qualifying loans, has disproportionately affected speeds on newer loans, refinances of which are increasingly streamlined.**

- **We therefore introduce adjustments to speeds during the early months that depend on the assumed likelihood that a loan would benefit from these programs, particularly to obtain a PIW.**

Source: eMBS

Peak Speeds on FNMA Majors/FHLMC MLGs (continued)
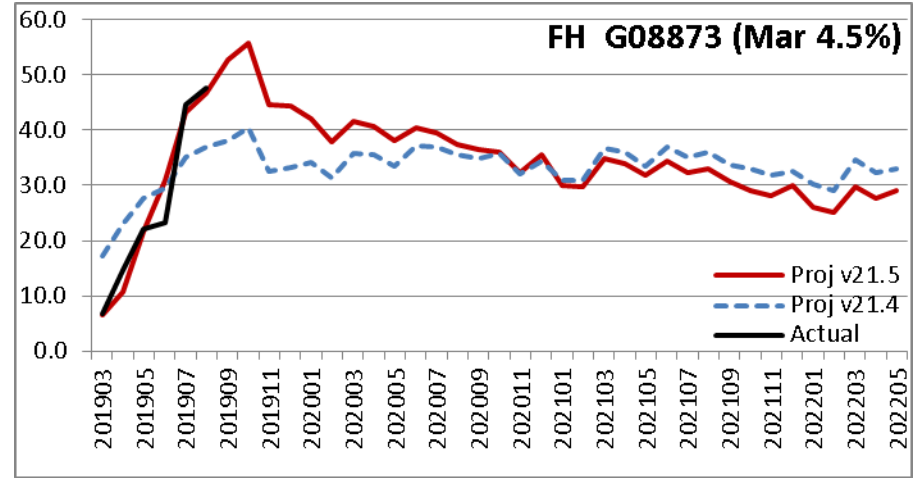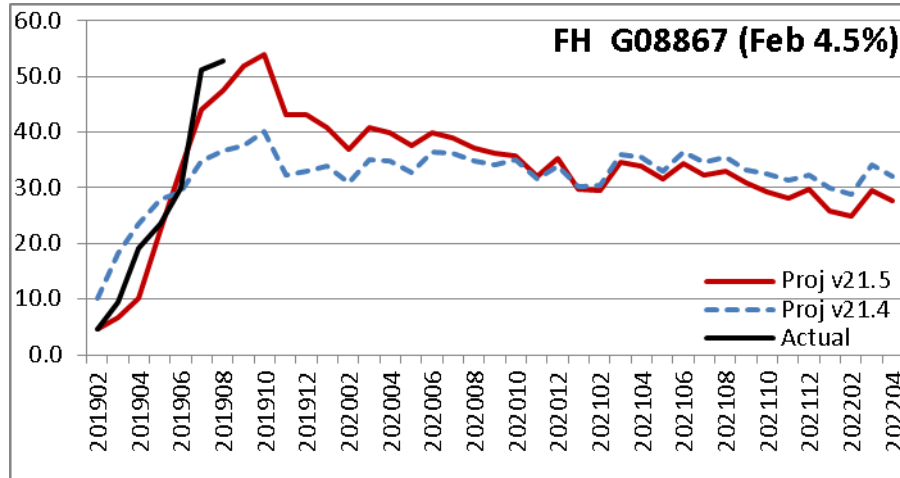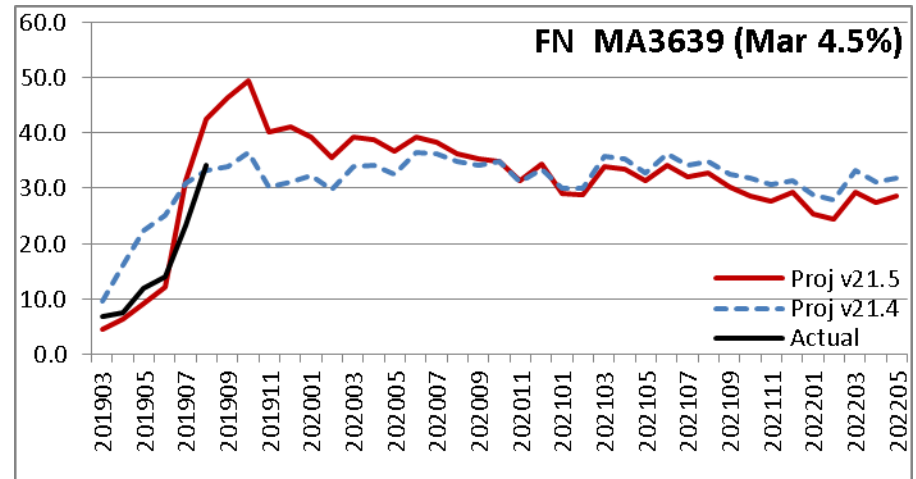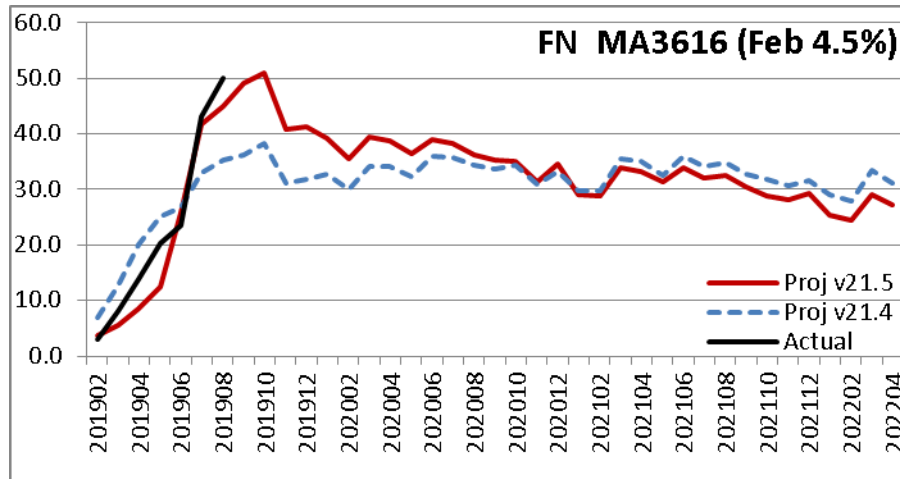
- **The S-curve in v21.5 has a flatter slope and higher amplitude than v21.4 in the early years, better capturing observed relative speeds on higher versus more moderate incentive levels.**

- **While peak speeds tend to be higher in v21.5, the speeds in the first few months are lower, better reflecting the obstacles to a refinance earlier than 4-6 months into a new loan. The flatter long-term S-curve reflects the likely pull-forward of the most responsive borrowers.**

Source: eMBS

Moderately Seasoned Conventionals Slower in v21.5
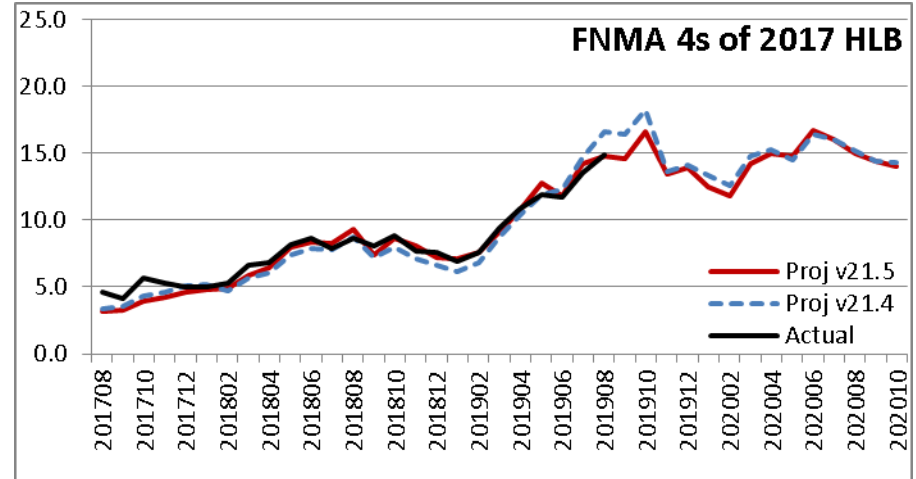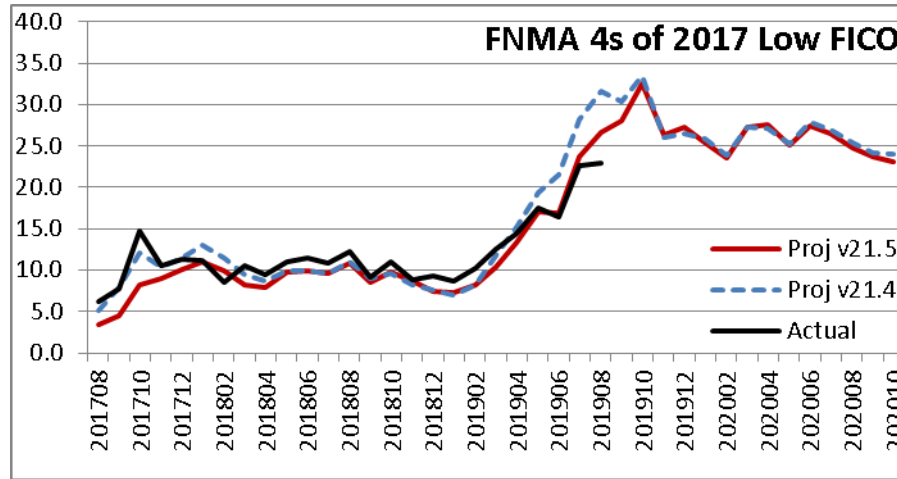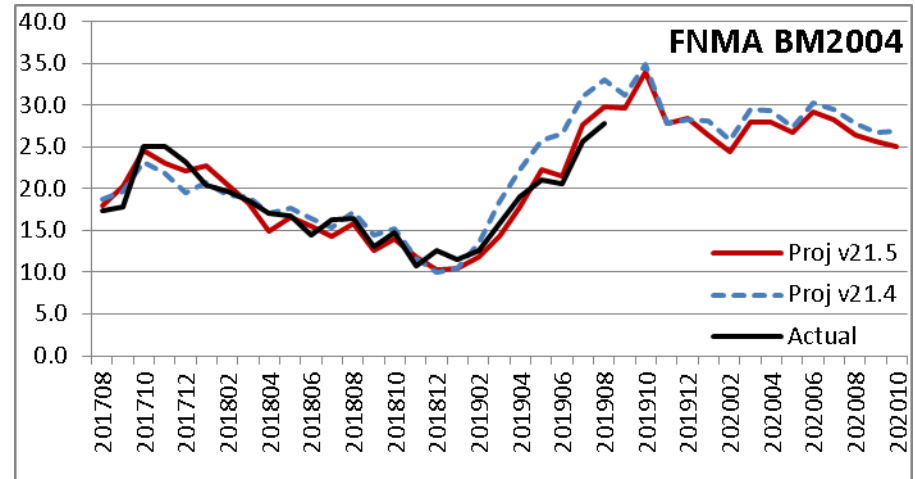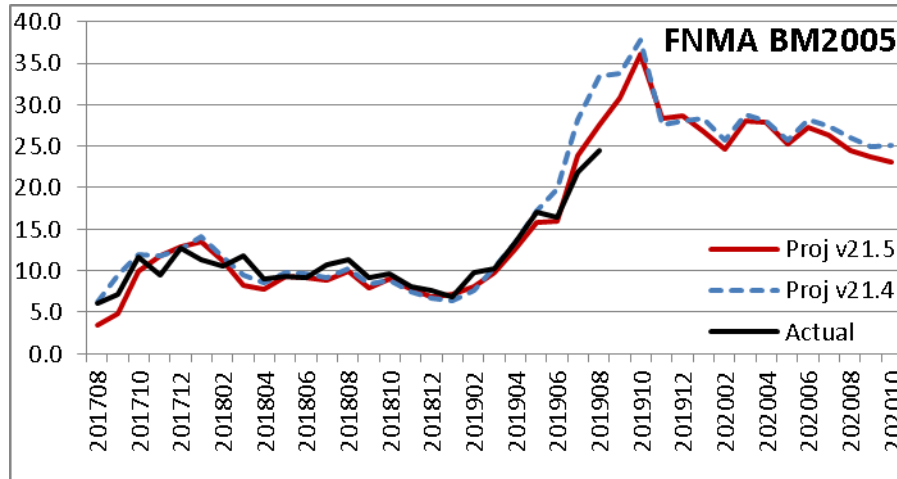
- **The refinancing response on moderately seasoned premiums has been weaker than model v21.4 projected, and the difference between 4-10 WALA and 24-60 WALA collateral has been striking, although there are clear differences in burnout, credit quality, servicer mix, WAC and loan size.**

- **Model v21.5 has larger differences in refinancing response by loan size and impairment than v21.4. In part, this reflects the availability of PIW to high-quality borrowers.**

Source: eMBS

Model v21.5 Better Captures Variations Across Spec Pools

FNMA 4s of 2018 Jumbo

FNMA 4.5s of 2018 200k Max

FNMA 4.5s of 2018 HLB

FNMA 4s of 2018 NY

Legend: Proj v21.5, Proj v21.4, Actual
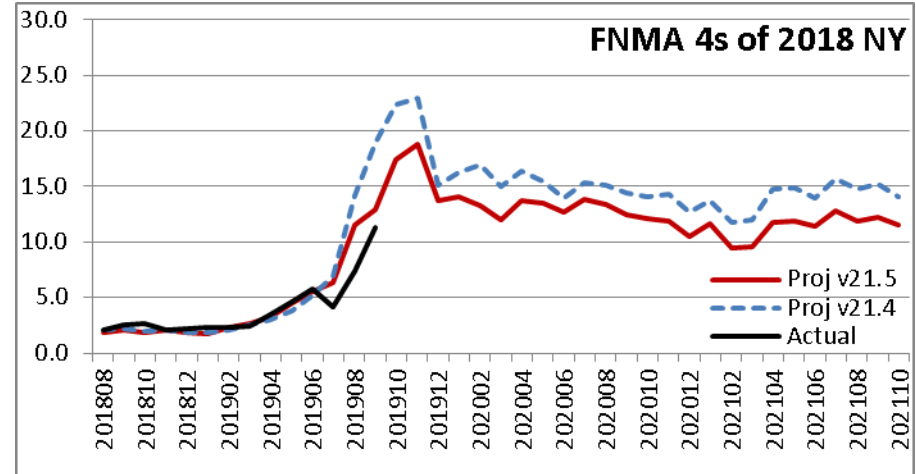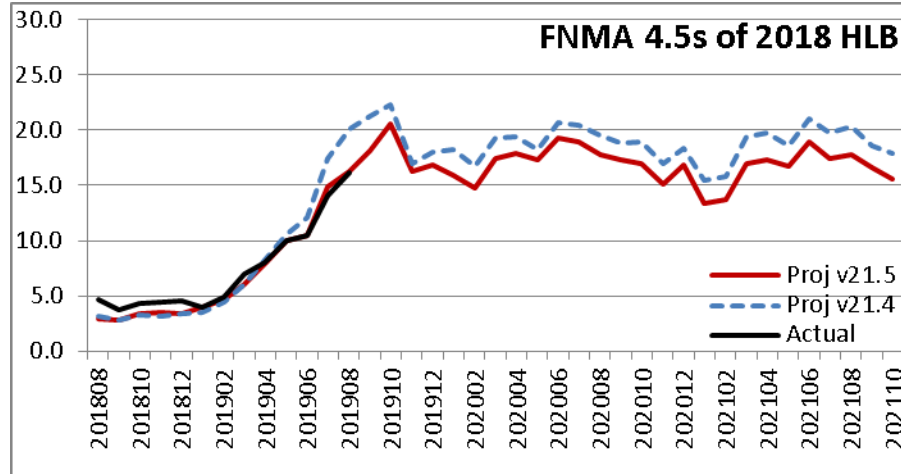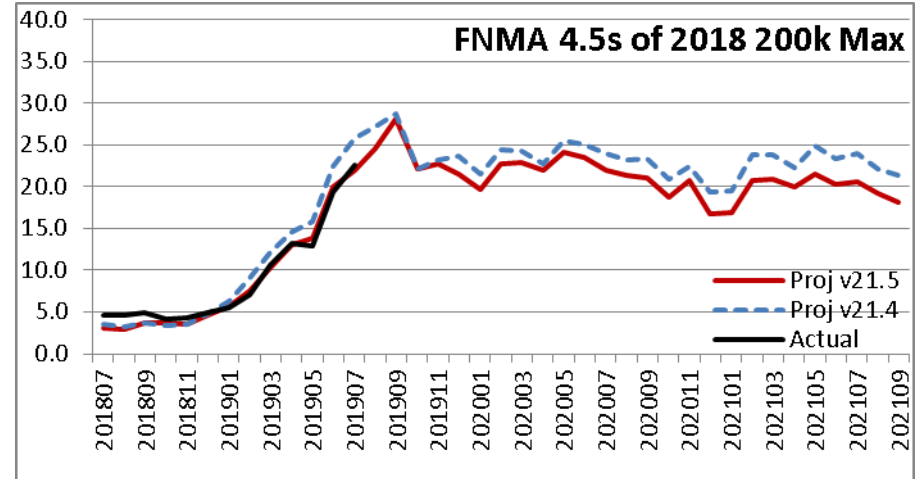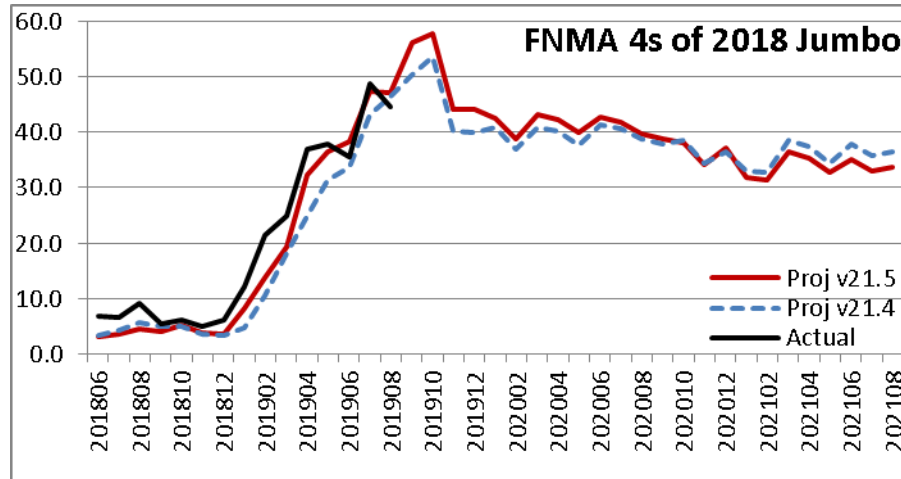
- **Model v21.5 better captures the jumbo ramp, incorporating both strong early adjustments for underwriting efficiency/PIW noted earlier, plus a shortening of lags that now depends on SATO and loan size as well as loan age.**

- **Model v21.5 slows the ramp on lower loan balance, NY, and other specified pools as they benefit less from underwriting efficiency/PIW. There will likely be some catch-up if rates remain low.**

24   Source: eMBS

Model v21.5 Slower on Fixed-Rate Pre-HARP and MHA/CQ
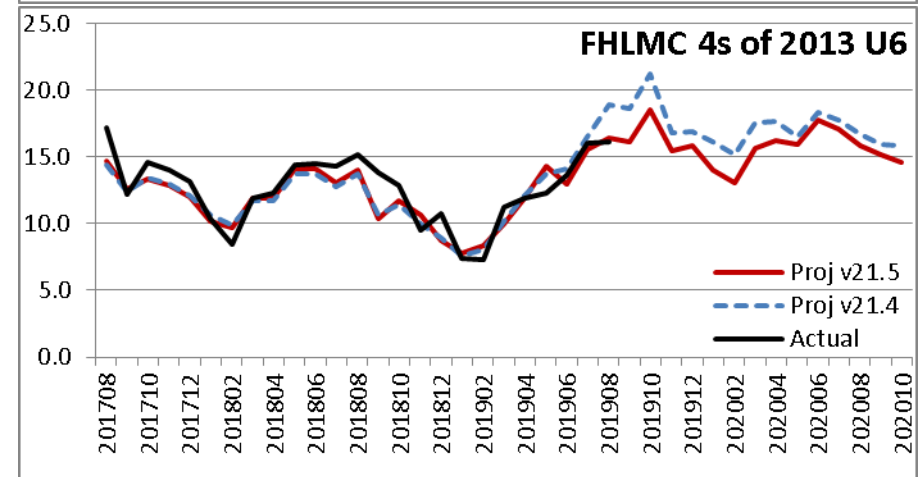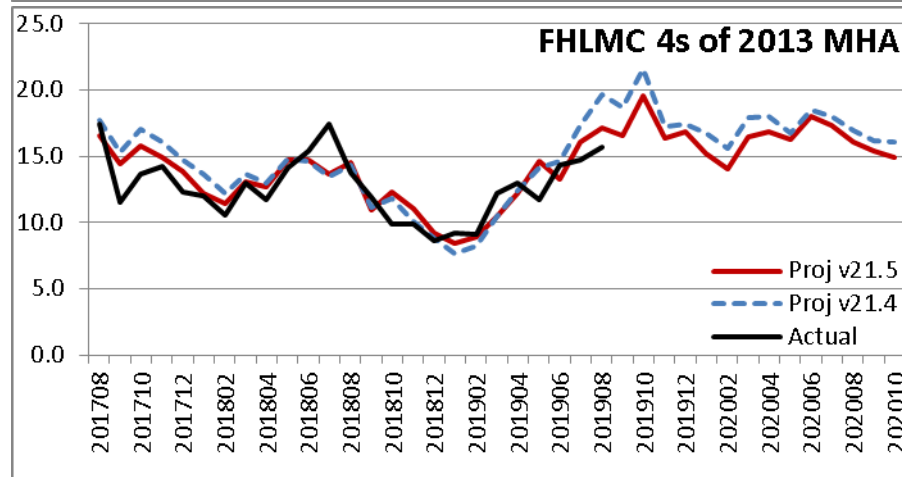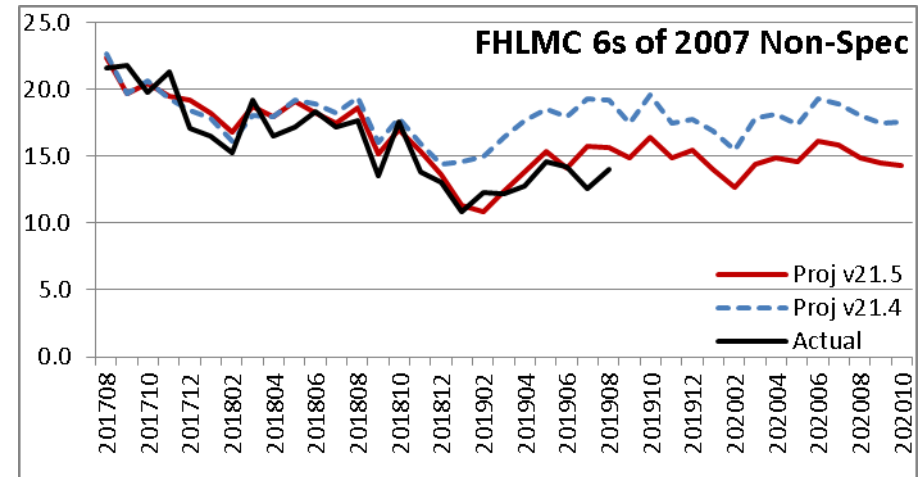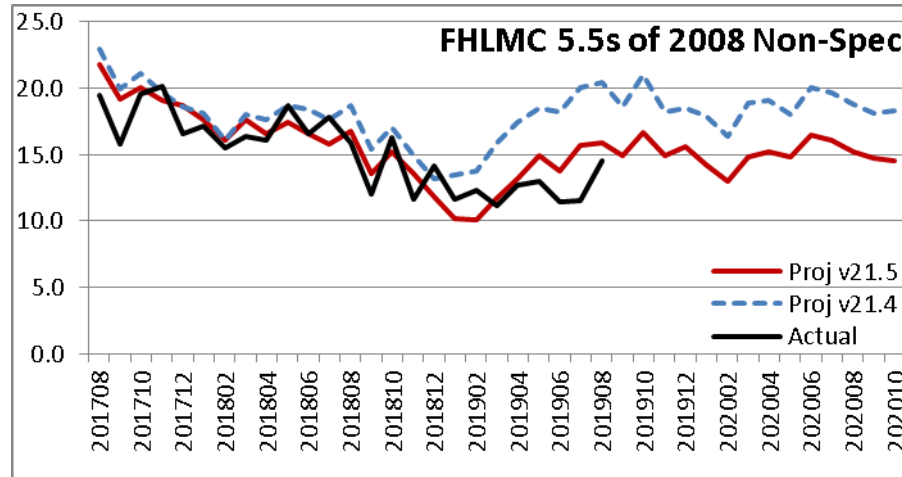
- **Fixed-rate pre-HARP projections have been slowed in model v21.5 vs. v21.4, particularly on 2006-2008 collateral, by adjusting cash-out/HARP refi mix; the decline in speeds leading up to and following HARP expiration appeared to indicate more HARP refis than assumed in v21.4.**

- **Higher coupon MHA/CQ rally response has been quite muted so far, seeming to indicate a flatter S-curve, consistent with other seasoned and/or impaired cohorts.**

25   Source: eMBS

Impact of v21.5 Changes to GNMA II Multi-Issuer Pools
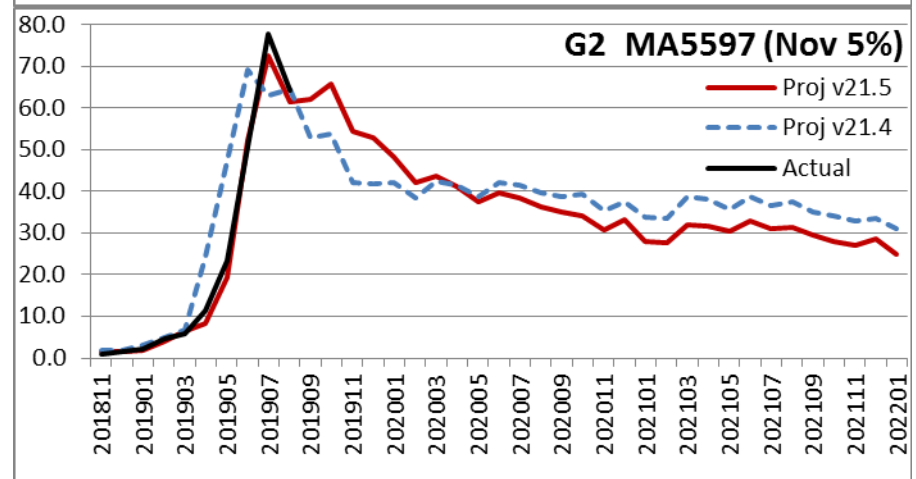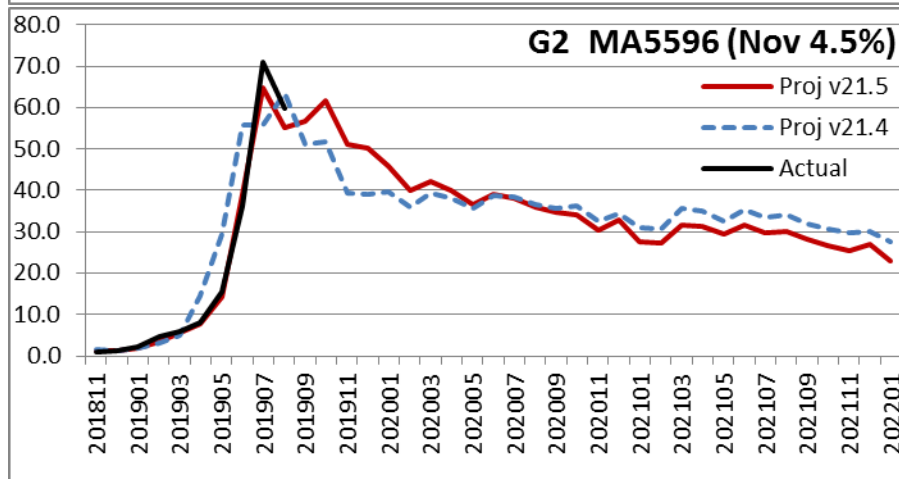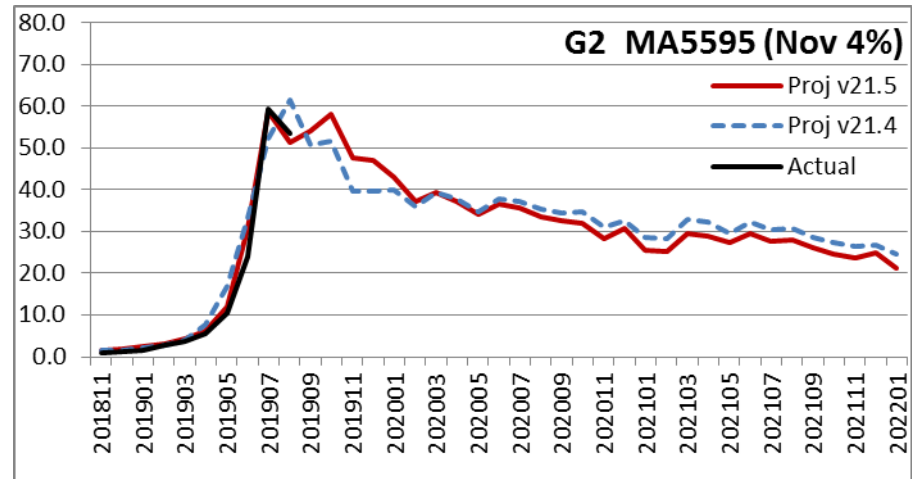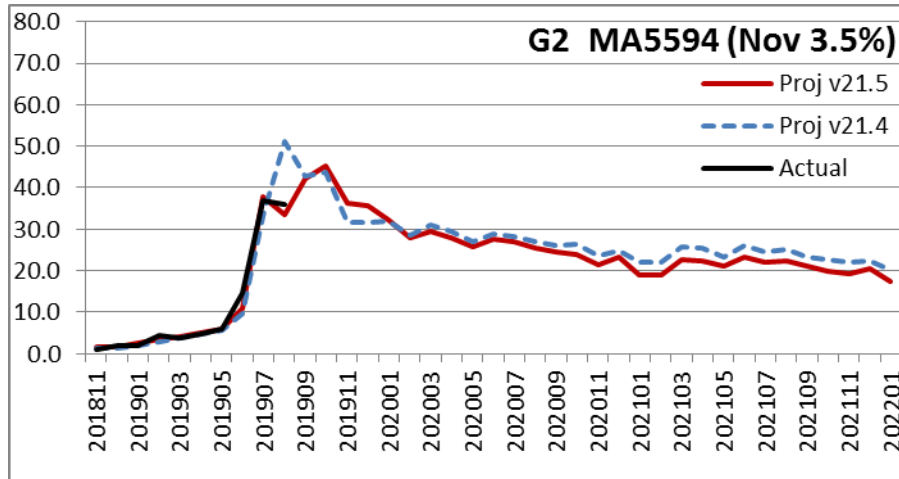
- Model v21.4 performance varies significantly by pool. In general, the ramp timing may be off on certain pools, and overall projected peak speeds have been too sensitive to rallies and selloffs. There continues to be some performance variation by pool, however, as the peak speeds can be highly idiosyncratic.

- For model v21.5, peak ramp refinancing multipliers have been reduced on the fast-responding portion of the population to reduce rate sensitivity, and the impact of a high-WALA tail on the age distribution estimate has been reduced to better capture peak ramp timing in certain cases.

Source: eMBS

Many Large GNMA II Servicers Still Very Fast at Peak Ramp

MA5331 (Jul 4.5) March CPRs	FHA	VA
ALL	27	65
Lakeview	35	65
Money Source	35	78
Nationstar	34	68
Pennymac	27	74
Quicken	23	51
Wells Fargo	17	36

MA5595 (Nov 4) July CPRs	FHA	VA
ALL	36	76
Lakeview	38	75
Money Source	39	90
Nationstar	45	91
Pennymac	38	77
Quicken	43	73
Wells Fargo	20	48

- **Model version 21.4 was released shortly after the start of GNMA's crackdown on servicers with outlier prepayment speeds. Prior to the crackdown, we observed mainstream non-bank servicers prepaying at about 1.5 times Wells speeds at peak ramp, and expected this to be within bounds acceptable to GNMA.**

- **Most non-bank servicers appear to be prepaying at up to 2 times Wells at peak ramp on recently issued GNMA II multi pools, with the overall universe (now dominated by non-banks) paying very fast at 1.5 times Wells or higher.**

- **Model version 21.5 generally caps servicer speeds at about 2 times Wells Fargo speeds. The very high speeds appear to apply to most non-bank servicers across the board. While the initial group of outliers appears to have been eliminated, there is still a very substantial difference between non-banks on the one hand and banks/credit unions on the other.**

Source: eMBS

Model v21.5 Better Captures Variations in GNMA Spec Pools
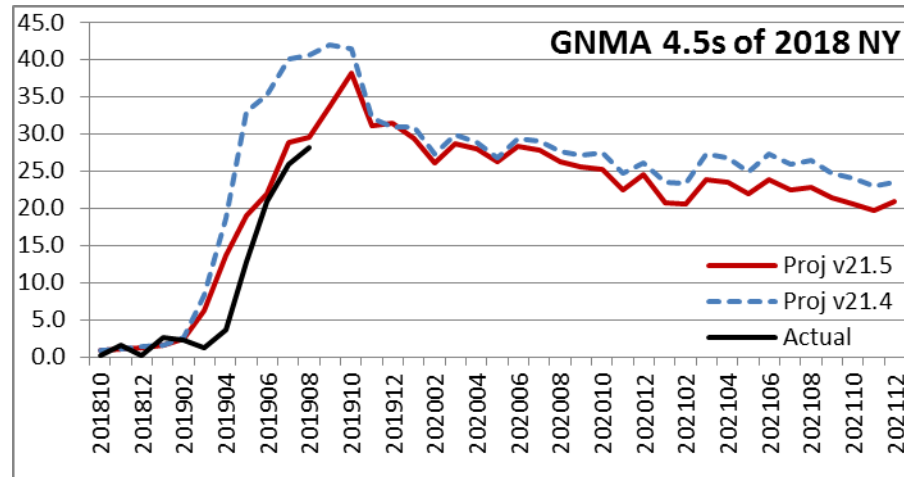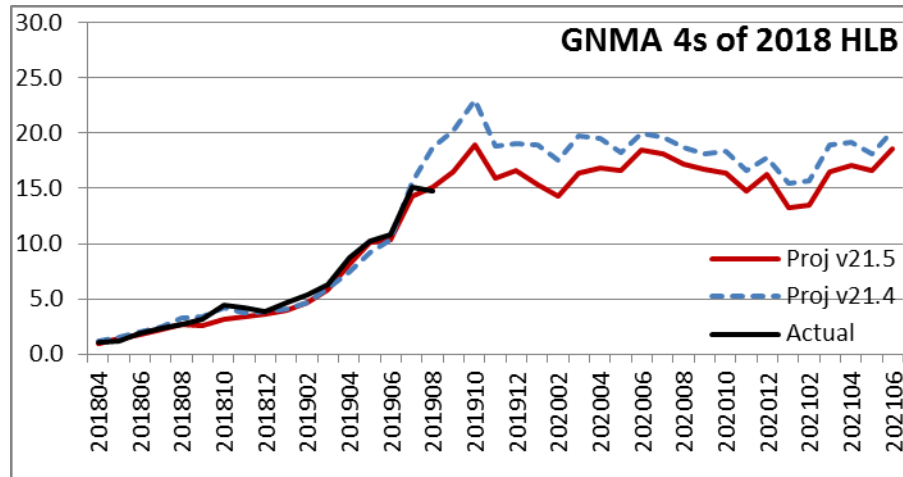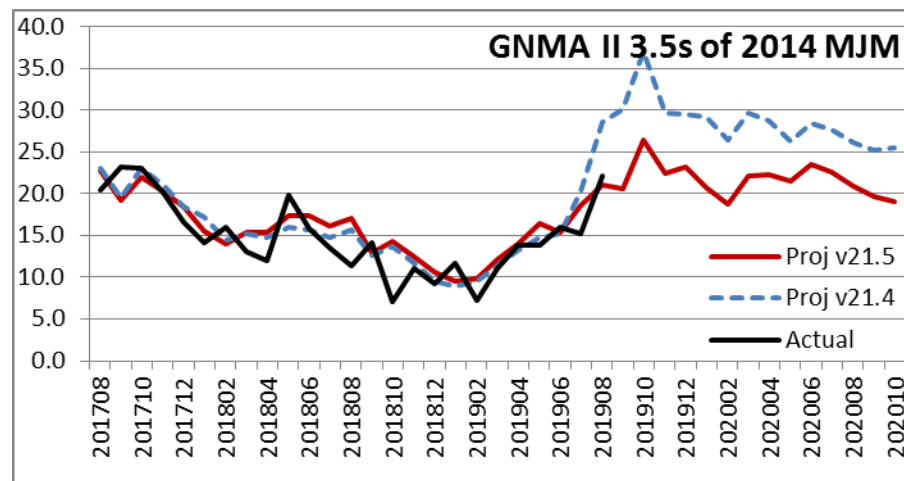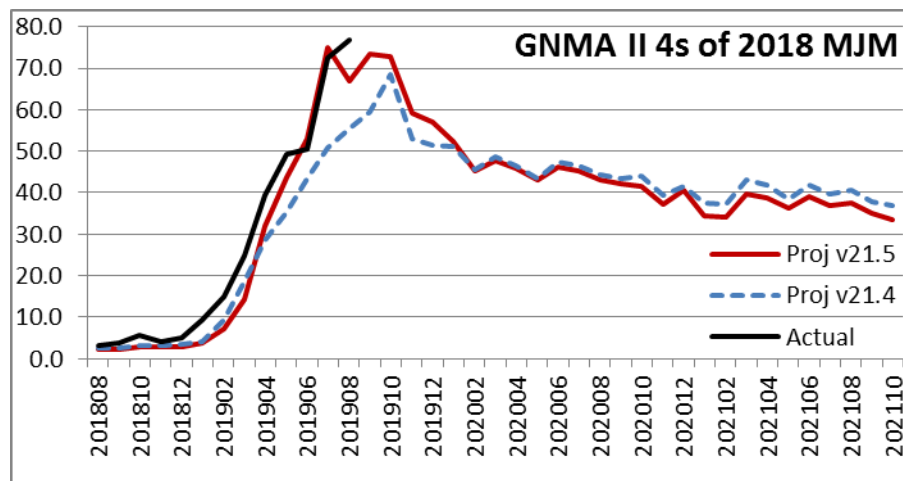
- **Model v21.5 better captures the jumbo ramp, incorporating both overall peak speeds adjustments plus a shortening of lags that now depends on SATO and loan size as well as loan age. It also better captures overall burnout as evidenced by rally speeds on seasoned MJMs so far.**

- **Model v21.5 slows the peak ramp on lower loan balance and NY collateral, as v21.4 did not adequately capture the lower likelihood that these borrowers complete an early refinance.**

Source: eMBS

Model v21.5 Slower on Triple-MIP GNMAs
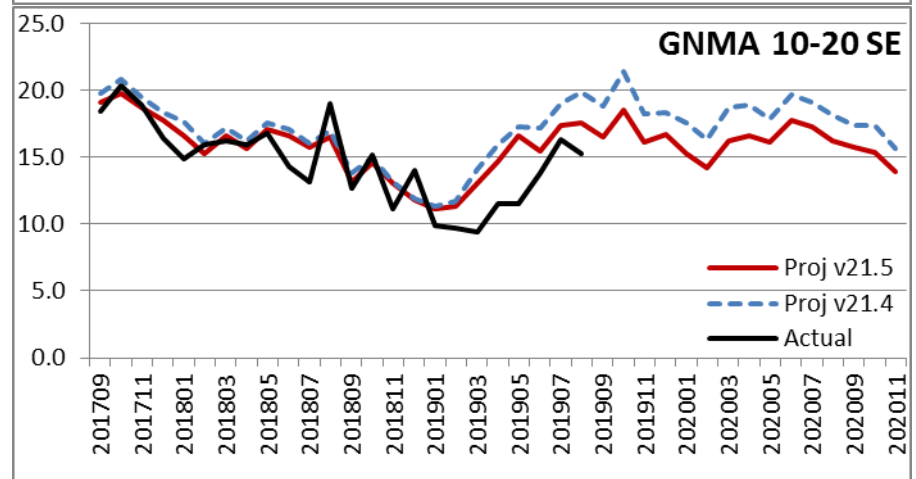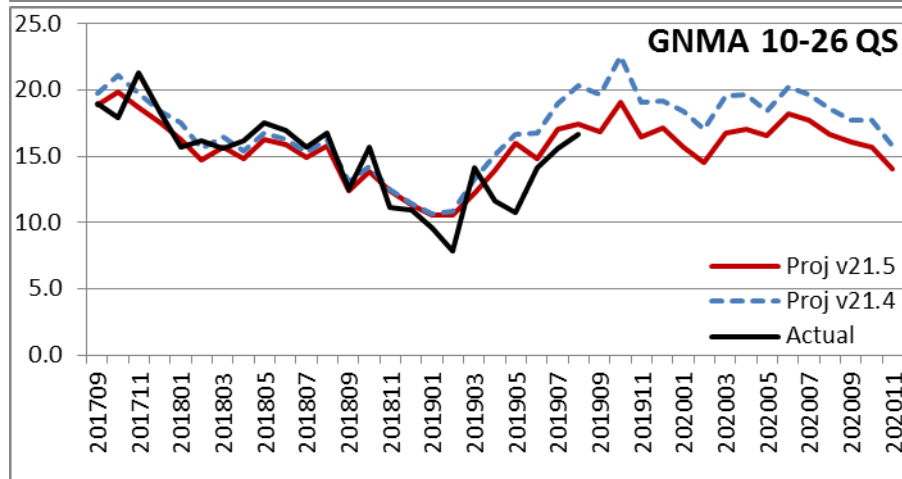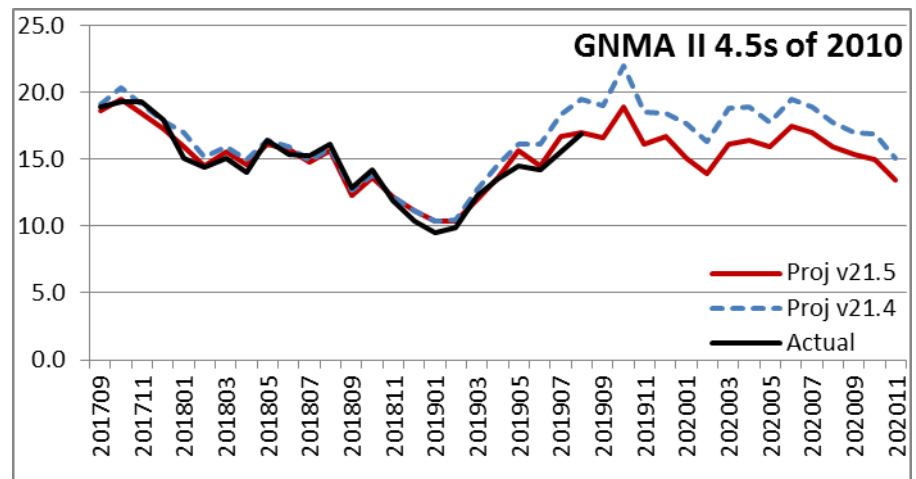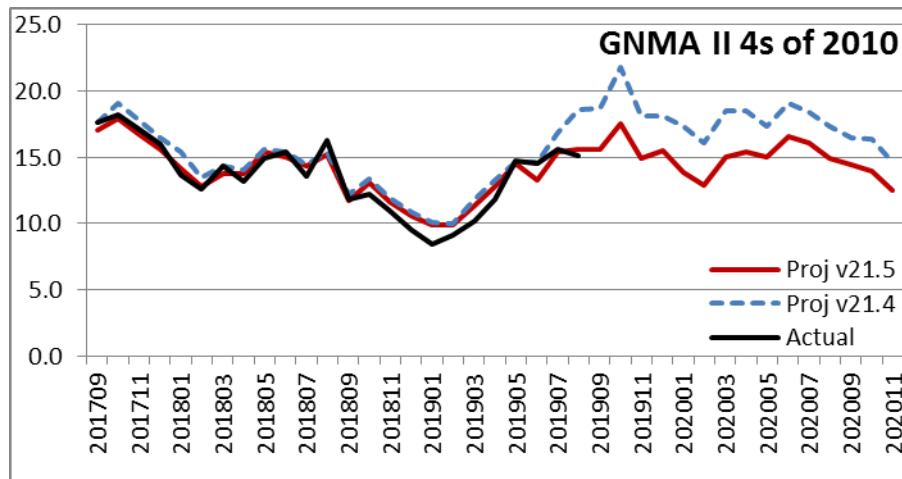
- **Model v21.4 has projected speeds above actuals for large triple-MIP GNMA and GNMA II cohorts**

- **Modifications have been made in v21.5 to better model FHA MIP cancellation on eligible collateral, including use of estimated amortized LTV for only FHA loans in the pool as the driver (as opposed to using the estimated average amortized LTV for the whole pool), and adjusting the timeline over which anticipated or actual MIP cancellation impacts speeds.**

Source: eMBS

Model v21.5 Better Captures Affordability Program Speeds
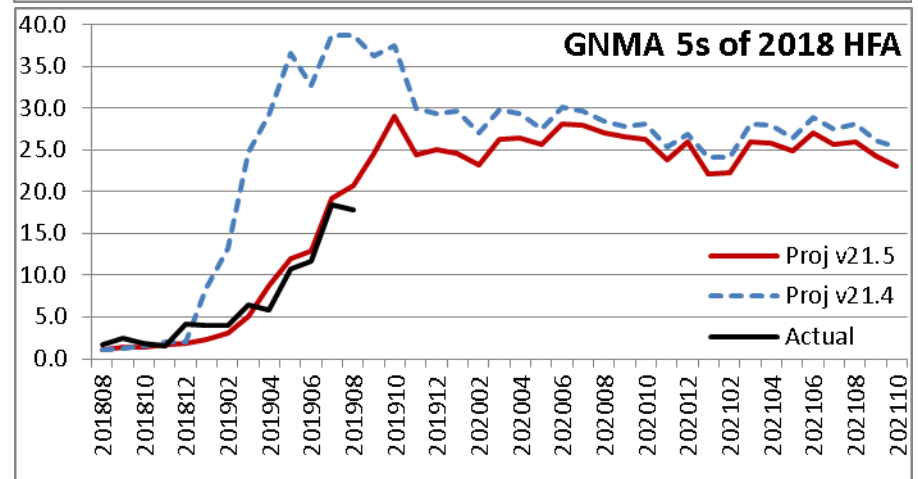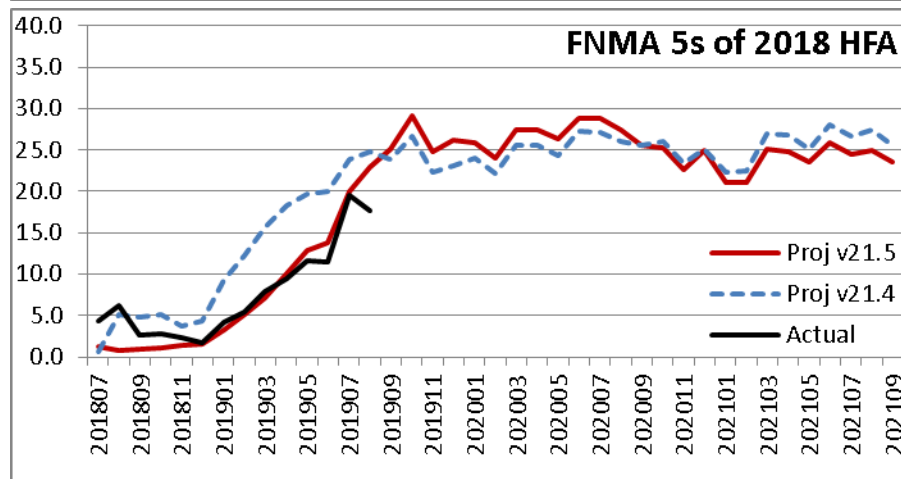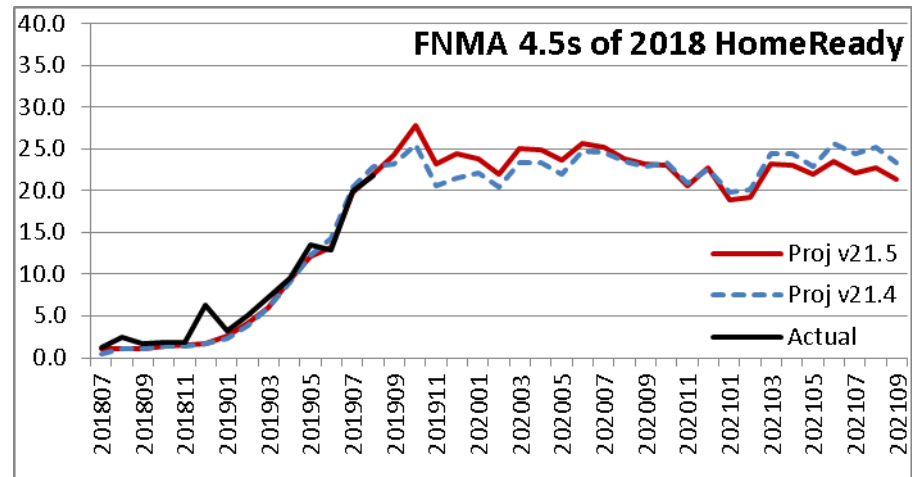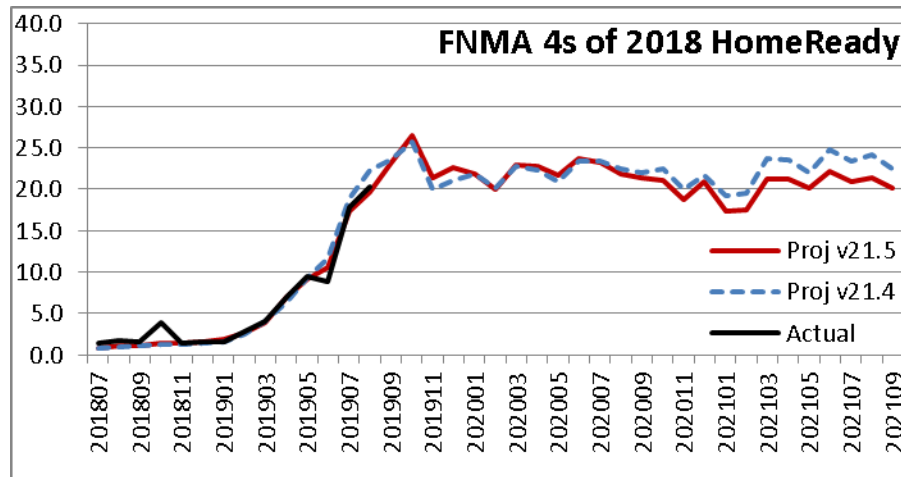
- **Model v21.5 projections on HomeReady and HomePossible collateral are generally similar to v21.4.**

- **Model v21.4 incorporated the different LLPA/PMI regimes for conventional HFAs; it also slowed refis, but generally not nearly enough for newer loans, particularly for GNMAs.**

- **While model v21.5 better captures the HFA sector as a whole, there can be substantial variations by program; a subsequent model release will introduce program-by-program adjustments.**

Source: eMBS

Model v21.5 Better Captures Recent Post-Reset ARM Speeds
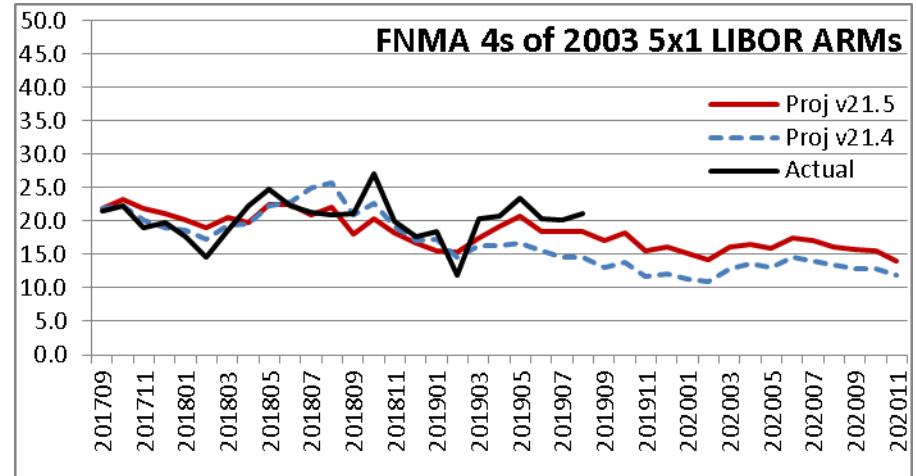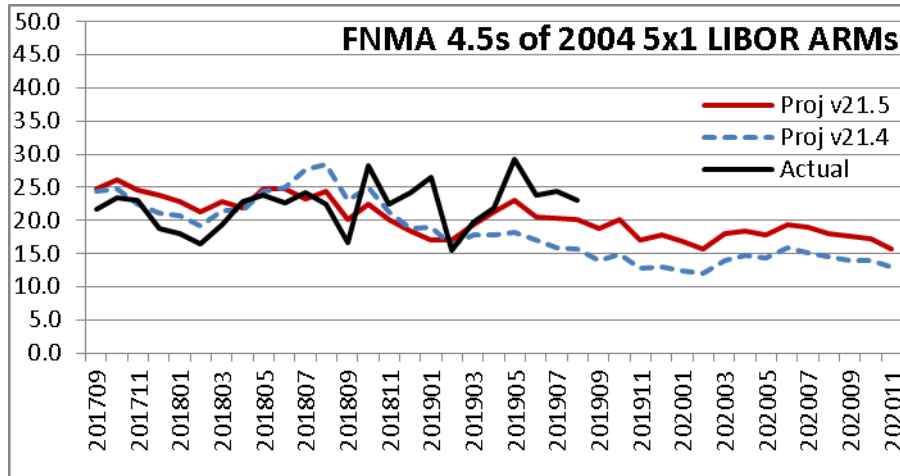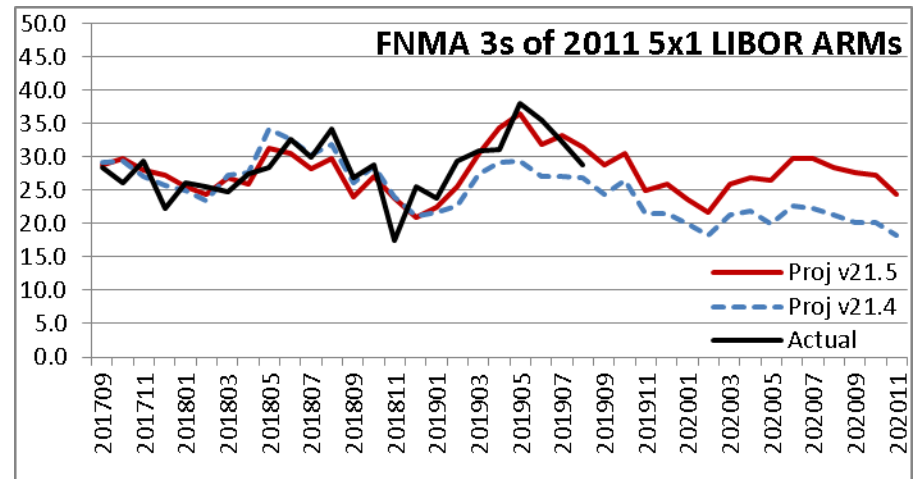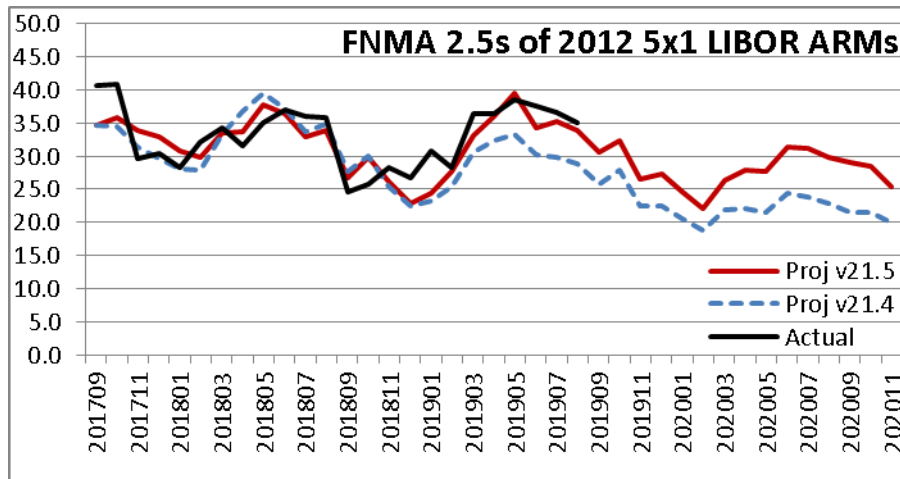
- Model v21.4 assumed that the end of the Fed hiking cycle would dramatically slow post-reset ARM speeds, but it seems likely that the shape of the curve is more important.

- Speeds have been quite high recently as the flat curve has likely encouraged ARM borrowers close to reset or post-reset to refinance into a fixed-rate loan.

- Speeds should moderate if the Fed reduces short-term rates substantially.

Source: eMBS

ADDITIONAL UPDATES

MIP Expiration Speed Drop Similar But Less Gradual in v21.5

Triple-MIP Avg CPR by amortized LTV Since 2016

Triple MIP CPR by Amortized LTV Over Time

Actual Speeds on 78-79 vs. 74-75 Jan 2019 Amort LTV

Expected Period of Divergence
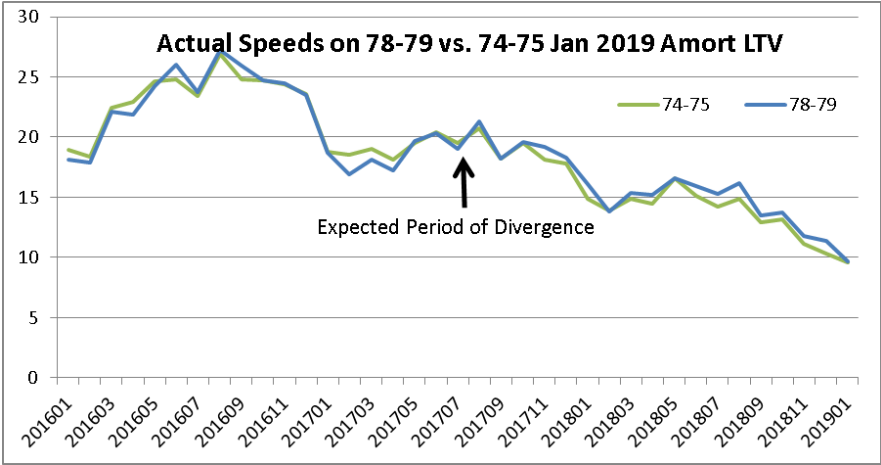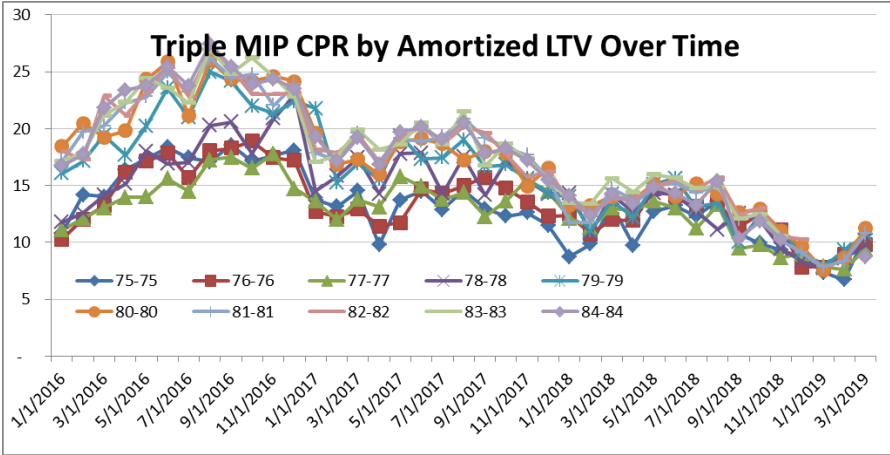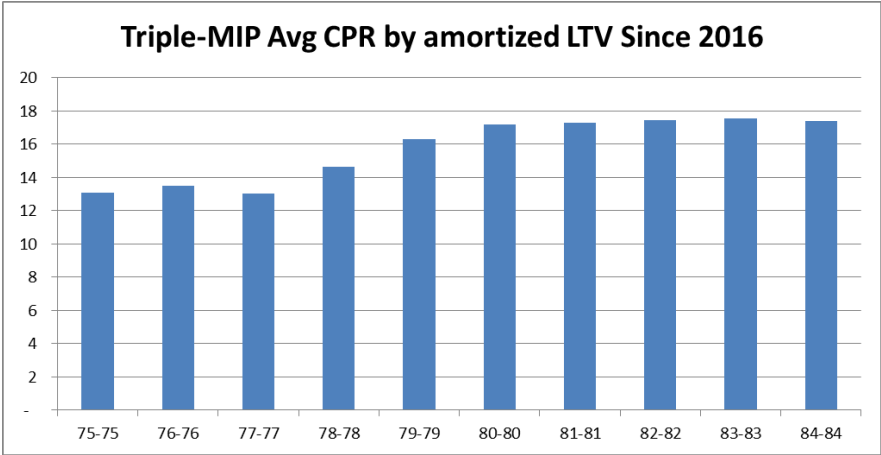
	WAC	FICO	Orig Loan Size
78-79 AmLTV	4.63	698	217k
74-75 AmLTV	4.66	696	219k

- The decline in speeds on FHA loans upon the expiration of MIP (which continues to expire for FHA loans originated prior to mid-2013) have been noted as 3-5 CPR in the past at modest incentives, based on top charts.

- These do not account for differences in attributes and burnout; the decline in fixed sets of loans with different amortized LTVs but otherwise similar attributes appears less dramatic, apparently about 1.5 to 2 CPR in 2017.

- This is largely consistent with v21.4, but expiration is assumed to start driving the slowdown well in advance; model v21.5 will push most of the slowdown to the period around and immediately following expiration.

Source: eMBS

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National HPA Similar for v21.5, But Will Differ by State

- **Assumption for national HPA in v21.4 is 4% for 2019 and 3% thereafter.**

- **Our national assumption is the same in v21.5.**

- **State level assumptions will differ, because we assume that the relative state-level price changes for the 12 months prior to the FHFA HPA reporting date will persist at a linearly declining level for the next 36 months.**

- **The v21.4 starting point for the 36-month convergence to national average is July 2018, and the v21.5 starting point is July 2019; the trailing 12-month histories are Q3 2017 through Q2 2018 for v21.4 and Q3 2018 through Q2 2019 for v21.5.**

Model Version 21.4
Nevada - Nat'l HPA 12m hist = 10.4%

Year	US HPA	NV HPA
2019 H2	4.0%	9.9%
2020	3.0%	6.3%
2021	3.0%	3.4%
2022	3.0%	3.0%

Model Version 21.5
Nevada - Nat'l HPA 12 hist = 1.6%

Year	US HPA	NV HPA
2019 H2	4.0%	5.4%
2020	3.0%	4.0%
2021	3.0%	3.5%
2022	3.0%	3.1%

Source: FHFA

Servicer Refi Adjustment Changes: v21.5 vs. v21.4

Conventional*

Slower	Similar		Faster
Bank of America	360 Mortgage	MB Financial	Flagstar
BB&T	Academy	Midfirst Bank	Freedom*>
Chase (Retail only)	American Financial	The Money Source	Fremont
Citi (Retail only)	Amerihome	Mtg Rsrch (VA United)	Guaranteed Rate
PHH	Banco Popular	Movement Mortgage	Guild
PNC	BOKF	Nationstar***	Homestreet Bank
USAA	Caliber	Nations Lending	Impac*>
USB	Cardinal Financial	Navy Federal	Loan Depot
Umpqua Bank	Carrington	New American	Pennymac
Wells (Retail only)	Central Mtg (Arvest)	New Day Financial	Provident
	Chase (TPO)	New Freedom	Quicken*>
	Citi (TPO)	New Residential	Roundpoint
	CIS Financial	New Penn	United Shore
	CMG Mortgage	NYCB	
	Colonial Savings	Oceanside Lending	
	Cornerstone Home	Ocwen	
	DHI Mortgage	Pacific Trust Bank	
	Embrace Home	Pacific Union	
	Everbank	Pingora	
	Fairway Indep.	Plaza	
	FHLB Chicago	Primelending	
	Fifth-Third	Prospect	
	Finance of America	Pulte Mortgage	
	First Guaranty	Redwood	
	First Key	Seneca	
	Franklin American	Sierra Pacific	
	Gateway Mortgage	Stearns	
	Greentree/Ditech	Stonegate	
	Homebridge	Suntrust	
	Home Point Fin.	Sun West Mortgage	
	Homeward Resid.	SWBC Mortgage	
	Housing Fin Agy**	United Security	
	Lakeview*>	Universal American	
	M&T Bank	Village Capital	
	Matrix	Wells (TPO)	

GNMA*

Slower	Similar		Faster
Bank of America	Amerihome*>	Impac	360 Mortgage
BB&T	Academy	M&T Bank	American Financial
Chase (non-RH)<*	Banco Popular	Matrix	Chase (RH)<*
Citi	BOKF	Midfirst Bank*<	Caliber*>
Colonial Savings	Cardinal Financial	Mtg Rsrch (VA United)	Carrington
Cornerstone Home	Central Mtg (Arvest)	Movement Mortgage	CIS Financial
Fifth-Third	CMG Mortgage	Nationstar	Finance of America
Franklin American	DHI Mortgage	New American	First Guaranty
Gateway Mortgage	Embrace Home	NYCB	Flagstar
Homestreet Bank	Everbank	Ocwen	Freedom*>
MB Financial	Fairway Indep.	Pacific Trust Bank	Lakeview*>
Navy Federal*<	FHLB Chicago	Plaza	Loan Depot*>
PHH	First Key	Primelending	The Money Source*>
PNC	Fremont	Prospect	Nations Lending
Roundpoint	Greentree/Ditech	Provident	New Day Financial
Suntrust	Guaranteed Rate	Pulte Mortgage	New Freedom
SWBC Mortgage	Guild	Redwood	New Penn
USAA<*	Homebridge	Seneca	New Residential
USB	Home Point Fin.	Sierra Pacific	Oceanside Lending
Umpqua Bank	Homeward Resid.	Stonegate	Pacific Union
Wells Fargo*<	Housing Fin Agy**	Universal American	Pennymac*>
			Pingora
			Quicken
			Stearns
			Sun West Mortgage*>
			United Security
			United Shore
			Village Capital

* Applies only to fixed rate post-HARP collateral.   ** Covers housing finance agencies in various states; HFA adjustments currently not differentiated by servicer
*> Cash-outs adjusted faster (independent of rate refis)   *< Cash-outs adjusted slower (independent of rate refis)

Slower than v21.4	Faster than v21.4	Newly added

Source: Citi.

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Other Model Changes

- **PMI model overhauled – more important, given higher affordability product issuance**
  - Estimate breakdown of PMI into borrower and lender paid (BPMI / EPMI)
  - Account for expected relative payoff rates of loans with and without PMI
  - Adjust cancellation efficiency to match historically observed cancellation
  - Converge assumed relative payoffs and cancellations to disclosed data

- **Property type and number of borrowers added as model inputs, to capture higher turnover on condos/PUDs and higher defaults/turnover for single-borrower loans**

- **Higher turnover assumed on delinquent loans, especially when HPA is strong, as evident in data; largely offset by other adjustments on the aggregate level**

- **Jumbo spreads to conforming will be modeled as a function of media effect as well as unemployment and HPA; spread observed to widen in rallies of 2015 and 2016**

- **Turnover seasonality increased on VA loans as observed in speeds and based on discussion in articles addressed to military families, e.g.,**
  https://www.military.com/money/pcs-dity-move/peak-moving-season-here-make-move-plans-now.html

- **Model rate lags have traditionally varied only by age; loan balance/SATO dependence to be added to better capture shorter lags on new high quality and/or jumbo loans**

- **Sensitivity added for volatility of rates within a month; for a given average rate level, speeds expected to be higher if rate volatility is higher**

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APPENDIX

Summary of Changes from Prior Version (v21.4)

- Increased impact of GSE/originator streamlining (e.g., via PIW), driving stronger projected refis on new high quality loans
- S-curve generally flatter, leading to generally slower speeds on more seasoned and impaired collateral
- Burnout stronger in some cases, particularly on seasoned FHA loans and conventional 2012-2016 vintages
- Post-reset ARM speeds faster, resulting from increase in assumed sensitivity to flatter curve
- P/S spread baseline now dependent on refinancible universe, shape of curve, and assumed WAC spreads
- Near-term GN/FN primary rate spread now 20 bps below full GN/FN swap (FN-GN CMM102) due to high FN WAC spreads
- Federal funds rate now a model input; allows HELOC vs. fixed-rate comparison to influence cash-outs
- Cash-out lock-in reduced as a function of LTV and disincentive; cash-out elbow adjusted by loan balance and DTI
- Cash-outs assumed higher during periods of excess capacity, all else being equal
- More servicers adjusted for differences in cash-out speeds; banks/credit unions generally slower than non-banks
- Adjustments for VA cashout NTB interim rule, expected final rule, and GNMA pooling restrictions on 90+ LTV VA cashouts
- Adjustments to account for change in FHA maximum cash-out refinance LTV from 85 to 80
- Use FHA amortized LTV (from loan level data) rather than pool value for MIP cancellation
- Biennial turnover update -- add 2017 AHS housing stock data; adjust long-term rate and seasonals
- Reduced DTI/FICO impact on effective coupon blend (30yr/15yr) and impairment as collateral ages
- Adjusted turnover assumptions materially higher for delinquent loans, degree of increase depends on LTV
- Updated age dispersion algorithm to give higher success rates in the estimation from average/quartiles
- Jumbo rate spread to conforming now a function of media effect as well as unemployment and HPA
- Adjust lags by loan size/SATO and account for intra-month rate volatility to better model rally responses
- Defaults now sensitive to fraction with down payment assistance and multiple borrowers
- Turnover now sensitive to fraction with multiple borrowers and property type breakdown (SF, condo, PUD)
- Better capture speed differences by occupancy type (owner, second homes, investors)
- Improved VA mobility assumptions (adjusted lock-in/assumability, increased seasonality)
- PMI breakdown into BPMI/LPMI/EPMI to be estimated, based primarily on STACR/CAS disclosures and SATO
- Evolution of PMI over time modeled based on relative PMI/non-PMI payoff rates and revised cancellation efficiency
- Historical FHFA purchase only HPA updated thru Q2 2019 and projected 2019 HPA maintained at 4%; 3% 2020 and beyond
- Update unemployment to projections from the Sep 2019 FOMC meeting (rising from 3.7% gradually to 4.2% longer term)
- Other recalibration across collateral sectors and attributes based on v21.4 performance review and user feedback

Agency Prepayment Model Specification

- Model objective -- project prepayment rates on agency mortgage collateral from settlement date to maturity, given collateral characteristics and a macroeconomic scenario

- Agency mortgage collateral includes pools and CMOs backed by loans guaranteed by FHLMC, FNMA, or one of the four GNMA guarantors (FHA, VA, RHS, PIH).

- The prepayment model consists of numerous mathematical and computational algorithms coded in C and C++, along with parameters that specify scalars, vectors and functions of the data inputs to the algorithms. The parameters may be empirically estimated, postulated based on expert judgment, or definitively specified based on known relationships. The outputs of the model are the total prepayment rate and its components. The model may be represented schematically as follows:
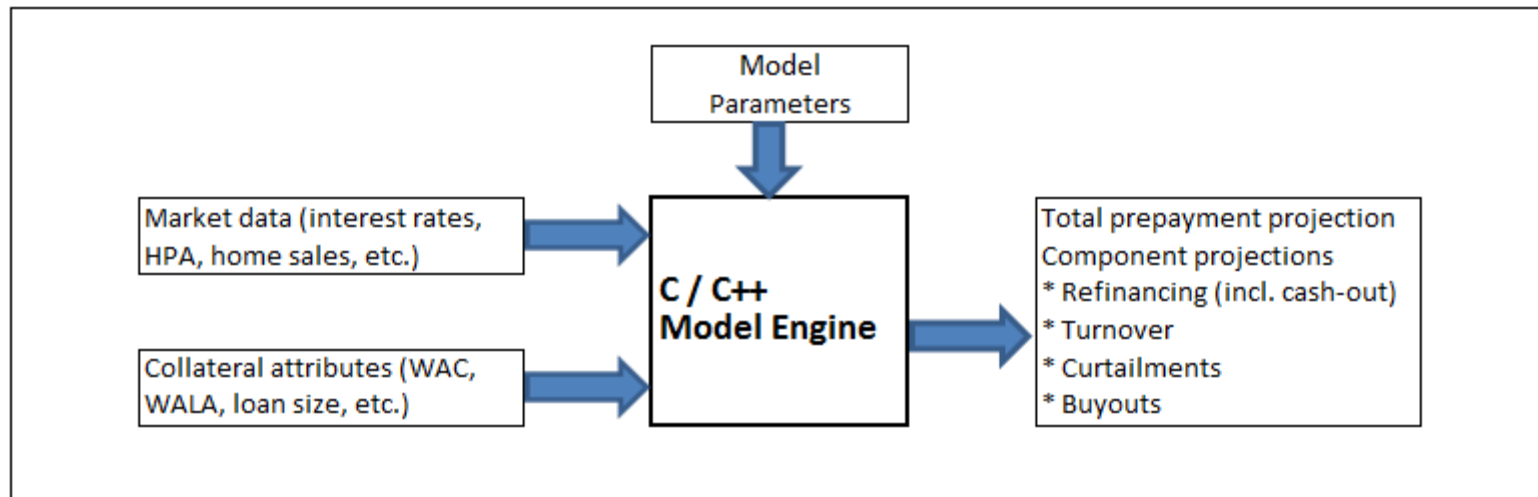
Agency Prepayment Model Dataset

- Collateral and prepayment data for agency MBS are obtained from a vendor (eMBS) which transmits it from the agencies (who in turn collect it from loan servicers) with no alterations.

- Market data are obtained from the appropriate Citi, government or association source.

- The data provided by Fannie Mae, Freddie Mac, and Ginnie Mae through eMBS are considered to be the industry standard. The data has been used for decades for not only modeling, but also for official cash disbursements to investors by trustees for MBS; the proper sourcing and reliability of the data can safely be presumed.

- The time periods for the data extend through multiple economic cycles, in many cases from the 1970s to the present.

- The model requires certain data transformations; major transformations are outlined below.

Data Element	Transformation
Prepayment Rates	Computed from pool factors according to industry-standard methods; checked vs. eMBS reported values for consistency
Mortgage Rates	Daily mortgage rates are computed from the weekly primary-secondary spreads derived from the FHLMC PMMS. Reported rates and points are combined to produce no-point primary mortgage rates before the current coupon (secondary) rate during the survey period is subtracted to obtain the spread. This spread is added to the current coupon each day to obtain daily 30-year rates; daily 15-year and 5x1 ARM rates are then derived from the 30-year rates and reported weekly spreads of 30-year rates to 15-year and 5x1 ARM rates. Daily rates are then averaged and lagged before being used to compute refinancing incentives and turnover lock-in. Effective with model v21.4, average GNMA mortgage rates are obtained by subtracting the spread between FNMA and GNMA II CMM102 from conventional mortgage rates, rather than by setting GNMA rates to conventional rates plus a fixed elbow shift.
Current LTV	Adjust original LTV by FHFA HPA and loan balance declines resulting from amortization and curtailments
SATO	Estimate spread of WAC at origination to prevailing mortgage rates based on assumed rate lock term and FHLMC PMMS.

Agency Prepayment Model Inputs

Collateral
- Collateral type (agency, mortgage term, fixed or hybrid adjustable rate, amortization type)
- Loan program (FHA/VA/RH for GNMA, HARP status for conventional)
- Loan purpose (purchase first-time or not, rate or cash-out refi, modification, reperformer)
- Origination channel (broker, correspondent, retail)
- Occupancy (Owner-occupied, second home, investor)
- Servicer (fraction serviced by significant servicers)
- Geography (fraction in each state)
- Presence of second lien
- Presence of PMI, and PMI coverage fraction (current and original)
- Units (single or 2-4 family)
- Down payment assistance
- Origination date (average and quartiles)
- Note rate (average and quartiles)
- Note rate spread to market rates at origination (SATO)
- Credit score (average and quartiles)
- LTV/Combined LTV/Current LTV (average and quartiles)
- DTI (average and quartiles)
- Loan size (average and quartiles)
- Number of borrowers on loan
- Property type (e.g., single family, condo, coop, PUD)
- Mortgage insurance premiums (upfront and annual) charged by GNMA guarantors, if applicable
- Eligibility for HARP and/or other streamline refinance program (including new FHFA HLTV program starting in 2019)
- Eligibility for affordable housing program (FNMA HomeReady, FHLMC HomePossible, state Housing Finance Agency (HFA) assistance)
- Modified loan info (performance history, payment reduction, number/type of mods, forbearance amount)
- Delinquency status distribution (current, 30-59 days delinquent, 60-89 days delinquent, 90+ days delinquent, 120+ days delinquent

Market
- Primary mortgage rates (30-year, 15-year, 5x1 hybrid, ARM indexed rates,
- Secondary mortgage rates (derived from FNMA and GNMA II TBA prices)
- \item Federal funds / LIBOR / short-term Treasury rates (for HELOC rates, ARM indexes, curve shape)
- Unemployment rate
- Home sales and housing stock (for turnover rate)
- Home price appreciation

Agency Prepayment Model Outputs

Each component of prepayments is modeled separately. Prepayment rates are projected for each component and added together to obtain the total prepayment rate.

Total Speed = Housing Turnover + Refinancing + Defaults + Curtailments/Payoffs

- **Housing Turnover.** An existing home sale generally leads to a mortgage prepayment if the seller carried a mortgage. An exception occurs if the seller had an FHA or VA loan and the buyer "assumed" the obligations of the existing loan.

- **Refinancings.** Refinancing refers to the retirement of an existing loan in favor of a new one on the same property. This is generally undertaken to take advantage of lower rates, but can also occur because the mortgagor wants to cash out equity in the home, or when borrowers with initially poor credit and/or high LTV take advantage of an improvement in their credit and/or an increase in their home value.

- **Defaults/Buyouts.** Defaults are prepayments caused by the foreclosure and subsequent liquidation of mortgage loans in the pool; buyouts are the repurchase of seriously delinquent loans from the pool. These constitute a minor component of aggregate prepayments in most cases, but may be more significant for GNMA loans, and during an economic crisis.

- **Partial Prepayments and Full Payoffs.** Some mortgagors send in more than the scheduled payment each month; full payoffs refer to mortgages that have been paid off completely, usually when the mortgages are very seasoned and the remaining loan balances are small.

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Agency Prepayment Model Design and Development

- Drivers of prepayment components are identified (market data and collateral attributes). Many drivers are well known; others are revealed by data analysis and in consultation with model users.

- Data is passed in as a single repline of average and quartile data for each collateral type (30-year, 15-year, ARM, etc.). Multiple replines are not used due to slower run-times and limited benefit in most cases.

- Functional forms to convert the drivers into prepayments are determined. The decision to select one functional form over another is based on prior experience and simplicity.

- Initial guesses are selected for optimization, generally from the prior model version, and optimization is performed on each sub-model. Back-testing is the primary testing method used during the preliminary optimization stage.

- Following preliminary optimization, model parameters and outputs are examined via scenario analysis, particularly for extreme scenarios; OAS, duration and convexity are reviewed for actively traded MBS; and model vs. market pay-ups are examined for specified pools. These tests result in additional optimization before the model is released for user testing.

- Feedback resulting from internal and external user alpha and beta testing is incorporated. The above-mentioned tests are repeated where necessary and the model is frozen for release.

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Agency Prepayment Model Segmentation

The agency prepayment model is segmented into sub-models by collateral type as follows.

Sub-Model Name	Collateral Type
FNMA30	FNMA single-family fixed-rate collateral with 30-year original term, excluding those with initial interest-only term. Includes original terms between 23 and 35 years.
FNMA20	FNMA single-family fixed-rate collateral with 20-year original term. Includes original terms from 17 years to below 23 years.
FNMA15	FNMA single-family fixed-rate collateral with 15-year original term. Includes original terms between 12 years and below 17 years.
FNMA10	FNMA single-family fixed-rate collateral with 10-year original term. Includes all original terms below 12 years.
FNMA40	FNMA single-family fixed-rate collateral with 40-year original term. Includes all original terms exceeding 35 years.
FNMA30_IO10	FNMA single-family fixed-rate collateral with 30-year original term and an initial interest-only period (typically 10 years). Includes all fixed-rate collateral that has an IO period of any length.
FNMA3X1_ARM	FNMA single-family 3-year hybrid ARM collateral (index=1-year CMT). Includes ARMs with no initial interest-only period, original fixed period between 25 and 48 months, and any index that is not a LIBOR rate.
FNMA3X1_ARML	FNMA single-family 3-year hybrid ARM collateral (index=1-year LIBOR). Includes ARMs with no initial interest-only period, original fixed period between 25 and 48 months, and any index that is a LIBOR rate.
FNMA3X1_IOARM	FNMA single-family 3-year hybrid IO ARM collateral (index=1-year CMT, initial interest-only period typically 10 years). Includes ARMs with an initial interest-only period, original fixed period between 25 and 48 months, and any index that is not a LIBOR rate.
FNMA3X1_IOARML	FNMA single-family 3-year hybrid IO ARM collateral (index=1-year LIBOR, initial interest-only period typically 10 years). Includes ARMs with an initial interest-only period, original fixed period between 25 and 48 months, and any index that is a LIBOR rate.
FNMA5X1_ARM	FNMA single-family 5-year hybrid ARM collateral (index=1-year CMT). Includes ARMs with no initial interest-only period, original fixed period between 49 and 72 months and any index that is not a LIBOR rate.
FNMA5X1_ARML	FNMA single-family 5-year hybrid ARM collateral (index=1-year LIBOR). Includes ARMs with no initial interest-only period, original fixed period between 49 and 72 months and any index that is a LIBOR rate.
FNMA5X1_IOARM	FNMA single-family 5-year hybrid IO ARM collateral (index=1-year CMT, initial interest-only period typically 10 years). Includes ARMs with an initial interest-only period, original fixed period between 49 and 72 months and any index that is not a LIBOR rate.
FNMA5X1_IOARML	FNMA single-family 5-year hybrid IO ARM collateral (index=1-year LIBOR, initial interest-only period typically 10 years). Includes ARMs with an initial interest-only period, original fixed period between 49 and 72 months and any index that is a LIBOR rate.
FNMA7X1_ARM	FNMA single-family 7-year hybrid ARM collateral (index=1-year CMT). Includes ARMs with no initial interest-only period, original fixed period between 73 and 102 months and any index that is not a LIBOR rate.
FNMA7X1_ARML	FNMA single-family 7-year hybrid ARM collateral (index=1-year LIBOR). Includes ARMs with no initial interest-only period, original fixed period between 73 and 102 months and any index that is a LIBOR rate.
FNMA7X1_IOARM	FNMA single-family 7-year hybrid IO ARM collateral (index=1-year CMT, initial interest-only period typically 10 years). Includes ARMs with an initial interest-only period, original fixed period between 73 and 102 months and any index that is not a LIBOR rate.
FNMA7X1_IOARML	FNMA single-family 7-year hybrid IO ARM collateral (index=1-year LIBOR, initial interest-only period typically 10 years). Includes ARMs with an initial interest-only period, original fixed period between 73 and 102 months and any index that is a LIBOR rate.
FNMA10X1_ARM	FNMA single-family 10-year hybrid ARM collateral (index=1-year CMT). Includes ARMs with no initial interest-only period, original fixed period exceeding 102 months and any index that is not a LIBOR rate.
FNMA10X1_ARML	FNMA single-family 10-year hybrid ARM collateral (index=1-year LIBOR). Includes ARMs with no initial interest-only period, original fixed period exceeding 102 months and any index that is a LIBOR rate.
FNMA10X1_IOARM	FNMA single-family 10-year hybrid IO ARM collateral (index=1-year CMT, initial interest-only period typically 10 years). Includes ARMs with an initial interest-only period, original fixed period exceeding 102 months and any index that is not a LIBOR rate.
FNMA10X1_IOARML	FNMA single-family 10-year hybrid IO ARM collateral (index=1-year LIBOR, initial interest-only period typically 10 years). Includes ARMs with an initial interest-only period, original fixed period exceeding 102 months and any index that is a LIBOR rate.
FNMA_ARM	FNMA single-family 1-year ARM (index=1-year CMT). Includes ARMs with an original fixed period of 24 months or less.
FHLMC30	FHLMC single-family fixed-rate collateral with 30-year original term, excluding those with initial interest-only term. Includes original terms between 23 and 35 years.
FHLMC20	FHLMC single-family fixed-rate collateral with 20-year original term. Includes original terms from 17 years to below 23 years.
FHLMC15	FHLMC single-family fixed-rate collateral with 15-year original term. Includes original terms between 12 years and below 17 years.
FHLMC10	FHLMC single-family fixed-rate collateral with 10-year original term. Includes all original terms below 12 years.
FHLMC40	FHLMC single-family fixed-rate collateral with 40-year original term. Includes all original terms exceeding 35 years.
FHLMC30_IO10	FHLMC single-family fixed-rate collateral with 30-year original term and an initial interest-only period (typically 10 years). Includes all fixed-rate collateral that has an IO period of any length.
FHLMC3X1_ARM	FHLMC single-family 3-year hybrid ARM collateral (index=1-year CMT). Includes ARMs with no initial interest-only period, original fixed period between 25 and 48 months, and any index that is not a LIBOR rate.
FHLMC3X1_ARML	FHLMC single-family 3-year hybrid ARM collateral (index=1-year LIBOR). Includes ARMs with no initial interest-only period, original fixed period between 25 and 48 months, and any index that is a LIBOR rate.
FHLMC3X1_IOARM	FHLMC single-family 3-year hybrid IO ARM collateral (index=1-year CMT, initial interest-only period typically 10 years). Includes ARMs with an initial interest-only period, original fixed period between 25 and 48 months, and any index that is not a LIBOR rate.
FHLMC3X1_IOARML	FHLMC single-family 3-year hybrid IO ARM collateral (index=1-year LIBOR, initial interest-only period typically 10 years). Includes ARMs with an initial interest-only period, original fixed period between 25 and 48 months, and any index that is a LIBOR rate.
FHLMC5X1_ARM	FHLMC single-family 5-year hybrid ARM collateral (index=1-year CMT). Includes ARMs with no initial interest-only period, original fixed period between 49 and 72 months and any index that is not a LIBOR rate.
FHLMC5X1_ARML	FHLMC single-family 5-year hybrid ARM collateral (index=1-year LIBOR). Includes ARMs with no initial interest-only period, original fixed period between 49 and 72 months and any index that is a LIBOR rate.
FHLMC5X1_IOARM	FHLMC single-family 5-year hybrid IO ARM collateral (index=1-year CMT, initial interest-only period typically 10 years). Includes ARMs with an initial interest-only period, original fixed period between 49 and 72 months and any index that is not a LIBOR rate.
FHLMC5X1_IOARML	FHLMC single-family 5-year hybrid IO ARM collateral (index=1-year LIBOR, initial interest-only period typically 10 years). Includes ARMs with an initial interest-only period, original fixed period between 49 and 72 months and any index that is a LIBOR rate.
FHLMC7X1_ARM	FHLMC single-family 7-year hybrid ARM collateral (index=1-year CMT). Includes ARMs with no initial interest-only period, original fixed period between 73 and 102 months and any index that is not a LIBOR rate.
FHLMC7X1_ARML	FHLMC single-family 7-year hybrid ARM collateral (index=1-year LIBOR). Includes ARMs with no initial interest-only period, original fixed period between 73 and 102 months and any index that is a LIBOR rate.
FHLMC7X1_IOARM	FHLMC single-family 7-year hybrid IO ARM collateral (index=1-year CMT, initial interest-only period typically 10 years). Includes ARMs with an initial interest-only period, original fixed period between 73 and 102 months and any index that is not a LIBOR rate.
FHLMC7X1_IOARML	FHLMC single-family 7-year hybrid IO ARM collateral (index=1-year LIBOR, initial interest-only period typically 10 years). Includes ARMs with an initial interest-only period, original fixed period between 73 and 102 months and any index that is a LIBOR rate.
FHLMC10X1_ARM	FHLMC single-family 10-year hybrid ARM collateral (index=1-year CMT). Includes ARMs with no initial interest-only period, original fixed period exceeding 102 months and any index that is not a LIBOR rate.
FHLMC10X1_ARML	FHLMC single-family 10-year hybrid ARM collateral (index=1-year LIBOR). Includes ARMs with no initial interest-only period, original fixed period exceeding 102 months and any index that is a LIBOR rate.
FHLMC10X1_IOARM	FHLMC single-family 10-year hybrid IO ARM collateral (index=1-year CMT, initial interest-only period typically 10 years). Includes ARMs with an initial interest-only period, original fixed period exceeding 102 months and any index that is not a LIBOR rate.
FHLMC10X1_IOARML	FHLMC single-family 10-year hybrid IO ARM collateral (index=1-year LIBOR, initial interest-only period typically 10 years). Includes ARMs with an initial interest-only period, original fixed period exceeding 102 months and any index that is a LIBOR rate.
FHLMC_ARM	FHLMC single-family 1-year ARM (index=1-year CMT). Includes ARMs with an original fixed period of 24 months or less.
GNMA30	GNMA single-family fixed-rate collateral with 30-year original term. Includes original terms of 23 years or more.
GNMA20	GNMA single-family fixed-rate collateral with 20-year original term. Includes original terms between 17 years and below 23 years.
GNMA15	GNMA single-family fixed-rate collateral with 10- to 15-year original terms. Includes original terms below 17 years.
GNMA_II30	GNMA II single-family fixed-rate collateral with 30-year original term. Includes original terms of 23 years or more.
GNMA_II20	GNMA II single-family fixed-rate collateral with 20-year original term. Includes original terms between 17 years and below 23 years.
GNMA_II15	GNMA II single-family fixed-rate collateral with 10- to15-year original terms. Includes original terms below 17 years.
GNMA3X1_ARM	GNMA single-family 3-year hybrid ARM collateral (index=1-year CMT). Includes ARMs with no initial interest-only period and original fixed period between 25 and 48 months.
GNMA5X1_ARM	GNMA single-family 5-year hybrid ARM collateral (index=1-year CMT). Includes ARMs with no initial interest-only period and original fixed period between 49 and 72 months.
GNMA7X1_ARM	GNMA single-family 7-year hybrid ARM collateral (index=1-year CMT). Includes ARMs with no initial interest-only period and original fixed period exceeding 72 months.
GNMA3X1_ARML	GNMA single-family 3-year hybrid ARM collateral (index=1-year LIBOR). Includes ARMs with no initial interest-only period and original fixed period between 25 and 48 months.
GNMA5X1_ARML	GNMA single-family 5-year hybrid ARM collateral (index=1-year LIBOR). Includes ARMs with no initial interest-only period and original fixed period between 49 and 72 months.
GNMA7X1_ARML	GNMA single-family 7-year hybrid ARM collateral (index=1-year LIBOR). Includes ARMs with no initial interest-only period and original fixed period exceeding 72 months.
GNMA_ARM	GNMA single-family 1-year ARM (index=1-year CMT). Includes ARMs with an original fixed period of 24 months or less.

Agency Prepayment Model Key Assumptions

- **The conditions and relationships observed in the past will generally hold going forward, with exceptions as appropriate when market conditions are not typical.** This is a broad assumption in that our model uses past actual speeds as a guide to model predicted future speeds; the past speeds are real observed data that should be given significant weight when current or future conditions are similar or expected to be similar.

- **Home price appreciation assumed to be 3% annualized over the long term, with modest adjustments in the short term**. It is reasonable to expect that given reasonable affordability by historical standards, home prices should appreciate slightly above long-term expected wage inflation, reflecting slightly higher wage growth for those capable of homeownership. Based on recent inventory, affordability, home price momentum and other relevant short-term factors, modest adjustment may be made over the year or two following the most recent historical data point. Model version 21.5 incorporates historical data through Q2 2019, a 4\% projection for the remainder of 2019, and 3\% annually thereafter. Note that projections for different geographies vary at the state level; a fraction of the appreciation difference between a given state and national over the past 12 months is applied to that state's HPA going forward; the fraction declines linearly from 1 to zero over the next 36 months.

- **Unemployment rates are assumed to follow a path consistent with the Economic Projections of Federal Reserve Bank Presidents and Board Members.** These forecasts are published quarterly (http://www.federalreserve.gov/monetarypolicy), and we believe that the Federal Reserve is among the best positioned to make accurate unemployment forecasts, although any forecast of unemployment is highly uncertain. Specifically, model version 21.5 is based on the September 2019 Fed forecast, and incorporates unemployment rising gradually from its August 2019 level of 3.7\% to 4.2\% over the next few years and remaining stable at that level in the long run.

- **The terms of the FHFA HLRO program for high LTV borrowers that replaced HARP at the start of 2019 are assumed not to change in the future.** In August 2017, FHFA announced an extension of HARP to December 2018, and established an eligibility cutoff for the previously announced HLRO along with a 15-month seasoning requirement. Only borrowers with note dates of October 2017 or later would be eligible for HLRO, and the seasoning requirement ensured that no such refinances would occur until HARP expired. In May 2018, Fannie Mae and Freddie Mac both announced LLPA caps for HLRO loans and confirmed that a minimum of a 97 mark-to-market LTV was required. Other than the high LTV requirement, and the ability to use HLRO multiple times (as opposed to single-use only for HARP), HLRO is substantially the same as HARP and the model assumes HARP-like speeds on loans that become eligible for the program if HPA declines.

- **The long-term US housing turnover level (including homes without a mortgage) is assumed to be about 5.2%.** This is about the average ratio of existing single family home sales (as published by the National Association of Realtors) to single family housing stock (as published by the Census Bureau) over the past forty years. The model also approximates the relative mobility of mortgaged borrowers to mortgaged borrowers at a ratio of 1.2, consistent with levels observed on average over time.

- **GSE guarantee fees are assumed to remain at current levels going forward.** In April 2015, FHFA announced very modest updates to its LLPA matrix, and indicated that they believed guarantee fees are generally at the appropriate level. G-fees were observed to decline slightly in 2016 and 2017, resulting in FHFA actions that impose minimum g-fee levels and ROE requirements to prevent or moderate further declines. No further proposals of g-fee changes have been made by FHFA, although Congress could impose increases to fund non-mortgage priorities (as occurred with one of the 10 bps increases in 2012). The lack of significant FHFA actions on the matter seems to indicate that no significant changes in GSE guarantee fess should be expected unless market conditions change dramatically. Note that the above-mentioned 10 bps g-fee increase mandated by Congress and passed directly to the U.S. Treasury is scheduled to expire in October 2021. However, given the uncertainty regarding GSE reform, including the possibility of a full-faith-and-credit guarantee, which would likely come with a cost, this additional 10 bps charge is not currently removed by the model at its stated expiration.

- **Mortgage insurance premiums (MIPs) for the four GNMA guarantors (FHA, VA, RH and PIH) are assumed to remain at current levels going forward.** In January 2015, FHA surprised market participants with an immediate 50 basis point reduction in annual MIP, before FHA's insurance fund had recovered substantially. A subsequent additional cut of 30 bps announced at the end of the Obama administration was rescinded immediately after the Trump administration took power in January 2017. FHA seems unlikely to consider an additional decrease at current reserve levels. Grandfathering of MIPs for borrowers originated prior to June 2009 is assumed to continue indefinitely. VA MIPs have not changed in many years. RH made gradual increases over several years after the crisis, followed by a reduction in October 2016. We assume no further changes in the foreseeable future for RH MIPs.

Agency Prepayment Model Key Assumptions (continued)

- **Primary mortgage insurance rates (PMI) applicable to conventional loans above 80 LTV are assumed to remain at current levels going forward.** PMI companies such as Arch, Radian, Genworth and MGIC made major changes to their pricing grids in early 2016, and subsequently adjusted rates lower in 2018 following the corporate tax cut (while adding overlays for high DTI loans). Given these fairly recent changes, the model assumes no further changes in the foreseeable future.

- **Conforming loan limits are assumed to grow in line with our HPA assumption after 2019.** While it is not clear what the ultimate government role in the mortgage market will be or what loan size limits will apply, we are assuming for now that GSE-type of guarantees will continue to be available for the existing limits, and such limits will increase in line with our expected long-term HPA assumption. Reinforcing this assumption was the decision by new FHFA director Mel Watt not to lower the existing loan limits in 2014, as well as the request for comment regarding FHFA's proposal regarding how the limits would be raised in the future (http://www.fhfa.gov//Media/PublicAffairs/Pages/Input-on-HPI-Measure-for-Conforming-Loan-Limits-for-Fannie-and-Freddie.aspx), which was subsequently implemented. The first loan limit increase in many years was announced for 2017, with larger increases applicable in 2018 and 2019 (latest announcement: https://www.fhfa.gov/Media/PublicAffairs/Pages/FHFA-Announces-Maximum-Conforming-Loan-Limits-for-2019.aspx).

- **LTV limits imposed by GSEs and FHA/VA/RH are not assumed to change going forward.** The GSEs allow LTVs up to 97\% on rate refinances (with some exceptions for loans originated through state housing finance authorities) and 80\% on cash-out refinances (down from 85\% effective in late 2014). FHA does not impose LTV limits on streamlined rate refinances, and allows cash-out refinances up to 80\% LTV (down from 85\% for FHA case numbers effective Sep 1, 2019) plus the financing of the upfront MIP. VA does not impose LTV limits on streamlined rate refinances and allows cash-out refinances up to 100\% LTV (effective Feb 15, 2019 the limit is reduced to 90\% unless one of a number of conditions are satisfied, and no longer allows the financing of the VA funding fee into the cash-out loan if it would bring the LTV over 100\%). Rural Housing does not impose LTV limits on streamlined rate refinances and does not permit cash-out refinancings. While cash-out NTB tests may become stricter, we assume no change in the maximum LTVs permitted as part of those revised tests.

- **Mortgage origination fees and costs are assumed to remain stable at current levels.** We assume that pricing for borrower-paid items, such as title insurance, legal fees, appraisals, etc. that are typically included in these fees will not change materially from current levels. Both Fannie Mae and Freddie Mac have introduced streamlined digital underwriting which offers appraisal waivers on many rate refinances and some purchase loans and cash-out refinances as well. The fraction of loans offered such waivers are available in data supplied by the GSEs, and the model accounts for the known data and expected trajectory. Overall, we believe regulatory changes have significantly increased origination costs and fees (including servicing costs) over the years following the housing bubble and its collapse in the 2000s, but these increases have been partially offset by efficiency improvements. At present, we assume no further reduction in origination costs and fees, either tangible or intangible (the latter referring to the perceived convenience of refinancing). However, increased digitization of mortgage underwriting could result in substantial efficiency improvements, which in turn could materially increase prepayments.

- **Primary secondary spread (versus CMM102) is assumed to be in the 50-125 bp range except under extreme conditions.** This is the range that has applied over the post-crisis history. While we believe it is possible that the spread could go outside of that range, particularly under extreme conditions, a materially lower value is likely to make originations uneconomical, while a materially higher value would likely drive significant competitive pressures and regulatory scrutiny. The lower end of this range has been reduced over the past few years as a result of stronger competition, a flatter yield curve and particularly due to high WAC spreads in late 2018 and early 2019. The high WAC spreads compressed the TBA stack and increased the spread between CMM102 and CMM100, driving originators to pool their loans into lower coupons (their excess servicing valuations or the pricing they received from the GSEs for buying up the guarantee fee exceeded the servicing value implied by TBA prices). It should be noted that model version 21.5 attempts to model the baseline as a function of expected competition (i.e, more competition when the refinancible universe is smaller), the shape of the curve, and the expected WAC spread (expected to decline following limitations on excess servicing spread imposed by the GSEs in June 2019).

- **Levels of 15-year and hybrid ARM mortgage rates relative to 30-year mortgage rates are closely correlated to changes in 5-year swap rates relative to 10-year swap rates.** The model assumes that the shape of the curve is the primary driver of relative 30-year, 15-year and 5x1 ARM mortgage rates.

Agency Prepayment Model Key Assumptions (continued)

- **Underwriting standards are assumed to remain consistent with current levels over the next few years.** The economic/housing crisis of 2007-2011 resulted in a swing from very loose to very tight underwriting standards; which have loosened somewhat as home prices have recovered over the last few years, and we assume that given the strong HPA over that time, further loosening is unlikely as home prices increases flatten out. The memory of the crisis is likely to persist for at least a generation, and we believe a return to pre-crisis underwriting will not occur in the foreseeable future.

- **Model refinancing S-curves are assumed to shift somewhat higher than 2012-2016 S-curves for new collateral, but not to fully revert to much higher pre-crisis S-curves.** As mentioned above, the regulatory and underwriting changes since the crisis are expected to be long-lived. Without significant streamlining of the refinance process, either from technological advances or the implementation of a streamline refinance program from the GSEs that is not limited to very high LTV loans on depreciated homes, S-curves are unlikely to return to levels of the 1990s or early 2000s, or even to the modestly higher levels of 2010 (when all new regulations were not fully in place and many refinances were highly streamlined due to the initial roll-out of HARP). However, technological advances, seem to have accelerated in recent years with Quicken's Rocket Mortgage and similar programs from other originators, and increasing adoption of and enhancements to the GSE automated underwriting programs (FNMA's Day One Certainty and FHLMC's LoanAdvisor Suite). We believe this has begun to shift S-curves higher for newer, high-quality loans that are most likely to benefit from these programs, particularly for borrowers that are able to obtain a property inspection waiver (PIW) that eliminates the need for an appraisal. In addition to these advances, it is also possible that at some point, FHFA and the GSEs will move toward universal streamlined refinancing (as permitted by the three major GNMA guarantors -- FHA, VA and RH) over time. This would likely accelerate prepayment rates more broadly and more significantly.

- **A presumed surge in cash-out refinancings in the spring and summer of 2018 is modeled as temporary in part; cash-out declines are modeled for GNMAs from an assumed final VA cash-out NTB test and future FHA cash-out NTB test.** A number of factors created a "perfect storm" to drive cash-out refinancings in 2018, in our view. These include a back-up in interest rates and new refinancing restrictions for GNMA loans that left many originators with excess capacity; a housing inventory shortage that made it difficult for many homebuyers to upgrade, leaving them to renovate via cash-out financing instead; a tax-cut that increased awareness of cash-out lending and provided more disposable income for the same; sharply rising short-term rates that make the cash-out vs. HELOC equation more favorable for the former, more permissive DTI requirements from the GSEs (these were partially rolled back in late 2018), and special cash-out provisions for those paying off student loans. The model generally assumes that a more normalized cash-out environment has developed, and the impact of short-term rates and excess capacity are modeled explicitly for model versions 21.5 and later. It is also assumed that the final VA cash-out NTB rule will be stricter than the interim rule, and that FHA will make changes to cash-out rules, such that non-economic cash-out refinances under both guarantors will be reduced.

Agency Prepayment Model Limitations

The basic premise for the agency prepayment model is that conditions and relationships observed in the past will hold going forward. If certain collateral prepaid at a certain rate under certain interest rate, housing market, and economic conditions, the model generally assumes a similar prepayment rate under similar conditions in the future. Such an approach has a number of important limitations.

- A large body of data now exists on prepayments, but it still only partially covers the range of interest-rate and macroeconomic environments that is possible over the term of a mortgage-backed security (MBS). In particular, in the past there have not been negative interest rates, and in the recent past (since the early 1990s) there have been few periods of interest rates much higher than the mortgage rates for loans deliverable into the lowest coupon TBA.

- Other factors that determine prepayments that are not necessarily or directly related to collateral attributes or macroeconomic environments -- borrower demographics, loan origination and servicing practices in the mortgage lending industry, government regulations, the costs and ease of refinancing, borrower responsiveness, etc. -- change over time, often in unpredictable ways. In particular, the impact of digital mortgage technology could ultimately be quite disruptive, but the model cannot reasonably predict this except to the extent that it is reflected in past data and is based on specific program announcements (e.g., Day One Certainty from FNMA and LoanAdvisor Suite from FHLMC, including requirements to obtain a PIW).

- Much uncertainty surrounds the future of the GSEs (FNMA and FHLMC). The long-term status of these entities is unclear, given their failure during the 2008 housing crisis, their current status in government conservatorship, and the numerous GSE reform proposals under consideration. Even absent any material change in the status of the GSEs, future policy changes by the GSEs or their regulator (The Federal Housing Finance Agency, or FHFA) could still have a significant impact on prepayment rates. It is not clear whether, for example, a crisis would prompt an expansion of the high-LTV streamlined refinancing program that FHFA established to start after HARP expiration in December 2018. At present, this program is only available to borrowers whose loans did not originate through the HARP program and whose LTVs exceed the normal maximums permitted by the GSEs (97 for most loans). This streamline refinance program could be expanded immediately during a crisis, especially under a significant rally when many borrowers could benefit, or more gradually over time absent a crisis.

- The Qualified Mortgage (QM) standards went into effect in early 2014. While the existing GSE and government loans are exempt, all guarantors are likely to converge to these standards over time. The exemption for GSE loans expires in October 2021 and a re-examination of QM rules is underway. Particularly affected may be loans with DTIs exceeding 43, which do not receive safe harbor QM status under existing QM rules and made up more than 25% of GSE loan production throughout much of 2018 and early 2019. Furthermore, new Truth in Lending Act and RESPA Integrated Disclosure requirements became effective in late 2015. These new regulatory requirements have already affected the underwriting environment to some degree, and may ultimately cause underwriting standards to vary from our assumptions.

- There is uncertainty regarding the breakdown of voluntary prepayment speeds into housing turnover, rate refinance, cash-out refinance, and full payoff components of model projections, as these speeds cannot be observed directly.

- The crisis period from 2007 through 2011 was characterized by falling home prices, tight underwriting, high unemployment, and low home sales. Over the ensuing years, home prices turned around and the other issues have eased; at the same time, new non-bank servicers have emerged that refinance borrowers very aggressively. Clearly, sharply changing conditions can and has led to model errors.

- Collateral attributes (with the exception of loan size and LTV, which change based on assumed amortization and state-level actual and projected home price appreciation) do not change over the model projection period. This may introduce errors, particularly from changes in critical attributes like WAC, credit scores, DTI ratios, guarantor distribution, origination channel distribution, and servicer distribution. While some of this drift could be captured with a multiple repline approach, there is still a great deal of uncertainty about evolution of collateral attributes over time. For example, unless each repline is completely homogeneous, some drift will occur within the repline. Furthermore, attributes of individual loans (e.g., credit score and DTI, and improvements or deterioration in the underlying property) are likely to change over time, and are not updated (and in many cases could not be updated) in the monthly agency disclosures.

Agency Prepayment Model Framework And Dependencies

The model's framework and dependencies are illustrated by the diagram below.
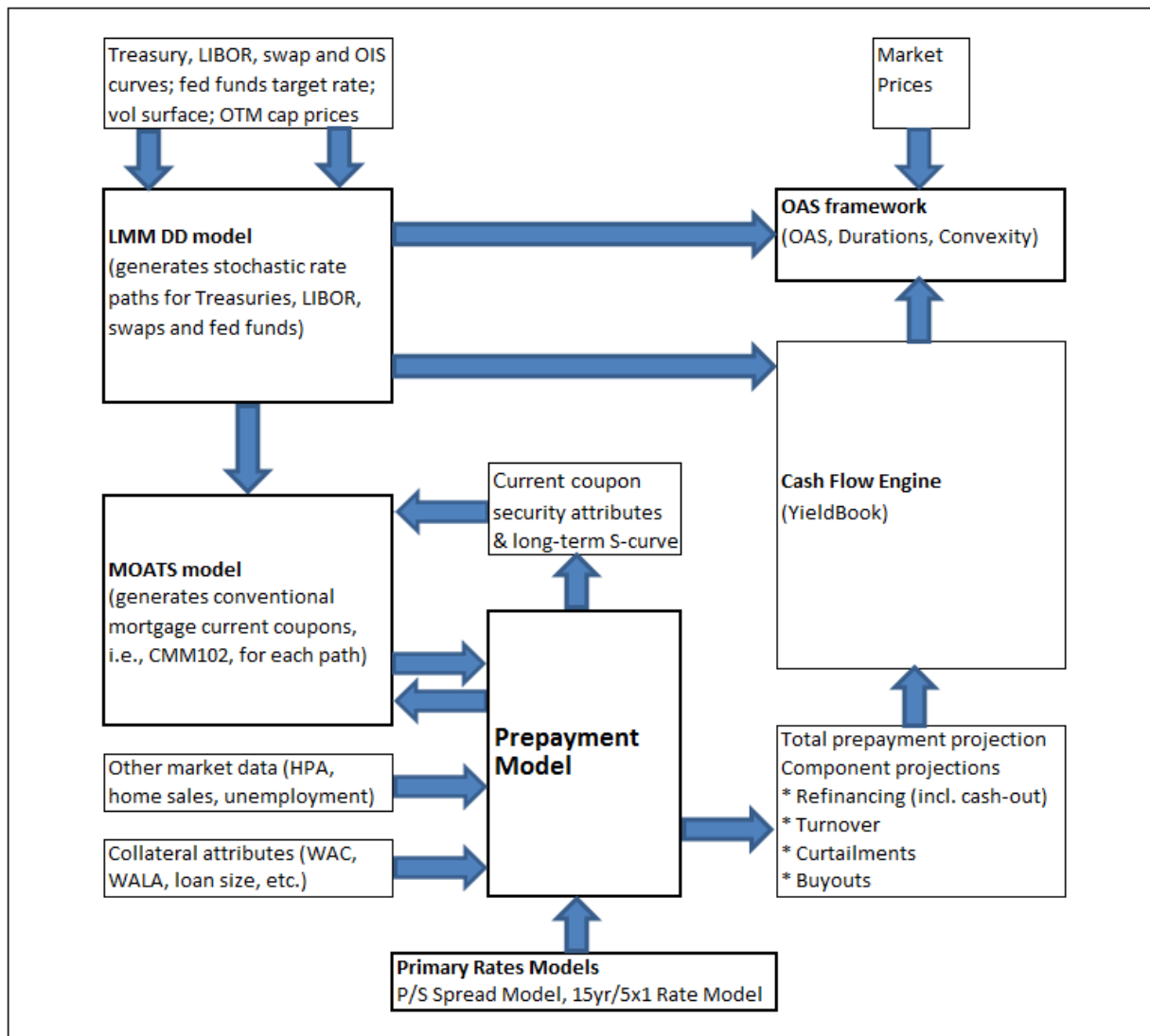
Notes:

For stochastic paths, secondary mortgage rates are determined by the LMM DD interest rate model (based on normal vols and supporting negative interest rates) iand the MOATS current coupon model.

Prepayment model parameters determine the MOATS S-curve (calibrated to match the long-term model projections for different incentive levels) and MOATS current coupon security repline (whose attributes are set to match new production TBA collateral).

Primary mortgage rates are derived from secondary rates using a P/S spread model and a 15-year/5x1 rate model.

The Yield Book provides the cash flow engine to incorporate prepayment projections into security cash flows.

The OAS framework uses discount factors from the LLM model and cash flows from the cash flow engine to compute option-adjusted spread, duration and convexity.

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