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Agency RMBS Prepayment Model

Release of Model v21.6 on Yield Book

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Highlights of Major Model Updates from v21.5 to v21.6

COVID-19 Impact

- **P/S Spread baseline up 25 bps with onset of COVID-19, normalizing to 2013-2018 average by end of 2021**
- **Incorporate forbearance and post-forbearance modification policy announcements from GSEs/FHA/GNMA**
- **FHA/GSE guidance on refis of loans in forbearance incorporated; refinement expected in future updates**
- **Higher roll rates, but lower fraction of D120+ bought out for conventionals, and over a more gradual period**
- **Bank servicers modeled to buy out defaulted GNMA loans aggressively; non-bank buyouts minimal initially**
- **Model uses past 24 months of delinquencies to make future and recent past buyout projections consistent**
- **FHFA adverse market refinance fee incorporated for refis into conventional loans; no assumed expiration**
- **HPA base case adjusted to 6% in 2020 (+7% Q3-Q4 after about 5% in Q1-Q2) and 3% thereafter**
- **Unemployment based on Sep Fed forecast: ~7.5% Q4, then 5.5%/4.6% by Q4 2021/2022, 4.1% long run**

P/S Spread Model Update

- **Spread more sensitive to rally/backup at high media effect levels, reducing primary rate volatility**
  - Previously assumed regulator scrutiny and originator pricing power limited movement at these levels
  - Neither seems applicable in current market, so these features have been removed
- **Currently, no assumptions made for changes in g-fees (Treasury or FHFA), but material changes possible**
- **P/S spread decline slowed during very strong rallies when capacity expansion may be more difficult**
- **GNMA/FNMA swap impact on long-term GNMA base rate removed; phased slowly back in over coming year**

Recalibrated Refi Response – PIW, Media Effect, Burnout, Spec Category Review

- **Conventional/GNMA refi ramps further recalibrated, based on recent major/multi pool speeds**
- **PIW / media effect recalibrated for very strong recent speeds and better distribution across coupon stack**
- **Most specified pool sectors also recalibrated to account for unexpectedly strong prints relative to generics**
- **Capture property valuation method disclosures from GSEs, but no adjustment yet, as true driver unclear**

Other Key Updates

- **Distribute base, downside and upside HPA and unemployment scenarios across rate paths**
- **PIW-driver for refi speeds assumed to weaken if housing market declines sharply**
- **Lock-in assumed stronger for a given disincentive level if rates back up to levels not seen in a long time**

Mortgage Index Comparisons: v21.6 vs. v21.5

9/21/2020	1-YEAR CPR			Long-Term CPR			OAS			EFF DUR			EFF CONV		
	v21.6	v21.5	Diff	v21.6	v21.5	Diff	v21.6	v21.5	Diff	v21.6	v21.5	Diff	v21.6	v21.5	Diff
Total	36.8	37.6	-0.8	26.3	27.0	-0.7	40.7	38.6	2.1	1.2	1.4	-0.2	-0.8	-0.4	-0.5
FNMA	35.3	35.9	-0.6	25.7	26.4	-0.7	33.2	33.8	-0.6	1.0	1.4	-0.4	-0.9	-0.4	-0.5
FHLM	36.3	36.5	-0.3	26.1	26.8	-0.7	33.8	34.5	-0.7	1.0	1.4	-0.4	-0.9	-0.3	-0.5
GNMA	39.8	41.6	-1.8	27.5	28.3	-0.8	60.3	50.9	9.4	1.7	1.5	0.1	-0.6	-0.4	-0.2
30 Year	37.7	38.7	-0.9	26.6	27.4	-0.8	43.0	40.3	2.7	1.2	1.4	-0.3	-0.9	-0.4	-0.5
FNMA	36.5	37.2	-0.7	25.9	26.8	-0.9	35.4	35.6	-0.2	1.0	1.4	-0.4	-1.0	-0.4	-0.6
FHLM	37.5	37.8	-0.3	26.5	27.3	-0.8	35.9	36.3	-0.4	0.9	1.3	-0.4	-0.9	-0.3	-0.6
GNMA	39.8	41.6	-1.8	27.5	28.3	-0.8	60.3	50.9	9.4	1.7	1.5	0.1	-0.6	-0.4	-0.2
15 Year	28.4	28.2	0.2	23.9	23.5	0.4	20.5	23.2	-2.7	1.4	1.5	-0.1	-0.6	-0.4	-0.2
FNMA	28.3	28.0	0.3	23.9	23.4	0.5	19.2	22.8	-3.6	1.4	1.5	-0.2	-0.6	-0.4	-0.2
FHLM	28.3	28.3	0.0	23.8	23.5	0.3	20.3	22.6	-2.3	1.4	1.6	-0.1	-0.7	-0.4	-0.2
GNMA	29.4	30.0	-0.6	23.6	24.6	-1.0	47.0	38.4	8.6	1.7	1.5	0.3	-0.4	-0.4	0.1

- Model projections overall are slightly slower in the new model for conventionals. This is caused by slower speeds on many large 2019-2020 2s to 3s cohorts (in part due to higher assumed P/S spreads), offset by faster speeds on more seasoned collateral. This is generally true for both the 30 year and 15 year sectors.

- Despite moderately lower prepayment speeds, OASs and durations are lower in the new model, based primarily on a stronger media effect and weaker burnout of the PIW effect. Convexities are more negative for the same reason.

- GNMA speeds are projected slightly lower overall, with stronger media effect and higher buyouts mostly offset by higher P/S spreads and changes in our assumed GNMA primary rate (please see rates sub-model section below), as well as recalibration of peak ramps and subsequent burnout on new pools.

- OASs are higher and durations are slightly longer for GNMAs due to the primary rate and ramp/burnout changes just mentioned. Convexities are modestly more negative.

Source: Yield Book, Citi

TBA and Spec Comparisons: v21.6 vs. v21.5

Curve/Trade Date: 9/17/2020							1 Yr Proj			LT Proj			OAS			Eff Duration			Eff Convexity		
Agency	Coupon	Tranche	level	Age	Wac		Old	New	Diff	Old	New	Diff	Old	New	Diff	Old	New	Diff	Old	New	Diff
FNMA	2.0	Gen	103.02	54	2.86		17.3	17.2	-0.1	16.5	15.4	-1.1	38	33	-5	3.8	3.4	-0.3	-2.5	-2.8	-0.4
FNMA	2.5	Gen	104.79	53	3.20		25.6	25.7	0.2	20.6	19.1	-1.5	39	36	-3	2.5	2.2	-0.3	-2.1	-2.5	-0.5
FNMA	3.0	Gen	104.74	53	3.70		35.5	36.8	1.3	26.0	24.5	-1.5	69	66	-2	1.9	1.5	-0.5	-1.1	-1.5	-0.5
FNMA	3.5	Gen	105.37	42	4.07		37.2	37.2	0.1	26.6	25.0	-1.7	95	98	3	1.8	1.5	-0.4	-0.7	-1.3	-0.6
FNMA	4.0	Gen	106.68	38	4.48		36.1	35.8	-0.3	26.9	25.4	-1.5	106	113	7	1.7	1.3	-0.4	-0.3	-0.8	-0.5
FNMA	4.5	Gen	108.19	23	5.14		37.7	37.9	0.2	29.4	28.8	-0.5	92	100	8	1.4	0.9	-0.5	0.3	0.0	-0.3
FNMA	5.0	Gen	109.64	22	5.67		34.2	33.6	-0.6	27.4	27.0	-0.5	111	120	9	1.8	1.4	-0.4	0.3	0.1	-0.2
GNMAII	2.0	Gen	103.45	90	2.48		12.1	10.5	-1.7	9.9	9.5	-0.4	60	60	0	5.0	5.2	0.1	-0.7	-0.6	0.1
GNMAII	2.5	Gen	104.81	6	3.03		52.4	53.6	1.3	30.9	34.4	3.5	-14	-25	-11	-0.1	-0.1	0.0	-1.1	-0.8	0.3
GNMAII	3.0	Gen	104.53	8	3.49		56.7	59.6	2.9	35.3	40.5	5.2	22	6	-16	0.3	0.1	-0.2	-0.1	-0.3	-0.2
GNMAII	3.5	Gen	105.04	12	4.01		50.8	47.1	-3.6	35.8	34.6	-1.2	55	72	17	0.6	1.1	0.4	-0.1	-0.3	-0.2
GNMAII	4.0	Gen	106.61	12	4.52		51.4	45.0	-6.4	38.0	34.2	-3.7	28	69	41	0.3	1.1	0.8	0.6	0.1	-0.5
GNMAII	4.5	Gen	107.42	12	4.98		50.4	41.3	-9.1	38.9	32.6	-6.3	33	98	64	0.4	1.5	1.1	0.9	0.2	-0.7
GNMAII	5.0	Gen	108.63	15	5.54		56.7	51.3	-5.5	44.8	39.2	-5.6	-40	34	74	0.2	1.1	0.9	1.7	0.7	-1.0
FNM30	2.0	2020 GEN	103.02	2	2.98		41.9	22.7	-19.3	28.2	20.1	-8.1	-3	11	14	1.2	2.8	1.6	-4.0	-3.5	0.5
FNM30	2.5	2019 GEN	104.79	11	3.49		52.8	45.3	-7.5	37.6	30.8	-6.8	-34	-10	24	-0.2	0.4	0.6	0.0	-1.6	-1.7
FNM30	2.5	2019 LLB	107.98	10	3.10		8.0	8.5	0.5	9.6	10.5	0.9	44	35	-8	5.7	5.2	-0.5	-1.1	-1.5	-0.4
FNM30	2.5	2019 MLB	107.42	11	3.21		12.7	12.4	-0.3	11.6	12.5	0.9	35	28	-7	4.5	4.1	-0.3	-1.6	-1.8	-0.2
FNM30	2.5	2019 HLB	106.54	11	3.26		15.1	16.0	0.9	13.9	14.9	1.1	33	25	-8	3.6	3.3	-0.3	-2.2	-2.2	0.0
FNM30	2.5	2019 HHLB	106.11	12	3.42		20.6	20.0	-0.6	17.4	17.2	-0.2	23	20	-3	2.6	2.6	0.0	-2.2	-2.3	-0.1
FNM30	2.5	2019 MAX200K	105.73	11	3.30		23.1	20.7	-2.4	18.2	17.3	-0.9	24	24	0	2.3	2.4	0.1	-2.4	-2.6	-0.1
FNM30	2.5	2019 NY	106.61	12	3.52		26.2	18.7	-7.5	17.4	14.8	-2.5	10	17	7	2.5	2.9	0.4	-2.3	-2.8	-0.5
FNM30	2.5	NEW	104.82	1	3.36		53.8	35.2	-18.6	37.5	28.1	-9.4	-31	3	34	-1.0	1.0	1.9	-0.6	-2.3	-1.7
FNM30	3.0	2019 GEN	104.74	11	3.89		48.2	44.7	-3.5	34.3	31.5	-2.8	28	40	12	0.8	0.8	0.0	-0.6	-1.4	-0.8
FNM30	3.0	2019 LLB	109.99	11	3.65		12.3	13.4	1.0	12.4	13.4	1.0	42	33	-9	4.3	3.8	-0.5	-1.2	-1.4	-0.2
FNM30	3.0	2019 MLB	109.11	11	3.70		15.4	17.0	1.6	14.4	15.6	1.2	38	28	-10	3.3	2.9	-0.4	-1.6	-1.7	-0.1
FNM30	3.0	2019 HLB	108.18	11	3.78		21.9	22.6	0.7	17.9	18.5	0.6	29	25	-5	2.3	2.1	-0.2	-1.6	-1.6	-0.1
FNM30	3.0	2019 HHLB	107.11	11	3.81		28.3	27.1	-1.2	22.0	21.1	-0.8	26	29	3	1.5	1.6	0.1	-1.4	-1.7	-0.3
FNM30	3.0	2019 MAX200K	106.36	11	3.83		32.8	31.0	-1.8	24.5	23.0	-1.5	30	35	5	1.2	1.3	0.1	-1.2	-1.6	-0.5
FNM30	3.0	2019 NY	107.99	11	3.74		27.7	23.2	-4.5	18.7	16.7	-2.0	27	32	6	2.0	2.0	0.0	-1.6	-2.2	-0.7
FNM30	3.0	NEW	105.30	1	3.87		53.4	40.0	-13.5	41.2	32.6	-8.7	-17	27	43	-0.6	0.7	1.4	0.6	-1.2	-1.8
FNM30	3.5	2019 GEN	105.37	14	4.38		46.7	46.1	-0.6	34.6	34.0	-0.6	54	61	7	1.0	0.6	-0.4	-0.1	-0.5	-0.5
FNM30	3.5	2019 LLB	111.55	12	4.03		14.5	15.6	1.1	13.6	14.5	0.8	54	46	-8	3.7	3.3	-0.4	-1.1	-1.2	-0.1
FNM30	3.5	2019 MLB	110.43	12	4.09		18.8	20.5	1.7	16.3	17.4	1.1	47	38	-9	2.6	2.2	-0.4	-1.3	-1.3	0.0
FNM30	3.5	2019 HLB	108.99	13	4.21		27.6	27.9	0.3	20.9	21.2	0.3	38	37	-1	1.6	1.5	-0.1	-0.8	-1.1	-0.2
FNM30	3.5	2019 HHLB	107.99	13	4.33		34.9	33.0	-1.9	26.2	24.7	-1.5	27	38	11	1.0	1.0	0.0	-0.3	-0.9	-0.6
FNM30	3.5	2019 MAX200K	107.24	14	4.36		38.7	36.8	-1.9	28.9	27.1	-1.8	30	42	12	0.9	0.8	0.0	-0.1	-0.8	-0.7
FNM30	3.5	2019 NY	109.24	13	4.16		34.2	29.4	-4.8	21.6	19.2	-2.4	28	42	14	1.5	1.5	0.0	-0.6	-1.5	-0.9
FNM30	3.5	NEW	106.24	2	4.38		48.8	38.5	-10.3	38.6	31.3	-7.3	3	50	47	0.1	0.9	0.8	0.8	-0.7	-1.5
FNM30	4.0	2019 GEN	106.68	16	4.83		46.0	45.2	-0.8	34.4	33.9	-0.5	54	64	10	1.0	0.6	-0.4	0.3	0.1	-0.3
FNM30	4.0	2019 LLB	113.87	14	4.55		18.0	19.1	1.2	15.3	15.9	0.6	44	36	-7	3.0	2.7	-0.3	-0.8	-0.9	-0.1
FNM30	4.0	2019 MLB	112.62	14	4.60		23.4	24.7	1.2	18.7	19.5	0.8	29	23	-6	1.8	1.6	-0.2	-0.7	-0.8	-0.1
FNM30	4.0	2019 HLB	110.55	15	4.71		31.9	30.8	-1.1	23.7	23.4	-0.2	26	33	7	1.2	1.1	-0.1	-0.2	-0.5	-0.4
FNM30	4.0	2019 HHLB	109.05	16	4.82		38.3	35.2	-3.1	28.7	26.7	-1.9	25	45	20	0.8	0.8	0.0	0.4	-0.3	-0.7
FNM30	4.0	2019 MAX200K	108.43	16	4.81		41.3	38.2	-3.2	30.9	28.7	-2.3	27	48	22	0.8	0.7	-0.1	0.6	-0.1	-0.7
FNM30	4.0	2019 NY	111.18	15	4.64		36.0	32.0	-4.0	23.3	21.4	-1.9	18	37	19	1.4	1.0	-0.4	0.1	-0.8	-0.9
FNM30	4.0	2019 NEW	107.62	2	4.82		52.7	42.7	-9.9	43.5	36.3	-7.2	-48	21	69	-0.3	0.3	0.5	1.9	0.3	-1.6
FNM30	4.5	2018 GEN	108.19	26	5.11		37.6	42.7	5.1	29.9	31.9	2.1	86	72	-14	1.4	0.6	-0.8	0.3	0.3	0.0
FNM30	4.5	2018 LLB	115.32	26	5.02		19.5	22.2	2.7	16.2	17.0	0.8	52	41	-10	2.8	2.5	-0.3	-0.5	-0.7	-0.1
FNM30	4.5	2018 MLB	113.82	26	5.00		24.4	27.8	3.3	19.7	20.9	1.2	39	27	-12	1.8	1.4	-0.4	-0.3	-0.5	-0.1
FNM30	4.5	2018 HLB	111.94	26	5.01		30.5	32.3	1.8	23.6	24.0	0.5	40	39	-1	1.3	1.0	-0.3	0.1	-0.2	-0.3
FNM30	4.5	2018 HHLB	110.50	26	5.07		34.6	36.0	1.3	27.3	27.0	-0.4	43	48	5	1.1	0.8	-0.3	0.5	0.1	-0.4
FNM30	4.5	2018 MAX200K	109.94	26	5.09		36.5	38.9	2.4	28.8	28.9	0.1	46	47	1	1.1	0.6	-0.5	0.7	0.3	-0.4
FNM30	4.5	2018 NY	112.19	25	4.98		27.8	33.6	5.9	21.1	22.5	1.3	66	49	-17	2.1	0.9	-1.1	0.3	-0.1	-0.4
FNM30	4.5	NEW	109.13	1	5.16		35.5	32.4	-3.0	33.1	30.7	-2.4	33	58	25	0.8	0.8	0.0	0.8	0.0	-0.8

Source: Yield Book, Citi

COVID-19 Impact – More PIW, Massive Rally, Varied Buyouts

- The P/S spread baseline assumption is now 25 bps higher than prior to the start of the COVID-19 crisis, and we now assume normalization by the end of 2021. We expect that over the next 12-18 months, significant additional capacity will be added, while at the same time the refinancible universe should decline substantially after a long period of speeds likely averaging above 30 CPR at current rate levels. However, there are some reports of bottlenecks impairing capacity additions, which could worsen in a further rally; the model has been adjusted to extend the ramp-up of capacity if such a rally materializes.

- The rally to unprecedented rate levels, combined with aggressive PIW offers from originators and more interaction of borrowers with lenders during the crisis, is assumed to drive extremely strong refinance rates. While this may to some extent result in more burnout, the shift to digitization that was already underway has been accelerated by the crisis, which should permanently elevate the refinancing response.

- We assume largely normalized turnover after the COVID-driven decline and subsequent pent-up demand.

- Home prices have been very resilient, so we now assume HPA of 6% for full-year 2020 and 3% thereafter. Employment has also recovered faster than initially expected, and our base case forecast now follows the September Fed forecast of about 7.5% in Q4, 5.5% by Q4 2021, 4.6% by Q4 2022, and 4.1% long run.

- The GSEs have indicated they will not buy out loans in forbearance, nor those resolved by reinstatement, repayment plans or payment deferral mods, so we assume modestly elevated buyouts over the next year on conventionals as borrowers unable to resume their existing payment are modified. For GNMAs, we assume banks will continue to aggressively buy out loans immediately upon eligibility, with non-banks generally delaying them until modification is necessary…please see following page.

- Both the GSEs (as announced by FHFA on May 19, 2020) and FHA (via ML 2020-30 on September 10) generally allow borrowers that exited forbearance to refinance after three payments, with fully reinstated loans (GSEs) or credit-qualifying borrowers (FHA) eligible immediately…please also see following page.

COVID-19 Impact – Policy Driven Buyout Changes

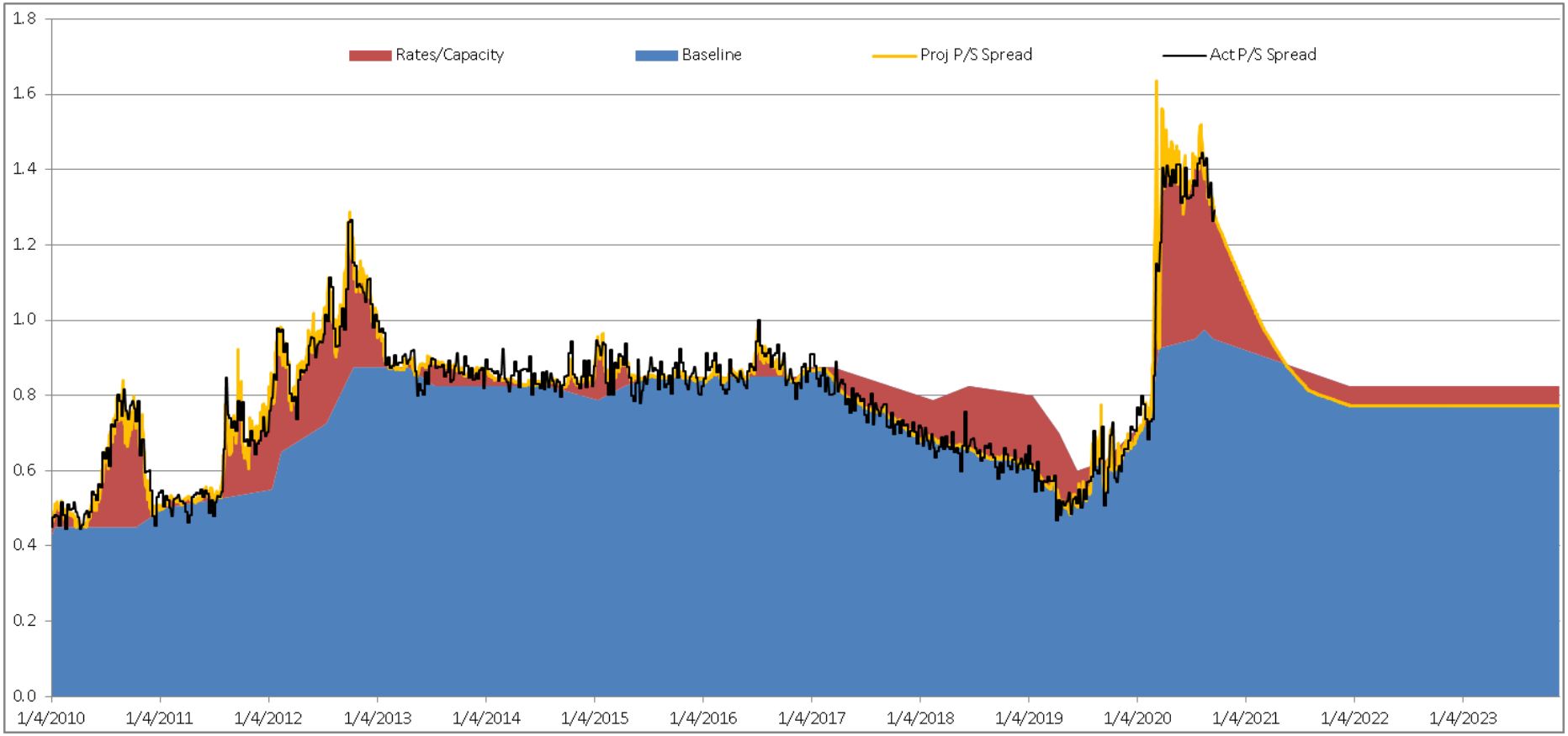
Model v21.6 incorporates GSE and HUD/GNMA announcements regarding forbearance, loss mitigation, and buyouts:

Policy Announcement	Model Impact
CARES act mandates up to 12 months of forbearance upon borrower attestation of hardship	We assume much higher roll rates on delinquent loans than normal; most initial forbearance plans were for 90 days. Based on a non-trivial fraction seeming to exit after this initial period, we assume gradual resolution rather than assuming all borrowers remain in forbearance for the full available term.
GSEs indicate no buyouts of loans in forbearance; payment deferral mod option added	Instead of the traditional assumption of immediate buyouts at 120 days of delinquency, model v21.6 assumes a gradual resolution of loans in forbearance over the next year, with about 75% of loans in forbearance able to resume payments and remaining in the pools, based on Fed unemployment projections.
FHA announces COVID-19 partial claim as primary loss mitigation option for borrowers able to resume pre-COVID payment, and additional options for those that cannot	A buyout is permitted but not required to complete an FHA COVID-19 partial claim. Thus we maintain assumptions of immediate buyouts by bank servicers with access to cheap capital, but delay them for non-banks, especially in light of updated GNMA policy discussed further below. Given the elimination of TPP requirements for COVID-19 related mods, we do assume more non-bank mods/buyouts of loans in forbearance, with about 50% of non-bank FHA loans resuming payments/remaining in pools, with the remainder modified/bought out.
No changes so far to VA and RHS modification options	Existing VA and RHS disaster modification options generally extend the term of the loan, and therefore would require buyouts to complete any modification. We therefore assume that substantially all loans in forbearance that do not fully cure (i.e., about 50% for VA and 25% for RH assumed to cure) are gradually repurchased by non-bank lenders after modification.
GNMA requires that any loans eligible to remain in existing pools but nevertheless bought out must be re-pooled into non-deliverable customs, and only after a six-month payment history (APM 20-07)	We eliminate immediate buyouts from non-banks, as we assume they are unwilling to tie up significant capital unless resolution of the bought-out loan is certain in short order. Notably, the GNMA announcement exempted mods from the restrictions, and given elimination of TPP requirements by FHA for COVID mods, more aggressive buyouts from non-banks and/or a revision to APM 20-07 from GNMA to require separate pooling of COVID mod loans is possible.
GSEs and FHA relax payment history requirements for refinances, generally permitting them after three payments are made post-forbearance, and in some cases immediately upon forbearance exit	The model assumes loans that are current may refinance, regardless of past delinquency (in any case, “dirty current” fractions are not generally available for agency pools). In effect, FHA and the GSEs are allowing this, with a three month delay in some cases and no delay in other cases. Thus the model broadly captures the reality in principle, in concert with existing general impairment adjustments. We will consider refinements where appropriate in future updates.

Source: HUD, FHFA, Ginnie Mae, Fannie Mae, Freddie Mac

KEY MORTGAGE RATE SUBMODEL CHANGES FOR V21.6

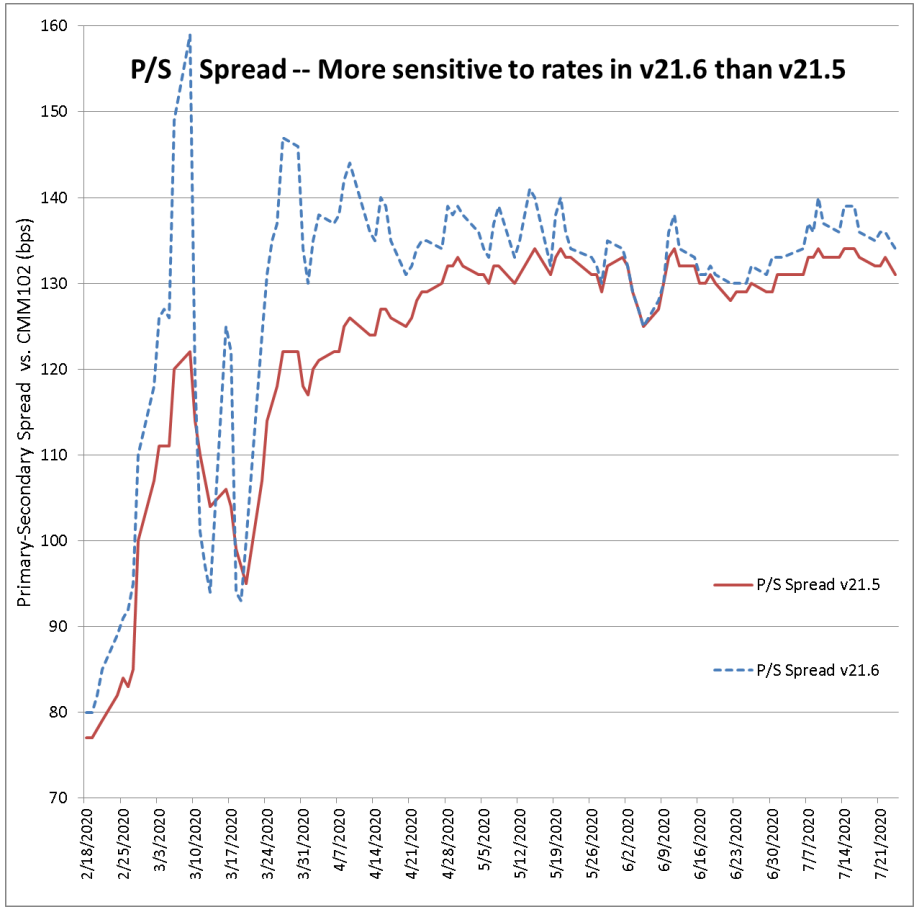
P/S Spread Modeled to Normalize by the End of 2021

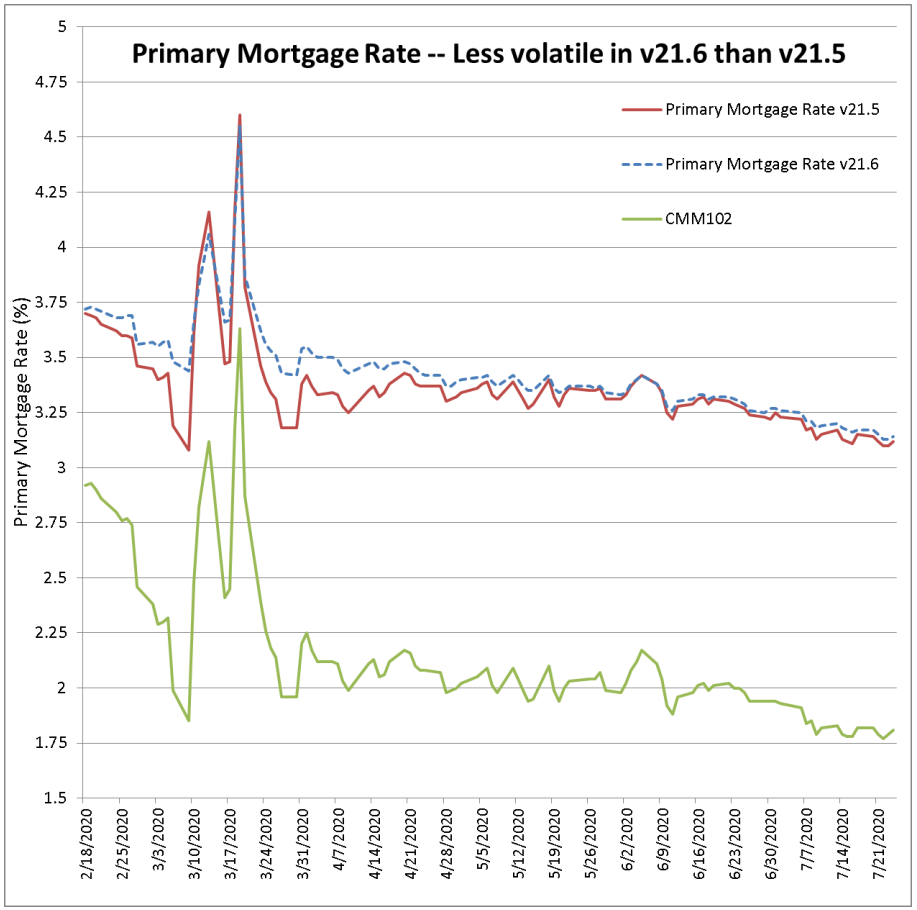


- **The baseline component of the model P/S spread (vs. CMM102), as shown by the piecewise linear portion of the plot above, was stable between the 2012 g-fee increases and the emergence of very high WAC spreads in early 2019.**
- **The red portion represents the impact of rates/capacity, and pushes spread above baseline during sharp rallies and tight capacity, and below baseline at times of rate backups, flat yield curves, and excess capacity.**
- **Consistent with feedback from originators, a significant portion of the now elevated spread is modeled as driven by capacity constraints, which we expect to ease over the next year or so. COVID-19 related uncertainty should also wane over the same period, allowing spreads to return to historical levels by the end of 2021 if CMM102 is flat.**

Source: Freddie Mac

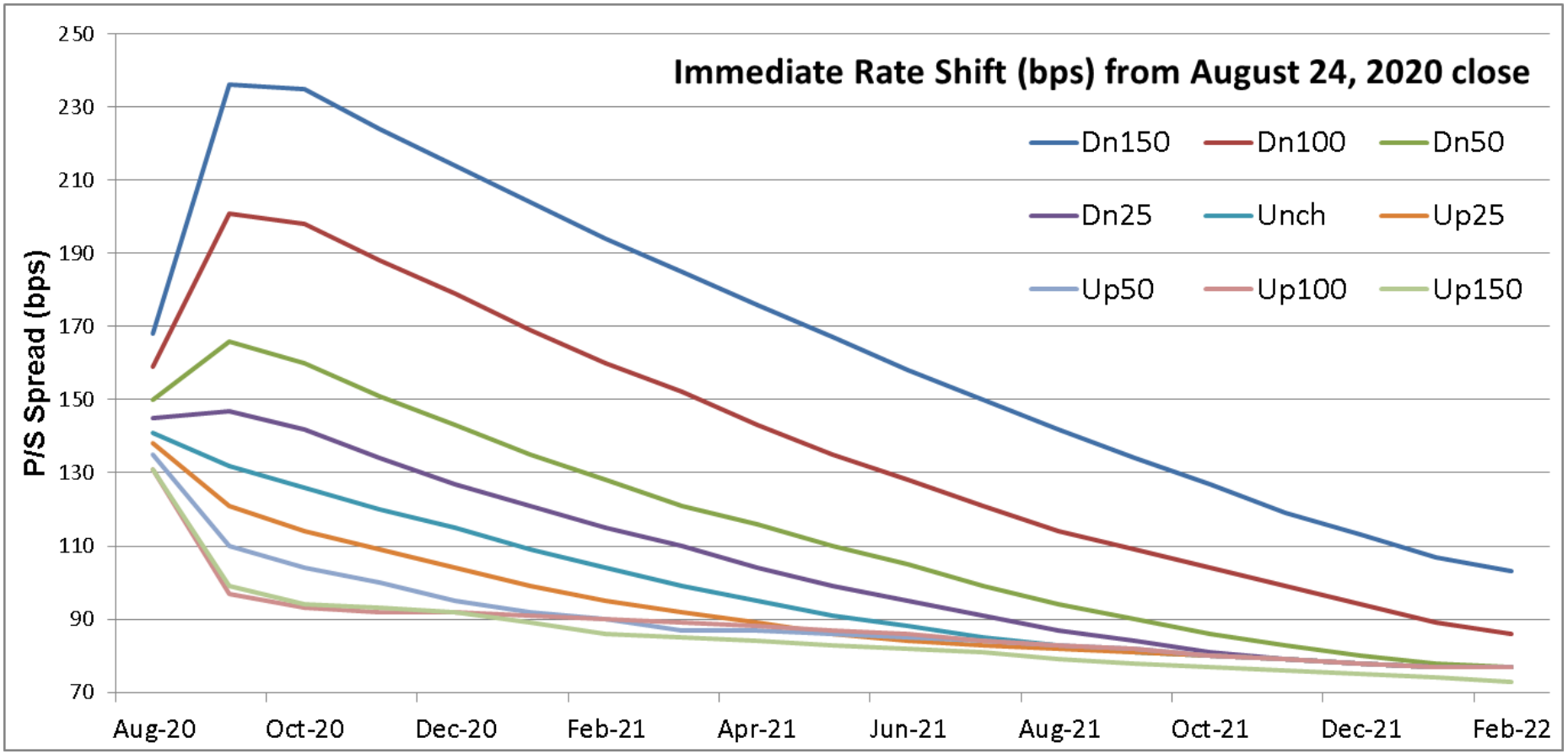
P/S Spread More Sensitive to CMM102 Movement in v21.6





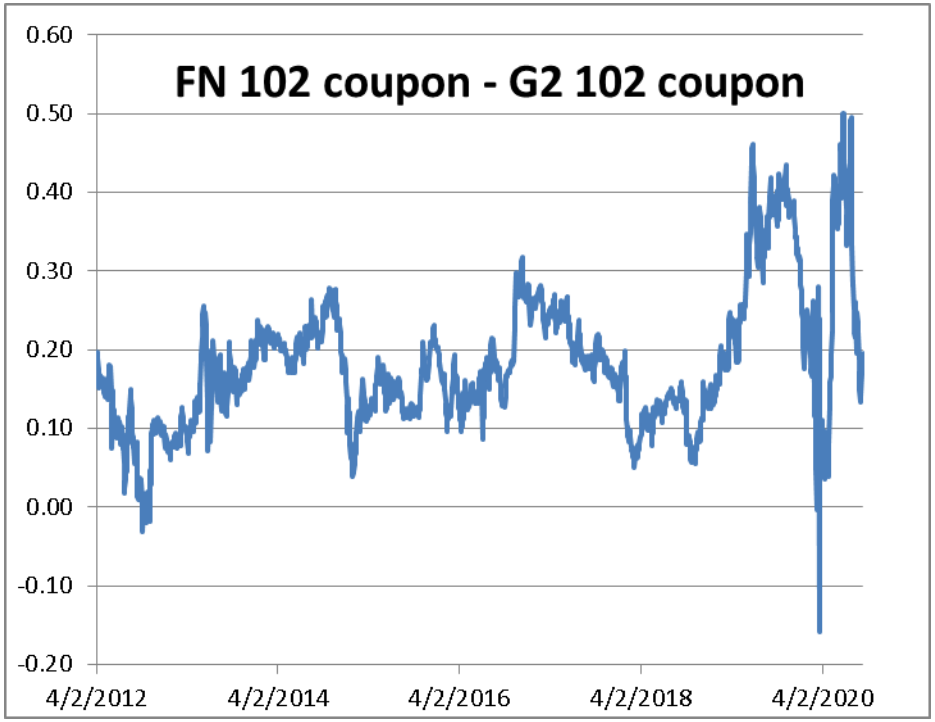
- **The P/S spread behavior in v21.5 is based on the 2012-2013 experience, when originators were better able to hold margin, but faced scrutiny when the spread was wide. Accordingly model v21.5 had limits on how much and how quickly the spread could rise or fall from elevated levels.**
- **The updated model v21.6 removes these limits, as the current experience is evidently driven by much different factors, and there little to prevent the spread from reaching very wide levels at extremely low rates, or to collapse from these levels if the rally reverses and significant capacity frees up.**

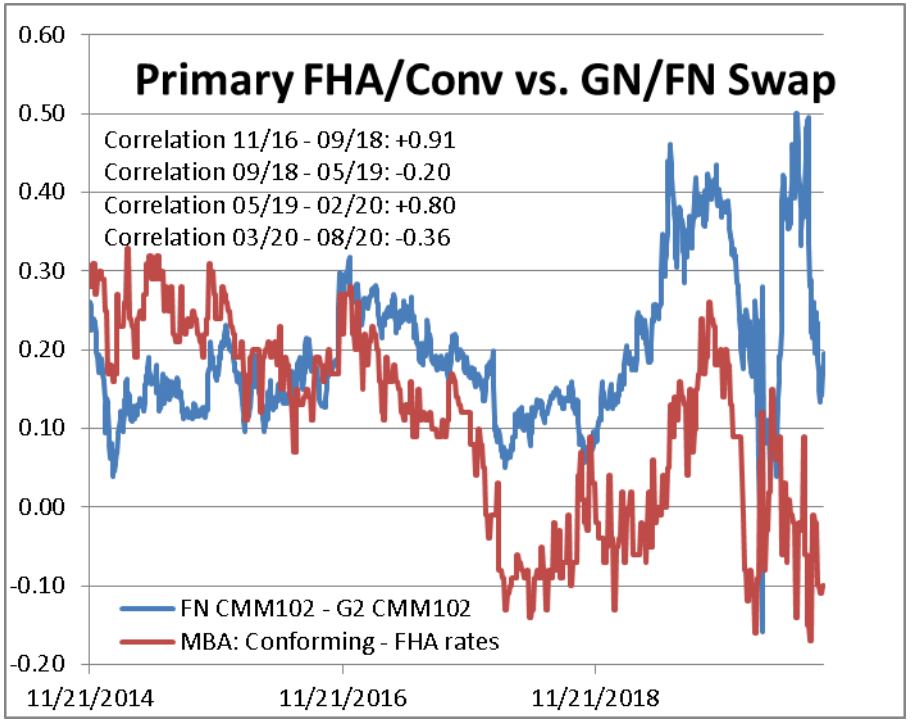
P/S Spread Normalization May Be Delayed in Extreme Rallies



- All recent model versions (including v21.5 and v21.6) have modeled P/S spread normalization to occur over about 12-15 months after a sharp rally followed by stable rates. Over that period, increases in capacity and declines in the refinancible universe should be enough to eliminate excess margin.
- Model v21.6 recognizes that in very extreme rallies, bottlenecks (e.g., lack of qualified underwriters) may develop that slow capacity addition. As a result, normalization may take longer than 12-15 months to occur; the impact is shown above for various rate shocks from recent levels.

GN/FN Swap Less Indicative of GN/FN Primary 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 supported by historical correlation at that time.**
- **However, two significant periods of non-correlation have occurred recently, once during the period of high WAC spreads leading up to single security, and the other during the current COVID-19 crisis.**
- **As a result, in model version 21.6 we have temporarily replaced the GNMA/FNMA swap (FN CMM102 – G2 CMM102) with a constant of 1/8 point as the spread to subtract from conventional rates to obtain the FHA rate.**
- **At present, we are debating whether the GNMA/FNMA swap should be removed as a driver of the difference between conventional and FHA rates, due to breakdown of correlation during periods of market disruption; for now the model slowly phases the GNMA/FNMA swap back into the computation of FHA rates between Q4 2020 and the end of 2021.**

Source: Freddie Mac, MBA

IMPROVED MODEL PERFORMANCE OF V21.6 VERSUS V21.5

Model v21.6 in Line with 3 and 12 Month Actuals In-Sample

					v2105				v2106			
Asset Class	Balance(mm)	Last Hist Date	3M Hist CPR	12M Hist CPR	3M Proj CPR	3M Ratio	12M Proj CPR	12M Ratio	3M Proj CPR	3M Ratio	12M Proj CPR	12M Ratio
FN30	2253343	202008	31.6	23.9	23.4	1.35	20.3	1.18	31.9	0.99	24.0	1.00
FN30HHLB	101935	202008	24.3	18.2	18.2	1.34	15.4	1.18	24.5	0.99	17.7	1.03
FN30HLB	119004	202008	21.9	16.6	16.9	1.29	14.4	1.15	22.4	0.97	16.3	1.01
FN30LLB	46785	202008	15.2	12.7	13.3	1.15	11.5	1.10	16.4	0.93	12.7	1.00
FN30MLB	67468	202008	18.2	14.4	14.6	1.25	12.6	1.14	19.0	0.96	14.3	1.01
FN30MAX200K	81298	202008	25.8	19.8	19.7	1.31	16.8	1.18	26.0	0.99	19.1	1.04
FN30JUMBO	64983	202008	48	34	36.2	1.33	27.9	1.22	49.0	0.98	33.8	1.01
FN30INV	36174	202008	23.2	19.1	20.4	1.14	18.3	1.05	23.8	0.98	19.5	0.98
FN30CQ	21202	202008	24.3	17.7	19.8	1.23	16.4	1.08	25.3	0.96	18.6	0.95
FN30CR	18918	202008	23.1	16.9	17.6	1.32	14.2	1.19	24.0	0.96	17.0	1.00
FN30NY	48634	202008	18.5	13.8	14.3	1.29	11.9	1.16	20.1	0.92	13.8	1.00
FN30FICO	124717	202008	28.6	23.8	23.9	1.20	21.6	1.10	29.8	0.96	24.2	0.98
FH30	1441019	202008	33.3	24.7	25.3	1.32	21.0	1.18	34.2	0.97	24.8	1.00
GNII30	1729343	202008	34	26.3	28.0	1.22	22.4	1.17	32.3	1.05	23.6	1.12
GNIIMAX200K	18740	202008	22.7	18.8	22.0	1.03	16.7	1.13	23.1	0.98	17.0	1.11
GNII30HHLB	33509	202008	25.8	20.8	23.9	1.08	19.3	1.08	26.1	0.99	19.6	1.06
GNII30HLB	65394	202008	24.7	17.9	20.9	1.19	16.8	1.06	24.4	1.02	17.4	1.03
GNII30MLB	29518	202008	21.1	15	16.6	1.27	13.5	1.11	20.6	1.03	14.2	1.05
GNII30LLB	18346	202008	17.6	12.4	13.5	1.30	11.1	1.12	17.9	0.98	12.1	1.02
GNIIJUMBO	47802	202008	48.3	38.4	42.2	1.14	31.7	1.21	48.0	1.01	34.7	1.11
GNIIRH	16640	202008	15.3	11.5	12.1	1.27	10.6	1.09	15.8	0.97	11.8	0.97
GNIINY	3514	202008	22.1	15.1	22.7	0.97	16.6	0.91	22.0	1.00	14.8	1.02
GN30	99573	202008	31.7	19.4	18.6	1.70	15.6	1.24	26.5	1.19	17.7	1.10
FN15	378808	202008	21.3	16.3	17.5	1.22	15.3	1.07	21.4	1.00	16.4	0.99
FH15	265626	202008	21.1	16.4	17.9	1.18	15.6	1.05	21.4	0.99	16.6	0.99
GNII15	27250	202008	26.6	20.6	22.1	1.21	17.5	1.18	26.0	1.03	19.4	1.07
GN15	3786	202008	26.2	16.9	14.9	1.76	13.2	1.28	19.1	1.37	14.8	1.14
FN20	136037	202008	26.7	19.4	19.2	1.39	16.2	1.20	27.0	0.99	19.7	0.99
FH20	87048	202008	25.9	18.8	19.7	1.32	16.4	1.15	26.4	0.98	19.1	0.98
FN10	18807	202008	22	18.4	20.0	1.10	17.8	1.03	21.8	1.01	18.0	1.02
FH10	2158	202008	22.6	18.8	20.6	1.09	18.5	1.02	22.2	1.01	18.7	1.01
FN5X1L	10432	202008	36.7	30.3	26.7	1.37	26.4	1.15	34.5	1.06	31.5	0.96
FN7X1L	16008	202008	42.4	32.9	30.4	1.39	26.2	1.25	43.2	0.98	35.0	0.94
FNTX1L	6766	202008	38.3	28.5	26.2	1.46	21.7	1.32	39.7	0.96	29.9	0.95
FH5X1L	6545	202008	38.3	32.5	28.7	1.34	28.7	1.13	36.9	1.04	34.1	0.95
FH7X1L	13611	202008	43.2	32.9	30.8	1.40	26.6	1.23	44.5	0.97	36.0	0.91
FHTX1L	6564	202008	35.7	26.9	24.7	1.45	20.8	1.29	38.2	0.94	28.9	0.93
GN3X1T	5343	202008	35.5	31.4	27.9	1.27	26.9	1.17	36.4	0.97	30.1	1.04
GN5X1T	7213	202008	48.2	35.9	29.2	1.65	26.1	1.38	43.9	1.10	33.9	1.06

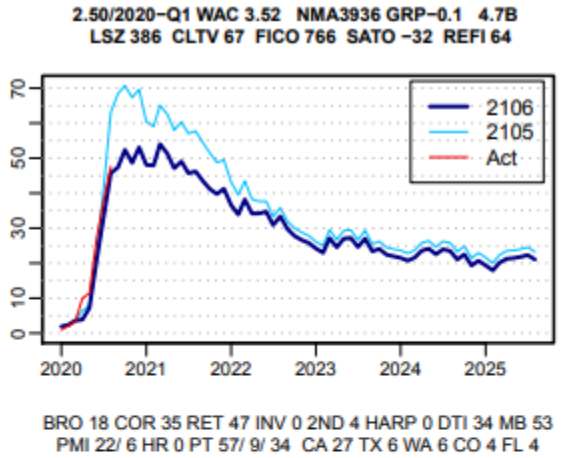
Model version 21.5 has generally projected slower speeds than actuals since it was released. It was particularly slow on GNMA IIs and several conventional spec categories.

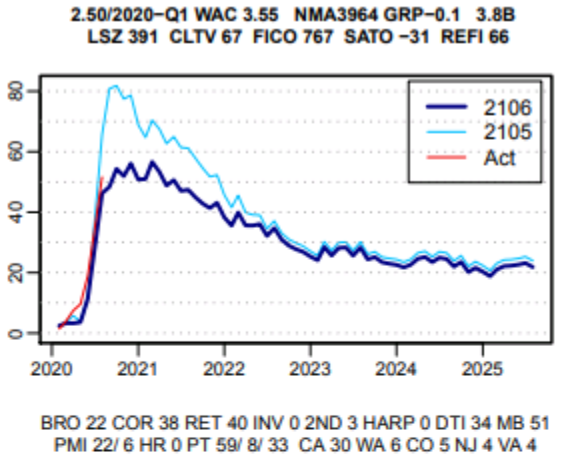
Model version 21.6 actual to projected ratios are close to 1.0 over the past three and twelve months for most sectors.*

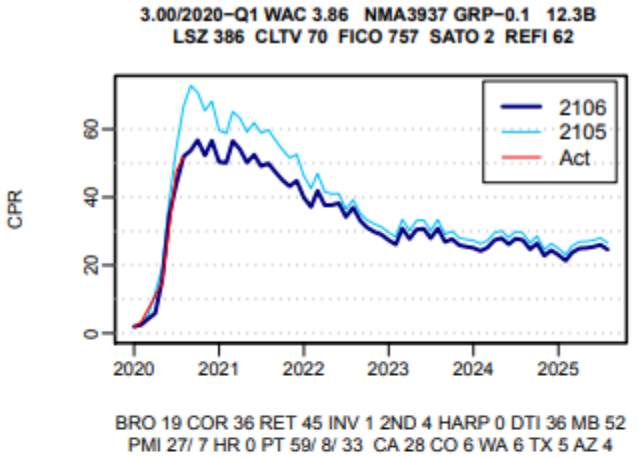
* Note that the historical model projections for v21.5 in this comparison exclude the impact of past delinquency data, since that model takes only a snapshot of current delinquencies. Therefore as a result of the recent buyout spikes from bank servicers, most GNMA sectors show as paying substantially faster than model. Model v21.6 includes historical delinquency data for the past 24 months of projections.

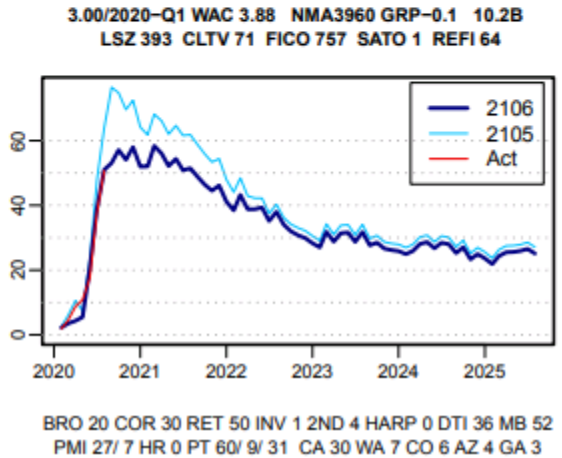
Source: eMBS

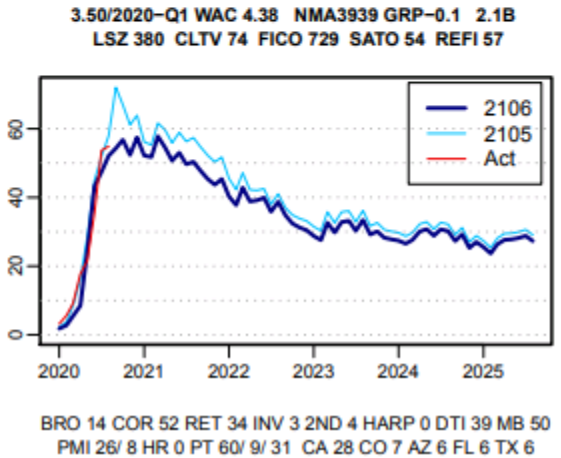
Initial Response More Restrained on Cuspy Majors/MLGs…

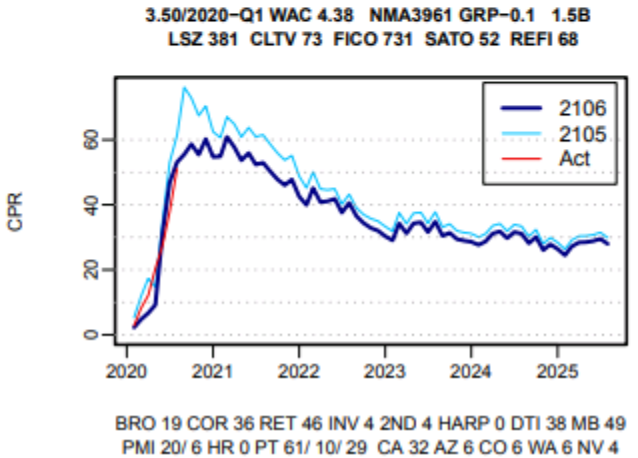








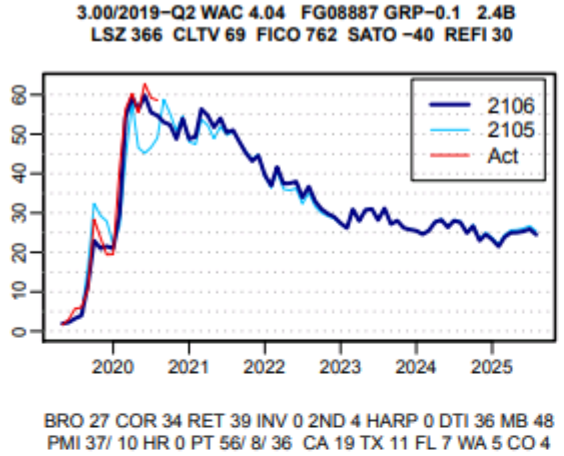


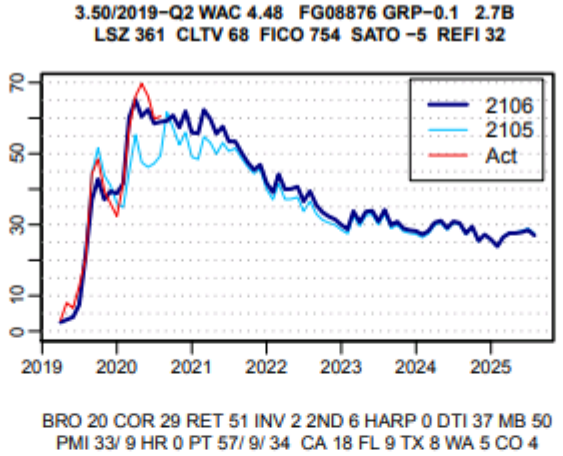


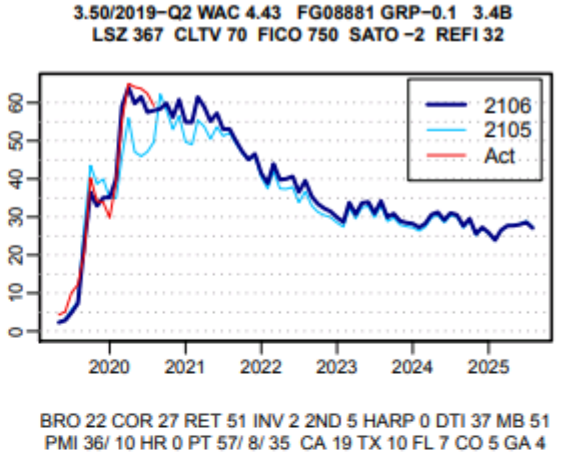
- **The updated P/S spread model reduces the initial response of cuspy collateral with excellent credit to rallies, and the media effect response to a gradual decline in P/S spread is reduced; these borrowers generally don't pay full P/S spread in the first place.**
- **In general, we also model a broader impact of PIW across all collateral types, which is somewhat less concentrated in the best credit, cuspiest collateral.**

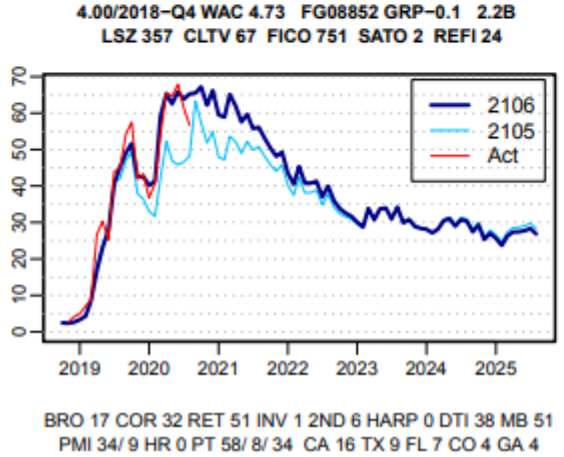
Source: eMBS

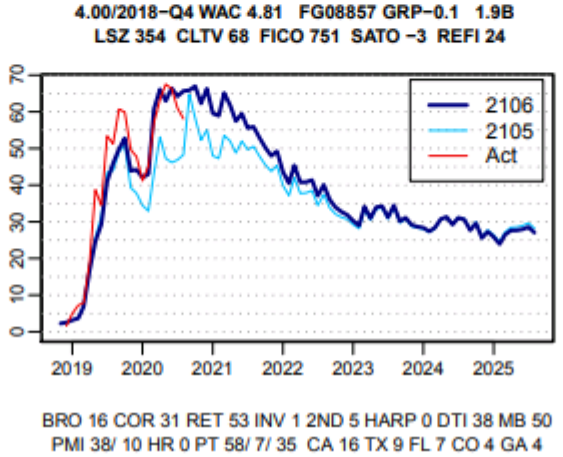
…but PIW and Media Effect Driven Ramps Extended…

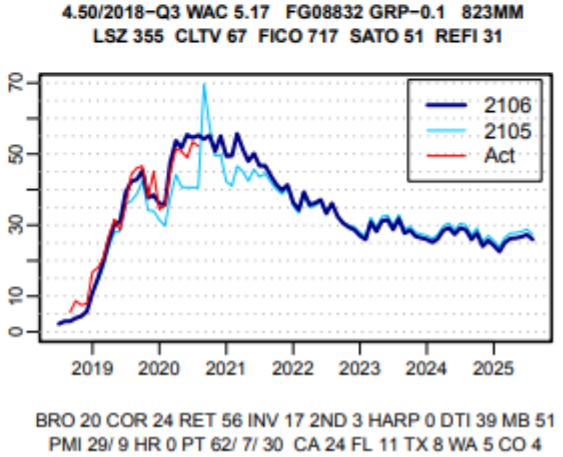








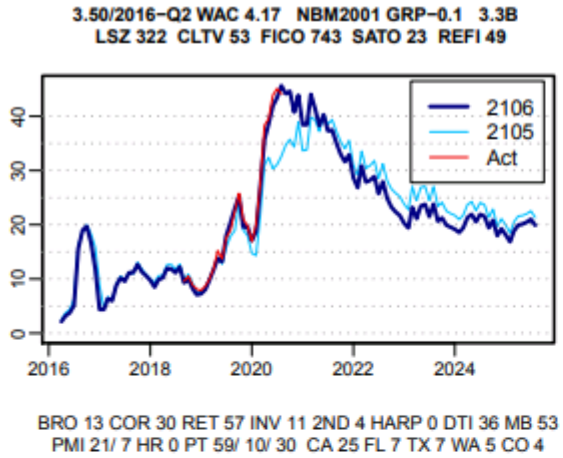


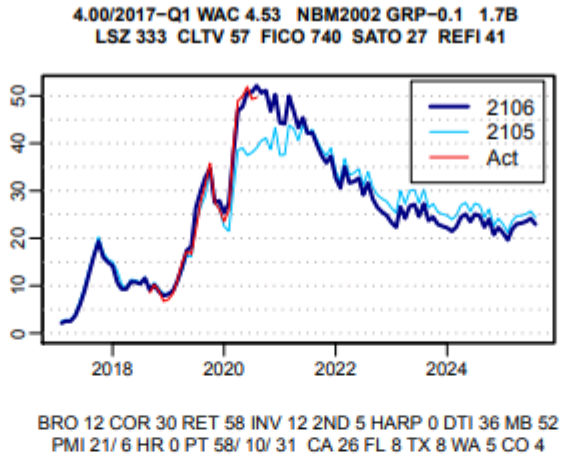


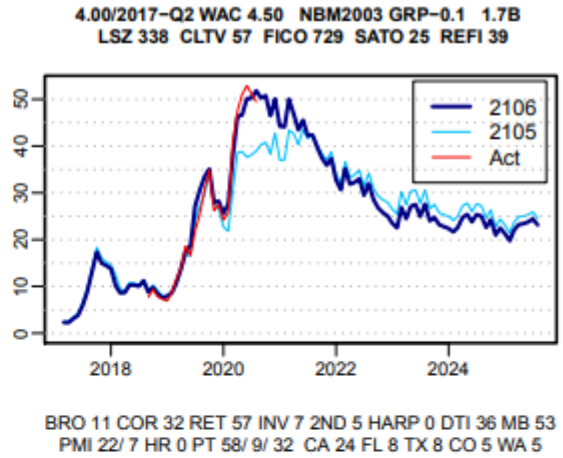
- **Peak speeds above 50-60 CPR, higher than at any time since 2003, have outrun v21.5 projections, although some burnout has recently emerged; the peak ramp has been extended in model v21.6.**
- **Increased use of PIWs and other automated underwriting features, accelerated by the COVID-19 crisis and now likely used for a substantial majority of conventional refinances, along with the media effect "waking up" slower paying borrowers, are modeled as primary drivers in v21.6.**

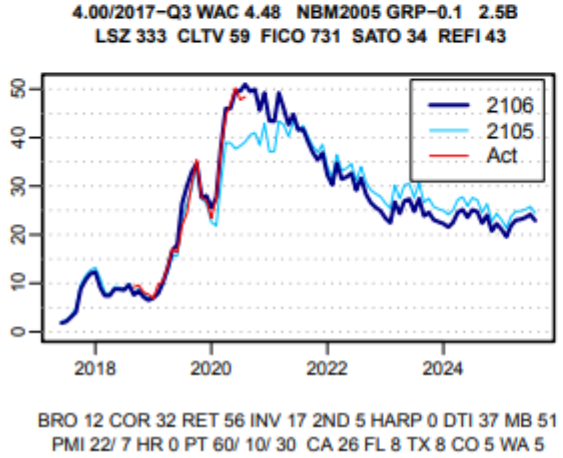
Source: eMBS

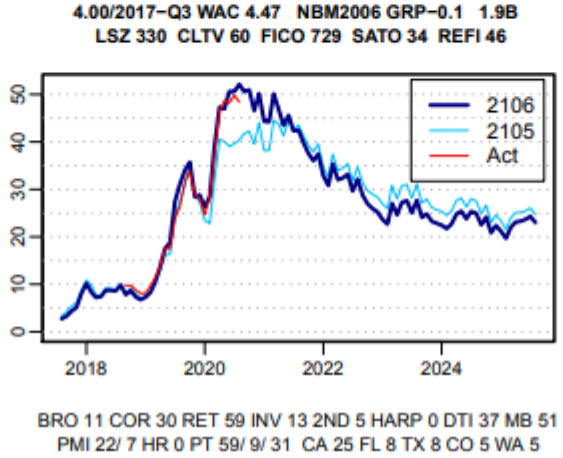
…and PIW/Media Effect Also Impacting Pre-2018 Collateral

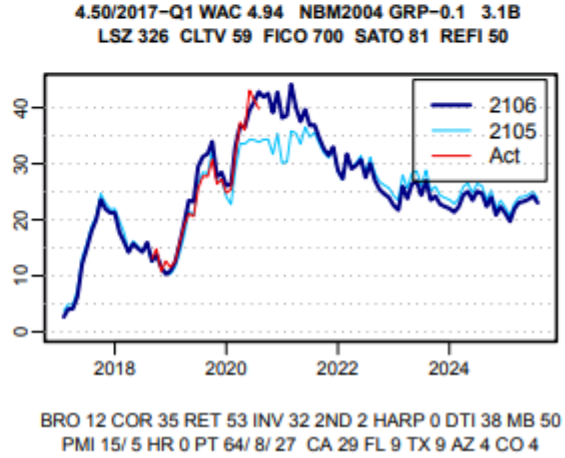








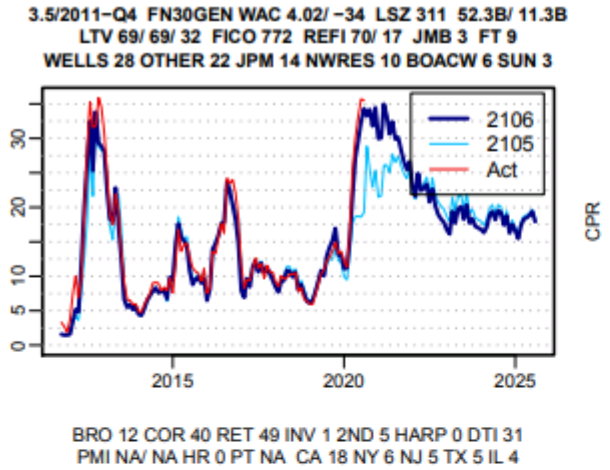


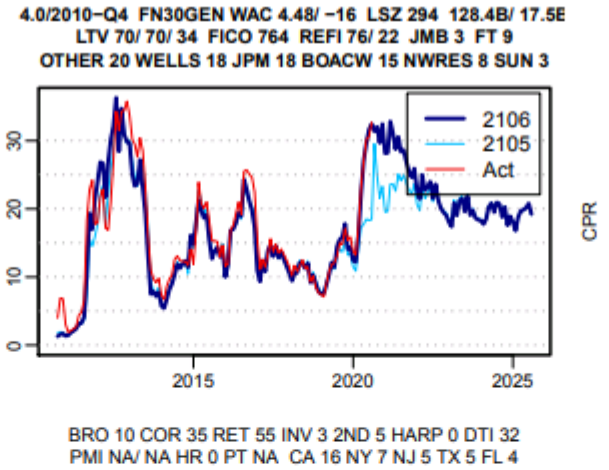


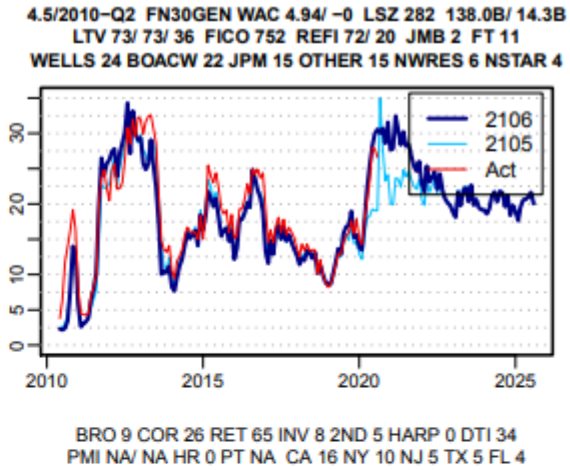
- **Post-HARP collateral from 2013-2017, represented above by the BM series of 2017 FNMA megapools, has been much more responsive this year than during the mid-2019 rally. This may reflect the extension of many more PIW offers to more seasoned borrowers.**
- **Almost all conventional cohorts in this category printed record high speeds in recent months; they have been recalibrated in v21.6 to incorporate both increased PIW offers and stronger media effect.**

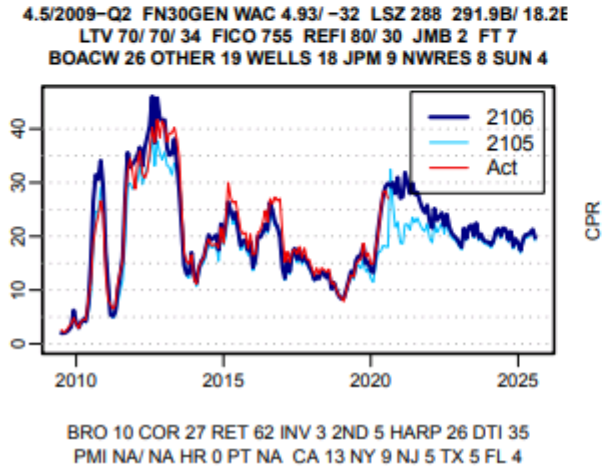
Source: eMBS

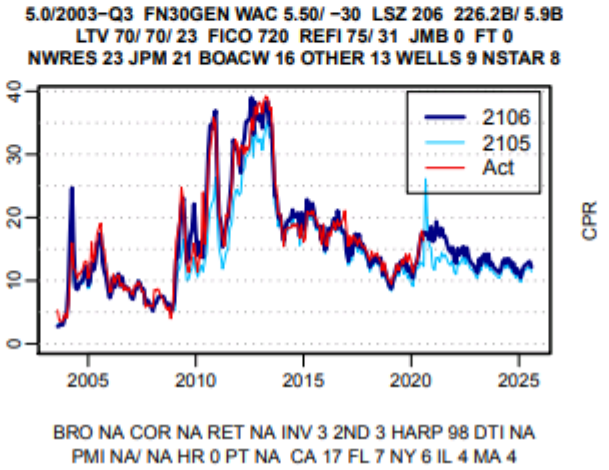
Pre/Early Post-HARP Responds, or at Least Shows a Pulse

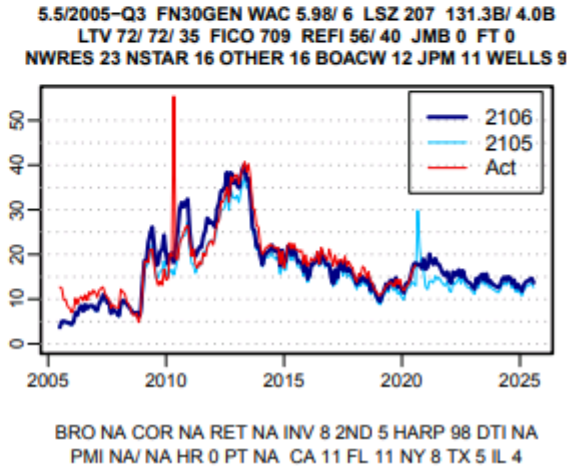








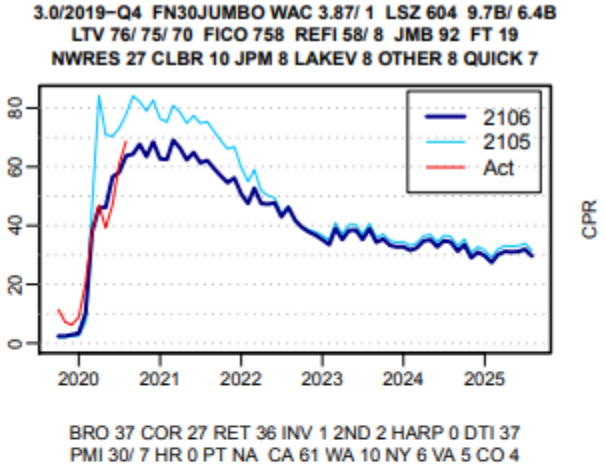


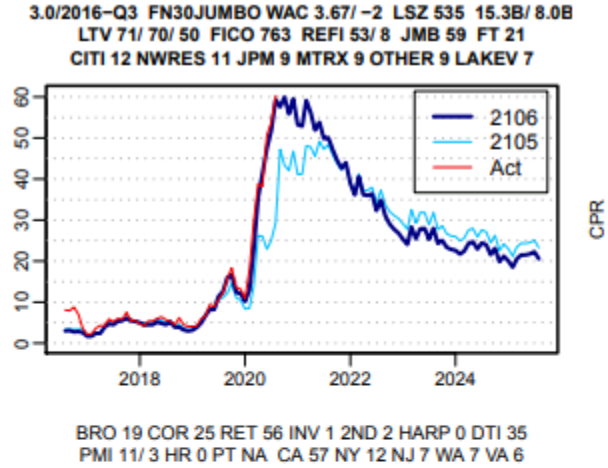


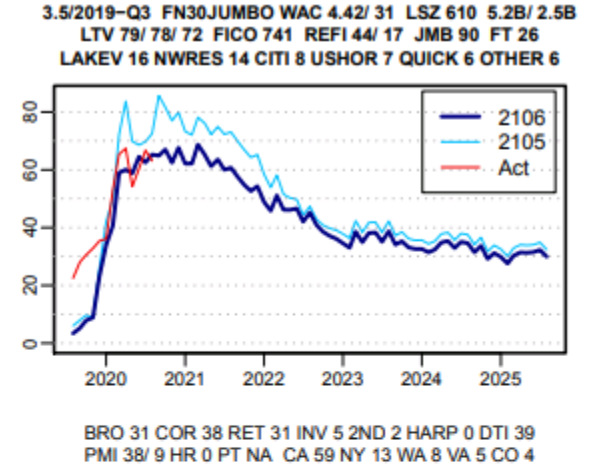
- **Post-HARP 2009-2011 cohorts have been vastly more responsive this year than in prior rallies from 2015-2019, and have come close to reaching their previous highs during the 2012-2013 boom.**
- **Even pre-HARP cohorts reached prints last seen in 2017 when HARP refis were still available; v21.6 better captures this with its recalibrated media effect. Note also the buyout spikes in the current model that have been moderated and spread out in the new model as previously discussed.**

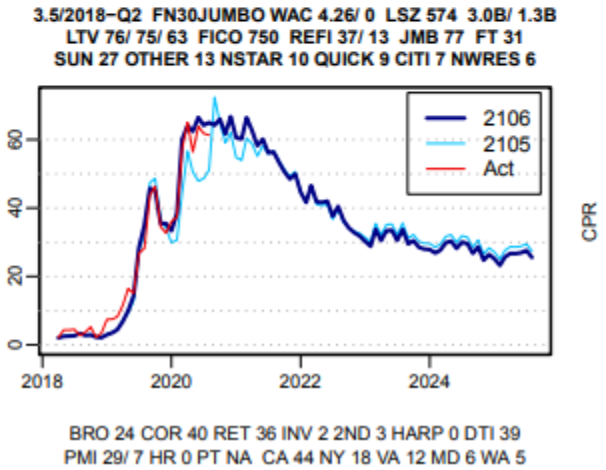
Source: eMBS

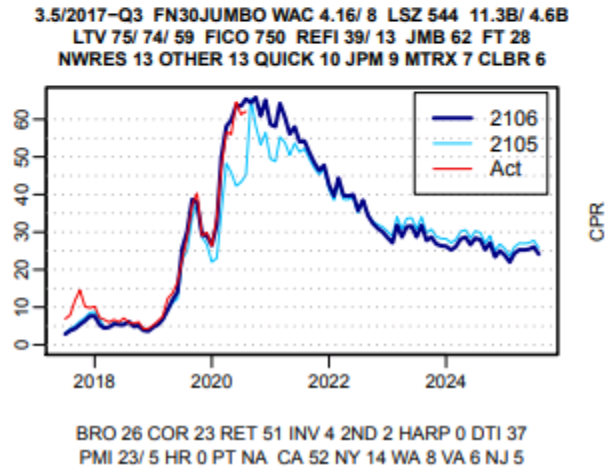
Jumbos Explosive As Usual; Surprisingly Slow on Some 4s

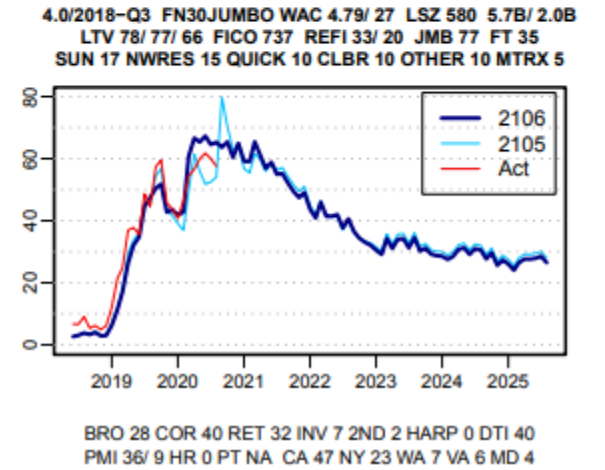








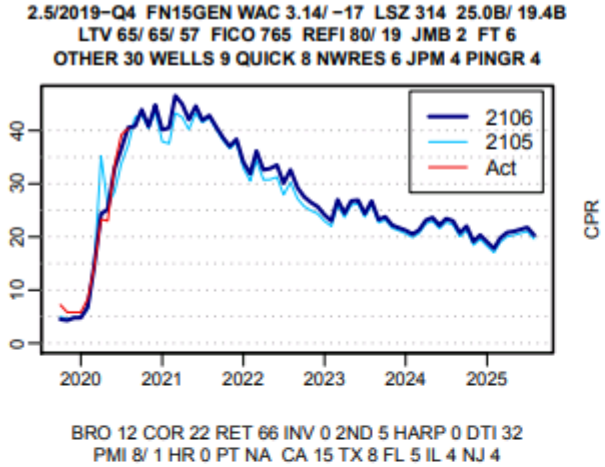


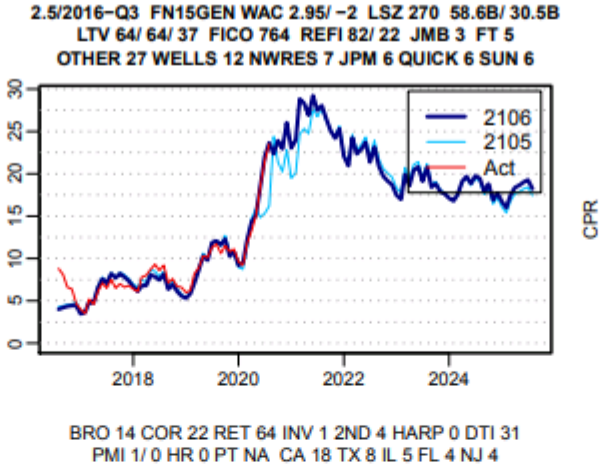


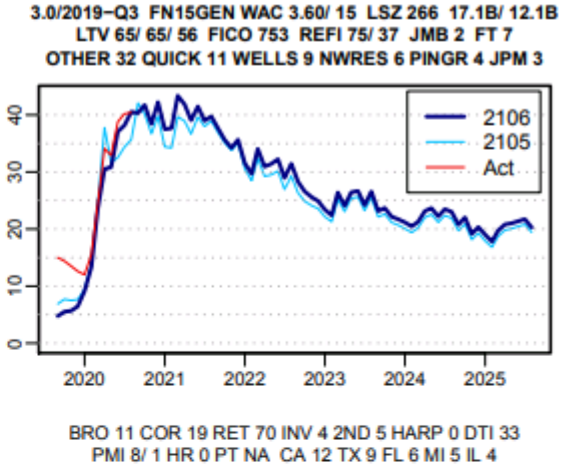
- **Jumbos remain highly responsive in v21.6, but not to the extremes seen in v21.5 for newer cohorts, which were affected by the manner in which the combination of P/S spread, media effect and PIW were modeled in v21.5.**
- **Moderately seasoned low coupon jumbos have printed very fast as modeled in v21.6, but jumbo 4s from 2017-2019 have printed slower (at least relatively speaking).**

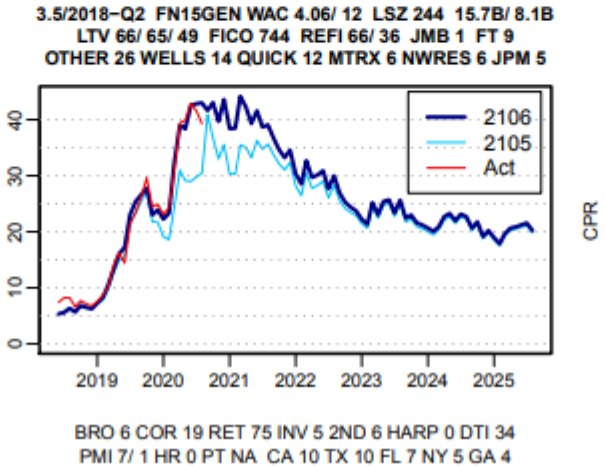
Source: eMBS

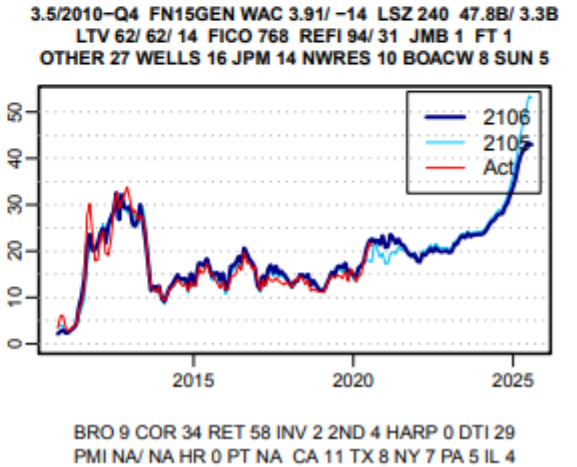
15-Year Also Very Responsive, Even Seasoned Cohorts







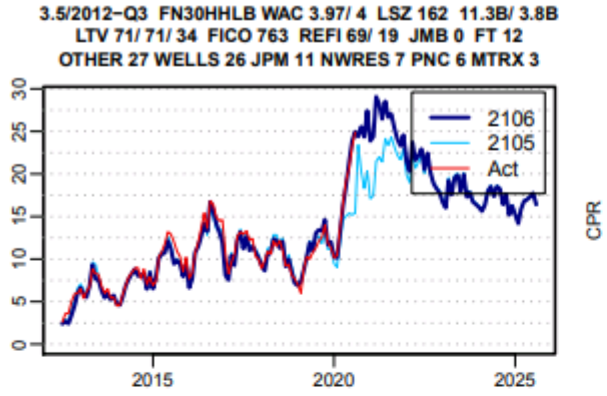


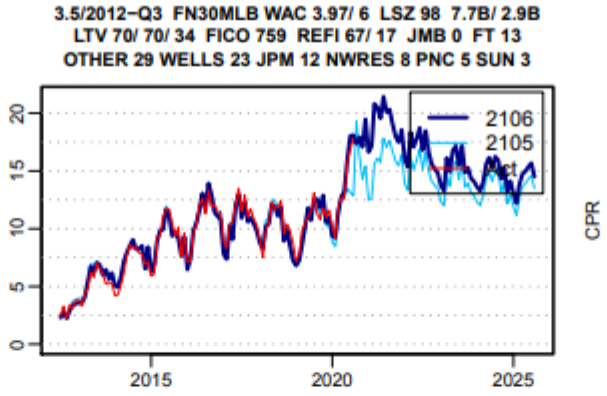


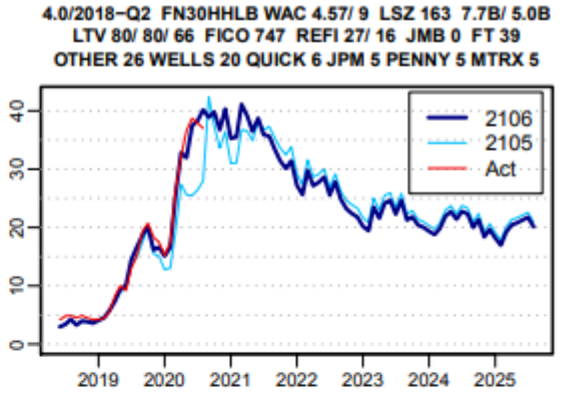
- **New and moderately seasoned 15-year cohorts mirror comparable 30-year cohorts in their strong responses, albeit peaking at lower levels; v21.6 model changes mirror the 30-year sector.**
- **Even very seasoned 15-year collateral, like 3.5s of 2010 with only about five years remaining on the loan and having amortized to a very small loan size, managed a meaningful increase in speeds over the last couple of months.**

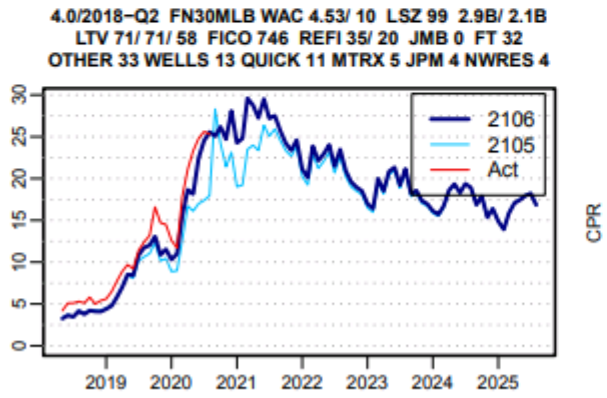
Source: eMBS

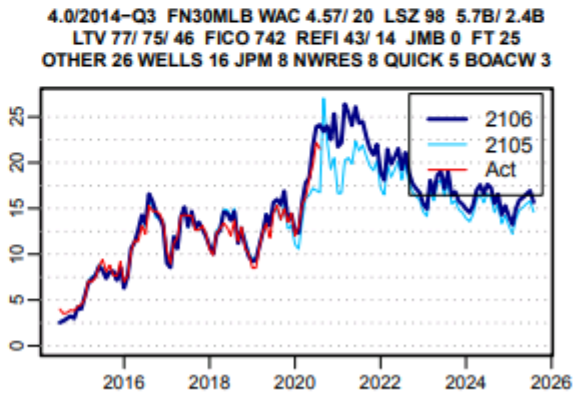
Loan Balance Strong; Seasoned MLB/LLB Relatively Weaker







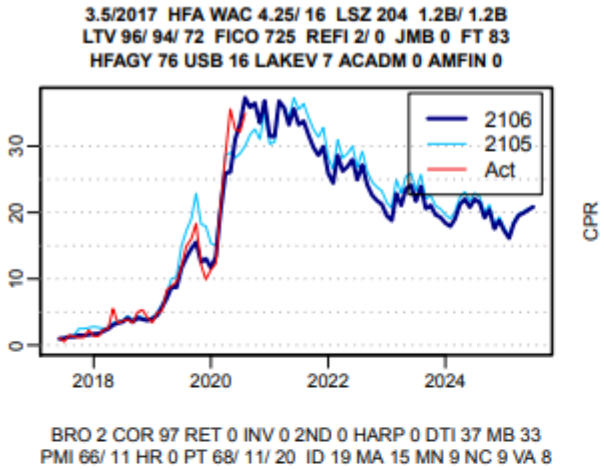


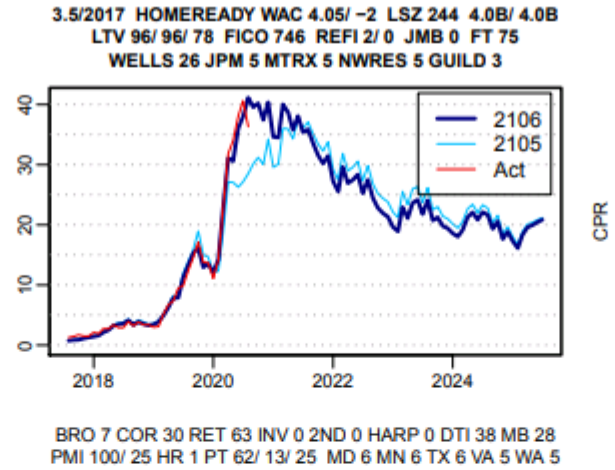


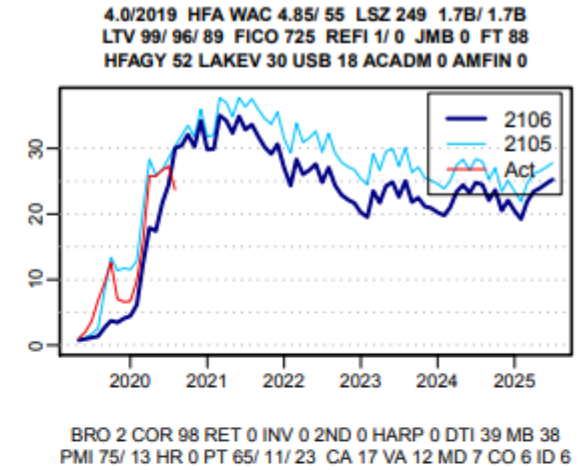
- **Speeds on key loan balance cohorts have been far more reactive in 2020 than in 2019, when the response was much more lagged. While modestly extended lags on this collateral during a sharp rally are normal, the degree to which it occurred in late 2019/early 2020 was very significant.**
- **This may have occurred due to the initial emergence of UMBS and widespread PIW. The lagged response is not evident in 2020, nor during rallies between 2010 and 2016.**

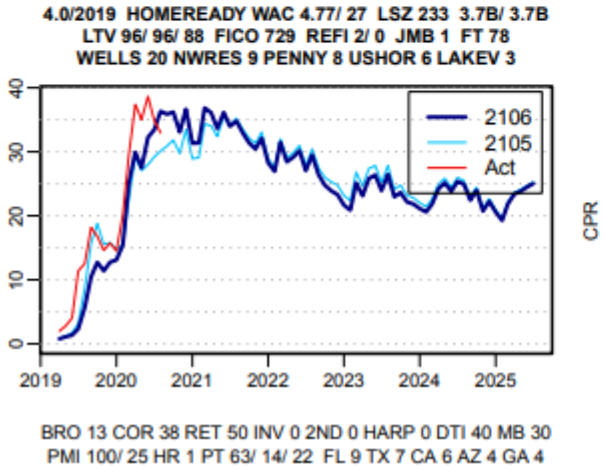
Source: eMBS

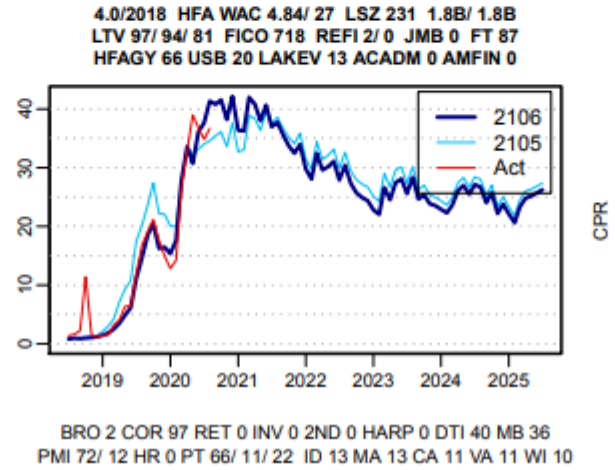
High LTV Prints Very Strong Even Before Reaching 80 LTV

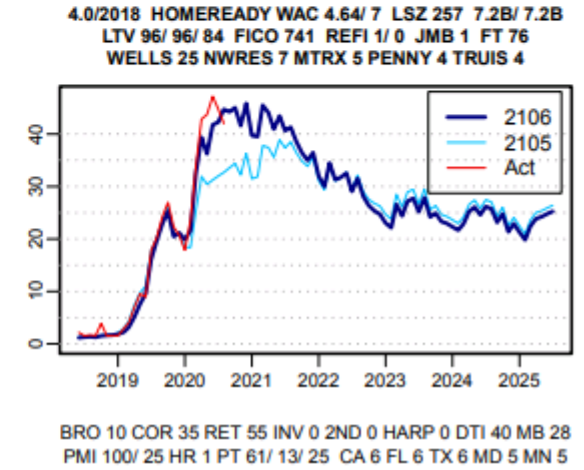








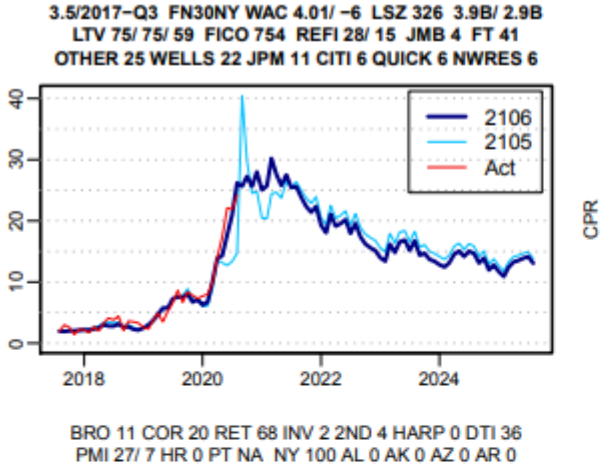


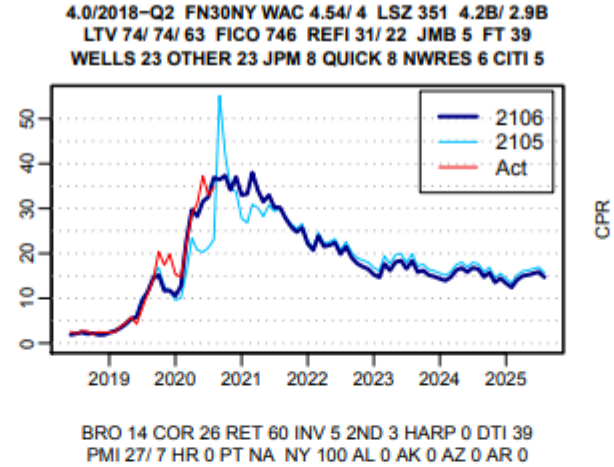


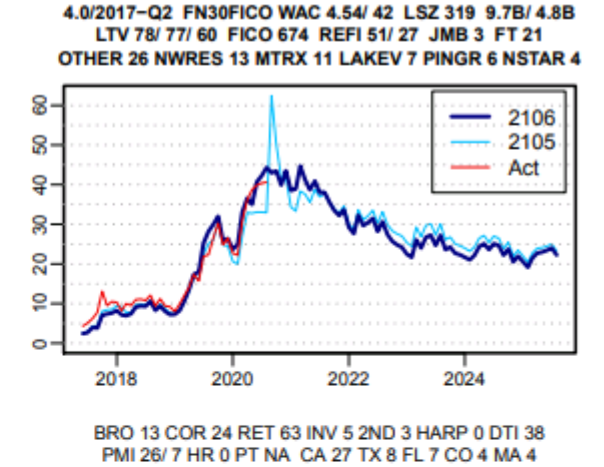
- **Model v21.6 increases the degree of PIW assumed to be available for borrowers over 80 LTV, given the very strong prints from FNMA HomeReady and HFA collateral from 2017-2018.**
- **Even 2019 cohorts have been quite strong already, with speeds exceeding 25 CPR on HFA and 35 CPR on HomeReady, somewhat surprising given that most of these borrowers are close and many remain above the 90 LTV maximum for PIW.**

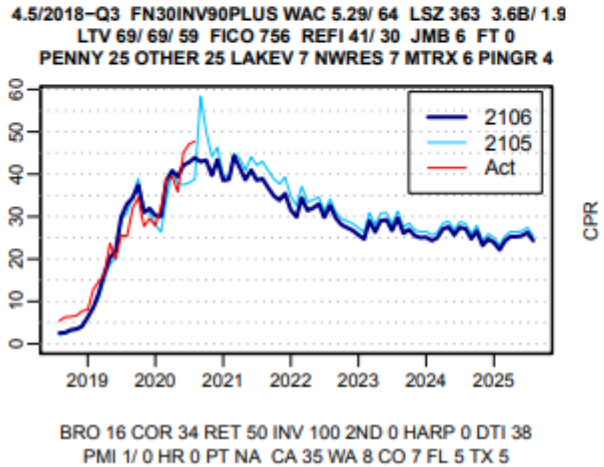
Source: eMBS

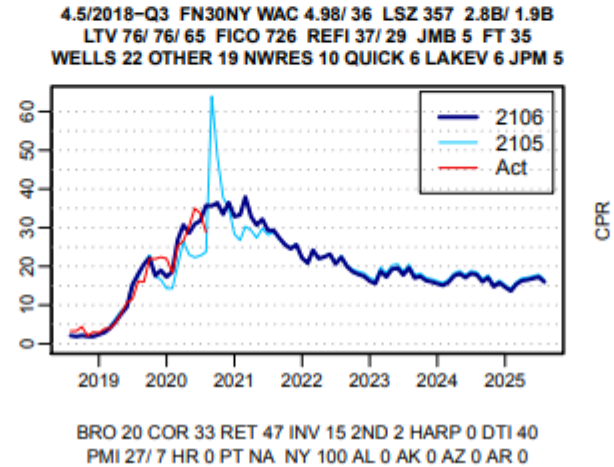
Most Specs Printing Above v21.5; Recalibrated in v21.6

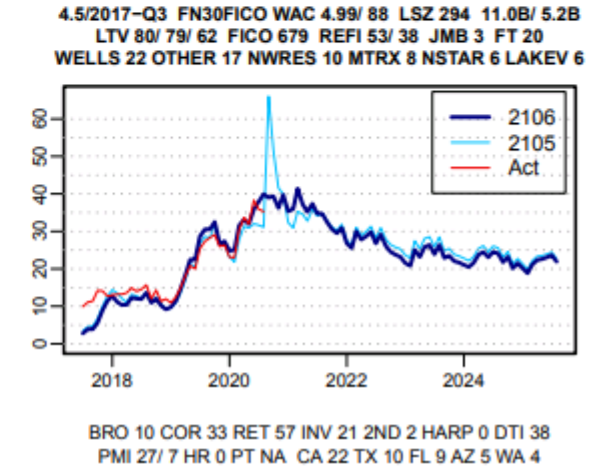








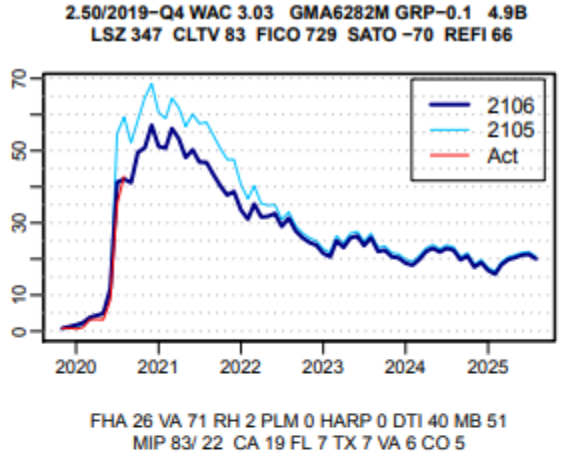


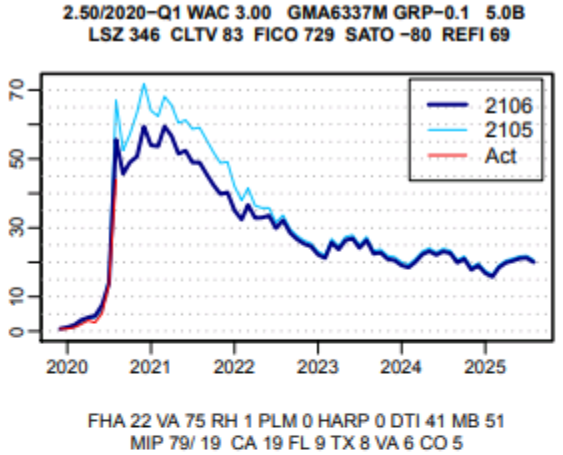


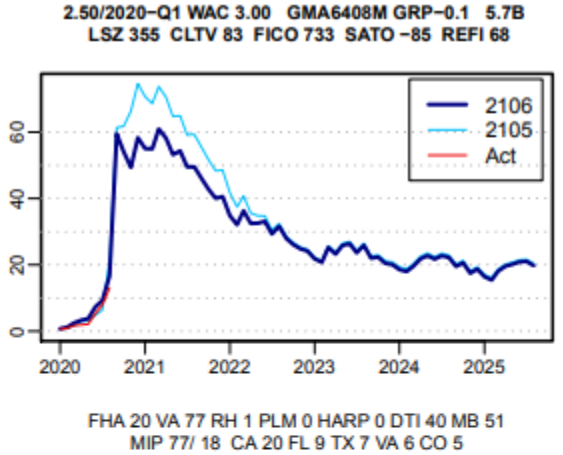
- **Speeds on most conventional specified pool sectors picked up in 2019 as the rally matured, and have been much more responsive in 2020. The extra contact with servicers related to forbearance may be leading to more refinances on normally slower sectors.**
- **The impact of COVID-19 forbearance on impaired sectors is reduced in model v21.6; GSE buyouts will not occur during forbearance or upon reinstatements/repayment plans/payment deferrals.**

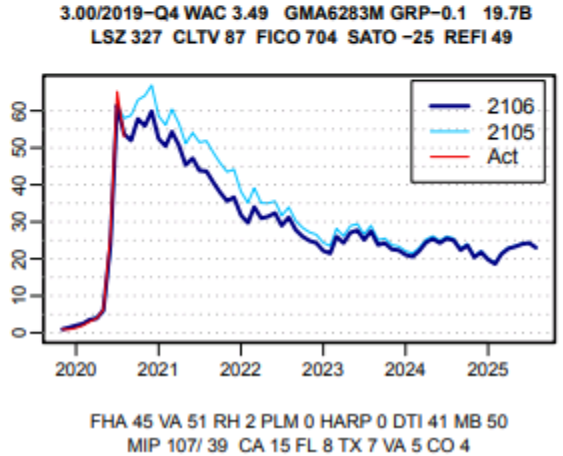
Source: eMBS

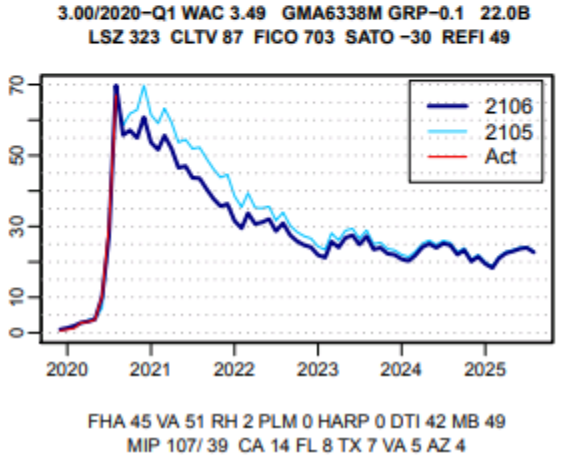
Primary Rate Change Improves G2 Low Coupon Projections

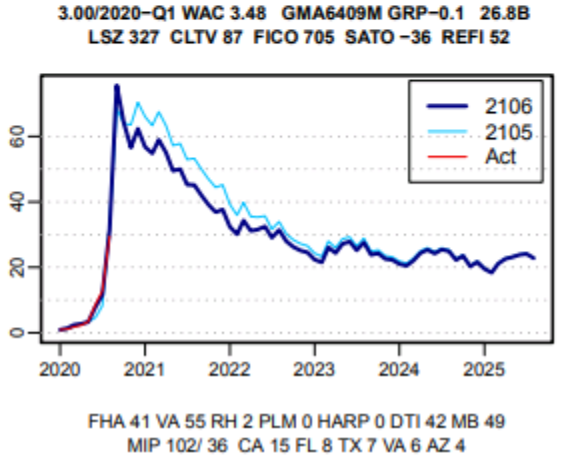








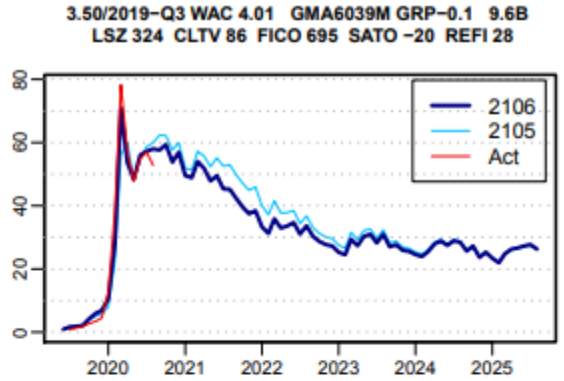


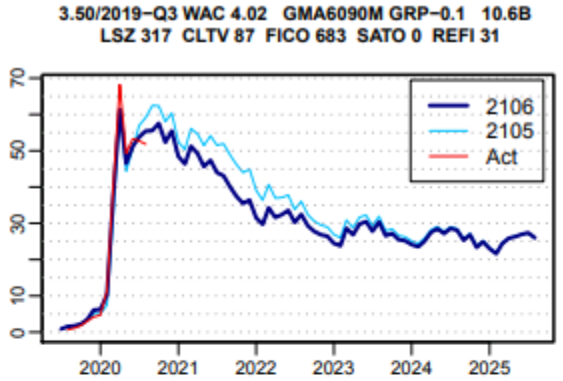


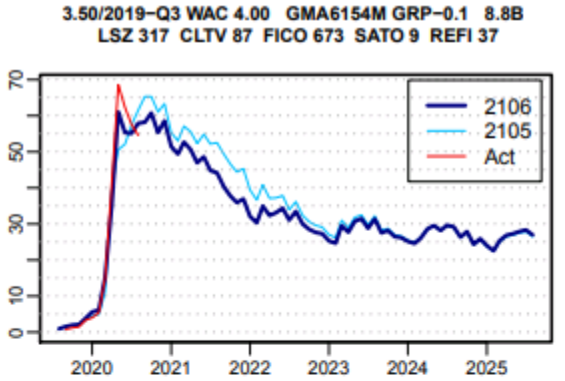
- **Model v21.5 used the difference between FNMA and GNMA II CMM102 to estimate GNMA primary rates from FNMA primary rates, which as mentioned earlier has been suspended for now in v21.6.**
- **Higher FHA/VA driving rates result in generally more reasonable projections, particularly for 2s and 2.5s; at one point GNMA CMM102 fell almost 50 bps below conventional CMM102, which was generally not indicative of primary rate differences between FHA/VA and conventional rates.**

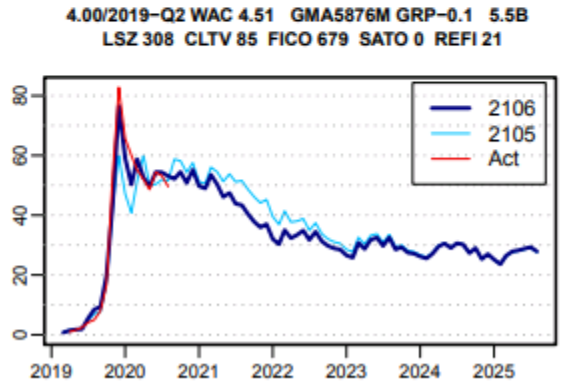
Source: eMBS

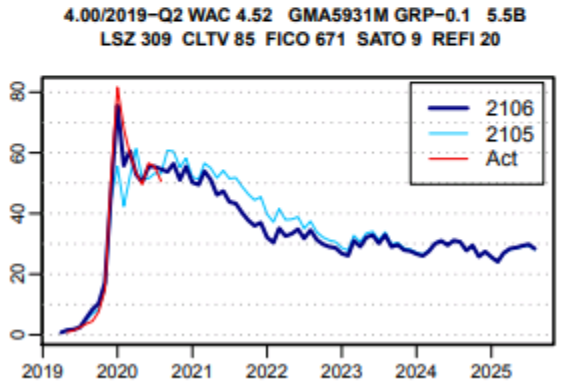
Ramp Recalibration Generally Improves Newer 3.5s and 4s

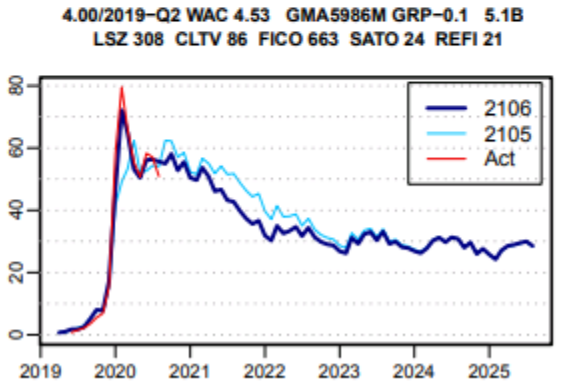








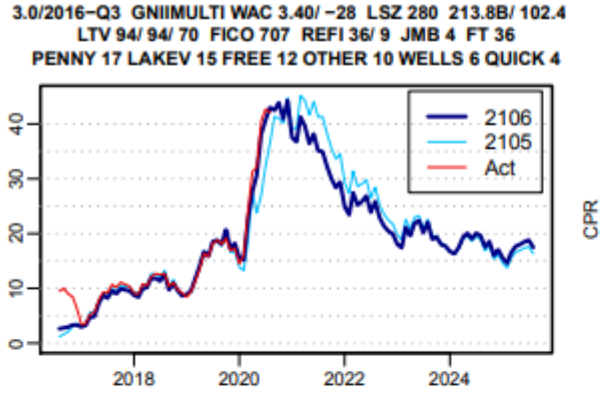


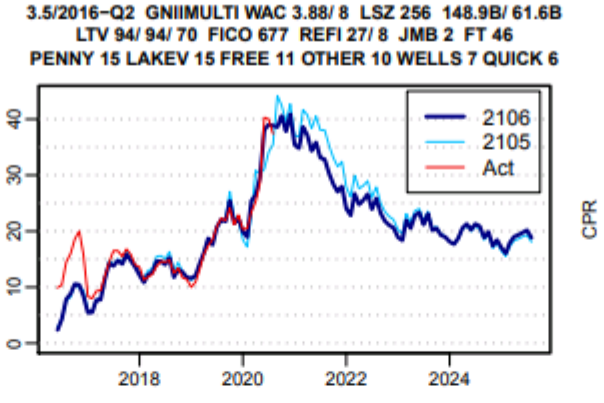


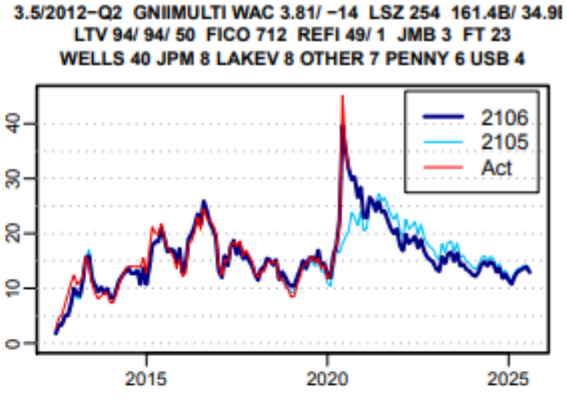
- **For premium GNMA coupons, peak speeds are higher from ramp recalibration for FHA and VA, but are lower in the out years due to the changes in GNMA primary rate mentioned earlier.**
- **Both the old and new models, however, fall short of the peak speeds seen in some of the smaller, recently originated higher-coupon pools.**

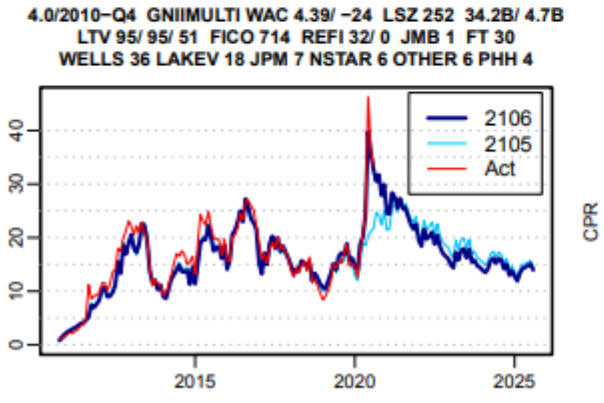
Source: eMBS

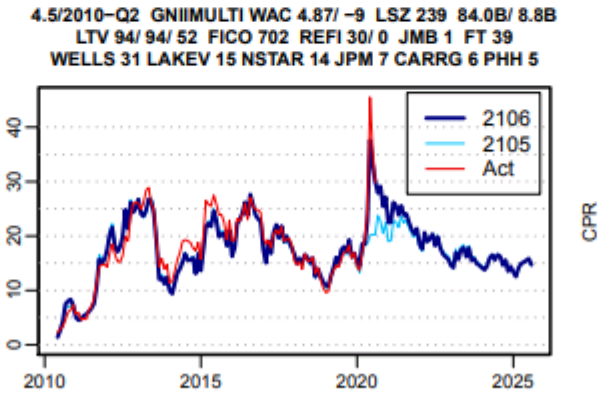
Seasoned GNMA IIs Affected by Media Effect and Buyouts

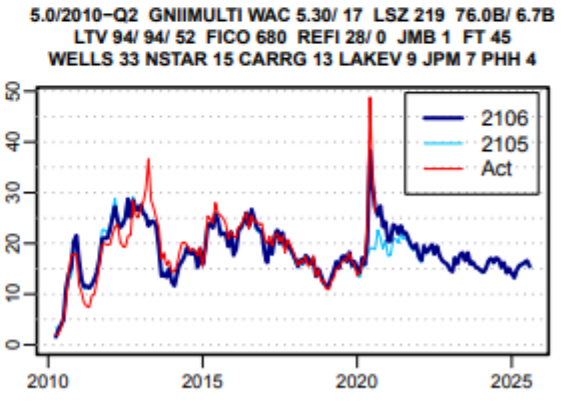








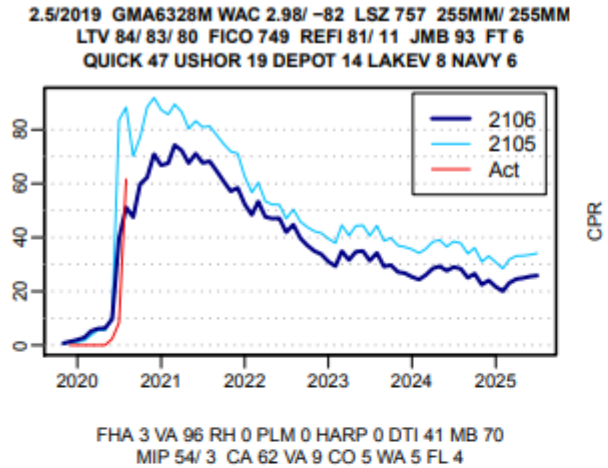


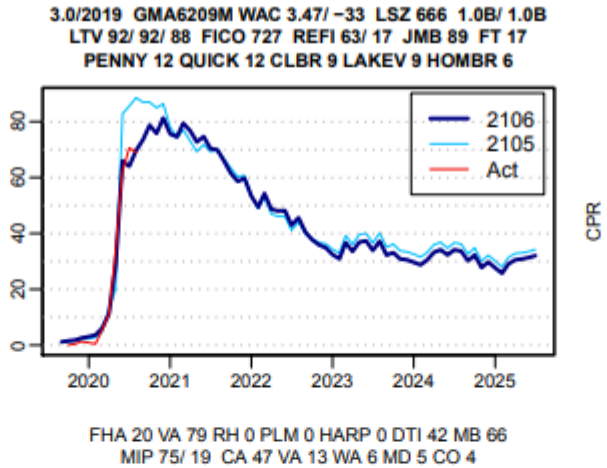


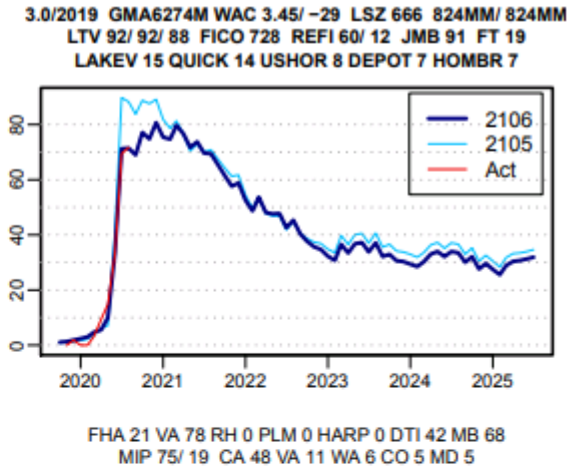
- **Seasoned GNMAs have printed very strong relative to the production model v21.5. Model v21.6 applies stronger media effect to seasoned GNMAs as it does for seasoned conventionals; many of these borrowers are strong candidates for refinances into conventional loans.**
- **Seasoned vintages from 2010-2012 have high bank servicing shares, driving significant buyout spikes better captured by model version 21.6.**

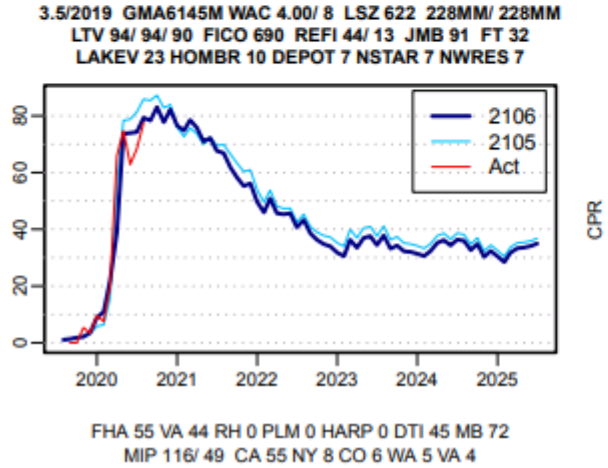
Source: eMBS

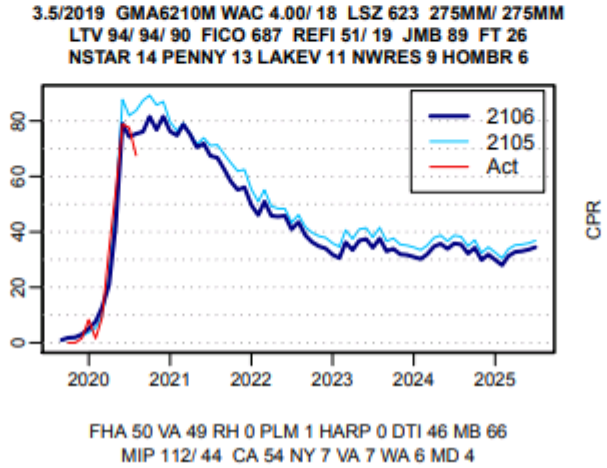
Model v21.6 Generally In Line on New G2 Jumbo Pools

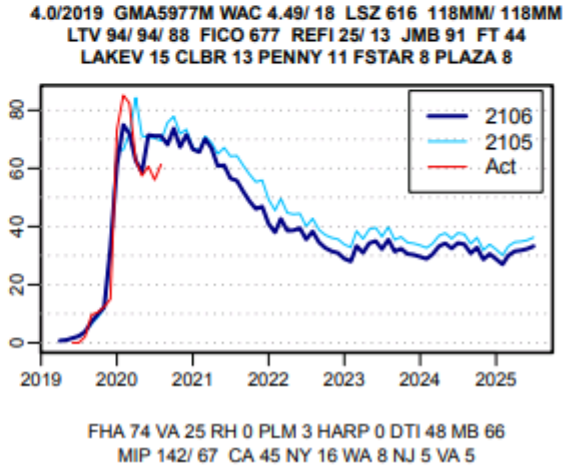








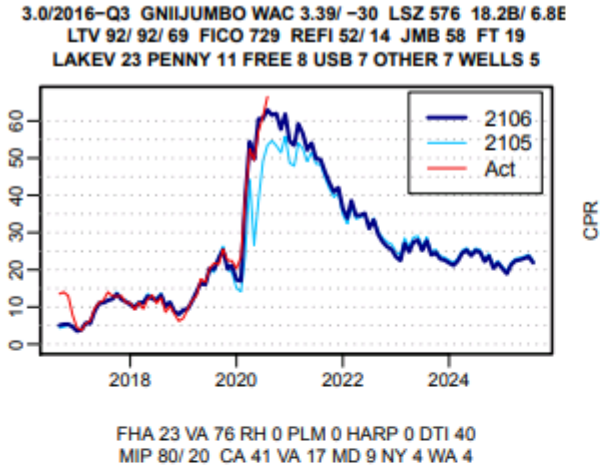


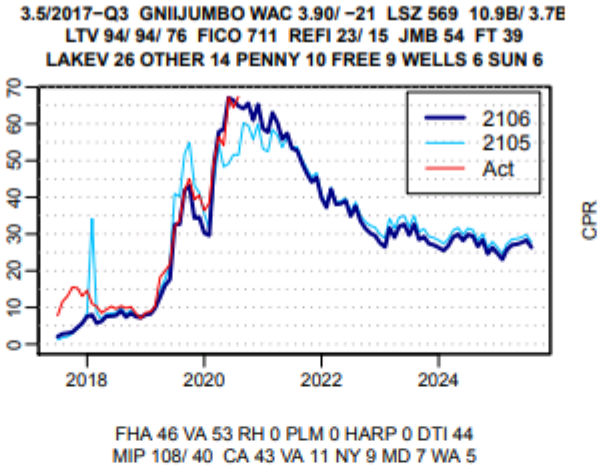


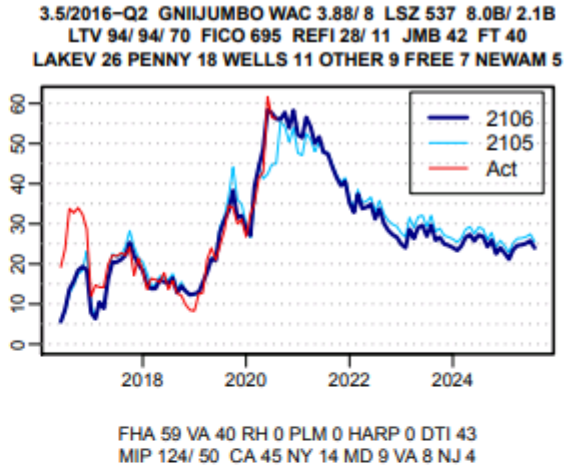
- **Peak ramp speeds on MJMs have been very strong, but generally not quite as strong as model v21.5 projected, due to the very low GNMA primary rate used in the production model.**
- **Model v21.6 generally captures the speeds on new MJM pools, although at times struggles to hit the very highest prints, north of 80 CPR, that are mostly driven by VA prints well above 90.**

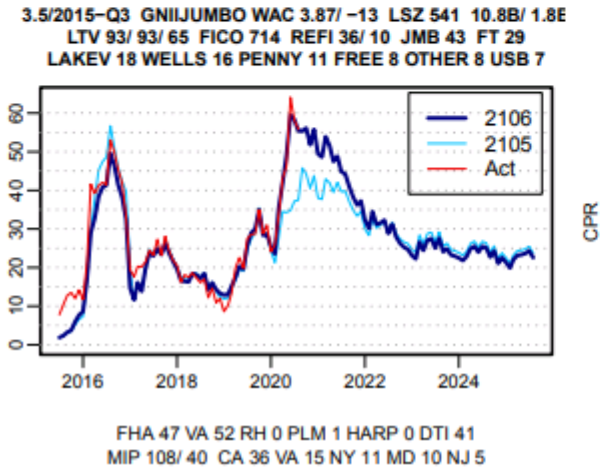
Source: eMBS

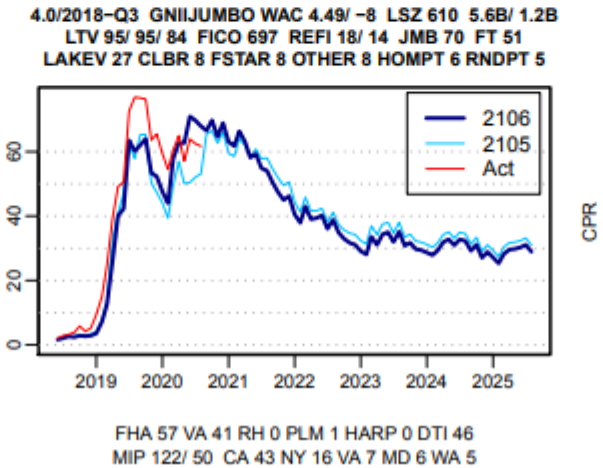
Model v21.6 Seasoned G2 Jumbo Projections Improve

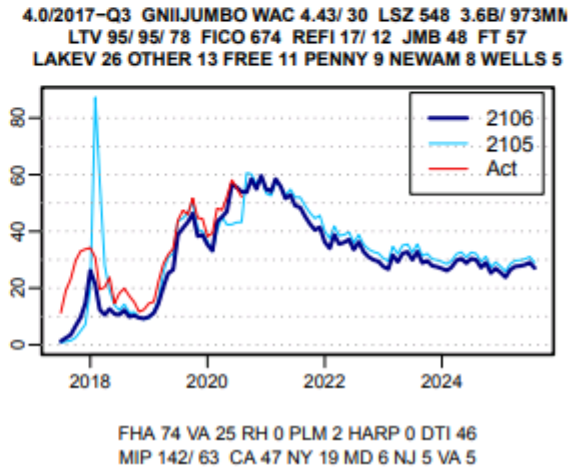








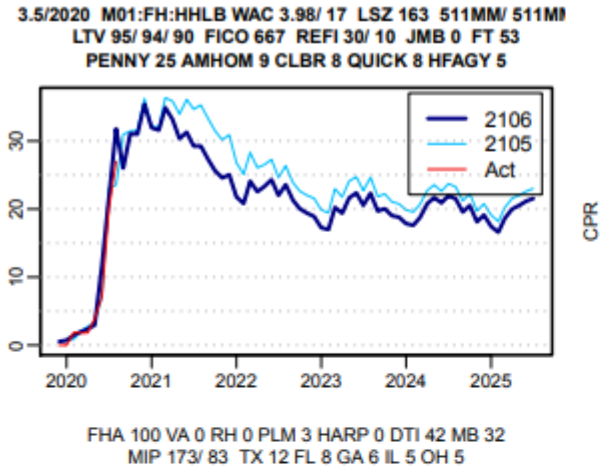


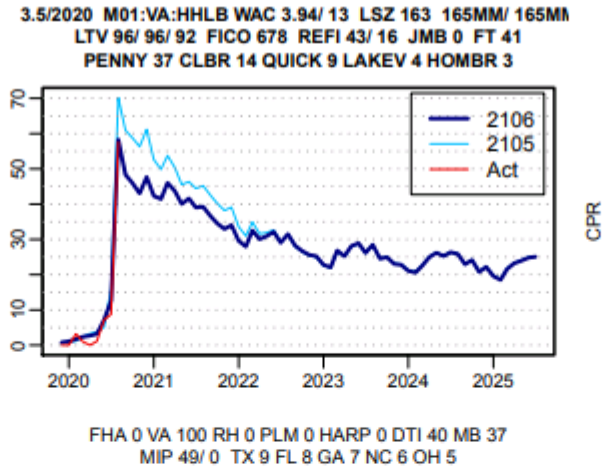


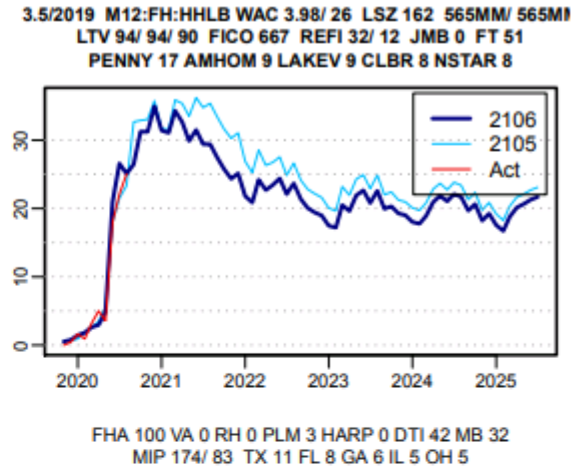
- **Peak speeds on seasoned GNMA II MJMs have substantially exceeded v21.5 projections despite the tailwind of the very low GNMA primary rate assumed in that model.**
- **The updated model v21.6 projects faster speeds, although remains below the actuals in some cases, particularly for 2018 originations peaking in 2019.**

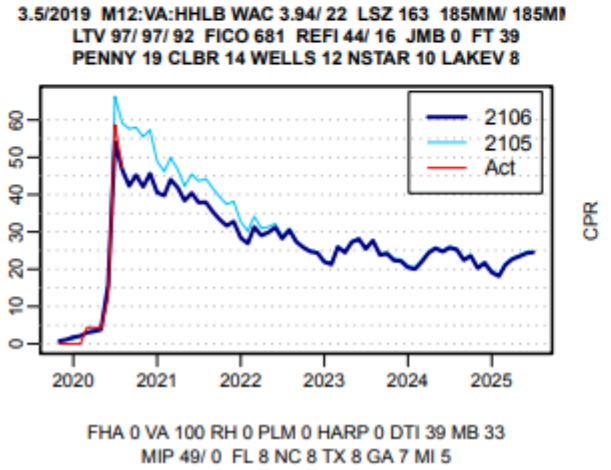
Source: eMBS

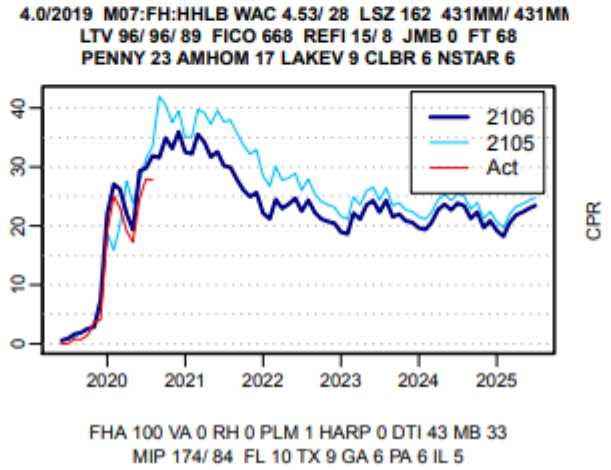
GNMA II Custom LB Ramps More Reasonable in v21.6…

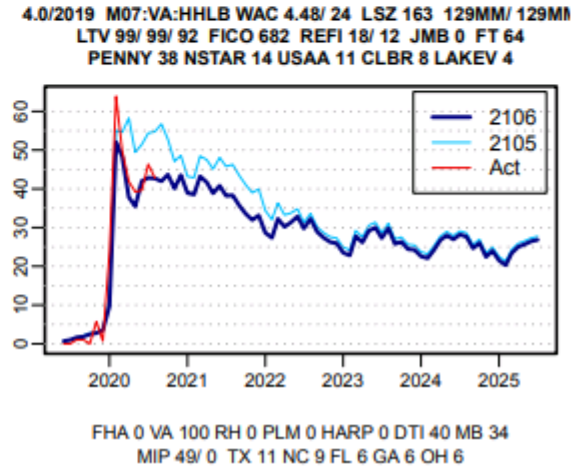








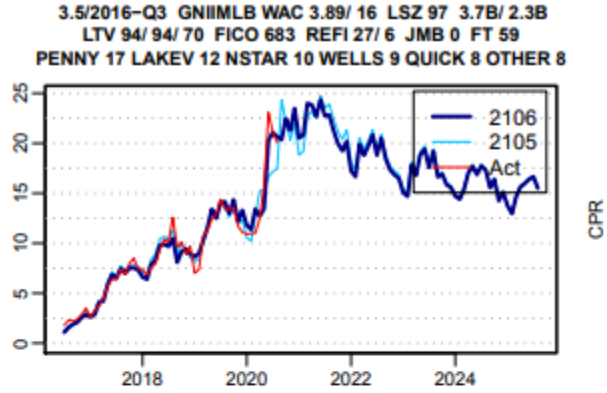


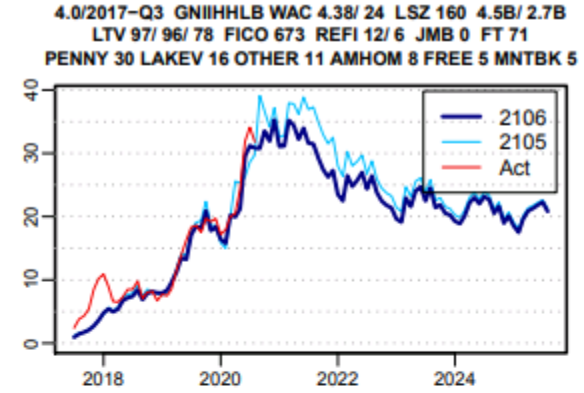


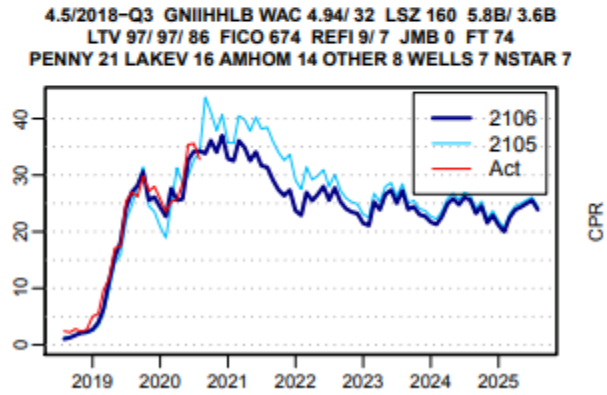
- **Single-month guarantor level custom loan balance ramps look more appropriate in model v21.6, combining ramp recalibration with the GNMA primary rate changes.**
- **The VA fractions of these cohorts, while a relatively modest portion, have an outsized effect on peak custom loan balance pool speeds, since VA peak speeds on HHLB/HLB can exceed 50 CPR.**

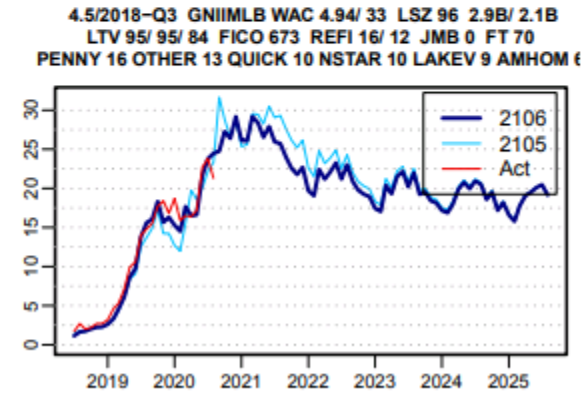
Source: eMBS

…and Seasoned GNMA II Custom LB Improves as Well





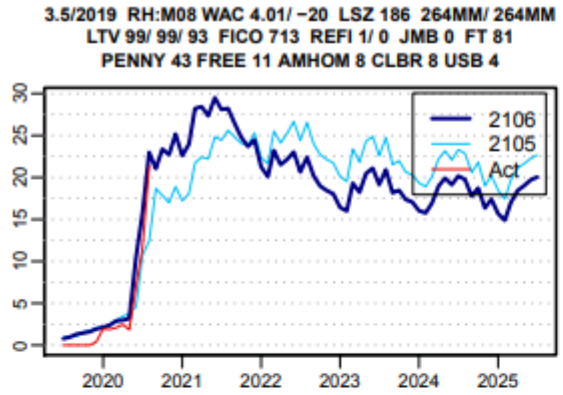


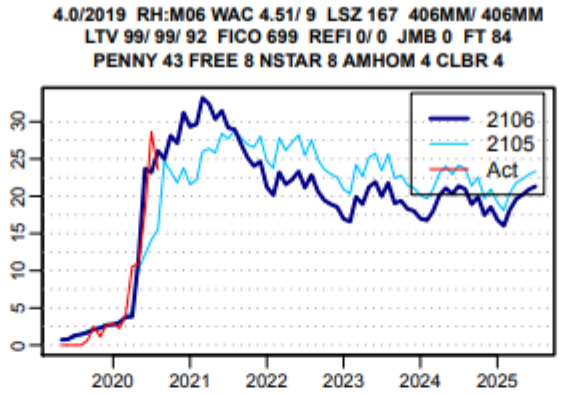


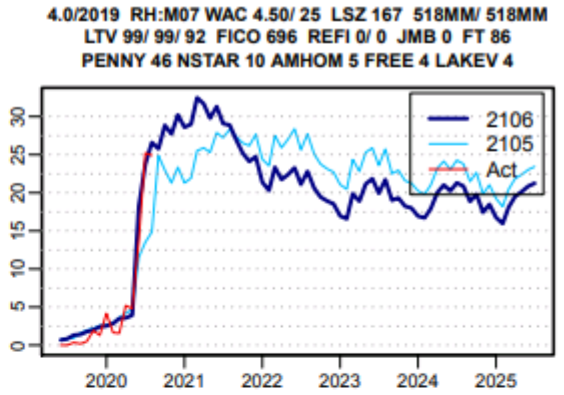
- **More seasoned custom loan balance cohort-level projections look more reasonable in model v21.6, combining media-effect recalibration with the new GNMA primary rate.**
- **Because buyouts can be such a large fraction of speeds on these pools, the buyout model is equally if not more important; buyout model adjustments are discussed further below.**

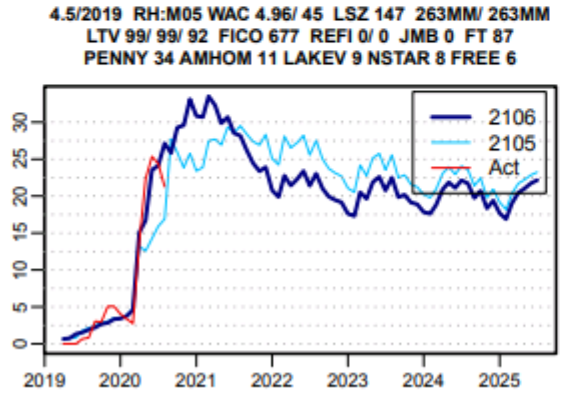
Source: eMBS

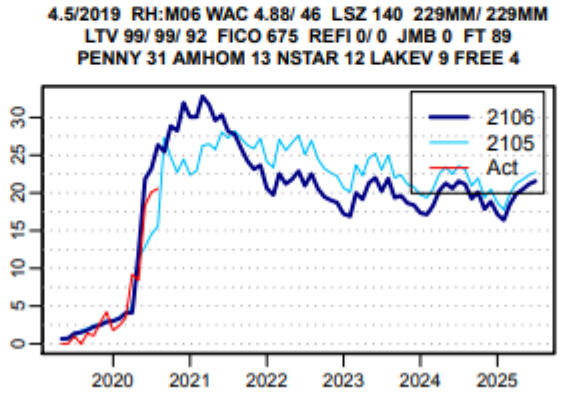
Newly Evident G2 Custom RH Ramps Captured by v21.6

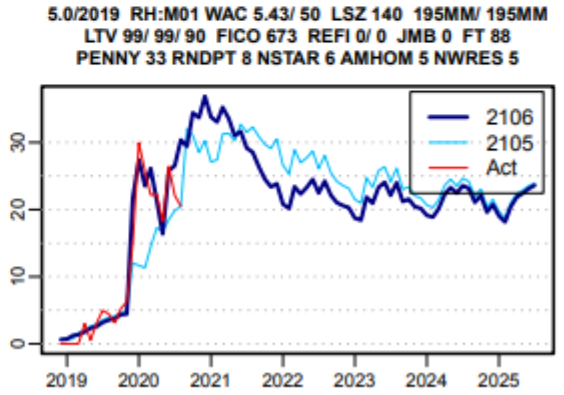








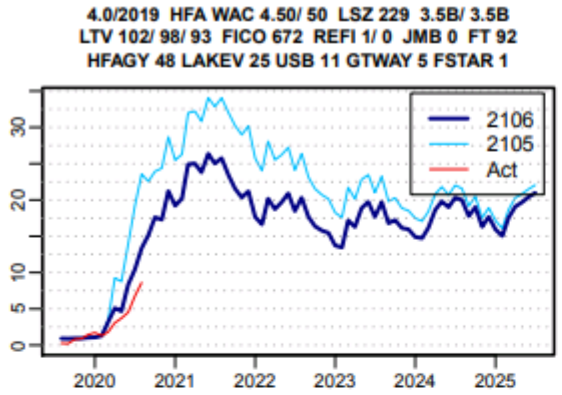


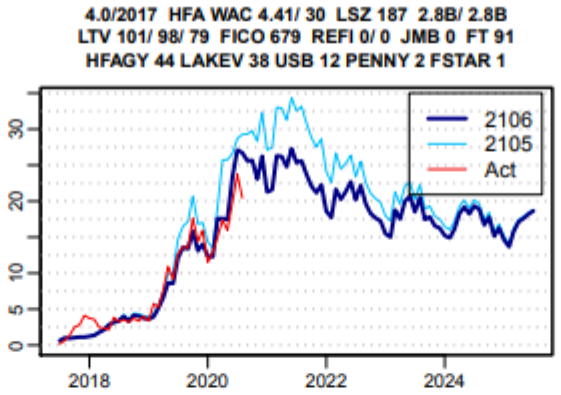


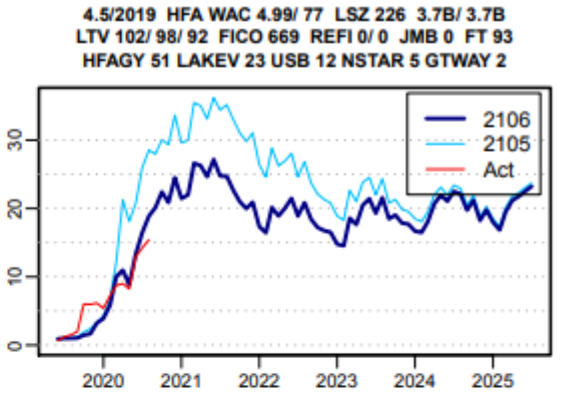
- **Shown above are RH loans in GNMA custom pools originated in specific months of 2019 to focus on the ramp. RH collateral has recently been more responsive after 12 months of seasoning; streamlined refinances on RH loans generally require 12 prior timely payments.**
- **The behavior change may be driven by the RHS Streamline Assist Refinance Program that became effective in 2016, as well as the recent dominance of non-banks in RH servicing.**

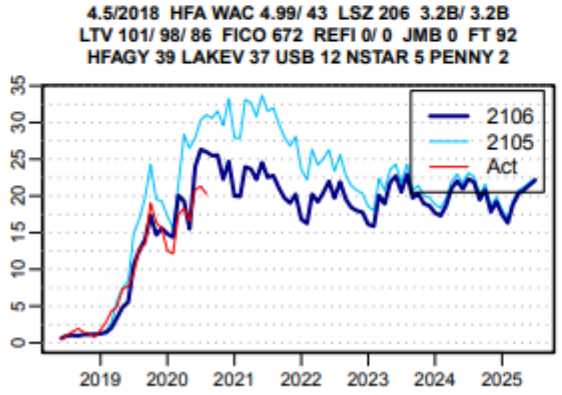
Source: eMBS

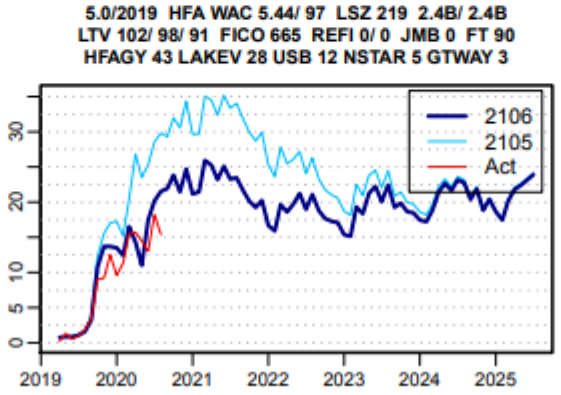
G2 HFA Projections Slowed Further in Model Version v21.6

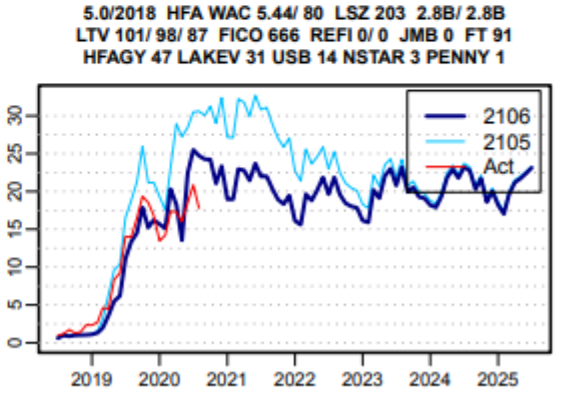










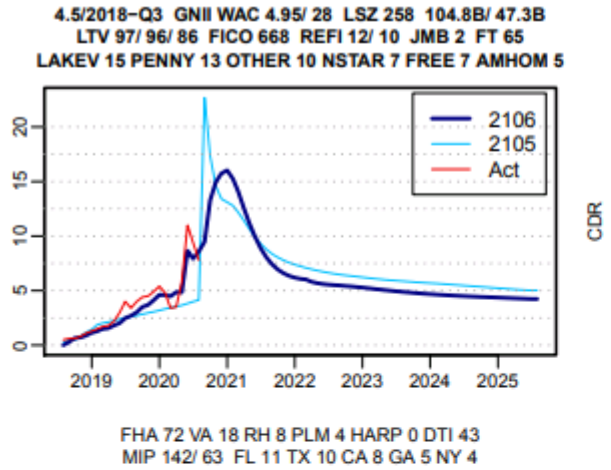


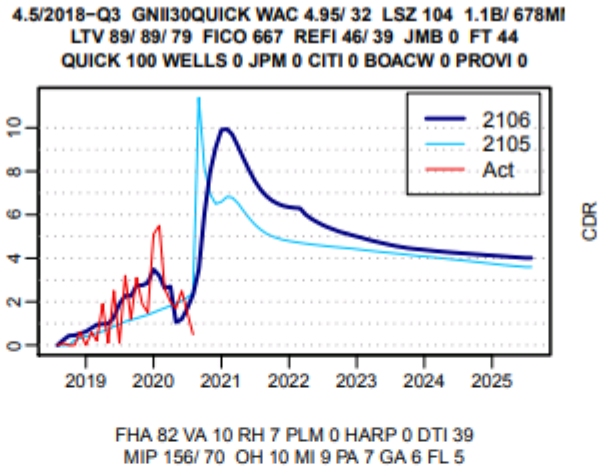
- **Despite material downward adjustments in model version 21.5, actual voluntary prepayments for GNMA II HFA collateral (in the aggregate) have remained below projections and therefore have been slowed further in v21.6, with most cohorts remaining even slower than the new model so far.**
- **HFA prepayments may vary significantly by geography; specific adjustments for selected individual state HFAs are expected to be included starting with model version 21.7.**

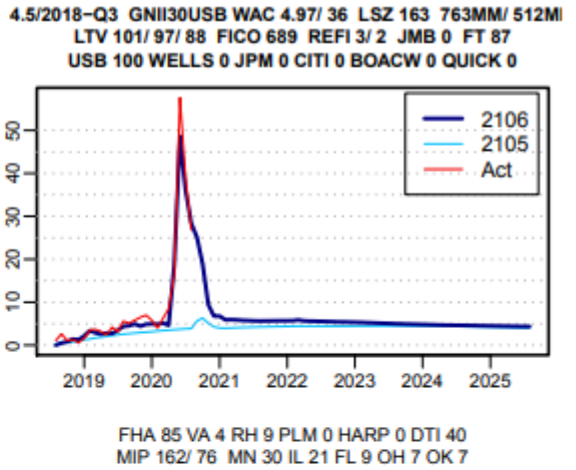
Source: eMBS

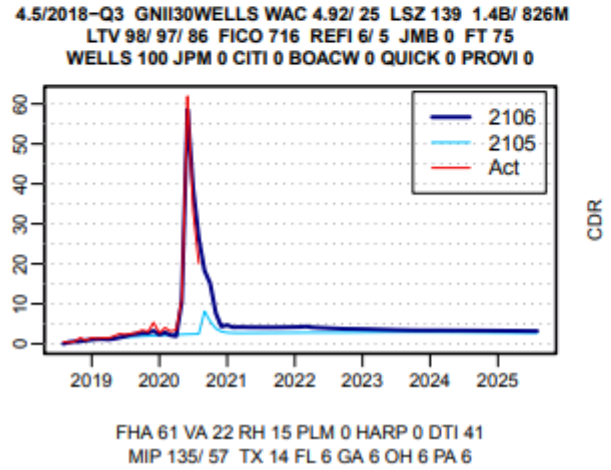
OTHER UPDATES TO MODEL V21.6

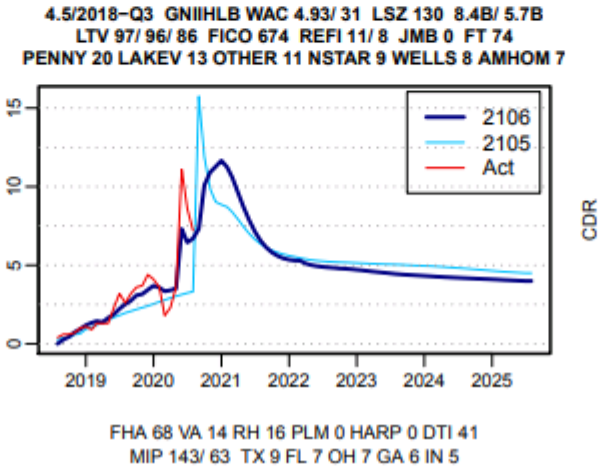
GNMA Buyout Model Overhauled; DQ History Incorporated

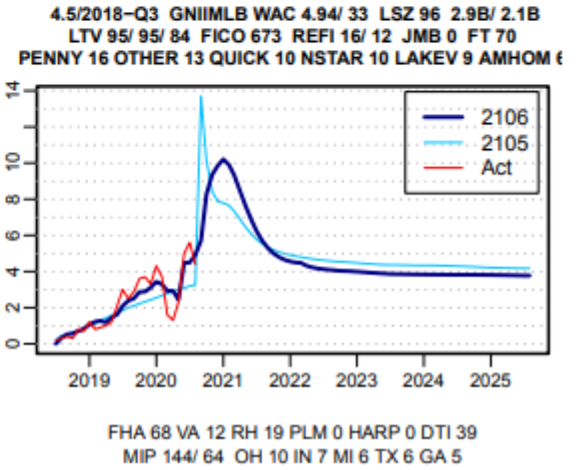










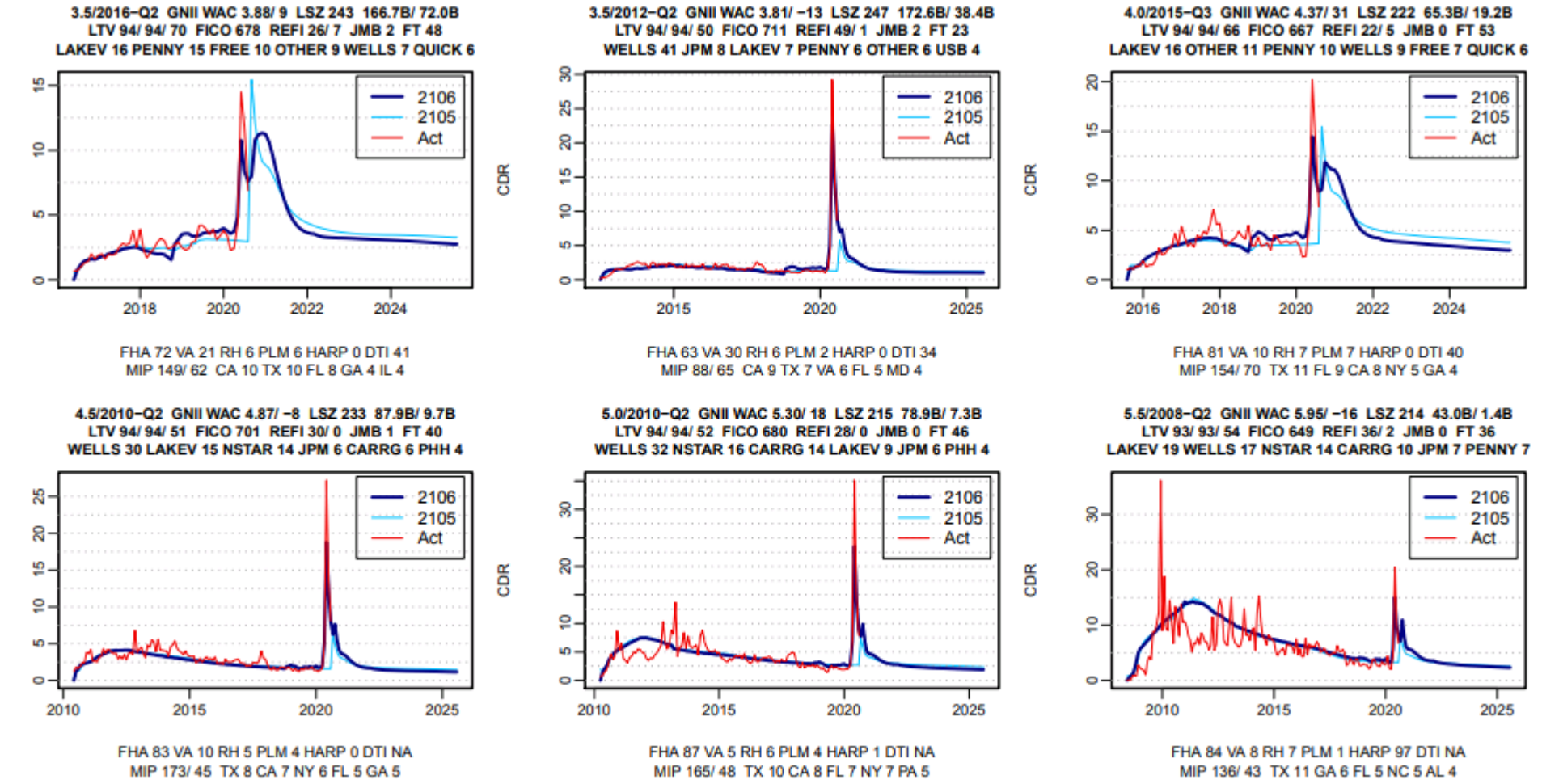


- **Key changes include higher roll rates for forborne loans, immediate buyouts of forborne loans by bank servicers, and minimal initial buyouts from non-bank servicers, followed by non-bank buyouts that are necessary to effect loan modifications. Significant uncertainty remains about the degree to which non-bank loans will be bought out, as opposed to modified in place via FHA COVID-19 partial claims.**

- **Historical delinquencies have been added as model inputs to allow buyout projections in the past.**

Source: eMBS

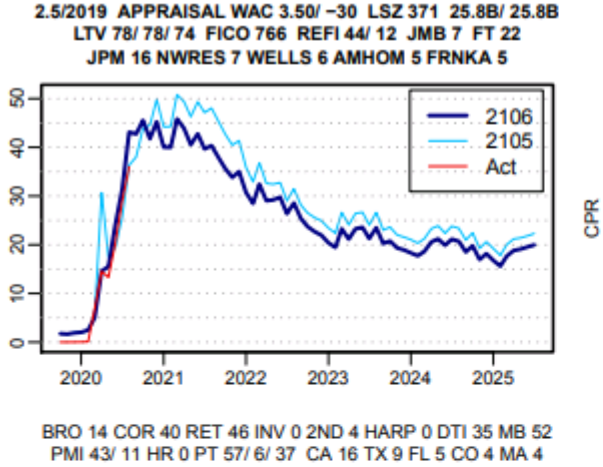
Post-COVID Buyouts Modeled Lower; Near Term Uncertain

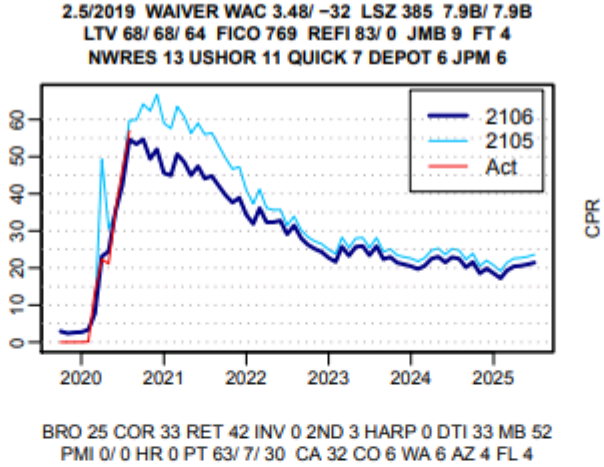


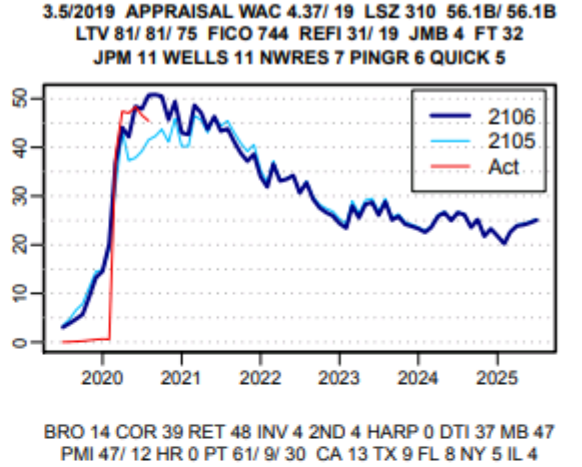
- **Model v21.6 has post-COVID buyouts somewhat lower than v21.5 (assuming unemployment falls in line with Federal Reserve forecasts), as borrowers able to continue or resume payments during or after the crisis should be a more resilient group going forward following buyout of weaker borrowers.**
- **Additional changes may be needed, since non-bank forbearance resolutions remain uncertain. We also hope to better align projections prior to and during the periods of available delinquency history.**

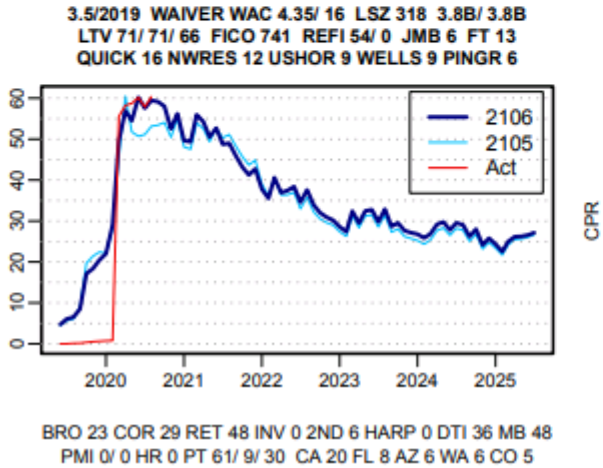
Source: eMBS

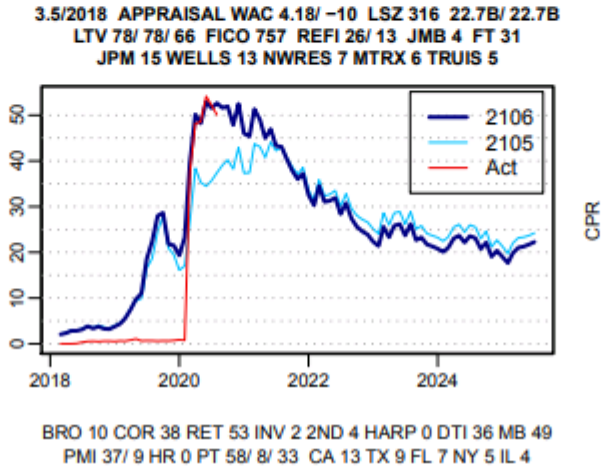
No Adjustments for Recent GSE PIW Disclosures in v21.6

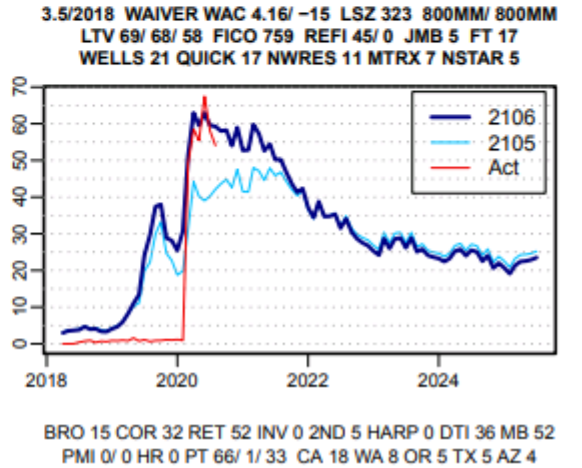












- **Model v21.6 has the property valuation method of the original loan (e.g., appraisal or waiver) available as an input, with parameters to adjust speeds accordingly, but no adjustments are made at this time.**
- **The collateral differences themselves (LTV, servicer mix, TPO, geography, loan size, loan purpose) seemed to capture the difference in some cases but not in others, as shown above for recent FHLMC loans. We will continue to assess whether differences are driven more by the waiver or by attributes.**

Source: eMBS

Model v21.6 Considers a Recession in Stochastic Analysis

HPA Scenarios (v21.6)

Months	Base	Down	Up	Average
1 - 12	0.5%	-9.5%	0.5%	-2.0%
13 - 24	3.0%	-1.0%	7.0%	3.0%
25 - 36	3.0%	3.0%	3.0%	3.0%
37 - 48	3.0%	3.0%	3.0%	3.0%
48 - 60	3.0%	3.0%	3.0%	3.0%

Unemployment Scenarios (v21.6)

Months	Base	Down	Up	Average
1 - 12	8.0%	18.0%	6.0%	10.0%
13 - 24	6.0%	10.0%	5.0%	6.8%
25 - 36	5.0%	7.0%	4.5%	5.4%
37 - 48	4.2%	5.2%	4.2%	4.5%
48 - 60	4.1%	4.1%	4.1%	4.1%

The most severe extension risk in mortgages would be expected to occur in recessionary scenarios when unemployment increases and HPA declines, and when (1) rates are not low enough to trigger a refi wave and/or (2) HPA does not decline enough to trigger widespread use of HLRO.

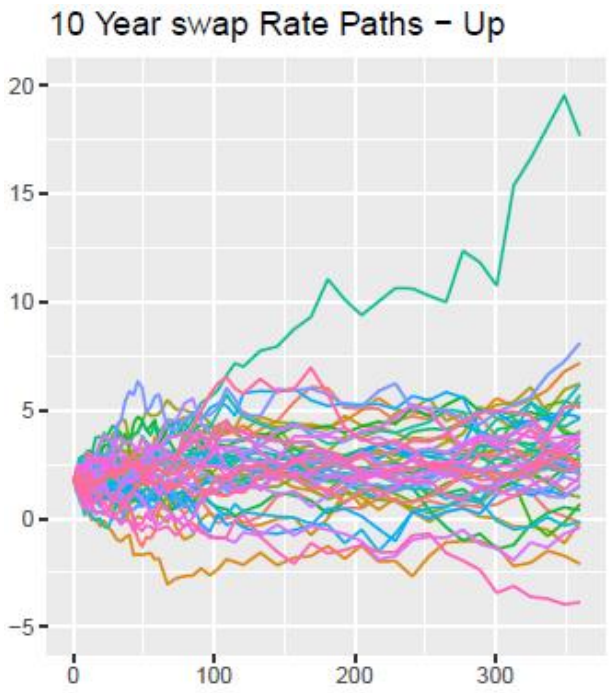
The production model (v21.5) does not capture such scenarios due to benign HPA and unemployment projections.

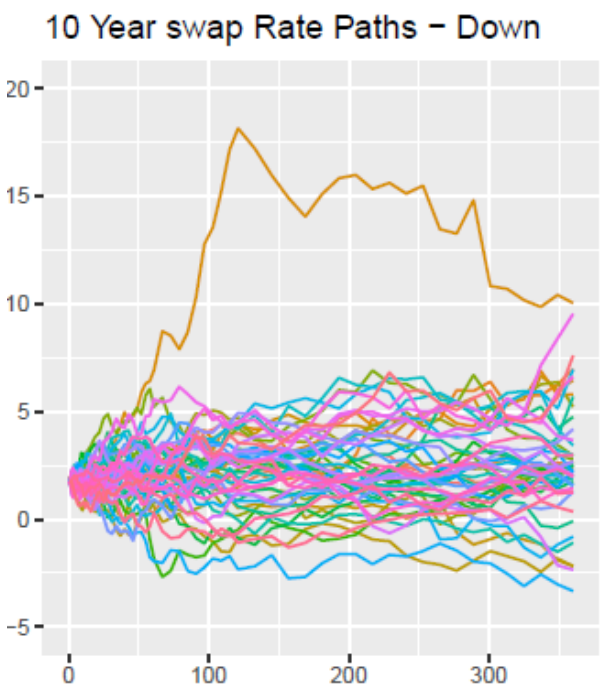
- The weightings have been set to 25% down, 25% up, and 50% base across the 200 rate paths. In effect, we are attempting to represent the worst 25% of outcomes, the middle 50% of outcomes, and the best 25% of outcomes. The blended HPI assumption is below the base case HPI assumption by about 2.5% over the short run, reflecting the view of Robert Young and others of modest overvaluation of the housing market before the COVID-19 crisis.

- OAS and durations are higher for most MBS when incorporating these scenarios, reflecting reduced cashouts, turnover, and non-streamlined rate refis in the downside HPA/unemployment scenario, partially offset by HLRO streamlined refinances in certain cases and a modest impact from the upside scenario.

- If specific HPA and/or unemployment scenarios are specified on Yield Book, they will be used on all paths. Thus the multi-scenario feature is disabled by setting scenarios explicitly to our base-case assumptions.

Path-wise HPA and Unemployment Scenario Assignment





- The objective is to assign down, base, and up HPA/unemployment scenarios across the 200 rate paths, such that the rate clouds are largely consistent across the three sets.
- This eliminates any assumed correlation between rates and unemployment. We believe there is little justification for assuming significant correlation. Recessionary scenarios have been associated with both high rate regimes (late 1970s/early 1980s) and low rate regimes (post crisis period following late 2008 housing collapse).
- As shown above, rate clouds for the three sets (shown as of 11/13/2019) are very similar (note that the base case has twice the density of the up and down cases, by design).

Path-wise HPA/Unemployment Scenario Assignment Method

Averages and quartiles of 10-year swap rate at different time points (as of 11/13/2019)

	Mean				25% Quartile				75% Quartile			
Term	Base	Up	Down	Max diff	Base	Up	Down	Max diff	Base	Up	Down	Max diff
12	1.84	1.80	1.82	0.03	1.47	1.32	1.54	0.22	2.25	2.35	2.13	0.22
24	1.89	1.92	1.94	0.03	1.16	1.29	1.23	0.12	2.55	2.55	2.60	0.05
36	2.01	1.94	2.02	0.08	1.35	1.13	1.38	0.25	2.84	2.58	2.60	0.26
60	2.17	2.15	2.14	0.03	1.27	1.22	1.38	0.16	3.03	3.08	2.90	0.18
84	2.29	2.33	2.29	0.05	1.11	1.17	1.26	0.09	3.38	3.67	3.41	0.28
120	2.51	2.49	2.47	0.02	1.25	1.49	1.16	0.33	3.39	3.64	3.34	0.30

Pool pricing using base HPA/unemployment scenario on each set of paths (as of 11/13/2019)

NMA3834 (3% Nov Major)	base (100 paths)	down (50 paths)	up (50 paths)
Average Price	101.11	101.34	101.58
Standard Deviation of Price	5.3	6.0	3.5

- The objective is to assign down, base, and up HPA/unemployment scenarios across the 200 rate paths, such that the rate clouds are largely consistent across the three sets.
- The method we employed was to perform thousands of iterations in order to converge to the closest match for average and 25% and 75% quartiles of 10-year swap rates (the closest proxy to 30-year mortgage rates) across multiple time points; averages turn out within about 5 bps and quartiles within about 25 bps.
- A typical TBA deliverable pool also priced within half a point across the three sets of paths, a far smaller variation than the standard deviations of prices across the paths.

Servicer Refi Adjustment Changes: v21.6 vs. v21.5

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

GNMA*			
Slower	**Similar**		**Faster**
Bank of America	Amerihome*>	Housing Fin Agy**	360 Mortgage
Chase<*	Academy	Impac	American Financial
Citi	Banco Popular	Loan Depot*>	Caliber*>
Colonial Savings	BOKF	Matrix	Carrington
Cornerstone Home	Cardinal Financial	Midfirst Bank*<	CIS Financial
Fifth-Third	Central Mtg (Arvest)	Mtg Rsrch (VA United)	Finance of America
Homestreet Bank	Citizens Bank	Movement Mortgage	First Guaranty
MB Financial	CMG Mortgage	Nationstar	Freedom*>
M&T Bank	DHI Mortgage	NYCB	Guaranteed Rate
Navy Federal*<	Embrace Home	Ocwen	Guild
PHH	Everbank/TIAA	Pacific Trust Bank	Homebridge
Plaza	Fairway Indep.	Primelending	Lakeview*>
PNC	FHLB Chicago	Prospect	The Money Source*>
SWBC Mortgage	First Key	Provident	Nations Lending
Truist	Flagstar	Pulte Mortgage	New American
USAA<*	Fremont	Redwood	New Day Financial
USB	Gateway Mortgage	Sierra Pacific	New Freedom
Umpqua Bank	Greentree/Ditech	Stonegate	New Penn
Wells Fargo*<	Home Point Fin.	United Shore	New Residential
	Homeward Resid.	Universal American	Oceanside Lending
			Pennymac*>
			Pingora
			Quicken
			Roundpoint
			Stearns
			Sun West Mortgage*>
			United Security
			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 v21.5 Faster than v21.5 Newly added

Source: Citi.

Glossary of Model Changes from v21.5 to v21.6

* Announcements regarding forbearance and post-forbearance modification policy from GSEs and FHA incorporated
* Default model incorporates spike in nonpayment from unprecedented high unemployment and forbearance offers
* Buyout model incorporates the new loss mitigation options (FHA COVID-19 waterfall and GSE payment deferral)
* Conventional loans in forbearance which do not ultimately require change in rate/term are assumed not to be bought out
* Most bank servicers assumed to continue immediate buyouts of eligible loans; non-bank buyouts delayed until modification
* Non-bank FHA loan mods modeled as more aggressive, and buyouts to occur sooner, since TPP not required for COVID-driven FHA mods
* FHA/GSE guidance on refis of loans in forbearance roughly incorporated, with refinement expected in future model updates
* P/S spread model adjusted to increase widening in extreme rate rallies (if CMM102 more than 1 point below recent average)
* P/S spread model also adjusted to revert more quickly to baseline if rates back up and reverse a previous rally
* P/S spread baseline increased by 25 bps from pre-COVID levels in response to the unique conditions brought on by the crisis
* P/S spread baseline assumed to decline gradually over 12-18 months, settling at about 2013-2018 average levels by end of 2021
* P/S spread model updated to slow the decline during very strong rallies when capacity expansion may be more difficult
* No P/S spread adjustments yet assumed for GSE proposed capital plan or possible changes to Treasury 10 bps surcharge
* FHFA Adverse market refinance fee announced on 8/12/20 and revised on 8/25/20 incorporated for refis into conventional loans
* For now, no expiration date is assumed for the adverse market refinance fee, in light of likely upward bias to future g-fees
* From Q2-Q3 2020, long-term base GNMA rate assumed at 1/8 point below conventional rate, independent of GN/FN swap (FN - GN CMM102)
* For Q4 2020 to Q4 2021, long term base GNMA rate spread to conventionals is equal to weighted average of 1/8 point and GN/FN swap
* Swap weight increased linearly over period until long term base GNMA rate spread to conventionals is again equal to GN/FN swap
* PIW effect on conventional speeds extended beyond 24-36 WALA, with stronger impact on moderately seasoned loans
* The propensity of the GSEs to grant PIWs is now a function of HPA; PIWs assumed less likely a down housing market
* Incorporate fraction of loans with PIW (disclosure provided by GSEs in March) as a driver of future refinancings
* PIW effect, media effect, and burnout recalibrated for very high recent speeds and more accurate levels across coupon stack
* Adjustments for fast conventional TPO and servicers generally moderated, as broad PIW adoption causes speeds to converge
* Lock-in is assumed to be stronger for a given disincentive level if rates back up to levels not seen in a long time
* Conventional low loan balance, NY, and CR/U9 collateral projections somewhat higher relative to generics
* GNMA II multi pool, jumbo and loan balance peak speeds are higher, particularly for the VA portion, all else being equal
* GNMA RHS premium coupon projections ramp up more sharply after 12 months of seasoning
* Historical FHFA purchase only HPA updated thru Q2 2020; base projection 6% for 2020 (7% for Q3-Q4 2020), 3% for 2021 and beyond
* Hist unemployment adds BLS classification adjustment (5.3/19.5/16.4/12.3/11.2/9.1 vs. 4.4/14.7/13.3/11.1/10.2/8.4 for Mar-Aug 2020)
* Update future unemployment to Fed Sep projections (~7.5% in Q4 2020, down to 5.5% by Q4 2021, 4.6% by Q4 2022, and 4.1% longer run)
* Introduce downside (average of worst 25% outcomes) and upside (average of best 25% outcomes) HPA and unemployment assumptions
* Downside HPA assumption (incremental relative to base): -10% 1st year, -4% 2nd year, 0% thereafter
* Upside HPA assumption (incremental relative to base): 0% year 1, +4% year 2, 0% thereafter
* Downside unemployment assumption (incremental relative to base): +10% year 1, +4% year 2, +2% year 3, +1% year 4, 0% thereafter
* Upside unemployment assumption (incremental relative to base): -2% year 1, -1% year 2, -0.5% year 3, 0% thereafter
* Rate paths divided into three groups (25% for downside, 50% for upside, 25% for base) to run the three HPA/unemployment scenarios
* Rate paths are assigned to the three groups in a manner designed to minimize correlation between rates and HPA/unemployment
* Recalibration across collateral sectors and attributes, primarily based on v21.5 out-of-sample-performance (from Sep 2019)

Medium/Long Term Development Plans (Post v21.6 Release)

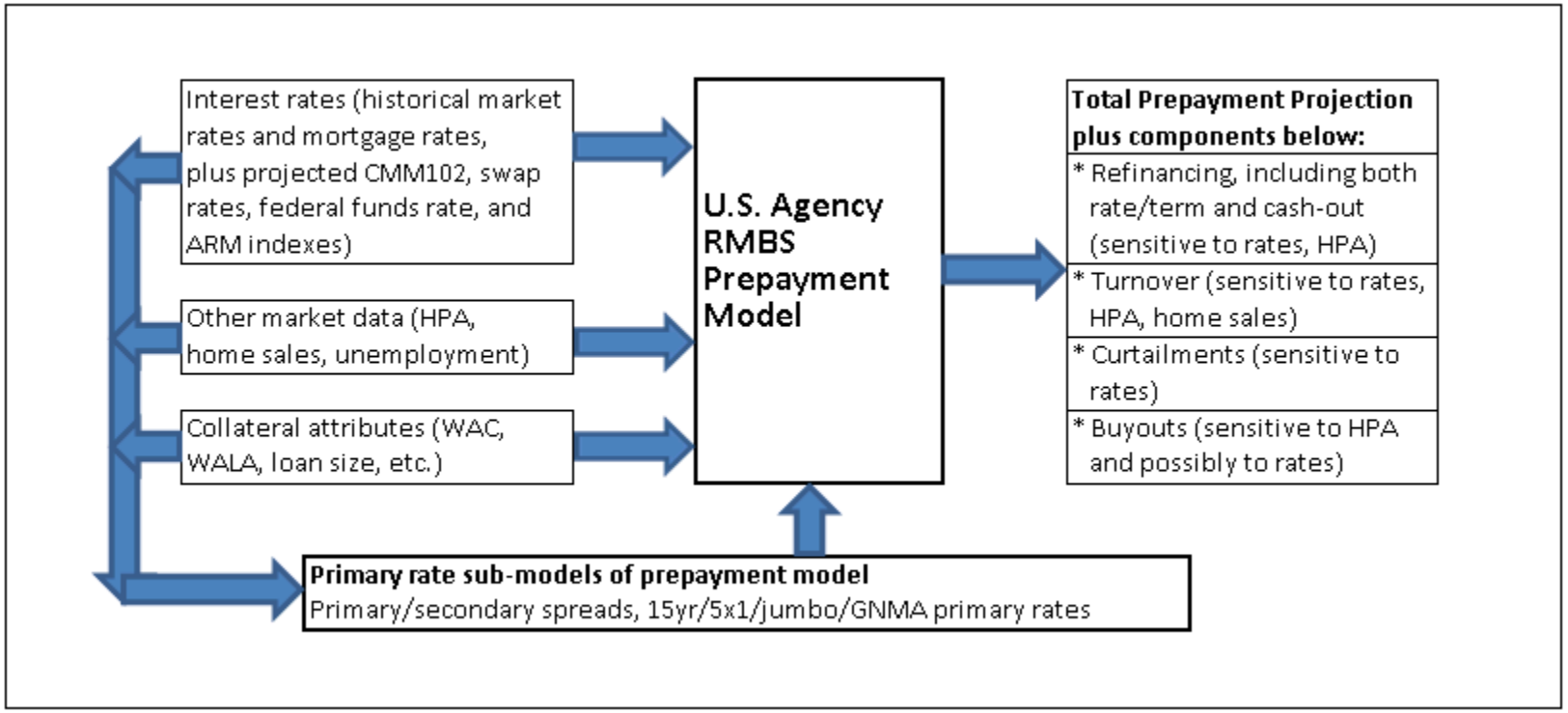
- A recalibration of LMMDD model vol skew is being considered, which would likely result in modestly improved model durations.
- We expect a MOATS update to eliminate excessive volatility that occurs on some paths for CMM102 vs. swap rates.
- We expect to adjust TPO collateral by seller rather than servicer; the broker populations working with a given seller are most relevant to speeds.
- For example, speeds on Quicken and United Shore originated collateral transferred to New Residential remain fast after the transfer; the current model slows speeds on these loans immediately after transfer.
- We also expect to consider adjustments for selected state-level HFAs on top of generalized HFA adjustments.
- While not planned for a near-term production release of the model, we expect to develop separate prepayment models for FHA, VA and RHS. These segments will ultimately be grouped separately in GNMA pools/deals.

APPENDIX – MODEL DESIGN AND DEVELOPMENT

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; important transformations that affect prepayment projections on almost all collateral 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 nay be 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)
- Property valuation method (e.g., appraisal, appraisal waiver, or none if a streamlined refinance)
- 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.

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.

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.
FNMA3Y1_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 not indexed to LIBOR or SOFR rate.
FNMA3Y1_ARML	FNMA single-family 3-year hybrid ARM collateral (index=12m LIBOR/6m SOFR). Includes ARMs with no initial interest-only period, original fixed period between 25 and 48 months, and indexed to LIBOR or SOFR rate.
FNMA3Y1_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 not indexed to LIBOR or SOFR rate.
FNMA3Y1_IOARML	FNMA single-family 3-year hybrid IO ARM collateral (index=12m LIBOR/6m SOFR, initial interest-only period typically 10 years). Includes ARMs with an initial interest-only period, original fixed period between 25 and 48 months, and indexed to LIBOR or SOFR rate.
FNMA5Y1_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 not indexed to LIBOR or SOFR rate.
FNMA5Y1_ARML	FNMA single-family 5-year hybrid ARM collateral (index=12m LIBOR/6m SOFR). Includes ARMs with no initial interest-only period, original fixed period between 49 and 72 months and indexed to LIBOR or SOFR rate.
FNMA5Y1_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 not indexed to LIBOR or SOFR rate.
FNMA5Y1_IOARML	FNMA single-family 5-year hybrid IO ARM collateral (index=12m LIBOR/6m SOFR, initial interest-only period typically 10 years). Includes ARMs with an initial interest-only period, original fixed period between 49 and 72 months and indexed to LIBOR or SOFR rate.
FNMA7Y1_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 not indexed to LIBOR or SOFR rate.
FNMA7Y1_ARML	FNMA single-family 7-year hybrid ARM collateral (index=12m LIBOR/6m SOFR). Includes ARMs with no initial interest-only period, original fixed period between 73 and 102 months and indexed to LIBOR or SOFR rate.
FNMA7Y1_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 not indexed to LIBOR or SOFR rate.
FNMA7Y1_IOARML	FNMA single-family 7-year hybrid IO ARM collateral (index=12m LIBOR/6m SOFR, initial interest-only period typically 10 years). Includes ARMs with an initial interest-only period, original fixed period between 73 and 102 months and indexed to LIBOR or SOFR rate.
FNMA10Y1_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 not indexed to LIBOR or SOFR rate.
FNMA10Y1_ARML	FNMA single-family 10-year hybrid ARM collateral (index=12m LIBOR/6m SOFR). Includes ARMs with no initial interest-only period, original fixed period exceeding 102 months and indexed to LIBOR or SOFR rate.
FNMA10Y1_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 not indexed to LIBOR or SOFR rate.
FNMA10Y1_IOARML	FNMA single-family 10-year hybrid IO ARM collateral (index=12m LIBOR/6m SOFR, initial interest-only period typically 10 years). Includes ARMs with an initial interest-only period, original fixed period exceeding 102 months and indexed to LIBOR or SOFR 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.
FHLMC3Y1_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 not indexed to LIBOR or SOFR rate.
FHLMC3Y1_ARML	FHLMC single-family 3-year hybrid ARM collateral (index=12m LIBOR/6m SOFR). Includes ARMs with no initial interest-only period, original fixed period between 25 and 48 months, and indexed to LIBOR or SOFR rate.
FHLMC3Y1_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 not indexed to LIBOR or SOFR rate.
FHLMC3Y1_IOARML	FHLMC single-family 3-year hybrid IO ARM collateral (index=12m LIBOR/6m SOFR, initial interest-only period typically 10 years). Includes ARMs with an initial interest-only period, original fixed period between 25 and 48 months, and indexed to LIBOR or SOFR rate.
FHLMC5Y1_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 not indexed to LIBOR or SOFR rate.
FHLMC5Y1_ARML	FHLMC single-family 5-year hybrid ARM collateral (index=12m LIBOR/6m SOFR). Includes ARMs with no initial interest-only period, original fixed period between 49 and 72 months and indexed to LIBOR or SOFR rate.
FHLMC5Y1_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 not indexed to LIBOR or SOFR rate.
FHLMC5Y1_IOARML	FHLMC single-family 5-year hybrid IO ARM collateral (index=12m LIBOR/6m SOFR, initial interest-only period typically 10 years). Includes ARMs with an initial interest-only period, original fixed period between 49 and 72 months and indexed to LIBOR or SOFR rate.
FHLMC7Y1_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 not indexed to LIBOR or SOFR rate.
FHLMC7Y1_ARML	FHLMC single-family 7-year hybrid ARM collateral (index=12m LIBOR/6m SOFR). Includes ARMs with no initial interest-only period, original fixed period between 73 and 102 months and indexed to LIBOR or SOFR rate.
FHLMC7Y1_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 not indexed to LIBOR or SOFR rate.
FHLMC7Y1_IOARML	FHLMC single-family 7-year hybrid IO ARM collateral (index=12m LIBOR/6m SOFR, initial interest-only period typically 10 years). Includes ARMs with an initial interest-only period, original fixed period between 73 and 102 months and indexed to LIBOR or SOFR rate.
FHLMC10Y1_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 not indexed to LIBOR or SOFR rate.
FHLMC10Y1_ARML	FHLMC single-family 10-year hybrid ARM collateral (index=12m LIBOR/6m SOFR). Includes ARMs with no initial interest-only period, original fixed period exceeding 102 months and indexed to LIBOR or SOFR rate.
FHLMC10Y1_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 not indexed to LIBOR or SOFR rate.
FHLMC10Y1_IOARML	FHLMC single-family 10-year hybrid IO ARM collateral (index=12m LIBOR/6m SOFR, initial interest-only period typically 10 years). Includes ARMs with an initial interest-only period, original fixed period exceeding 102 months and indexed to LIBOR or SOFR 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- to 15-year original terms. Includes original terms below 17 years.
GNMA3Y1_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.
GNMA5Y1_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.
GNMA7Y1_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.
GNMA3Y1_ARML	GNMA single-family 3-year hybrid ARM collateral (index=12m LIBOR/6m SOFR). Includes ARMs with no initial interest-only period and original fixed period between 25 and 48 months.
GNMA5Y1_ARML	GNMA single-family 5-year hybrid ARM collateral (index=12m LIBOR/6m SOFR). Includes ARMs with no initial interest-only period and original fixed period between 49 and 72 months.
GNMA7Y1_ARML	GNMA single-family 7-year hybrid ARM collateral (index=12m LIBOR/6m SOFR). 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.

- **The COVID-19 crisis will not worsen further, and will slowly resolve over the next 12-18 months, by which time the mortgage market is largely assumed to return to normal.** This assumption is built into various other model assumptions that are discussed further below.

- **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 over the long term, 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. At present, there is a stressed economic environment due to COVID-19, but housing prices and demand have been supported, and even enhanced, by very low mortgage rates and desire to invest in the home due to the isolation imposed by the virus. Therefore, model version 21.6 incorporates historical data through Q2 2020, a 7% annualized projection for the remainder of 2020, 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 21.6 is based on the June 2020 Fed forecast. Note that historical unemployment adds the BLS classification adjustment, meant to account for mis-reporting of COVID-related layoffs as temporary absences that are normally not considered as part of unemployment. Therefore for historical values, the model uses 5.3/19.5/16.4/12.3/11.2/9.1 vs. the official reported values of 4.4/14.7/13.3/11.1/10.2/8.4 for Mar-Aug 2020. Projected unemployment is ~7.5\% in Q4 2020, down to 5.5\% by Q4 2021, 4.6\% by Q4 2022, and 4.1\% 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 imposed minimum g-fee levels and ROE requirements to prevent or moderate further declines. And in August 2020, a 50 bps adverse market LLPA was imposed on all new GSE refinance loans. No other specific proposals of g-fee changes have been made by FHFA, although its recent proposed capital plan for the GSEs could result in increases required to generate an acceptable return on capital following exit from government conservatorship. Congress may also impose increases to fund non-mortgage priorities, as occurred with one of the 10 bps increases in 2012, which is passed directly to the U.S. Treasury; this is scheduled to expire in October 2021 but various proposals from the White House and Congress have included additions to or maintenance of this fee. Given all of the uncertainty described above, this additional 10 bps charge is not currently removed by the model at its stated expiration, nor is any expiration assumed for the adverse market refinance fee announced in August 2020.

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Agency Prepayment Model Key Assumptions (continued)

- **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 Mutual Mortgage Insurance Fund (MMIF) reserve levels. While reserves were fairly healthy before the COVID-19 crisis, they are likely to be significantly impacted by the large number of forbearance requests since March. Depending on the severity of the impact and the results of the 2020 election, an increase is also possible. Grandfathering of MIPs for FHA borrowers originated prior to June 2009 is assumed to continue indefinitely, although this is a small segment of the market now. With regard to other guarantors, 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. At this time, we assume no further changes in the foreseeable future for VA, RH, or PIH MIPs.

- **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 also adding overlays for high DTI loans). Given these fairly recent changes, the model assumes no further changes in the foreseeable future. That being said, it is possible that some pricing changes in the PMI market may ultimately occur if the GSEs enter the market with an enterprise PMI offering, which has been piloted by Fannie Mae. But because PMI typically affects only a limited subset of the refinancing market (i.e., those with LTVs over 80\% and not eligible for any grandfathering program such as HARP or HLRO), we expect any such pricing changes to have a minor impact relative to other factors that could increase or decrease the net cost of the typical mortgage loan (such as guaranty fees).

- **Conforming loan limits are assumed to grow in line with our HPA assumption after 2020.** 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/PublicAfofairs/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 additional increases applicable in 2018, 2019, and 2020 (latest announcement: https://www.fhfa.gov/Media/PublicAffairs/Pages/FHFA-Announces-Maximum-Conforming-Loan-Limits-for-2020.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\%). Effective November 1, 2019, GNMA does not allow VA cash-out loans with LTVs exceeding 90\% to be pooled into their TBA deliverable pools. 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). Increased digitization of mortgage underwriting could result in additional efficiency improvements, which in turn could materially increase prepayments; in our view, much of this has already been realized over the past few years.

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Agency Prepayment Model Key Assumptions (continued)

- **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 most of the post-housing-crisis history. While we believe it is possible that the spread could go outside of that range, particularly under extreme conditions (and has done so during the COVID-19 crisis), a materially lower value is likely to make originations uneconomical, while a materially higher value would likely drive significant competitive pressures and regulatory scrutiny. This range has expanded over the past few years. On one hand, stronger competition, a flatter yield curve and very high WAC spreads in late 2018 and early 2019 led to the lowest P/S spread levels in many years. 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 (because 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). On the other hand, the extreme rate rally, Fed intervention in the TBA market, and disruption of the mortgage origination process during the COVID-19 crisis resulted in the P/S spread widening to unprecedented levels in 2020.

- **The levels of 15-year and hybrid ARM mortgage rates relative to the 30-year mortgage rate will be consistent with levels over the past several years, and remain closely correlated to changes in 5-year swap rates vs. 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, and that the relationship between the spread of 30-year mortgage rates to 15-year/5x1 mortgage rates and spread of 10-year to 5-year swap rates will be consistent with the average since mid-2013, as estimated using a single-variable linear regression. Mid-2013 was chosen as a starting point for the estimation because it follows by several months the relative guaranty fee changes between 15-year and 30-year loans mandated by FHFA and implemented by the GSEs in late 2012. We recognize that additional factors may affect relative mortgage rates, such as different servicing costs for different mortgage types, varying levels of bank retention of shorter-term mortgages such as 15-year loans, and relative pricing in the secondary market for 30-year and 15-year TBAs. But such factors are not specified as part of scenarios such as CCAR or in the Monte Carlo simulations used to compute OAS/OAD/OAC, and in any case would be non-stationary and very difficult to observe and/or project.

- **The relationship between GNMA and conventional primary rates is related to the relationship between production UMBS and GNMA II TBA pricing under normal conditions.** During the relatively stable market and regulatory environments from late 2016 to late 2018 and mid 2019 to early 2020, correlation was very high between relative GNMA II and conventional TBA pricing, as measured by the spread between FNMA CMM102 and the GNMA II 102-priced TBA computed on the same basis. This correlation broke down during the run-up to the advent of UMBS in mid-2019, and then again during the COVID-19 crisis. Due to the continued disruption from the latter, model version 21.6 assumes that there is no significant correlation between FNMA/GNMA primary and secondary rate differences in the near term, but that this correlation will gradually resume over the next 12-18 months as the COVID-19 crisis is expected to wind down.

- **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. Underwriting standards loosened over the next several years as home prices recovered. We assume further loosening is unlikely, especially in light of the COVID-19 crisis that drove significant forbearance requests. The memory of the housing and COVID-19 crises are likely to persist for at least a generation, and we believe a return to underwriting standards prevailing before the housing crisis will not occur in the foreseeable future.

- **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 ultimately make changes to cash-out rules, such that non-economic cash-out refinances under both guarantors will be reduced. It appears that the COVID-19 crisis has delayed development of the final VA NTB test, and we are currently modeling no changes until the end of 2021. In any event, the impact of these changes on cash-out lending is minor compared to the impact of HPA, which we believe is the most important driver of cash-out refinancing.

Agency Prepayment Model Key Assumptions (continued)

- **Model refinancing S-curves are assumed to be materially higher than 2012-2016 S-curves for new collateral, but not to fully revert to peak S-curves from 2003.** 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 peak levels experienced in 2003. However, technological advances 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). These programs offer property inspection waivers (PIW) that eliminate the need for appraisals on many properties, and also automate other aspects of underwriting like income and asset verification. We believe mortgage digitization is the primary driver of the substantial shift higher for S-curves on newer, high-quality loans; and it appears that the benefits have spread more broadly during the COVID-19 crisis. The GSE programs also benefit mortgage originators, in that they reduce the risk that the loans are later found to be defective by FNMA or FHLMC. In addition to these advances, it is also possible that 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 even more broadly and significantly, but no such assumption is currently made for model version 21.6.

- **The surge in refinancings during the COVID-19 crisis is in part attributable to a temporarily elevated media effect and special appraisal flexibilities offered by the GSEs and GNMA guarantors.** We believe there is higher-than-normal borrower contacts with servicers due to the right to request forbearance under the CARES Act, as well as the economic slowdown and remote work requirements imposed by COVID-19. At the same time, the GSEs have offered significant appraisal flexibilities and appraisal waivers on refinances. This has likely carried over into an elevated media effect, greater than what would occur based solely on the declines in mortgage rates. As with elevated P/S spreads, we assume that media effect will return to normalized levels in 12-18 months as the COVID-19 crisis resolves.

- **The surge in delinquencies during the COVID-19 crisis will result in elevated buyouts from agency MBS pools over the next 12-18 months, and that no significant additional changes in workout waterfalls or buyout rules will occur.** Forbearance rates on MBS peaked between 6% and 7% for conventional agency MBS and around 12% for GNMAs. The GSEs (FNMA and FHLMC) have indicated that loans will not be repurchased from pools while in forbearance, nor would loans that are able to resume making the original contractual payments as part of a reinstatement, repayment plan, or payment deferral modification. Thus we assume that the level of buyouts for conventional loans will be substantially below the level that miss the four payments that typically result in a GSE buyout of the loan, and that the buyouts will be spread out over the period during which substantially all forbearances are expected to be granted and ultimately resolved (i.e., from the present to the end of 2021). For GNMAs, a larger fraction of the loans receiving forbearance are assumed to be bought out, as no buyout restrictions have been imposed by GNMA on servicers (for GNMA, it is the servicer rather than the guarantor that determines whether to buy out the loan). As for conventionals, reinstatements, repayment plans or payment deferrals (the latter of which are only available to FHA borrowers) do not require buyouts. But while some restrictions have been imposed on re-pooling loans that are not required to be bought out, bank servicers have nevertheless continued to buy out loans very aggressively given low financing costs, the high expected profitability of re-pooling the loans, and accounting rules that force banks to account for loans on balance sheet if an option to buy them is in-the-money. Non-banks have generally been much less aggressive, as financing is more costly and harder to come by. We assume that bank lenders will continue to buy out loans aggressively, and assume that a higher fraction of non-bank GNMA loans will ultimately be bought out than conventionals, since a greater fraction are likely to require modification (as GNMA borrowers typically are weaker financially). The ability to re-pool COVID-related FHA modifications quickly (no trial payment plan is required), and the lack of payment deferral options for VA or RHS loans, are assumed to further support higher buyout rates on non-bank GNMA loans relative to conventionals.

- **Borrowers obtaining forbearance may obtain new loans without the normal credit impact associated with borrower delinquencies.** Both the GSEs (as announced by FHFA on May 19, 2020) and FHA (via ML 2020-30 on September 10) generally allow borrowers that exited forbearance to refinance after three payments (including a non-credit qualifying streamlined refinance in the case of FHA), with fully reinstated loans (GSEs) or credit-qualifying borrowers (FHA) eligible immediately. And in most cases, VA borrowers may refinance when delinquent even if forbearance has not been granted. The model has never had any adjustments for “dirty current” fraction (which is not available on the pool level for agencies). So borrowers who are current (including after a COVID-19 payment deferral) are assumed to be permitted to refinance, regardless of past delinquency. In effect, FHA and GSEs are allowing that, with a three month delay in some cases and no delay in other cases. In general terms, model v21.6 therefore captures FHFA and FHA guidance in principle by its existing assumption that current loans may refinance, in combination with its existing impairment adjustments for weaker credit loans.

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).

- The long-term status of the GSEs (FNMA and FHLMC) 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 have a significant impact on prepayment rates. For example, a crisis could prompt an expansion of the high-LTV streamlined refinancing program (HLRO) that replaced the crisis-era HARP program in December 2018. At present, HLRO 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). HLRO 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. A re-examination of QM rules is underway, including the elimination of the maximum permitted DTI of 43 in favor of a price-based threshold, as well as the extension of the exemption for GSE loans until the earlier of the effective date of final amendments to the QM standards or the date the GSEs exit government conservatorship. Furthermore, new standards for compliance with Truth in Lending Act and RESPA Integrated Disclosure requirements became effective in late 2015. Finally, there have been significant changes to short-term underwriting and loan servicing requirements due to the COVID-19 crisis, some of which may become permanent or influence permanent updates. All of these new regulatory requirements have already affected the underwriting and servicing environment to some degree, and may (along with any additional changes in the future) ultimately cause underwriting standards to vary from our assumptions.

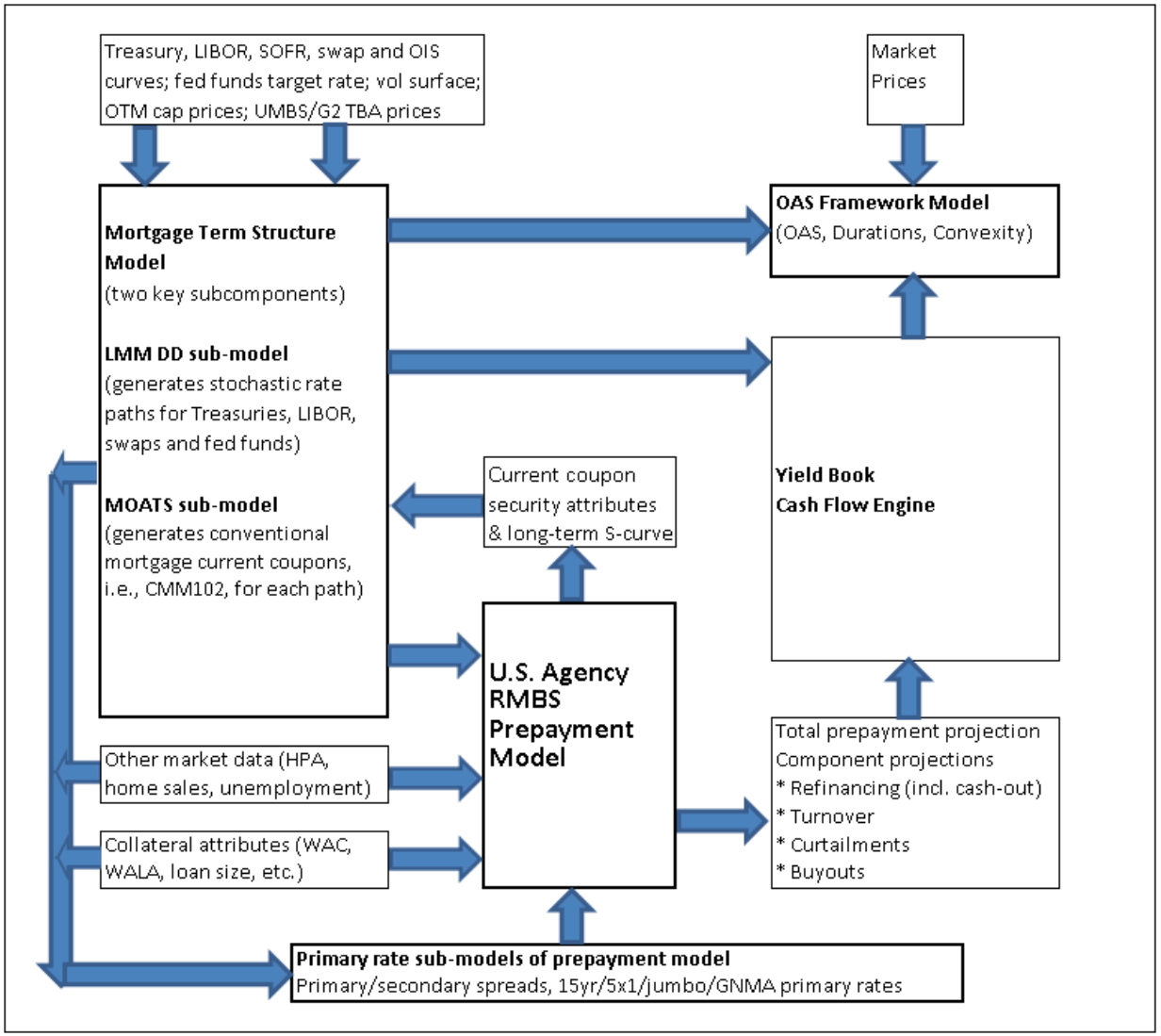
- There is uncertainty regarding the breakdown of voluntary prepayment speeds into housing turnover, rate refinance, cash-out refinance, and full payoff components of model projections, as these speeds cannot be observed directly.

- The crisis period from 2007 through 2011 was characterized by falling home prices, tight underwriting, high unemployment, and low home sales, dramatically affecting all three major components of prepayments (refinancings, turnover and defaults). Over the ensuing years, home prices turned around and the other issues have eased; at the same time, new non-bank servicers emerged that refinance borrowers very aggressively. In 2020, the COVID-19 crisis emerged, again dramatically affecting the three major components of prepayments. Clearly, sharply changing market 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 mortgage term structure model (LMM DD interest rate sub-model based on normal vols and supporting negative interest rates, and the MOATS current coupon sub-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 sub-model to obtain conventional 30yr primary rates; separate sub-models obtain 15-year/5x1/jumbo/GNMA primary rates from 30-year conventional rates.

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

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

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