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Prepayment Modeling – Melding Theory and Data into One

A New Prepayment Model for the Evolving Housing Recovery Landscape

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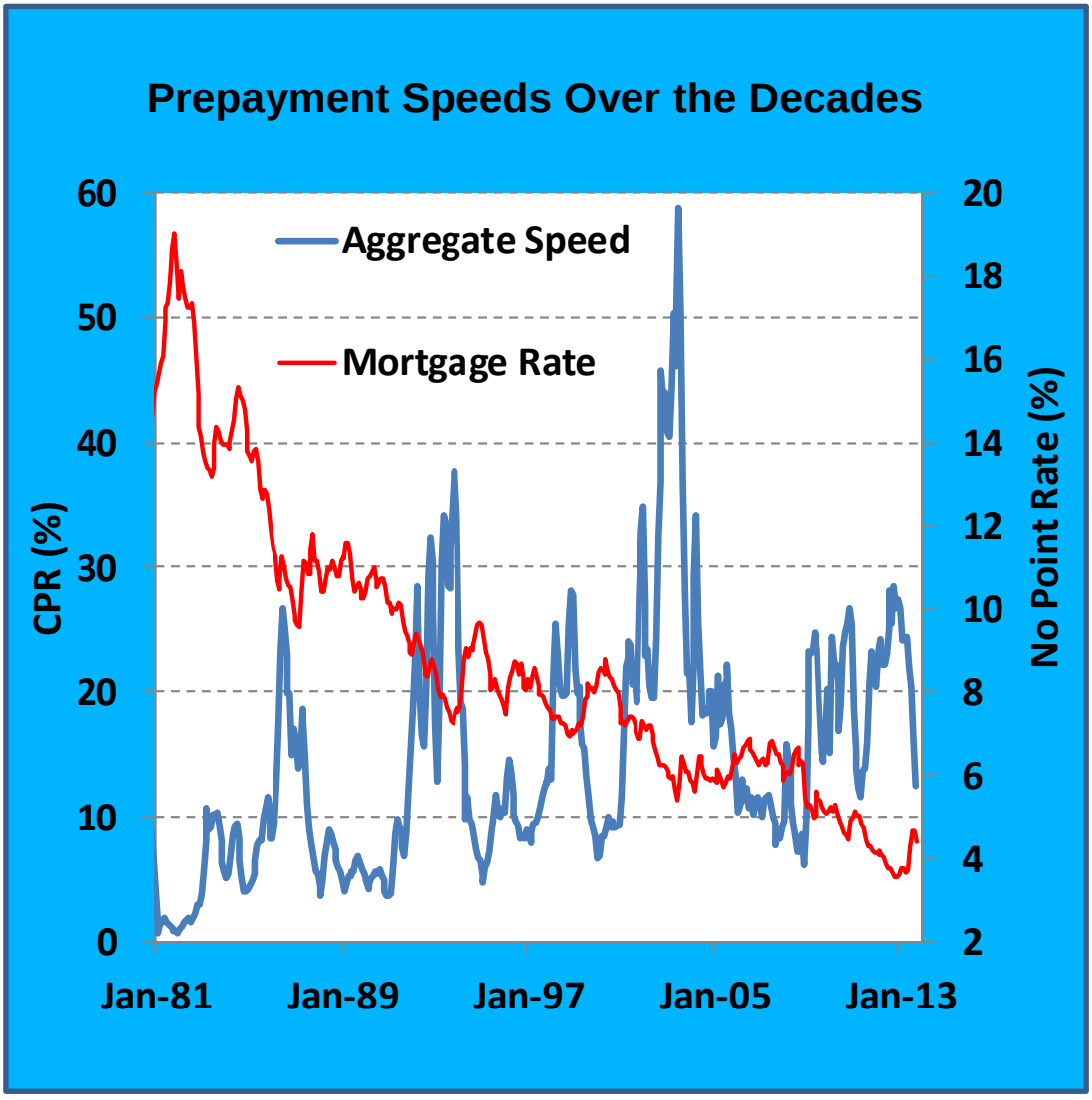

Source: Freddie Mac, Citi.

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Executive Summary – What Actually Changed?

The updated prepayment model addresses three major themes as the mortgage market emerges from the crisis, and which are consistent with recently observed prepayments: (1) strong home price appreciation (HPA) in a recovering market, (2) looser underwriting from very tight levels, and (3) more efficient capacity allocation by lenders.

The most important is likely the first; the old model assumed flat HPA, rising to low single digits by 2015. The new model uses updated FHFA data through mid-2013, followed by 10% the rest of this year, 6% in 2014, 4% in 2015 and 3% thereafter. This broadly impacts prepayment drivers and the various sectors of the mortgage market.

HPA momentum and increased home equity increase short-term turnover and drive refinancings, particularly on higher LTV collateral. GNMA speeds increase as the better-quality FHA borrowers refinance into conventional loans and avoid sharply increased mortgage insurance premiums (MIPs) on new FHA loans. High LTV conventional loans refinanced through HARP speed up as private mortgage insurers are more willing to write business; less pristine loans in general benefit from the **looser underwriting** that a housing recovery brings. Cash-out refinancings, while substantially below what was seen during the pre-crisis years, return and may have a disproportionate impact on lower loan balance collateral. Numerous model parameters were adjusted to translate the recovery into realistic projections.

Originator capacity has heavily influenced the pattern of prepayments recently. New regulatory burdens slow down the origination process and capital requirements for the origination business are higher in light of Basel III and the risks made apparent by the crisis. Originators thus tend to focus on refinancing high loan-size, "low-touch" (high credit quality, recent and clean documentation) during a rally to maximize their profitability.

Third-party originators (TPO) can be particularly aggressive on these loans. The model's well-known "media effect" that drives sharp refinancing increases is now restricted to "low-touch" loans, augmented by an increased TPO impact. "Higher touch" loans face a newly-added "anti-media effect" in the model, whereby speeds slow until capacity increases to absorb them.

The capacity effect may have been exacerbated by the **HARP program**, which (after its expansion in early 2012) essentially converted much of the refinancible

universe to a highly-profitable, "low-touch" category, with opportunities for GSE put-back risk reduction as well, diverting originator attention to this sector. The very high refinancibility of HARP-eligible collateral was increased further in the new model, although higher rates will moderate speeds. The model incorporates all of the policy changes related to the HARP programs of the GSEs (including the eligibility date measurement change made in October).

Defaults, usually a minor component of speeds for agency collateral, became very important during the crisis and remain important for GNMAs and higher-LTV collateral from HARP refinancings. The new model, in light of higher HPA and declining unemployment (and our base-case assumption that both trends will continue), **sharply reduces default projections** and moderates their sensitivity to impaired credit. For the first time, we have incorporated an unemployment forecast into the agency model (we assume a decline to 5.5% over 3-4 years). This allows the default model to be used, albeit cautiously, to evaluate agency risk-sharing deals like STACR and CAS.

The new model also better accounts for the **impact of government policy and regulation** on prepayments (with some benefit of hindsight).

An important but indirect impact of regulatory policy is on our assumptions about **primary/secondary spreads**. We replaced the existing model with one that incorporates both higher GSE guarantee fees (we assume at least another 10 basis-point increase by mid-2014) and a higher originator cost/profitability baseline to account for regulatory changes and increased capital requirements. While the P/S spread is still expected to widen sharply in a strong rally, we assume a faster decline to baseline, given the emergence of new originators and the scrutiny that high P/S spreads triggered last year.

In addition to HARP program changes mentioned earlier, the model incorporates changes to **FHA and RHS MIPs and streamlined refinance policy**. While the old model kept MIP rates on standard collateral up to date, the new model incorporates the FHA's elimination of automatic MIP termination and MIP adjustments by LTV and loan balance. The new model also captures the RHS (Rural Housing Service of the USDA) Refinance Pilot Program, which has increased speeds on this small but important sector of the GNMA universe.

We also **extensively recalibrated** model parameters across the major sub-models (refinancings, turnover, defaults and curtailments) and refined or added some collateral attributes relevant to the model. Amidst a broad recalibration, the following items are worthy of mention:

- A new weighted-average loan size estimation methodology from quartiles for pools without loan-level data. This moderates the impact of extreme values, and significantly improves the comparison of estimated and actual values for FHLMC collateral (which we used to evaluate our methodology). Estimated loan sizes come down, with the most significant influence on the large, highly diverse GNMA II pools.

- We now use current PMI data provided at the loan level and what we believe are more reasonable assumptions when loan level data is not available. The model incorporates the termination conventions for existing PMI and estimates PMI on a prospective new loan based on a broad array of factors considered by insurers.

- Updated geographic adjustments to reflect recent state-by-state refinancing and default trends; two effects are higher assumed speeds in California and higher buyouts on Puerto Rico collateral (a specified pool category).

- The turnover model was adjusted to (1) allow a "pre-seasoning" effect for refinance loans (resulting in a slightly steeper ramp for such loans); (2) moderate the affordability impact (since rates and turnover are not as correlated as in the past); and (3) modify GNMA assumability parameters.

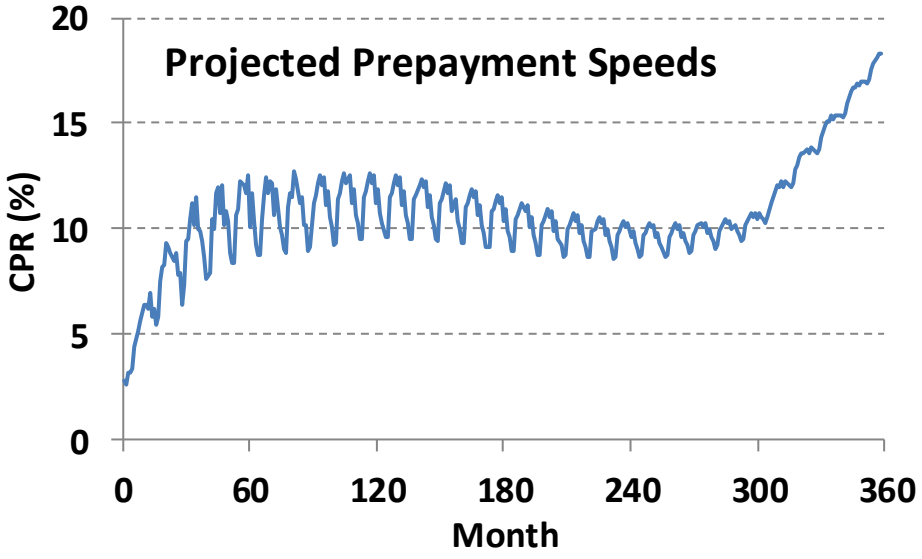
Finally, the new model also **expands sector coverage to 10-year fixed and hybrid ARMs**; these models previously used 15-year and older crisis-era parameters, respectively. For 10-year collateral, the changes better capture the high speeds from lower available rates and very high partial/full payoffs. For ARMs, the new model first incorporates the broad improvements in the fixed-rate model over the past couple of years. We also better capture the higher post-reset speeds resulting from HARP and low fixed rates, as well as the importance of the 30-year to hybrid ARM rate spread on the incentive structure facing hybrid ARM borrowers.

Introduction

Prepayment models are specialized econometric models that must project not only near-term prepayments, but also prepayment speeds extending out 30 years in many different scenarios. In order to do this, the theoretical underpinnings of the model must conform closely with both the call risk of mortgages as well as longer-term patterns of borrower behavior. *Prepayment modeling involves a mixture of art and science, psychology and finance, economics and demographics.* An example of monthly prepayment projections is shown in Figure 1. Some broader themes of prepayments may be observed:

- A seasoning ramp, reflecting the reluctance of borrowers who just purchased a home or refinanced their loan to move or refinance again;
- Oscillation in turnover as homeowners tend to move in the summer;
- Slow decline in speeds ("burnout") as a mortgage pool seasons, as borrowers most likely to move or refinance do so relatively early;
- Increasing speeds in the last few years as borrowers move to finish off their mortgage with partial or full payoffs of unscheduled principal.

Figure 1. Projected Monthly Speeds for a Typical Pool of 30-Year Mortgages



Source: Yield Book, Citi.

Needless to say, a thorough understanding of prepayments is needed to shape the model to give realistic prepayment projections. This is the reason for this paper being as much about prepayments as it is about the prepayment model.

Structure of the Paper

Due to the number and magnitude of the changes both in the marketplace and in the Citi agency prepayment models over the past few years, we have elected to go beyond a description of model updates this time, and provide a full write-up on our latest model.

The paper begins with an overview of prepayments and their components, followed by a review of our model structure and how it has evolved over the years since Citi (then Salomon Brothers) pioneered prepayment modeling in the 1980s. We describe the calibration process for our model.

We focus on the "agency" MBS market (consisting of pools with the explicit or implicit backing of the U.S. government through GNMA or Ginnie Mae (part of the Department of Housing and Urban Development) or one of the two government-sponsored enterprises, or GSEs, chartered to support the residential mortgage market and now under U.S. government conservatorship (FNMA or Fannie Mae, and FHLMC or Freddie Mac).

We attempt to build some intuition around the various components of prepayments before describing each one in detail (refinancings, turnover, partial/full payoffs and buyouts/defaults). Within each of these subsections, we detail the changes we made to the latest model to better capture them. Sidebar text in the left margin highlights new changes.

Sidebar text in the left margin highlights new model changes.

We move on to review our GNMA and hybrid ARM prepayment models; while the principles discussed in the prior sections are applicable here as well, GNMA and hybrid ARM collateral require some unique considerations and these are discussed in detail.

We return to broader themes by showing the impact of the model update (for example, prepayment projections, OAS, duration changes) on the Mortgage Index and various sectors of the mortgage market, including specified pools. A special section is dedicated to discount coupon valuation (important in the rising rate environment we currently face), and the relative importance of the components driving out-of-the-money prepayments, whose breakdown even seasoned MBS participants may find surprising.

The appendices discuss minor changes not covered in the body of the paper, and note some of the additional changes we are contemplating as part of our continual effort to enhance the Citi agency prepayment models.

Why Do Prepayments Occur?

Most readers will be familiar with mortgages and the various causes of prepayments. We use four categories to classify prepayments:

Housing Turnover

An existing home sale and resulting **Housing Turnover** generally leads to a mortgage prepayment if the seller carried a mortgage. An exception occurs if the seller had a Federal Housing Administration or Veterans Administration (FHA/VA) loan and the buyer "assumed" the obligations of the existing loan.

Refinancings

Probably the most important cause of prepayments, this refers to mortgagors refinancing out of an existing loan into a new one. This is generally undertaken to take advantage of lower rates, but can also occur because the mortgagor wants to cash out of equity in the house, 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. As we discuss shortly, **Refinancings** tend to be the most volatile component of speeds and constitute the bulk of prepayments when speeds are very high.

Defaults/Buyouts

Defaults are prepayments caused by the foreclosure and subsequent liquidation of a mortgage. They constitute a very minor component of aggregate prepayments in most cases, but can account for a significant proportion of prepayments on certain types of loans or during an economic crisis. The liquidation/prepayment from an MBS pool can occur earlier through **Buyouts** which can occur while the loan is delinquent prior to foreclosure. In the agency MBS market, principal and interest is advanced on delinquent loans, and default or buyout results in the full payment of the unpaid principal balance.

Partial Prepayments and Full Payoffs

Some mortgagors are in the habit of sending in more than the scheduled payment each month, as a form of forced savings and to build equity in their homes faster. The extra payments are referred to as **Curtailments** and show up as **Partial Prepayments** of principal. **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. **Full Payoffs** can also occur because of the destruction of the home from natural disasters such as hurricanes and earthquakes.

A Short History and Basic Model Structure

Early generation prepayment models were pioneered in the 1980s by Citi (then Salomon Brothers).[1] As more interest rate cycles were observed and more collateral data released, prepayment modeling increasingly became econometric-based, especially in the 1990s.[2] New disclosures by the agencies in the 2000s (e.g., LTV, FICO, loan level data from FHLMC) provided additional information that allowed for somewhat more complex modeling.[3] A very strong housing market prior to the 2007-2008 financial crisis led to above average turnover, high cash-out refinance rates and flipping, and ongoing Citi prepayment model releases sought to capture the changes in the marketplace.

Increasingly Complex Model – The complexity required of prepayment models has increased even further in recent years, as the crisis and related government programs (e.g., the Home Affordable Refinance Program, or HARP) have influenced prepayments significantly, and investor focus on call protection in a low rate environment has resulted in more substantive issuance of a wide variety of specialized collateral types (e.g., loan balance, high LTV, low FICO). Recent model versions[4] were designed to capture the impact of the crisis on the refinancibility of the agency universe, the HARP program that was intended to partially offset this impact, as well as the emergence of new and increasingly important specified pool categories.

The newly released Citi Prepayment Model (version 20, or v20, on The Yield Book) continues the tradition of being an econometric model designed to handle complex situations such as those related to the recovery in housing. It also retains the basic four component structure:

Total Speed = Housing Turnover + Refinancings + Defaults/Buyouts

+ Partial Prepayments/Full Payoffs

[1] *The Salomon Brothers Prepayment Model: Impact of the Market Rally on Mortgage Prepayments and Yields*, Salomon Brothers Inc., September 4, 1985.

[2] *Anatomy of Prepayments: The Salomon Brothers Prepayment Model*, Salomon Brothers Inc., Lakhbir Hayre and Arvind Rajan, June 1995.

[3] *Anatomy of Prepayments: The Salomon Brothers Prepayment Model*, Citigroup Inc., Lakhbir Hayre, Robert Young, Mikhail Teytel and Kevin Cheng, March 2004.

[4] Model versions 17, 18 and 19. Model version 19 (v19) was released in July 2012.

How the Model is Calibrated

As in the past, the new Citi Prepayment Model was calibrated manually by comparing projected and realized prepayments on a wide range of benchmark securities, and adjusting model parameters to improve the fit, paying particular attention to more recent prepayment behavior. This was followed by scenario and valuation analysis to confirm reasonableness[5]. The alternative to this approach is to algorithmically optimize a specially designed target function, which might be a weighted average of errors for benchmark cohorts. A manual calibration is preferred in our view, for the reasons listed below:

- **Mathematical Optimizations Are Prone To Overfitting** – Setting up a robust optimization is difficult and perhaps impossible, given the volatility of the market environment over time and large number of collateral attributes influencing prepayments in inter-related ways. Furthermore, in many cases important data is either sparse or missing. Finding a global minimum under these conditions is a very challenging task. In any case, a solely statistical fit may not be consistent with fundamental relationships likely to persist over time, based on borrower and originator psychology and economics. Furthermore, such a fit may not be dynamic and flexible enough to capture environmental changes over time.
- **Optimizations Do Not Work On Thousands of Free Parameters –** A corollary to the previous point. Most analysts realize how difficult it can be to mathematically optimize a system with just ten free parameters. ***The prepayment model is two orders of magnitude more complex, as it is built upon literally thousands of parameters.*** *Why so many?* Discussing specific parameters helps to illustrate why.
  - **Functions Are Often Nonlinear** – The degree to which collateral is not refinancable is partly based on credit score (as well as other factors such as LTV). As discussed later, originators do not assume credit score has a linear effect – for example, 740 is cited as a cutoff for borrowers to get the best mortgage rates. So the model assumes a refinancing eligibility "function" of credit score, which might have around half a dozen parameters for different credit score values.

[5] Citi posts actual vs. projected comparisons for several hundred cohorts each month on CitiVelocity, and has, under separate cover, made spreadsheets showing valuation differences and scenario analysis for a wide range of collateral types and specified pool categories available comparing Citi Model v20 with Model v19.1.

- **One Function Can Really Mean Multiple Functions** – In addition, this refinancing eligibility function could be different for conventional borrowers and FHA/VA borrowers given differences in underwriting and borrower profile (so we really have a multiple of the half a dozen free parameters per "function").
- **Many Different Effects in Many Parts of the Model** – The credit score parameter story is just beginning. In addition to this refinancing eligibility "function", a partial list of other parts of the model in which credit score has an impact (through other functions): Defaults, Curtailments/Full Payoffs, Cash-out Refinancings, PMI, TPO, Media Effect, and Anti-Media Effect.

- **Computers Are Not Good At Juggling Many Simultaneous Goals** – The choice of a target function to optimize is arbitrary and, for example, different choices of weights or time intervals may result in conceptually different solutions. *Furthermore, not only each of the four prepayment components, but also sub-components (like cash-out refinancings), individually need to be consistent and reasonable.* Manual calibration is more robust to the extent that an informed analyst can make a better decision on what constitutes a good fit.

- **Consistency Is Needed Across Many Collateral Types** – This is an extension of the previous point. Specified pools (relatively homogeneous pools with specialized attributes, such as high loan balance or high LTV, generally designed to provide call protection to investors and therefore trading at a pay-up to generic collateral) are an increasingly important sector of the market. A computer optimization would be required on each separate category, which again could result in conceptually different solutions that may not be consistent.

- **Mathematical Optimizations Are Not Good At Extrapolating** – The main objective of the model is to project prepayments into the future, and the majority of relevant scenarios, which include stochastic interest rate paths for OAS analysis, do not resemble past experience. In other words, the model must be capable of extrapolating prepayment behavior in a reasonable way into "uncharted waters". Therefore, as mentioned earlier, it is critical for the model to be based on a solid understanding of prepayment drivers, including borrower psychology and lender incentives. Optimization may not come up with a reasonable solution.

- **Guesswork is Required –** We state explicitly if not already apparent!

A Quick Tour of Prepayments

Some intuition behind the four components of prepayments:

A) **Slow Motion Prepayments – Housing Turnover, Defaults/Buyouts, and Partial Prepayments/Full Payoffs (TDP)** can be lumped together as the less volatile and relatively slow moving part of total prepayments (shown in Figure 2 top chart, Estimated CPR Excluding Refinancings, for Fannie Mae 4.5s originated in 2003). ***Compared to the very large up and down swings of the Refinancing component of prepayments*** (the difference between the Total CPR and TDP shown in Figure 2 top chart), ***TDP moves in slow motion*.**

Not Just Seasonal – Housing Turnover normally dominates TDP, which is why TDP can be observed to exhibit seasonal swings (turnover is shown in Figure 2 bottom chart). ***Although slow moving, TDP can be very important for discount coupon ("out-of-the-money") valuation*** – as was the case for the 4.5s of 2003 for the first 5 years shown in Figure 2 – since discount speeds have almost no refinancing component.[6] And as Figure 2 bottom chart shows, TDP does vary significantly – turnover reached (i) a high of over 7 CPR in 2005 at the height of the housing boom and summer seasonal activity, and (ii) a low in late 2008 when the financial world nearly ground to a halt at the height of the financial panic and crisis, in combination with lower seasonal factors near year-end.[7]

Subsequent increases in TDP occurred in 2009 and 2010, and can be explained by the fact that as turnover fell, defaults increased substantially in light of the recession and sharp declines in home prices. Then in 2012 the evidence of the improved housing market can be seen as home sales began to increase again.

For seasoned, shorter-term loans, curtailments and full payoffs can rise substantially and become a significant component of TDP.

[6] Refinancings for 4.5s of 2003 during the first 5 years of Figure 2, especially during the peak of the housing boom in 2004-2006, were likely cash-out refinancings, which means the borrower took out a larger mortgage in order to get cash.

[7] Unlike total actual prepayment speeds, housing turnover speeds are not directly observed and as a result must be estimated.

Predicting TDP – While long-term projections for any component are challenging, a rough but reasonable short-term projection for TDP for next month is just the previous month's speed adjusted by an appropriate seasonal factor.[8]

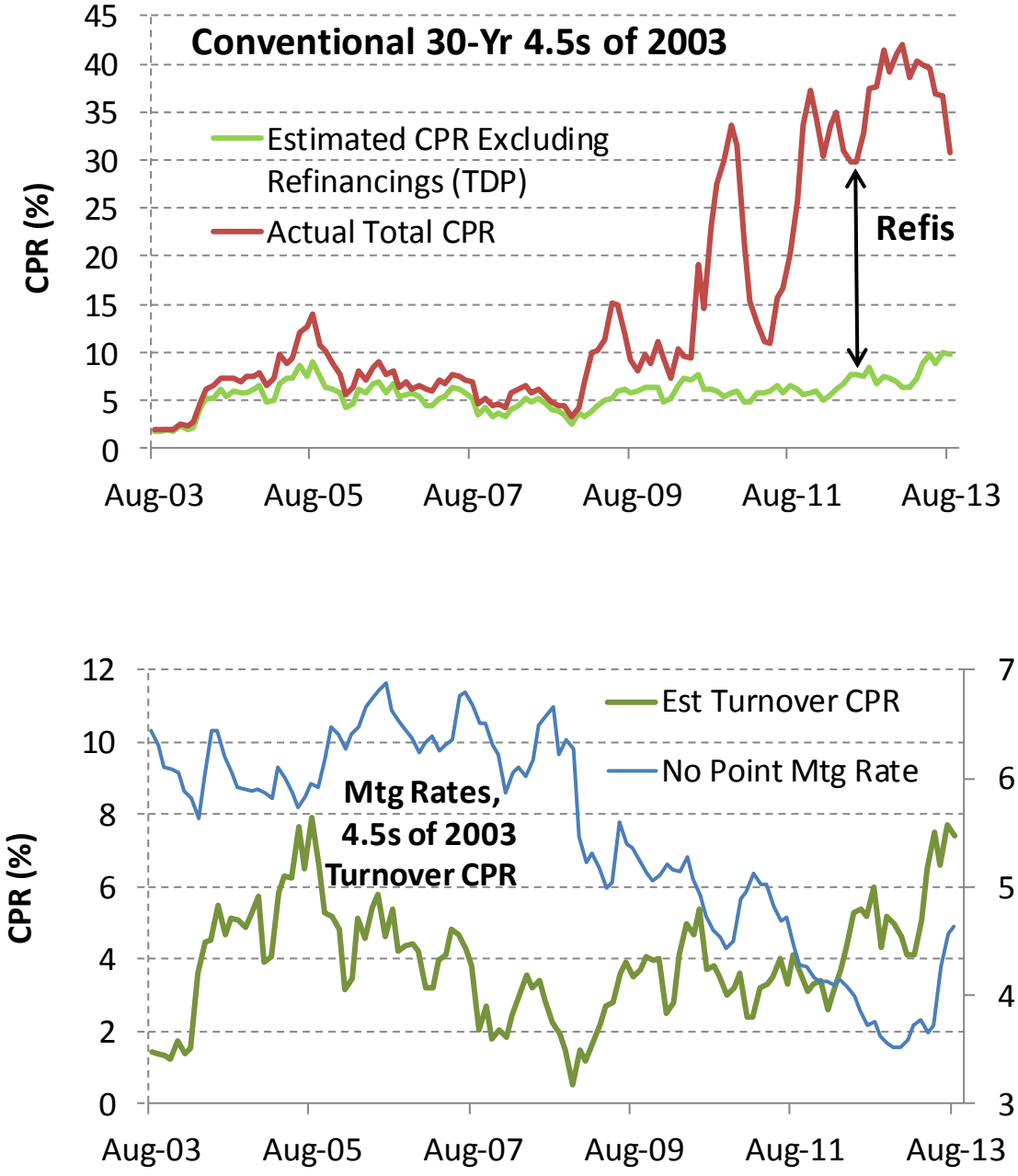
B) **Like a Tidal Wave** – The **Refinancing** component of prepayments can result in refinancing waves that come with the force of a Category 3, 4, or even 5 hurricane. Figure 2 top chart shows how (a) large and (b) volatile this component can be, especially relative to the other 3 components (TDP). **Needless to say, the refinancing component is (a) the heart of the prepayment model and (b) the most challenging part of the model to build and get right.**

For the sample collateral shown in Figure 2, conventional 30-year 4.5s of 2003, the refinancing response was quite dramatic as rates reached historic lows in late 2010, as many borrowers took advantage of the first significant opportunity they had to refinance. Given the seasoning, some of the borrowers likely moved to 15-year collateral, highlighting the importance of capturing the multiple mortgage types available. The response was again strong when rates rallied in 2011, despite some evidence of burnout, and an extra push occurred in 2012 as HARP program activity peaked. As mentioned, prepayment projections when collateral is refinancible can be very challenging, as numerous factors such as burnout, the array of refinancing options, capacity constraints, underwriting standards, and government programs all must be considered in concert with numerous collateral attributes.

C) **Quiz on Prepayments** – Given that the collateral 30-year 4.5s of 2003 in Figure 2 consists of borrowers paying (on average) a rate of 5.07%, and given the 100 basis-point back-up in mortgage rates to the 4.50%-4.75% area also shown (the bulk of the back-up occurred in May through June of 2013), what will the next (total) prepayment speed be (in September 2013, in the top chart of Figure 2)? The answer is provided in the Appendix at the end of this paper.

[8] Pending existing home sales data might also be useful for TDP short-term projections.

Figure 2. Prepayment Speeds for 4.5s of 2003 – Total and Excluding Refinancings (Top), Turnover and Mtg Rates (Bottom)



Source: Freddie Mac, Citi.

Refinancing Model

The basic structure of a refinancing model consists of the following steps:

1) computing an incentive to refinance
2) applying a response function to incentive to get a prepay speed
3) applying burnout

We examine each of these starting with the incentive, and discuss other important parts of the refinancing model as well.

Refinancing Incentive

Refinancing Incentive is simply estimated the way we believe most borrowers calculate it – the difference between borrower savings and refinancing costs:

Refinancing Incentive =

[(Old Mortgage Rate – New Mortgage Rate) * Loan Size

*** Expected Holding Time] – Refinancing Costs**

One reason for not taking a ratio of the old mortgage rate (or payment) to the new mortgage rate (or payment) is that the impact of loan size is somewhat more directly seen by using a difference expression. However this formulation is not without some additional complexities as described below.

Refinancing incentive nuances:

1) *Expected Holding Time*, which may be viewed as the remaining time the borrower expects their mortgage to be outstanding (or alternatively as a reasonable "payback period" for their investment of time and costs to refinance), eventually declines as the mortgage seasons – in particular as the loan approaches maturity. The *Expected Holding Time* would of course be capped by the remaining time to maturity (for example, a borrower with a mortgage that has only a two-year remaining term would not assume an *Expected Holding Time* greater than two years).

2) *Refinancing Costs* include well-known costs such as title insurance, legal, and appraisal fees.[9] Typical closing costs might run in the ballpark

[9] Borrowers who have recently refinanced may be able to get discounts for title insurance and may be able to take advantage of documentation used for their previous refinance.

The new prepayment model includes updated state-level adjustments related to refinancing incentive.

of 2% of the loan balance, but can vary substantially depending on costs such as title search, insurance and taxes.[10] These costs can often depend on the geographic location. For example, high mortgage taxes in New York elevate closing costs and depress speeds significantly in that state. Both the old and new Citi prepayment models attempt to capture these geographic differences; the state-level adjustments have been updated for Model v20. Refinancing costs also include "transient costs", which refer to the indirect cost of borrower and/or originator aversion to refinancing of very new mortgages, which essentially acts as an initial refinancing seasoning ramp. During a sharp rally, third-party originators (TPOs), particularly brokers, will aggressively target newer loans and partially or even more than fully offset these transient costs.

3) *New Mortgage Rate* estimation is an involved computation with a number of moving parts – we discuss this further after describing the Eligibility Framework, a related model feature.

Eligibility Framework

An "Eligibility Framework" breaks down a pool into six categories (see bottom row of Figure 3).[11] The three conforming loan categories that borrowers are broken down into are as follows:

a) Agency no rate premium – reflecting borrowers qualifying for the mortgage rates available to high credit quality borrowers with clean documentation and making a down payment of at least 20%.

b) Agency "Alt-A" – which represents borrowers who do not qualify for the better mortgage rates (for example, investor borrowers, or those with a moderately lower credit score) and need to pay some premium.[12]

[10] Bankrate's 2013 closing costs survey estimated a national average (excluding title insurance, title search and taxes) on a $200K loan of about $2,400, ranging from $2,100 to $2,900 by state. As Bankrate noted, this excludes the most highly variable components.

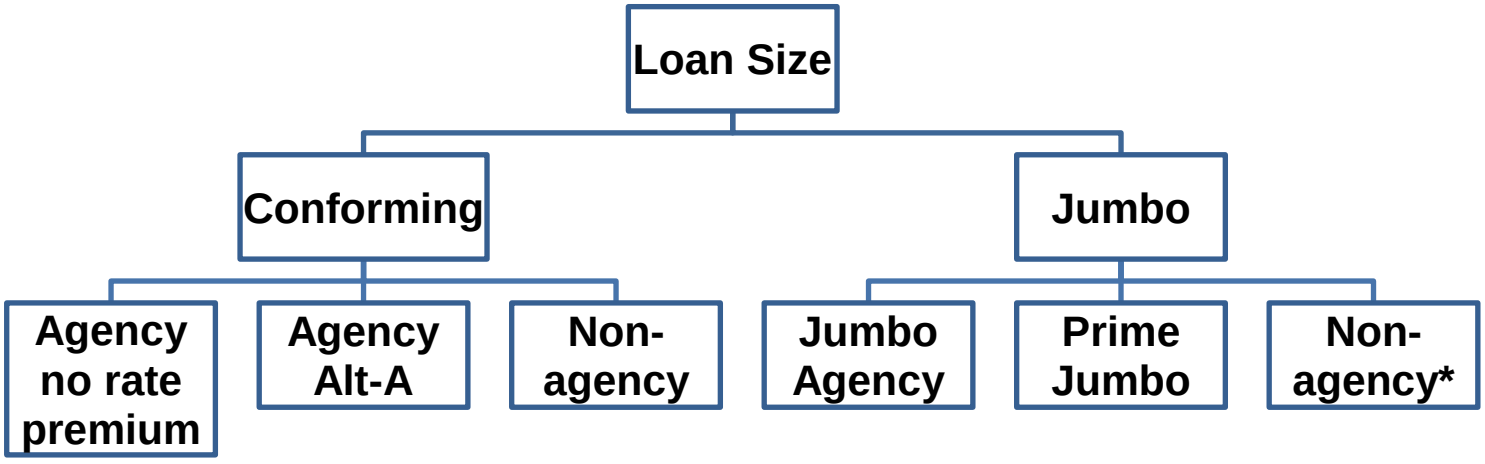
[11] "New Prepayment Model," *Markets Quantitative Analysis*, Mikhail Teytel, et al., November 3, 2009.

[12] These borrowers have moderate impairment, like (1) a moderately low credit score, (2) a high LTV that could be refinanced with PMI, (3) a moderately high DTI, or numerous other attributes or potential impairments, which means refinancing at a higher rate. Figure 4 shows related pricing adjustments the GSEs charge.

c) Nonagency – which represents borrowers largely shut out from refinancing due to some impairment. For example, prior to HARP, these could include agency borrowers that were deeply underwater on their mortgage. As part of our efforts to model HARP, we move some of the borrowers in this category to the other categories. In contrast, to better model borrowers who refinanced through HARP and may not have qualified under full underwriting, we move some of them from other categories into this category, since multiple refinances under HARP are not permitted at this time.

For jumbo collateral, there are three analogous categories. In general, for FHLMC and FNMA pools, most of the jumbo borrowers fall into the Jumbo Agency category.

Figure 3. Refinancing Model Eligibility Framework Six Categories (Bottom Row)



* "Nonagency" under the Jumbo grouping is really "Non-Prime Nonagency". Source: Citi.

Factors determining the distribution of collateral amongst the buckets are primarily loan size, FICO, LTV and occupancy. Additional adjustments depend on calendar time (to account for different underwriting environments) and origination year (to account for the quality of collateral issued during a given period). For investor properties, the breakdown is separate and only done between Agency Alt-A and Non-agency categories above; all investor properties are assumed to pay some premium above standard rates.

The new prepayment model uses a more refined eligibility breakdown.

The new prepayment model implements a more refined eligibility breakdown. In contrast to the old Citi Prepayment Model v19, whose distribution's dependence on FICO and LTV was simpler, the new Model v20 better recognizes nuances in FICO and LTV values. For example, the new model accounts for a 50-point

credit score difference between 700 and 750 having a greater impact than the difference between 750 and 800. The same is true for LTV; a 10-point difference is more significant between 80 and 90 than between 60 and 70.[13]

In addition, Model v20 allows for adjustment of the breakdown based on the well-known Spread-At-Origination (the difference between the borrower's rate and prevailing mortgage rates, also known as SATO), as well as loan purpose. Although a negative SATO can be an indicator of points paid, higher SATOs primarily seem to indicate some sort of impairment. Two loans with similar credit scores and LTVs may have different SATOs due to something like high DTI, poor documentation, the presence of a second lien, or simply because the borrower is less financially savvy. Thus we adjust our eligibility breakdown based on SATO. An origination-year based loan purpose adjustment is used to account for the fact that borrowers who refinanced through the HARP program may not have been subjected to full underwriting.

After the breakdown is determined, different rate adjustments are then applied to the 6 different buckets in this "Eligibility Framework". For nonagency buckets, the rate adjustment is generally high enough to preclude any refinancing.

New Mortgage Rate – The earlier *Refinancing Incentive* equation, which is computed separately for each eligibility bucket, depends on the estimation of a *New Mortgage Rate* (assumed to be a "no point" rate) available to the borrowers in each eligibility category, defined as:

New Mortgage Rate = Current Coupon Rate + Primary Secondary Spread + Rate Adjustments + Mortgage Insurance

1) *Current Coupon Rate* is typically the coupon rate for a par ($100) priced MBS.[14]

2) *Primary Secondary Spread* is the difference between typical primary market rates (what the borrower pays) and secondary market rates (Current Coupon), a spread that normally widens initially during a

[13] Model v20 essentially adds parameters to allow for non-linear dependence of the eligibility breakdown on FICO and LTV.

[14] In recent years, some have replaced the current coupon rate with a higher "production coupon rate" due to wide primary secondary spreads resulting in no below par MBS. Alternatively, one could "extrapolate" the coupon stack down to par.

refinancing wave due to mortgage industry capacity constraints (high demand results in less competitive mortgage rates) and often tightens when rates back up sharply due to excess capacity. The new prepayment model includes a new primary/secondary spread model, which is discussed further later.

3) *Rate Adjustments*, as indicated earlier in the Eligibility Framework section, include adjustments based on credit metrics like LTV and FICO. Figure 4 illustrates the fees in "points" charged by the GSEs based on LTV and credit score (loan-level price adjustments, or LLPAs). There are other modifiers to LLPAs based on loan purpose, presence of second lien, etc., and lenders may have their own overlays.[15] The model combines all of these effects into a rate spread. A combination of the rate spread computed in this manner and SATO are used to compute the *Rate Adjustment* used in the *New Mortgage Rate* equation. As mentioned, a very large additional adjustment is applied to the nonagency eligibility bucket that essentially reduces refinancings to zero.

Figure 4. Fannie Mae 30-Yr Loan Level Pricing Adjustments (LLPAs) by Credit Score and LTV Range – As of Sep 20, 2012

				LTV Range				
Credit Score	< 60%	60.01–70%	70.01–75%	75.01–80%	80.01–85%	85.01–90%	90.01–95%	95.01–97%
> 740	-0.25%	0.00%	0.00%	0.25%	0.25%	0.25%	0.25%	0.25%
720–739	-0.25%	0.00%	0.25%	0.50%	0.50%	0.50%	0.50%	0.50%
700–719	-0.25%	0.50%	0.75%	1.00%	1.00%	1.00%	1.00%	1.00%
680–699	0.00%	0.50%	1.25%	1.75%	1.50%	1.25%	1.25%	1.00%
660–679	0.00%	1.00%	2.00%	2.50%	2.75%	2.25%	2.25%	1.75%
640–659	0.50%	1.25%	2.50%	3.00%	3.25%	2.75%	2.75%	2.25%
620–639	0.50%	1.50%	3.00%	3.00%	3.25%	3.25%	3.25%	3.00%
< 620	0.50%	1.50%	3.00%	3.00%	3.25%	3.25%	3.25%	3.25%

These fees are in addition to a 0.25% "Adverse Market Delivery Charge." Source: Fannie Mae.

Rate Adjustments include effects such as credit curing – borrowers with an above prevailing market rate might gradually be eligible for a lower rate as their credit score improves and/or LTV falls over time. SATO can be used as an initial estimate of the *Rate Adjustment*, although as we mentioned, SATO can be negative due to points paid or borrowers getting below market rates for other reasons, and can be

[15] These fees normally can vary to some degree from lender to lender.

high for reasons other than LTV and FICO.

4) *Mortgage Insurance* is an increasingly important part of the refinancing incentive. A large portion of the housing-crisis era mortgages have been refinanced through HARP, which allowed grandfathering of existing mortgage insurance into the refinanced loan. A subsequent refinance would require a full premium based on the LTV and credit score, among other things. Thus PMI requirements can serve as a major headwind to a new refinance for some of these borrowers. With the help of better mortgage insurance information from agency disclosures, the new prepayment model is able to more accurately assess the impact of PMI. Accurate information about both existing PMI on a loan as well as the PMI requirements for a new loan, and incorporation of this information into the model, also allows us to capture the rising refinancing incentive of the many high LTV borrowers whose equity is currently growing.

The new prepayment model makes full use of PMI data available, as discussed further later.

Given the *New Mortgage Rate* equation just discussed, we can rewrite the *Refinancing Incentive* equation as

Refinancing Incentive =

[(–∆Mortgage Rate – ∆Rate Adjustments – ∆Mortgage Insurance)

*** Loan Size * Expected Holding Time] – Refinancing Costs**

where *Mortgage Rate* is the sum of *Current Coupon Rate* and *Primary Secondary Spread*.[16] This shows explicitly the two terms *∆Rate Adjustments* and *∆Mortgage Insurance* that would tend to "cure" over time.

Is the *New Mortgage Rate* a 30-year mortgage rate?

While for new 30-year mortgages, the *New Mortgage Rate* can essentially be a 30-year rate, this undoubtedly is not how all borrowers will estimate their incentive. Once their loans season, many borrowers choose to refinance into shorter-maturity mortgages, as evidenced by the fact that over 90% of 20-year, 15-year and 10-year mortgages result from refinancings (see Figure 5).

It is natural that a large number of borrowers in a position to refinance would not want to extend their term by going into another 30-year mortgage, especially (taking an extreme example) 30-year borrowers with only a 15-year remaining

[16] Change in *Mortgage Rate* has a negative sign since incentive is *Old Mortgage Rate* minus *New Mortgage Rate* (similarly for *Rate Adjustments* and *Mortgage Insurance*).

term, who would additionally benefit from a much lower 15-year mortgage rate. As 30-year mortgages season, the *New Mortgage Rate* used in the prepayment model to estimate the *Refinancing Incentive* gradually incorporates an increasing 15-year mortgage rate component.

Figure 5. Aggregate 2013 Origination Characteristics for Conventional 30-Yr, 20-Yr, 15-Yr, and 10-Yr Collateral – Oct 2013

Collat Type	Bal ($B)	WAC	Wgtd Ln Sz ($K)	Orig LTV	FICO	Retail %	Corresp%	Broker %	Purch %	Refi %	Investor %
30-Yr	551	3.84	245	75	754	56	33	11	35	65	9
20-Yr	43	3.68	186	71	753	76	17	7	4	96	7
15-Yr	175	3.02	202	65	761	65	25	10	10	90	6
10-Yr	20	2.95	141	51	765	73	18	9	3	97	4

Source: CPR&CDR, Citi.

15-Year and 5x1 Hybrid ARM Mortgage Rate Model – In addition to projecting 30-year mortgage rates for OAS purposes with the well-known MOATS model,[17] we separately project 15-year mortgage and 5x1 Hybrid ARM rates used for the *Refinancing Incentive* estimation just discussed. After using either MOATS or a specified rate scenario to obtain secondary market 30-year rates, the primary-secondary spread model mentioned earlier (and discussed in more detail later) is used to determine primary 30-year mortgage rates. Shorter-maturity mortgage rates are then obtained based on projections of the swap curve. The projected change in the 30-year-to-15-year mortgage rate spread and 30-year-to-5x1 spread is each taken to be a function of the change in the spread between these two swap rates. We also assume a long-term reversion to the mean of the spread between 30-year mortgage rates and the shorter-maturity mortgage rates.

Rate Adjustments vs Eligibility Distribution Shifts

So how does one decide whether to (1) shift more weight into the nonagency eligibility category, or (2) increase rate adjustments to slow down projections in order to model for example very high LTV CQ/CR/U6/U9 collateral?

As mentioned, *Agency no rate premium* category borrowers (Figure 3) have very good credit and can generally refinance at the lowest rates. In the case of very high LTV collateral, this would be a relatively small bucket that grows over time as borrowers from the other two categories (*Agency Alt-A* and *Nonagency*

[17] "Projecting Mortgage Rates for MBS Valuation – Citigroup's MOATS Model," Ranjit Bhattacharjee and Lakhbir Hayre, Nov 9, 2010 (first published Jun 7, 2005).

in the left half of Figure 3) gradually shift over to this bucket. For collateral with an LTV well over 100%, it would seem that no borrowers could refinance. But a small number can (perhaps because of a sudden availability of cash, or renovations that increased the value of the home). Without the ability to classify a small portion of borrowers as refinancible without a rate penalty, it would be difficult to model the trickle of refinancings that we believe (i) to be occurring in very high LTV collateral speeds and (ii) that will grow over time.

At the other end of the spectrum, *Nonagency Category* borrowers (like many of those in CQ/CR/U6/U9 pools[18]) could have (1) an extremely low credit score, (2) a very high LTV, and/or (3) a very high DTI, which makes the prospect of getting another mortgage highly unlikely, at least initially. These borrowers need to "cure" by shifting to another bucket in order to become refinancable. Given the high LTVs and lower credit scores of CQ/CR collateral shown in Figure 6, the *Nonagency Category* would naturally be much larger for CQ/CR collateral.

Figure 6. Characteristics of Very High LTV Categories CQ/CR vs All FN 30-Yr 3.5s of 2013 – As of Sep 2013

Collateral	Out Amt ($b)	WAC	Orig LTV	FICO	Inv (%)	TPO (%)
ALL	94.1	4.01	78	741	18	34
CQ	10.2	4.09	114	717	18	11
CR	10.7	4.13	155	717	21	9

Source: Citi.

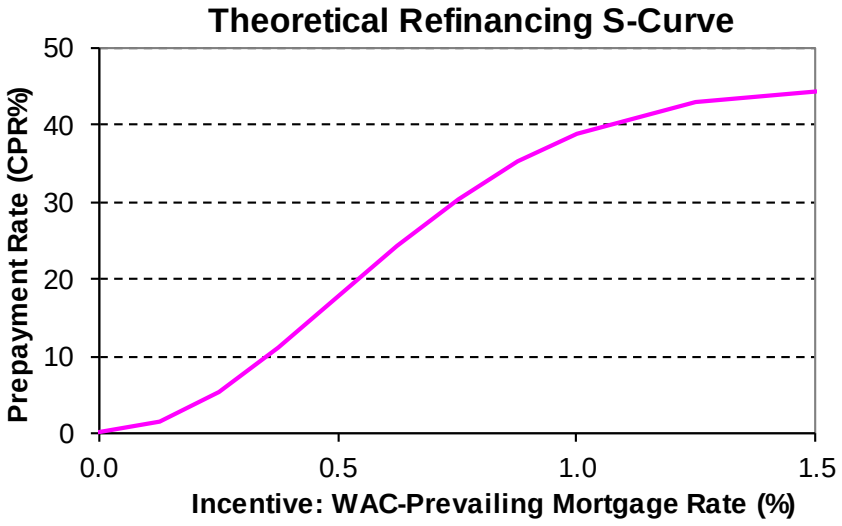
While, in principle, an initially large rate adjustment that declines over time could produce behavior similar to the eligibility buckets, interest rate scenarios would potentially be problematic. In a very large rally scenario, a large rate adjustment would be more than offset by the rate move, resulting in very fast prepay projections on collateral with high premium coupons, but which in reality should be highly impaired. In contrast, the eligibility bucketing framework allows projected speeds to be limited by the fraction of borrowers not in the nonagency category (since borrowers in the nonagency category are assumed to be locked out from refinancing, even if deeply "in-the-money"). The eligibility bucketing framework also allowed us to model behavior in the latter half of 2012, when S-curves were inverted for both pre- and post-HARP collateral, in part because the higher-coupon collateral was more impaired and less able to refinance.

[18] CQ and U6 borrowers have original LTVs 105 < OLTV <=125, while CR and U9 have LTVs > 125. CQ/CR are 30-year/20-year Fannie Mae pool prefixes, while U6/U9 are 30-year Freddie Mac pool codes.

Going From Incentive to Speeds – Heart of Refinancing Model

S-Curves take the estimated refinancing incentive as input and produce a base projected refinancing CPR as output (Figure 7). This type of curve is selected because the refinancing response rises sharply as the rate incentive increases to a material amount (say half a point), but as incentive increases to much higher levels, the acceleration slows down and then starts to reverse. Many borrowers with very high incentives are those that, given a failure to refinance for a lower but still attractive economic benefit, are impaired or burned out.

Figure 7. Refinancing "S-Curve"



Source: Citi.

Other effects are then applied to this base projection:

1) **Media Effect** – Discussed extensively in previous papers, the media effect represents the turbocharging of refinancings that occurs when mortgage rates reach historic low levels.[19] The strength of the media effect is determined in our models by how much mortgage rates have fallen relative to a past average of rates. We believe media effect is less important than in the past because (i) rates have been falling for a long time and (ii) stricter underwriting standards and more onerous documentation requirements since the crisis limit the ability of originators

[19] *Anatomy of Prepayments: The Citigroup Prepayment Model*, Lakhbir Hayre, et al., Citi, March 2004 (re-published with updated disclaimer in October 2010). *New Prepayment Model V19 Update*, Mikhail Teytel, et al., Markets Quantitative Analysis, July 12, 2012.

Media effect remains important for better collateral in the new model, but reduced overall.

to process high volumes of loans quickly. Model v20 thus reduces the media effect somewhat overall, but it remains important for the "lower-touch" loans that are most profitable for lenders to refinance. Media effect is largely eliminated for all but the highest quality collateral. In fact, as discussed further later, an "anti-media effect" may apply for loans requiring more underwriter attention ("higher-touch" loans), which get pushed to the back of the line when volumes are high.

2) **HARP** – The Home Affordable Refinance Program (HARP), first announced in 2009 and modified several times since, has been very successful over the past couple of years after a slow start.[20] The streamlined refinancing process of HARP results in a *semi-permanent media effect* for collateral falling within the HARP cut-off window (originally (a) mortgages sold to the GSEs prior to June 1, 2009, changed in October 2013 to (b) mortgages closed prior to June 1, 2009).

   Furthermore, the impact of impairment (low FICO, high LTV, interest-only loans) on speeds is sharply reduced, as the ability to refinance through HARP is based primarily on recent payment history (six months clean and only one 30-day late payment during the preceding six months). Indeed, some of the fastest speeds came in on collateral that was the most impaired, as rep-and-warrant relief and special solicitation provisions for loans with LTVs above 80% drove extremely high speeds on these loans.

New model HARP projections are higher, and we continue to expect a moderate slowdown in HARP speeds.

   Citi prepayment models have always been projecting fast HARP speeds (previous feedback on Model v19.1 was that its HARP projections were faster than other models). Actual HARP speeds, including on lower loan balances later in the surge, exceeded even those aggressive forecasts, so we raised HARP projections further in the new model for a given level of incentive. High HARP speeds involve both adjusting the amplitude of the S-curve and adjusting borrower eligibility to reflect the dramatically streamlined underwriting. Of course, there has been a slowdown in HARP overall amidst higher rates and some signs of burnout, concentrated in the lower coupons (4.5s and 5s).

[20] For a good summary of the evolution of FHFA and GSE HARP guidelines over time, see Agency MBS Weekly, Citi Research, Ankur Mehta et al., November 1, 2013

Projections continue to be differentiated by servicer, less so than in Model v19.1 due to recent convergence in speeds across servicers; all differences are assumed to disappear by the end of 2014.

HARP Eligibility Estimation – Our pool characteristics identification system determines the fraction of each pool that we believe is HARP-able. Previously based on issuance date (used as a proxy for GSE ownership date), it was adjusted following the October 2013 eligibility change mentioned in the previous paragraph, and is now based on first payment dates (when loan level data is available) and WALA quartiles.[21]

Incentive, Loan Size, and the Cost of Living – While financial incentive generally grows linearly with loan size (as seen in the Refinancing Incentive formula given earlier), the *utility of refinancing* may not grow in a similar fashion.

A. **Diminishing Returns** – One reason is the well-known "flattening" of the refinancing "S-Curve" (right part of Figure 7) when incentive gets very large. In addition to the impacts of impairment and burnout mentioned earlier, the incremental desire to refinance may wane as incentive increases – if one borrower can reduce their monthly payment from $1500 per month to $1000 per month, then the additional desire to refinance may only be marginally higher for another larger loan size borrower that can save a further $50, taking their $1650 monthly payment down to $1100.

B. **Cost of Living Differences** – Another reason could be that the borrower with the larger loan also has a higher cost of living. As a result, $550 in monthly savings feels the same as $500 in savings seen by the lower cost of living, smaller loan size borrower (and the savings for each is the same in percentage terms). This is the rationale for adjusting the borrower incentive when these differences may be material – for example, some low loan size borrowers may value a dollar of savings more than corresponding large loan size borrowers. This is referred to as the "loan-size effect" – a dollar of incentive is valued more by the model for lower loan sizes than for higher loan sizes.

[21] While the old eligibility criteria was largely based on issuance date, we also assumed some multiple issuer pools that came out with seasoned collateral originated prior to the May 31, 2009 cut-off to be HARP-able before the October 2013 change that more clearly made these pools HARP eligible. See Yield Book announcement "HARP Eligibility Update," June 21, 2013.

Dynamics of the Refinancing Model

Burnout is one prominent aspect of modeling changes in the population of borrowers. It is modeled by tracking the evolution of a "slow" prepay speed population and "fast" prepay speed population (with the "fast" population having a smaller impact on total projected speeds as it becomes a smaller fraction of collateral – see Figure 8). The difference in the two populations is customized inside the model, based on loan size dispersion seen in quartile and loan-level data; the slow population is modeled as having both below-average loan size and a less steep and/or lower-amplitude S-curve (although the differences between slow and fast populations are assumed to be much lower for super-conforming high loan balance pools, or **jumbos**.) The model reacts less to a subsequent rally in rates versus a similar earlier rally simply because the population of "fast" borrowers will have declined as a result of the earlier rally.[22]

Figure 8. Simple Example of Burnout Mechanics – Initial Speed of 40 CPR Burns Out Down to 25 CPR After One Year

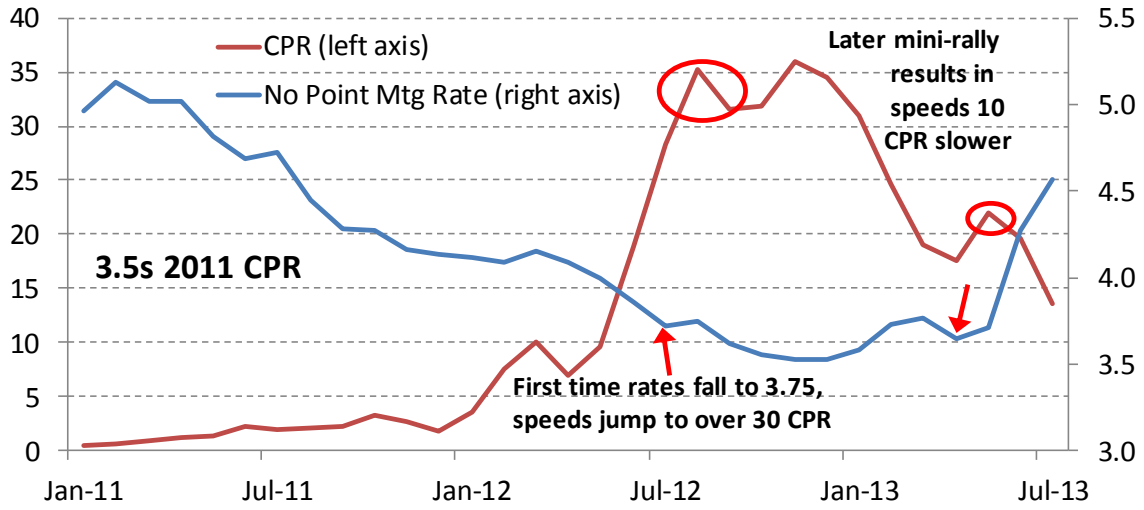
	Fast Population Weight (70% CPR)	Slow Population Weight (10% CPR)	"Pool" Aggregated Speed
Initially: Population Distribution and Resulting Aggregate Initial Speed	50%	50%	(50%*70 + 50%*10)/(50%+50%) = **40 CPR**
After 1 Year: Distribution And Aggregate Speed	50%*(100%-70%) = 15%	50%*(100%-10%) = 45%	(15%*70 + 45%*10)/(15%+45%) = 15/0.6 = **25 CPR**

Source: Citi.

This phenomenon can be observed in speeds of conventional 3.5s of 2011 shown in Figure 9. Mortgage rates first hit around 3.75% in summer 2012, and resulting speeds surpassed 30 CPR. In contrast, after a long period of low rates and subsequent back-up, a mini-rally that brought rates back to similar levels in spring 2013 (red arrows in Figure 9) pushed speeds up to levels 10 CPR lower than in 2012.

[22] See "A Simple Statistical Framework for Modeling Burnout and Refinancing Behavior," Lakhbir Hayre, *Journal of Fixed Income*, December 1994.

Figure 9. 3.5s of 2011 Speeds vs Mtg Rates – Summer 2012 CPRs Over 30 Burned Out in Spring 2013 to Just Over 20 CPR



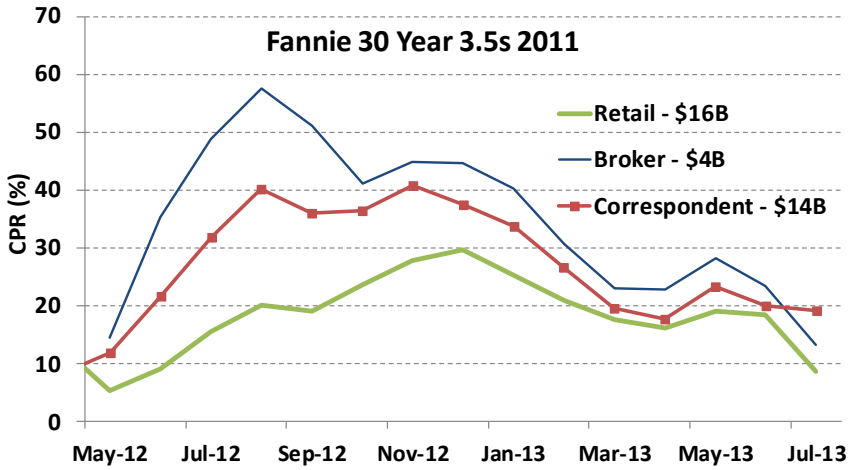
Source: Freddie Mac, Citi.

Credit Curing is a second aspect of modeling changes in the population of borrowers. As discussed earlier, both *Rate Adjustments* and the eligibility breakdown incorporate this effect. Borrowers with rates above prevailing market rates might gradually be eligible for a lower rate as credit score improves and/or LTV falls over time; and some that were initially locked out of the market may later be able to refinance. While monthly agency disclosures do not update LTV and credit scores, the model captures credit curing in part by computing current LTV from original LTV plus actual and projected HPA, amortization and curtailments. As collateral ages, we also reduce the importance of higher SATO as a proxy for impairment.

Refinancing Efficiency Increases for TPO Channel

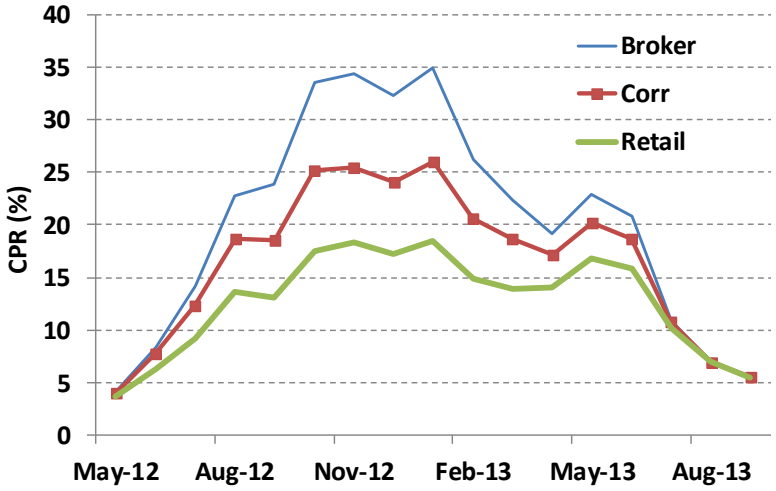
As seen from the sharp increases in speeds of 2010 4s and 2011 3.5s, TPO and in particular broker channel speeds have been very reactive to rate rallies. Figure 10 shows that the broker channel has both exhibited: (a) the fastest speeds, and (b) the greatest burnout (as seen by how much lower spring 2013 speeds are versus 2012 peak speeds). The "TPO effect" is especially important for fairly new collateral; brokers tend to solicit refinancings very aggressively as early as six months after origination.

Figure 10. Actual Speeds of 3.5s of 2011 by Channel – Massive Burnout in Broker Channel CPRs, Little Burnout in Retail



Speeds not controlled for factors like loan size. Amt outst ($ billions) also shown. Source: Citi.

Figure 11. New Model Channel Impact – Only Channel Differs Across 3 Sets of Projections Shown for 3.5s of 2012

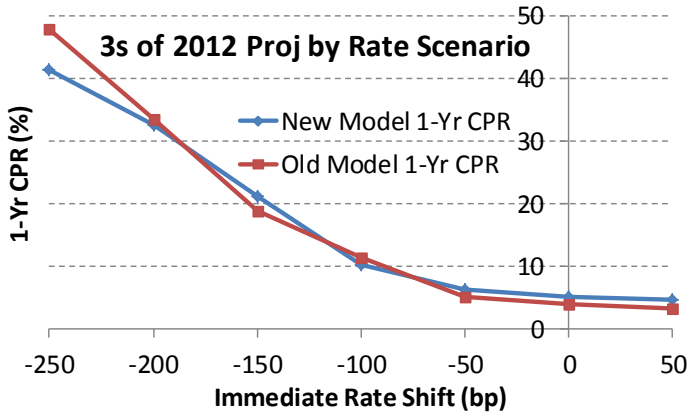


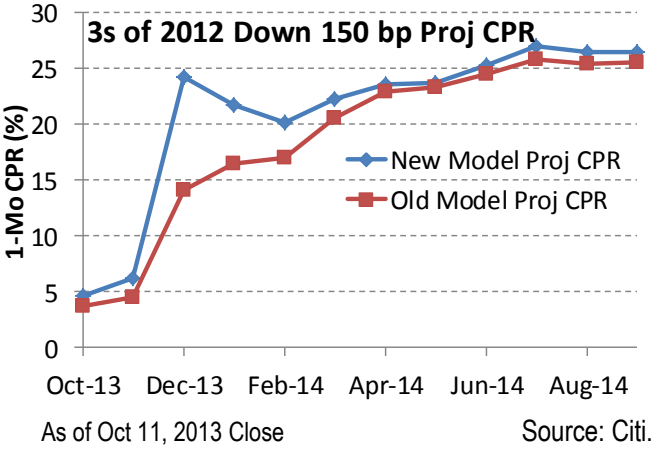
Unlike Figure 10, loan size and other factors are same across 3 sets of projections. Source: Citi.

The broker and to a lesser extent the correspondent effect is even greater in the new model.

This is reflective of the efficient origination business models of mortgage brokers, who can offer the lowest rates available from different lenders and solicit/target borrowers with the best credit to refinance. As a result, the broker and to a lesser extent the correspondent effect was increased in the new model; and the TPO effect has been modeled to reflect both lower costs and higher solicitation intensity. While the overall impact is not completely clear-cut (left chart in Figure 12) due to the impact of other model changes (for example, the primary-secondary spread model change discussed later affects the size of the rally the borrower actually experiences in each rate scenario), near-term projections can be seen in the right chart in Figure 12 to be clearly higher.

Figure 12. New Model Enhanced TPO Effect for FN 30-Yr 3s of 2012 – Modest Impact on Avg CPRs (Left Chart), But Near-term Projections Ramp Up More Quickly in Very Large Rally (Immediate Down 150 bp Scenario Proj CPR in Right Chart)





As of Oct 11, 2013 Close Source: Citi.

Capacity Constraints, Credit Curing, and Seasoning Lags

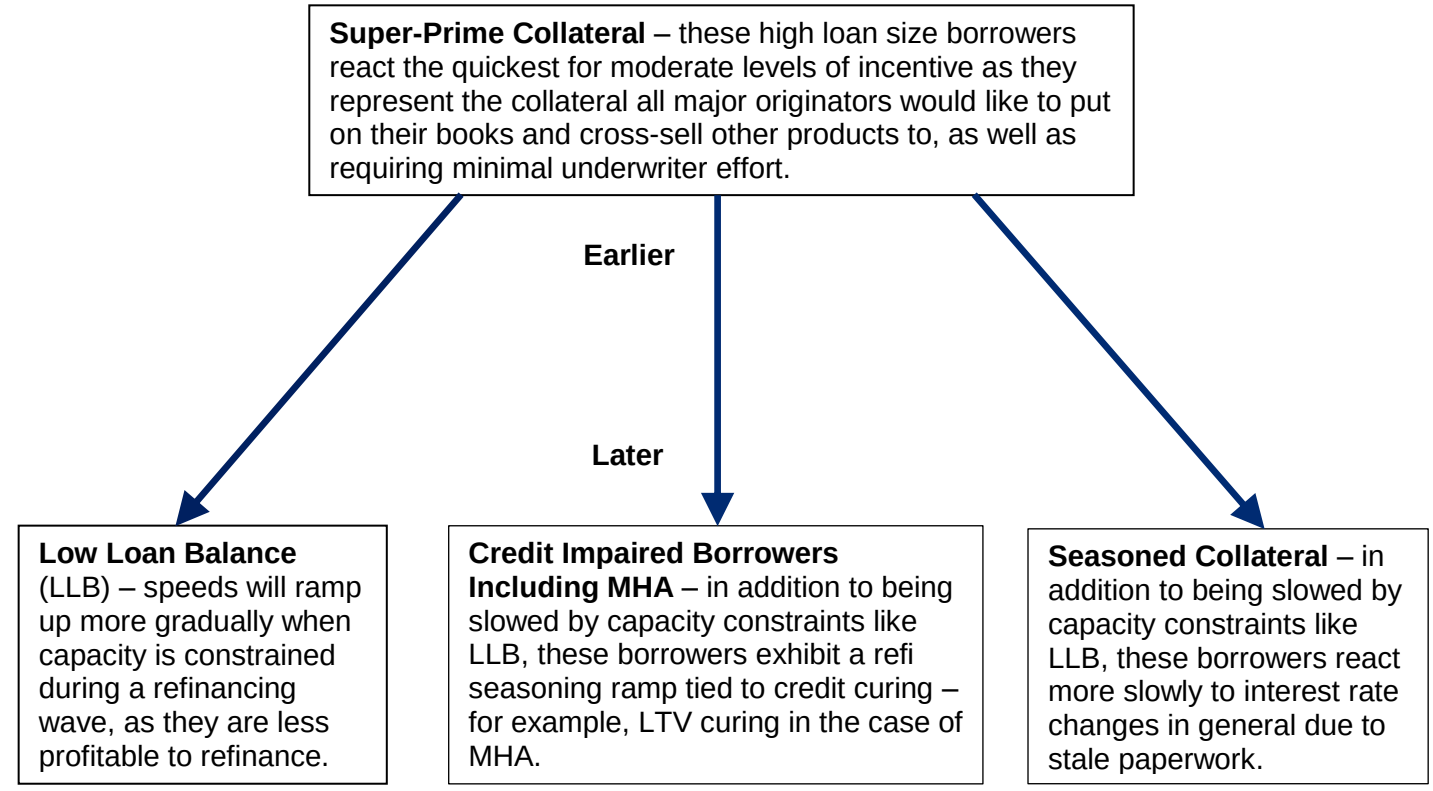
The "Anti-Media Effect" is a new model feature that slows the ramp-up in refinancings of "off-the-run" collateral in a sharp rally.

Because they have overlapping effects on model projections, we compare and contrast these 3 aspects of the model. In a nutshell: (a) ***Capacity Constraints*** model lender behavior to maximize profit – this effect can also be described as an "***Anti-Media Effect***," given that it decelerates the ramp-up in speeds for "off-the-run" or "higher-touch" collateral[23] in a sharp rally,[24] (b) ***Credit Curing*** models both borrower incentive (in terms of reducing assumed rate premiums applied, see earlier *Rate Adjustment* discussion) and eligibility (as reflected by a change in the allocation of borrowers into the eligibility breakdown shown in Figure 3) as it changes over time, and (c) ***Seasoning Lags*** models the greater difficulty of gathering paperwork for a seasoned borrower versus a new borrower. We describe them pictorially in Figure 13.

[23] "Off-the-run" collateral refers to any borrowers (such as low loan balance, high LTV, and low FICO) that would be less profitable to refinance than super-prime high loan size borrowers like 3.5s of 2011 and 3s of 2012. "Higher-touch" refers to a higher degree of underwriter attention required to service and/or refinance the loan.

[24] For ARMs, one can argue there is an "*Anti-Anti-Media Effect*," when rates begin to rise and the curve is steep. Like the regular "*Anti-Media Effect*," it involves originators reacting to a change in volume, but in reverse. In other words, the extra "*Anti*" refers to when (a) rates rise rather than fall, and (b) originations fall (resulting in solicitation of ARM borrowers who can refi into another ARM due to a steep curve) rather than rise.

Figure 13. Refinancing Hierarchy Flow Chart (Arrows Mean Originators Refinance Super-Prime Borrowers First)



Source: Citi

Example – ***Seasoned CQ/U6 Collateral*** (105-125 original LTV) would be impacted by all 3 effects as it would: (a) gradually react to low mortgage rates in a refinancing wave due to capacity constraints, and (b) gradually cure, or in other words, experience greater incentive as its LTV declines, and (c) react slower to interest rate changes in general because it is seasoned.

The new model uses capacity and home price momentum adjustments to help capture speeds on high-LTV collateral.

Some of the largest surprises in the prepayment speeds recorded in the first half of 2013 were in our view driven by relief of capacity constraints, which combined with looser underwriting and higher HPA, drove speeds on high-LTV collateral (CQ/U6, CR/U9 and the so-called MHA sector (refinance loans with LTVs above 80 and below 105, named after the "Making Home Affordable" government program), as well as other impaired collateral such as higher-SATO and sub-700 credit-score collateral, to unexpected levels; Model v20 better captures these speeds with its adjustments for capacity and HPA momentum.

Private Mortgage Insurance (PMI)

PMI is insurance against loss by lenders and/or the GSEs in the event of a default by a mortgagee. It is designated as "private" since it is provided by private insurance companies, as distinguished from government-insured mortgages such as FHA loans. The *coverage ratio* or *coverage level* is the percentage of the outstanding balance that the insurer has agreed to cover in the event of a default.[25] The borrower is typically responsible for any upfront or monthly premiums due to the insurer.

For example, a borrower with a 760 credit score taking out a 30-year fixed-rate 90 LTV mortgage of $200,000 might pay an annualized premium of 44 bps.[26] The borrower would thus pay $73.33/month for the 25% coverage ratio required by the GSEs for this loan. In the event of a default, the insurer is responsible for paying up to the first 25% of unpaid principal balance of the loan.[27] Figure 14 shows a subset of typical PMI rates. A number of other factors are considered besides LTV and FICO; premiums are typically adjusted for other factors such as whether the refinance was a cash-out (requires higher premium), occupancy (second homes pay higher premiums), loan size (jumbos pay higher premiums), whether the loan was for a corporate relocation of an employee (relos pay lower premiums) and amortization term (20-year, 15-year and 10-year borrowers pay lower premiums than 30-year borrowers).

[25] Percentage of loss coverage on loan that a mortgage insurer is providing (on a first loss basis) to cover losses incurred as a result of default. Typical coverage ratios are 25% or 30%. According to Freddie Mac, standard coverage for loans with LTVs in the range of 90-95% is 30%; 85-90% requires 25% coverage; and 80-85% requires 12% coverage. This coverage may be reduced for loans with shorter tenors such at 15 or 20 year mortgages

[26] Based on the MGIC borrower-paid monthly premiums rate-card http://www.mgic.com/lowerpremiums/index.html (MGIC's website is best place to view current rates.) The amount of coverage that is required by the GSEs as well as the monthly premiums paid to the insurer are determined by the type of loan, the term of the loan, the coverage level, and the credit quality of the loan.

[27] The insurer may also be responsible for accrued interest as well as liquidation expenses. Ignoring accrued interest and liquidation expenses, if the borrower were to default on the entire amount of the loan, the insurer would be responsible for $50K in the example given. Frequently, insurance policies give the insurer the option to pay 100% of unpaid principal and take title to the property, thus avoiding additional accrued interest and liquidation expenses.

Figure 14. Standard Borrower Paid Monthly PMI Premiums (Rates are Paid Annually as a Percentage of Principal Balance)

LTV	Term	Coverage	Credit Score			
			760+	720-759	680-719	<680
90-95	30	30%	0.59	0.72	1.04	1.45
	≤ 20	25%	0.55	0.67	0.94	1.33
85-90	30	25%	0.44	0.54	0.72	1.01
	≤ 20	12%	0.34	0.44	0.54	0.77
<85	30	12%	0.28	0.37	0.48	0.69
	≤ 20	6%	0.26	0.35	0.44	0.63

Units are in %, so 0.44 for example means 44 bp on top of borrower mortgage rate. These rates are effective as of Dec 2, 2013, reflecting a 5 bp reduction in MGIC premiums (MGIC's website is the best place to view current rates). Premiums shown include add-ons for rate-term refinancing (+5 bp, +10 bp, +15 bp, +30 bp for 760+, 720-759, 680-719, <680 credit score categories, respectively). Source: MGIC.

The new prepayment model makes full use of PMI data available.

PMI is disclosed at the loan level by both GSEs. Freddie and Fannie both disclose initial coverage levels for each loan in a particular pool.[28] This coverage is aggregated within the new model into two model inputs for each pool: *PMI percentage*, percent-by-balance of loans carrying PMI, and *PMI coverage*, percent coverage of the entire pool. The new prepayment model makes full use of PMI data available to estimate both (a) the amount of PMI being paid on the old/existing mortgage, and (b) the likely PMI needed on a new mortgage. The difference of these represents the *Mortgage Insurance* term shown earlier in the *Refinancing Incentive* equation.

PMI Estimation – The new prepayment model estimates the existing PMI by considering the original LTV, Coverage Ratio, FICO score, loan purpose, occupancy, and loan size to mimic how PMI providers set PMI rates.

PMI Cancellation – The new prepayment model also assumes some borrowers with mortgage insurance cancel their policy (or have it automatically cancelled for them) when LTV gets to around the 75% to 80% area.[29]

MHA – The HARP program was created in order to offer underwater borrowers

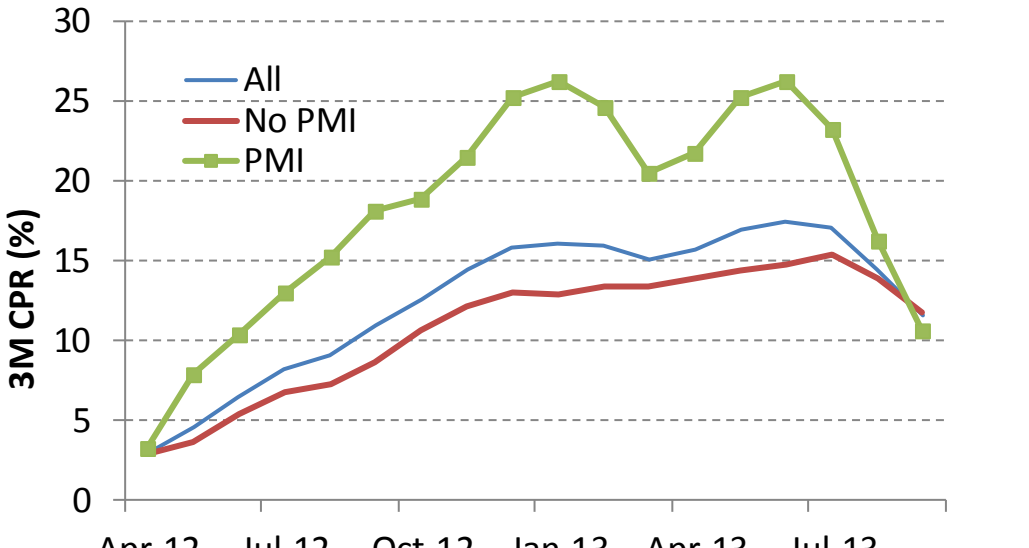
[28] Fannie Mae provides loan level PMI data for pools issued after May 2012. Freddie Mac provides the data for pools issued after December 2005.

[29] Lenders must cancel PMI when amortized LTV reaches 78% according to the Homeowners Protection Act of 1998, which became effective July 29, 1999. Borrowers must be allowed to cancel if the mark-to-market LTV reaches 80% and 5 years of premiums have been paid (or LTV reaches 75% and 2 years of premiums have been paid) according to GSE rules.

the option to refinance their mortgage into a lower rate. Pools issued after the HARP program began that are 100% refinance loans and have a minimum LTV greater than 80 are assumed to consist of loans of this type and often trade with a payup.[30] Because borrowers were allowed to grandfather their existing PMI coverage level, if any, into their new mortgage, mortgages that have gone through the HARP program may carry PMI coverage below the typically required amount for that loan, or no coverage at all if their original mortgage did not require it. These high LTV loans with low or no PMI face additional hurdles to refinancing their mortgages a second time (beyond just having a high initial LTV, which applies to all MHA collateral) due to the full PMI that will be required on the new loan. This gives pools with loans of this type some degree of additional call protection for investors.

In Figure 15 we observe that FHLMC 30-year fixed 4.0s of 2011 MHA90 (100% refinance loans with 80 < minimum LTV ≤ 90) loans with no PMI coverage offer significant call protection versus loans that already carry some level of PMI.

Figure 15. No PMI Slower Due to PMI Hurdle – Freddie MHA90 4s of 2011 With PMI vs No PMI (Controlled for Loan Size)

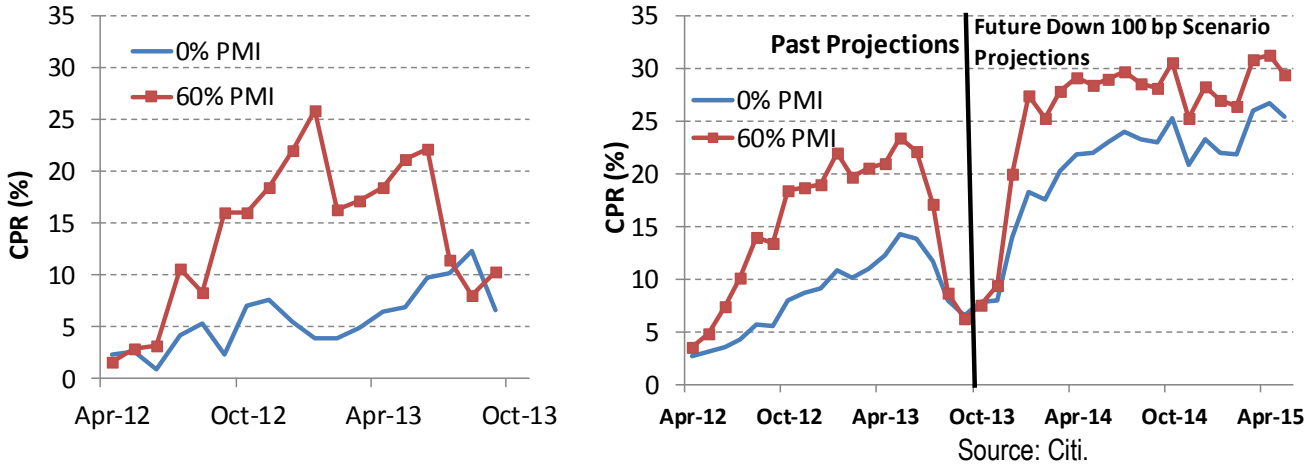


PMI buckets shown were controlled for loan size. Source: CPR&CDR, Citi.

[30] Since these loans are a result of the "Making Home Affordable" program, which refers to housing legislation and policies of the U.S. government intended to mitigate the impact of the housing crisis, pools of such loans have been designated "MHA" pools.

The new model is better able to capture this distinction since it more accurately factors the required PMI coverage into the refinance incentive as well as taking into account any existing PMI coverage. Figure 16 shows actual speeds (left chart) and model projections (right chart) for two portfolios of MHA90 4s of 2012 pools with (a) 0% PMI and (b) with greater than 50% PMI (aggregated to 60% PMI overall). A down 100 bps scenario was applied in the projections so that the coupon would be in the money going forward to better illustrate how the model differentiates levels of PMI. The cohort with 0% PMI shows significantly slower CPR projections due to the additional disincentive to refinance resulting from having no PMI.[31]

Figure 16. Actual PMI Cohort Speeds (Left) and New Prepay Model Projections (Right) Exhibit Similar Behavior for MHA90 4.0s of 2012 – Additionally Right Chart Assumes Down 100 bps Scenario for Future Projections (Right of Vertical Line)



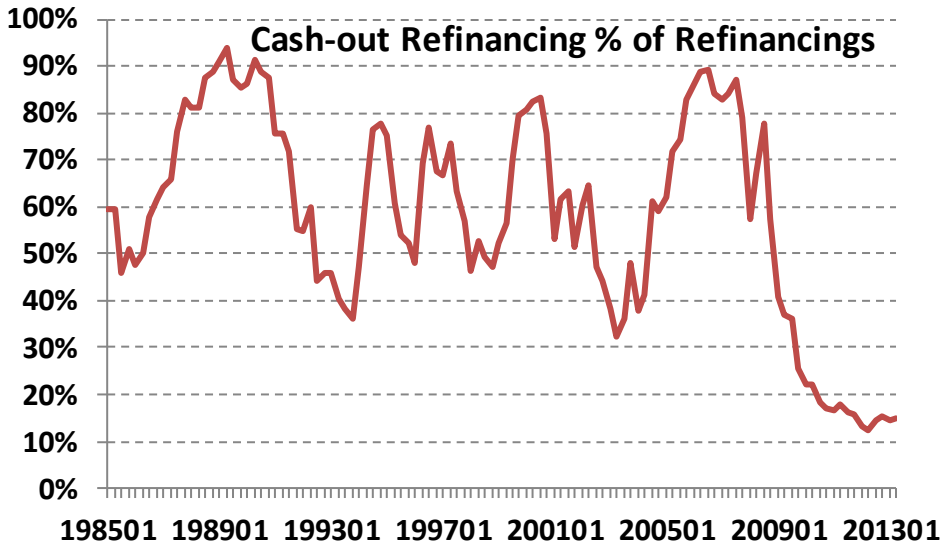
Source: Citi.

Cash-out Refinancing

Cash-out refinancings are primarily a function of incentive, LTV, home price momentum, and equity growth since origination. In the current environment of relatively tight underwriting (despite some loosening recently), and given the memories of how aggressive cash out activity during the housing bubble years ultimately came back to haunt both borrowers and lenders, we assume cash-out refinancing to be modest in the new model. Figure 17 shows how cash-out refinancings have dropped to multi-decade lows.

[31] For both portfolios, the aggregate LTV was 84, but the loan sizes were 302K (>50% PMI) and 247K (0% PMI). Although the loan size difference contributes to speed difference in Figure 16, much of the difference is due to the difference in PMI.

Figure 17. Percentage of Freddie Mac Refinancings Resulting in Cash-out of At Least 5% of Amortized Loan Amount



Source: Freddie Mac, Citi.

It is important to note that many cash-out refinancings combine (a) taking out a larger mortgage with (b) lowering the rate on one's mortgage. A significant portion of them probably would not have occurred but for the fact that the borrower was able to obtain a more favorable mortgage rate. From a modeling perspective, we view most of these combined greater loan size/lower rate refinancings as regular refinancings, primarily driven by rate incentive. *Cash-out refinancings within the prepayment model are only the subset of total cash-out refinancings that are primarily equity take-out driven.*

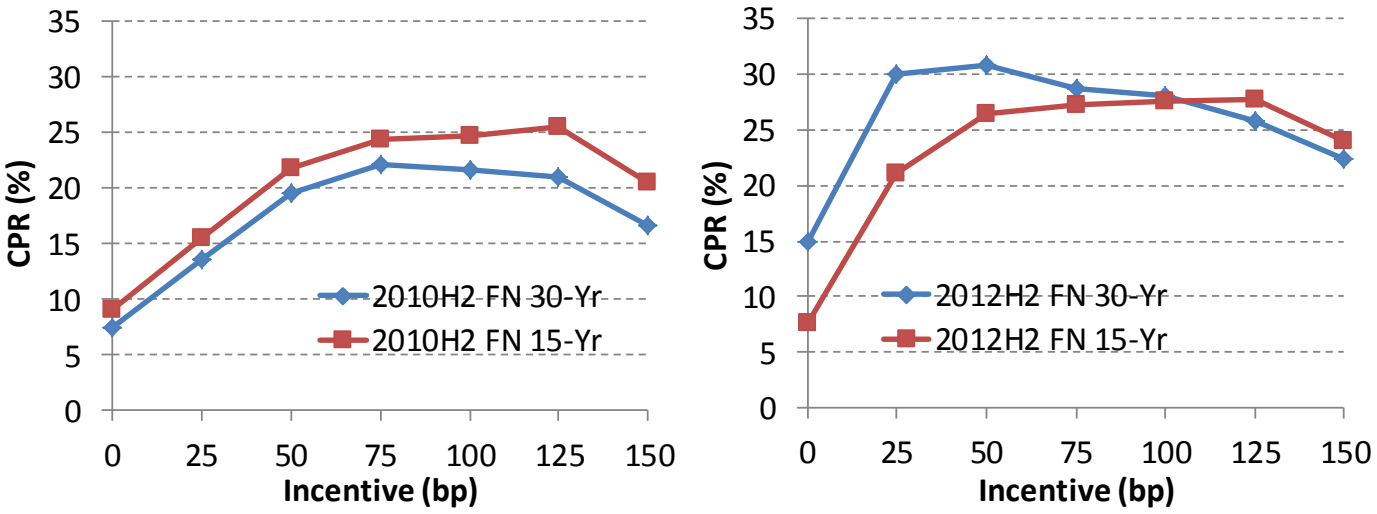
While cash-outs are modest in the new model, they were almost non-existent in the old model; this results in higher baseline speeds for near-the-money cohorts with LTVs comfortably below 80 and reasonable credit scores.

15-Year and Low Loan Balance – Less Impacted by Recovery

15-Year Loans – Rising home prices, looser underwriting, and greater refinancing efficiency have had a substantial impact in raising 30-year speeds. There has been less impact on 15-year speeds. Figure 18 shows that the 15-year non-HARP S-curve was above the 30-year S-curve for the high refinancing environment of the second half of 2010 (left chart), but that 30-year speeds

overtook 15-year in the second half of 2012 (right chart).[32]

Figure 18. 30-Yr and 15-Yr S-Curves Based on Actual Speeds from Jul-Dec 2010 (left) and Jul-Dec 2012 (right)



For Both Charts, 7-18 WALA Collateral Excluding Loan Balance Pools

Source: CPR&CDR, Citi.

In the aftermath of the financial crisis, lending was severely restrained due to super-high delinquency levels. The very tight underwriting in 2009 and 2010 impacted 30-year borrowers more than 15-year borrowers, given higher 15-year credit scores and (especially) lower 15-year LTVs (Figure 5).[33]

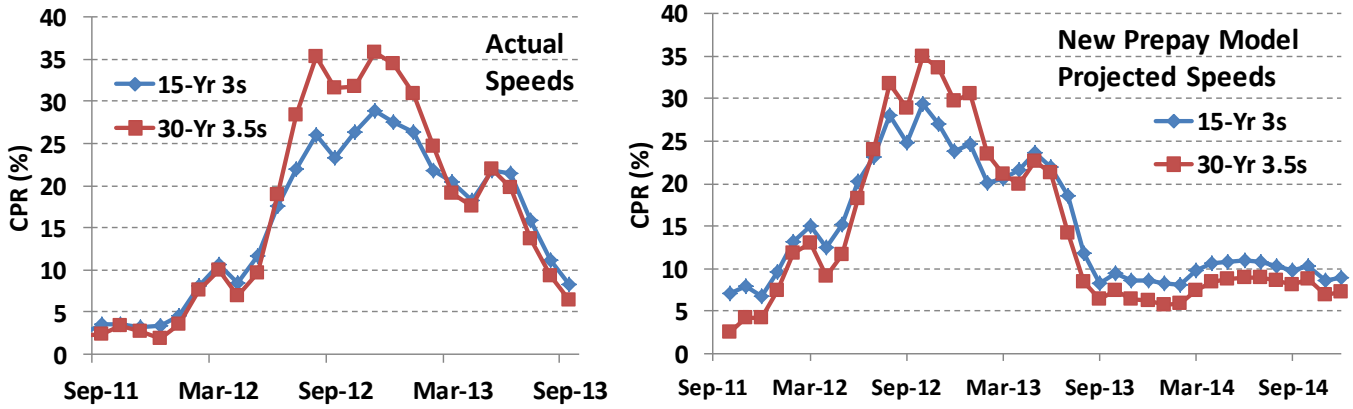
The new prepay model incorporates the lower responsiveness of 15-yr collateral versus 30-yr as seen in late 2012.

The new prepay model incorporates the lower responsiveness of 15-year collateral versus corresponding 30-year paper seen in late 2012 (which can be attributed to lower loan sizes and lower TPO percentage). For example, 15-year 3s of 2011 did not reach 30 CPR in the rally of 2012, but 30-year 3.5s of 2011 reached 35 (Figure 19 left chart shows actual speeds), despite high spreads (70-80 basis points) between 30-year and 15-year rates. The right chart in Figure 19 shows that new model projected speeds exhibit the same pattern as actual speeds.

[32] HARP 1.0 may have contributed to the relatively fast 15-Yr speeds in 2010 since it had a large impact on good credit borrowers with low LTVs. See "2012 Outlook for Speeds – The HARP Surge", Robert Young and Xing Wei, Dec 22, 2011.

[33] Interestingly, 20-Yr is even more of a refinance product than 15-Yr (Figure 5) even though the average rate for 20-Yr is closer to 30-Yr. Similar comments apply to 10-Yr collateral. Yield Book has a separate model for 20-Yr collateral.

Figure 19. 15-Yr 3s vs 30-Yr 3.5s of 2011 Actual Speeds (left) and New Model Projected (Past and Future) Speeds (right)

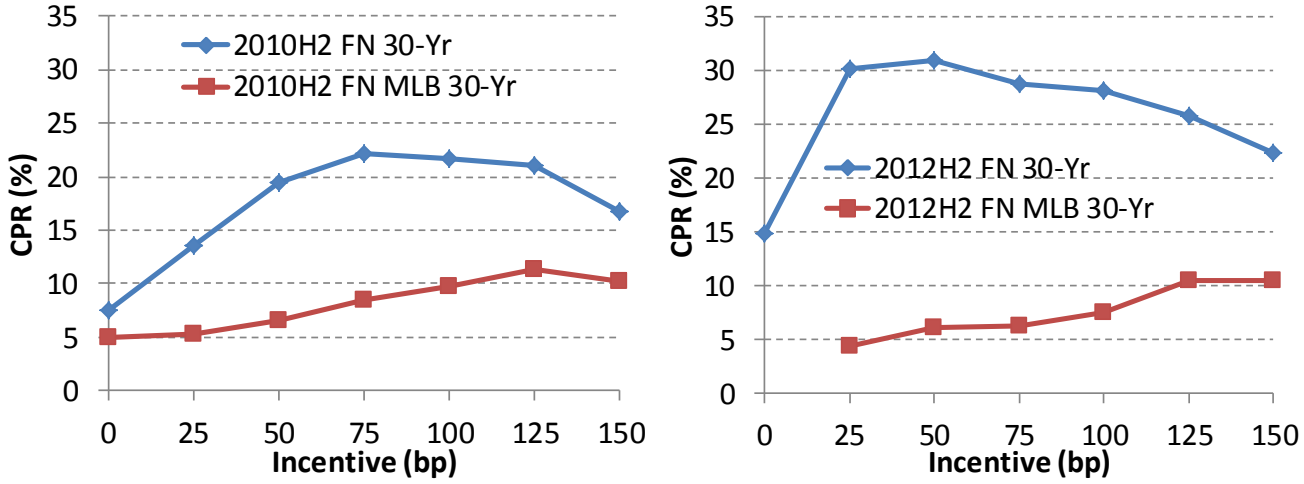


Source: Yield Book, CPR&CDR, Citi.

Low loan balance collateral is another sector for which the new prepay model incorporates lower responsiveness vs generic 30-yr as seen in late 2012.

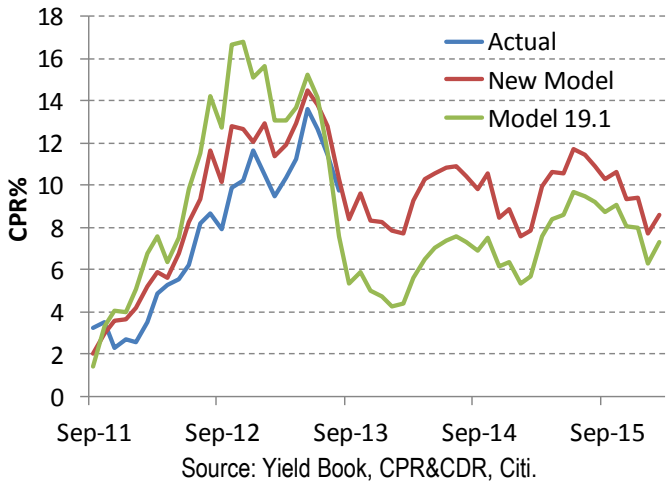
Loan Balance – Another sector that been less impacted by the positive cycle in housing/underwriting is loan balance collateral (Figure 20). While baseline speeds may be slightly faster due to higher HPA (which may lead to more cash-out refinancings), we expect that the response in a rally will be quite muted, due to originator focus on larger loan sizes and generally modest borrower benefits except at high incentives. The new model better recognizes call protection provided by post-HARP loan balance paper (Figure 21). While other call-protected stories have proven to be less resilient than their initial billing, post-HARP loan balance has continued to provide substantial call protection.

Figure 20. 30-Yr Excluding Loan Bal Pools vs MLB S-Curves – Jul-Dec 2010 Actual Speeds (left) and Jul-Dec 2012 (right)



For both charts, 7-18 WALA collateral; zero incentive 2012 MLB point excluded due to small outstanding balance. Source: CPR&CDR, Citi.

Figure 21. MLB Conventional 4s of 2011 – New vs Old Model Projections



Source: Yield Book, CPR&CDR, Citi.

20-Year and 10-Year Prepayment Models

The new prepayment model includes a separate 10-Year Model for the first time, in addition to a recalibrated 20-Year Model.

While the 30-year and 15-year models are naturally more prominent, Yield Book has long had a separate 20-year model. Furthermore, for the first time, a separate 10-year model is being released. 20-year collateral can be quite reactive to rates – Figure 23 shows how 20-year speeds can sometimes surpass 30-year speeds as they did in 2013 (top left chart).[34]

This is especially the case after the collateral is seasoned two or three years; 15-year mortgage rate tend to be much lower than 20-year rates, more than what the difference in term would seem to imply. Almost all 20-year loans are refinances, and most are likely 30-year borrowers who didn't want to extend their mortgage to 30 years again, but couldn't afford a 15-year mortgage payment. But it is reasonable that 20-year borrowers who couldn't afford the 15-year payment initially will aggressively refinance once they can. The behavior of 20-year relative to 30-year collateral is captured by the new prepayment model (top right chart).

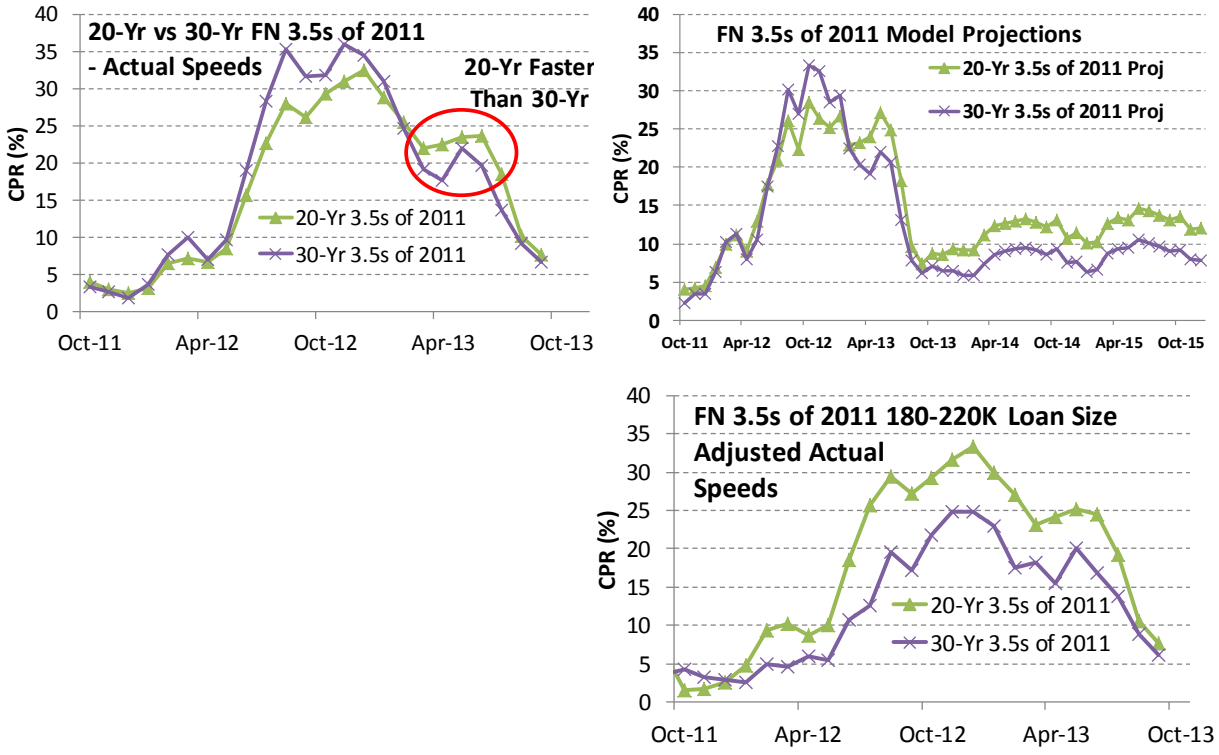
[34] And 20-year speeds appear to be even faster after adjusting for loan size (Figure 23 bottom chart) – while this exaggerates 20-year speeds to some extent since 20-year mortgage rates are lower (about 20 bp lower in Oct 2013), the main point is that 20-year collateral is about as reactive to rates as 30-year collateral.

Figure 22. Comparison of Monthly Payments for 30-Yr, 20-Yr, 15-Yr, and 10-Yr Mortgages ($200K Loan Size) – Although 20-Yr Rate is Closer to 30-Yr, Monthly Payment is in the Middle of 30-Yr and 15-Yr Monthly Payments

Product	Term (Mos)	Rate	Monthly Payment ($)	% Increase
30-Yr	360	4.375	999	
20-Yr	240	4.125	1225	23%
15-Yr	180	3.5	1430	17%
10-Yr	120	3.25	1954	37%

% Increase is change in monthly payment vs product directly above. Source: Citi.

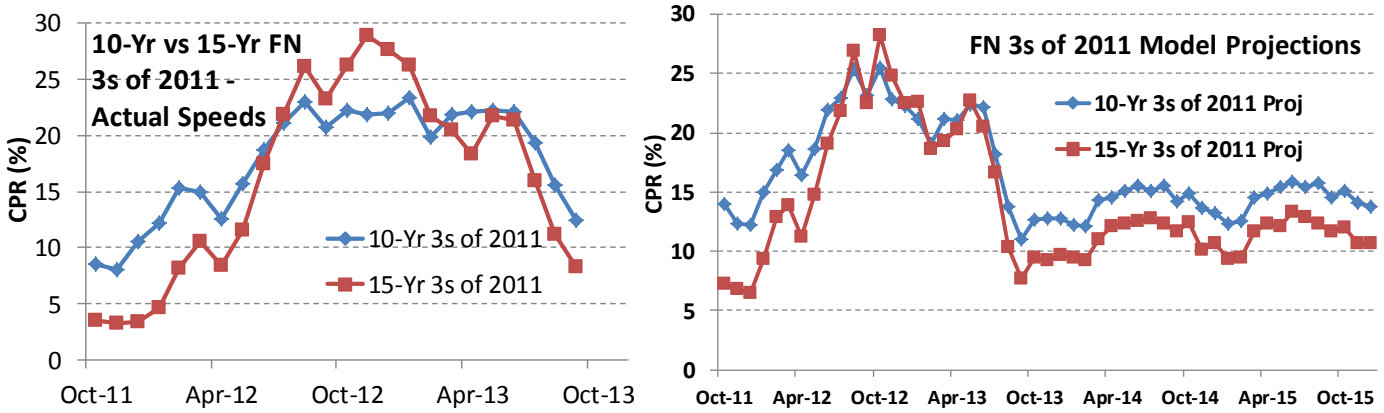
Figure 23. 20-Yr Actual Speeds Can Be As Fast As 30-Yr (Top Left) and New Prepay Model Projections (Top Right) Capture When 20-Yr Faster Than 30-Yr in 2013 – Bottom Shows 20-Yr Actual Loan Size Adjusted Speeds Appear To Be Even Faster



Lower chart excludes loan balance and high LTV specified pools. Source: CPR&CDR, Citi.

Figure 24 similarly compares 10-year versus 15-year actual speeds (left chart) as well as new prepayment model projections (right chart). Key considerations for 10-year collateral are (i) very fast curtailments, which become especially prominent after the collateral has seasoned several years, and (ii) lower responsiveness to rate rallies, as 10-year borrowers are driven to pay down their loan quickly; many are not inclined to extend their term again, or to incur closing costs when they can simply accelerate repayment of their existing loan.

Figure 24. 10-Yr vs 15-Yr Actual Speeds (Left) and New Prepay Model Projections (Right) for 3.0s of 2011



Source: CPR&CDR, Citi.

Primary-Secondary Spread Model

The new prepayment model includes a new primary-secondary model that better captures volatility dynamics of spread as a function of rates and embeds higher guarantee fees and originator costs.

The role of a primary-secondary spread model is to (1) capture the slower drop in primary mortgage rates relative to secondary rates in a rally; originators have pricing power when there is insufficient industry capacity to serve the entire population of borrowers that want to refinance, and (2) slow the rise in mortgage rates relative to secondary rates in a rate back-up scenario, due to originator excess capacity. The spread tightening in the latter case is usually far less than the widening in the former case, as (i) there is a limit to how low the spread can go before originators consider the business uneconomic, and (ii) volatility tends to have a widening effect on the spread regardless of the direction of rates.

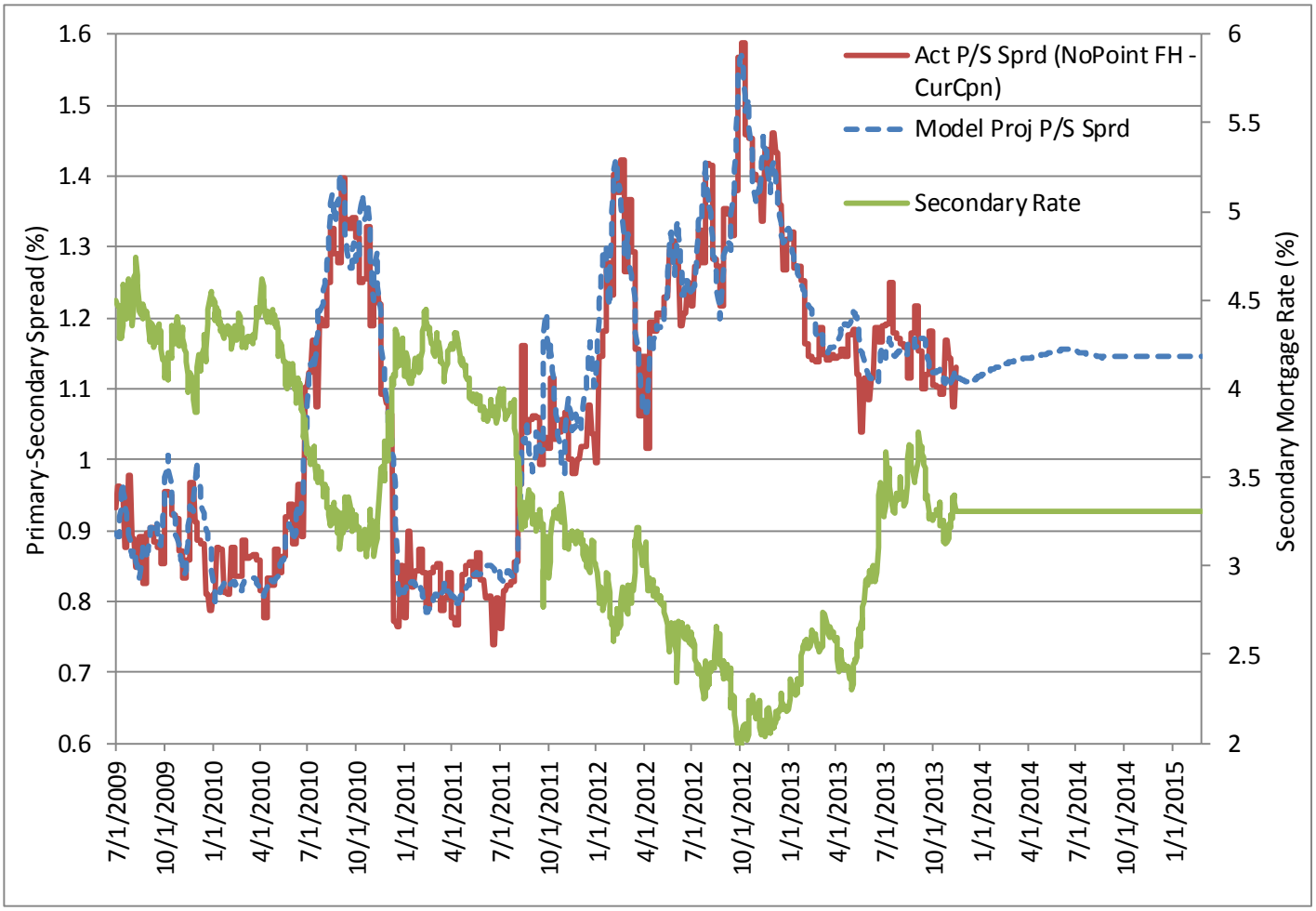
The primary-secondary spread model compares recent mortgage rates to average rates over 12 to 18 months, using the difference as a proxy for estimating the likely shortage or excess of industry capacity. It also incorporates "stickiness" as the spread begins to contract after a rally; contraction is slowed by originator efforts to maintain existing profitability levels.

Updated Primary/Secondary Spread Model – The new prepayment model includes a revamped primary-secondary model that better captures the volatility dynamics of the spread as a function of rates and embeds the higher GSE guarantee fees following increases in 2012 (note that past g-fee increases were included in Model 19.1 as well). The new model also assumes higher originator costs and profit targets, due to increased regulation and higher perceived and actual risks in the origination business. GSE put-back requests and various lawsuits and related settlements around questionable pre-crisis originations were and continue to be very costly to many originators.

As shown in Figure 25, the new model tracks historical P/S spreads closely. Comparing spreads during relatively stable periods in early 2011 and late 2013 shows the impact of the GSE g-fee increase (20-25 basis points) and a slight additional widening (10 bps). We expect the spread to tighten back to 2011 g-fee adjusted levels, but likely offset by an additional 10 bps g-fee increase by the end of 2014 (FHFA's public statements continue to imply further increases).

Changes in the primary/secondary spreads in different scenarios are shown in Figure 26. One interesting aspect of the interaction of the primary-secondary spread model with the refinancing component of the model is that despite the large primary-secondary spread widening projected in a 200 basis-point rally, new model projections for super-prime collateral still rapidly rise due to the turbocharged TPO refinancing effect discussed earlier (see Figure 12).

Figure 25. New Primary-Secondary Spread, Actual Versus Projected, With Secondary Mortgage Rates



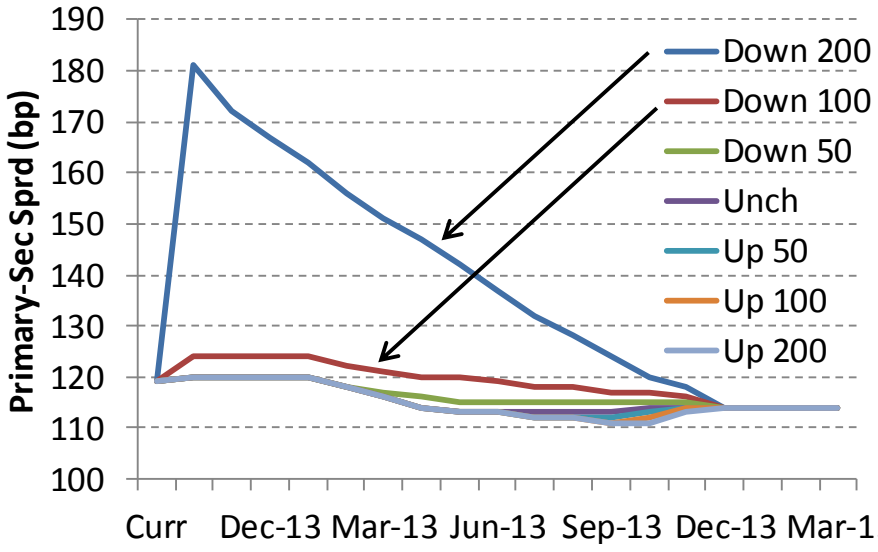
Source: FHLMC, Citi.

Why do primary/secondary spreads widen so much in a 200 bps rally? Figure 26 shows a much more dramatic widening with rates down 200 basis points than down 100 basis points. While a ***100 bps rally*** is a major drop in rates, if the rally starts from around 4.625%, it does not bring mortgage rates to new lows since no-point mortgage rates were previously in the 3.5% area (see earlier Figure 2 bottom chart). As a result, we would not expect a huge refinancing wave that would lead to major capacity constraints and cause a very large rise in primary-secondary spreads. For example, the large 3% and 3.5% cohorts produced in 2012 would not be substantially in the money.

In contrast, a ***200 bps rally*** would result in record low mortgage rates that would essentially make the entire mortgage universe refinancible; this would lead to another large-scale refinancing wave, causing significant capacity bottlenecks. Originators would therefore be reluctant to lower their rates as much as secondary market rates fall. Simply stated, why would they lower prices for consumers who are willing to pay more; indeed, maybe the better question is how could they, with their call centers and underwriters already working beyond full capacity?

Of course, as shown by the chart, increases in capacity, along with increased regulator and media scrutiny around high lender origination profits, would eventually lead to a contraction in the spread, forcing it back to the baseline (which we do expect to be higher than pre-crisis levels, for the reasons discussed earlier).

Figure 26. New Primary-Secondary Spread Model Behavior in Different Interest Rate Scenarios, September 2013



Source: Citi.

Housing Turnover Model

Housing Turnover is often the most important component of discount coupon "out-of-the-money" speeds (collateral for which the **Refinancing** component is small). This is especially true during the early years in the life of a mortgage pool. We model this component as the product of a number of factors that are (i) given in the following equation, (ii) briefly described in the table in Figure 27, and (iii) described in greater detail in the rest of this section.

Turnover Speed Projection = Overall Housing Turnover * Seasoning * HPA/LTV Adjustment * Lock-In * Mobility * Seasonality

Figure 27. Housing Turnover Components – Brief Descriptions

Component	Brief Description	Examples/Comments
Overall Housing Turnover	Average Fraction of Homes Sold	Base level that is high in a strong housing market and low in a weak housing market, and that is assumed to gradually mean revert to a long-run average.
Seasoning	Ramp-up	When a borrower moves again depends on how much time has passed and whether job or family circumstances would encourage or require a move.
HPA/LTV Adjustment	Home Equity Impact	High LTVs and home price depreciation impair turnover as borrowers may not be able to afford a down payment on another home and may not wish to incur a loss; on the other hand, strong housing markets and low LTVs will encourage and facilitate turnover.
Lock-In	Interest Rate Impact	Level of rates not only creates financial incentive/disincentive to refinance, but also (to a lesser extent) incentive/disincentive to move.
Mobility	Collateral Type Relative Impact	ARM borrowers move often (high mobility) while seasoned borrowers move less frequently (low mobility).
Seasonality	Summer High and Winter Low Cyclical Pattern	Parents prefer to move when their children are not in the middle of a school year; weather better in the summer.

Source: Citi

Overall Housing Turnover

Overall Housing Turnover is assumed to be determined by existing home sales normalized by housing stock, which is the number of houses.[35] It is a measure of the average frequency a house is sold, expressed as a percentage (so 5% means 5 out of 100 homes are sold annually on average).

[35] An adjustment to remove distressed sales is applied within the model, as foreclosure and short sales in most cases should be modeled as (and would also be reported as) defaults/buyouts.

Existing Home Sales vs New Home Sales – The reason for focusing on existing home sales is that these properties potentially have a mortgage that will be prepaid when the property is sold.[36] New homes do not initially have a mortgage associated with them. In addition, the number of existing home sales is much larger than new home sales – recently annual existing home sales have been in the neighborhood of five million (5,000,000), while new home sales have been about 400,000. Existing home sales do not exactly measure turnover prepayments as the data can be revised and many home sales do not involve a mortgage,[37] but existing home sales is more closely correlated to turnover prepayments and less noisy than new home sales.

The new prepayment model assumes housing turnover to be similar to mid-1990s housing turnover.

Projecting Overall Housing Turnover – Recent housing turnover levels serve as a starting point in the model, from which housing turnover projections begin; subsequent projections gradually transition from recent levels to a long-run level over a period of about three years.[38] Both Model v19.1 and Model v20 compare single-family home sales reported by the National Association of Realtors with the single family housing stock data reported by the Census Bureau to estimate long-term overall housing turnover. In Model v20, long-run housing turnover is assumed to be similar to that seen in the mid-1990s, which is about the same to slightly above recent housing turnover levels (Figure 28), and consistent with the long term average since the 1970s. This revised assumption is also slightly below the rate in Model v19.1. Weak income growth[39] and persistently higher than average unemployment suggest home sales may not follow a trajectory

[36] For most mortgages in the US, there is a "due on sale clause," which means the mortgage must be repaid when the house is sold. FHA/VA mortgages are an important exception; these are "assumable" by the new buyer of the home.

[37] Accounting for homes sold for cash is easier said than done. Even if we know a third of home sales are sold for cash, it may be that those homes turn over less frequently since a buyer needing a mortgage is more likely younger and more likely to move. And there is no easy way to divide the data into two "cash" and "mortgage" home categories.

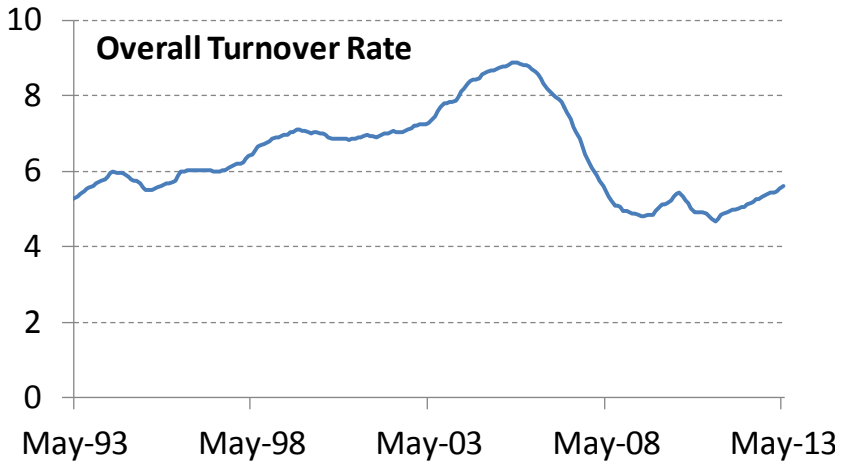
[38] While home price appreciation (HPA) is correlated with overall housing turnover, it is not an input for this component of the housing turnover model since in the near term it is automatically accounted for as the model starts from recent actual housing turnover levels. HPA of course does impact the housing turnover model overall, as discussed later.

[39] Median household income adjusted for inflation has been nearly flat from 2010 to 2013, and remains significantly below the levels seen prior to the 2008-2009 recession.

substantially higher.[40] Demographics may now also be less favorable to the housing market; the baby-boom generation, which played a role in high turnover in the late 1990s and early 2000s, is aging and unlikely to drive future turnover.

Model v20 and Model v19.1 apply similar geographic adjustments to home sales to capture variances by state.

Figure 28. U.S. Overall Housing Turnover Rate – Recent Levels Similar to Mid-1990s



Source: Citi.

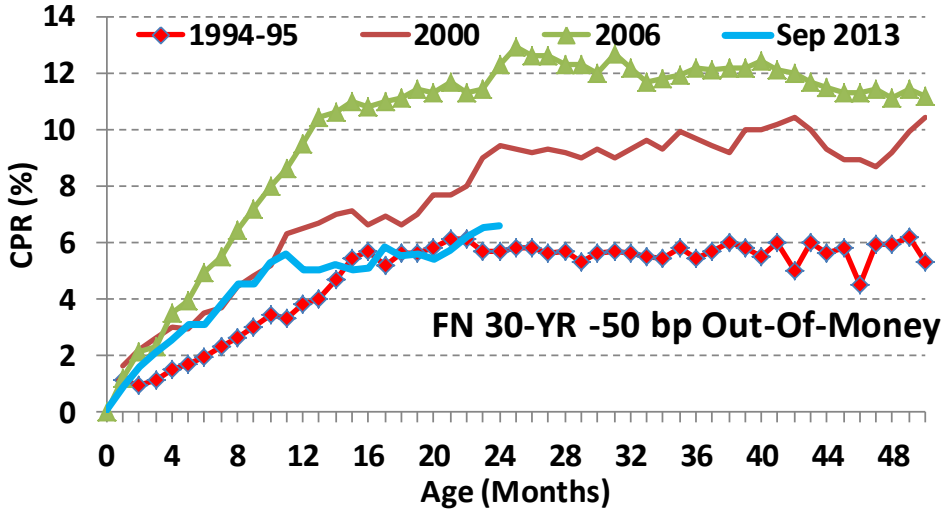
Seasoning

Seasoning refers to the PSA ramp-like behavior of the rising probability of a borrower moving as their new mortgage ages.[41] The act of taking out a mortgage, especially a fixed-rate mortgage, normally suggests that the borrower is unlikely to be moving in the near future. But as time passes, changes in job, income and family increase the likelihood of moving and a resulting home sale. After about two or three years, the probability of moving flattens out and remains relatively constant for many years – this is when the collateral is said to be "fully seasoned." Figure 29 compares modestly out-of-the-money seasoning ramps from different periods, illustrating that while the level of turnover at the top of the ramp may vary, the length of the seasoning period is fairly consistent.

[40] Whether mid-1990s housing turnover is historically average or low depends on whether one includes super-low turnover data points from the early 1980s when super-high mortgage rates averaged around 15%.

[41] The PSA ramp assumes (at 100 PSA) a linear ramp-up from 0 to 6 CPR over the first 30 months of the life of the mortgages and then remains constant at 6 CPR thereafter.

Figure 29. Discount Collateral Seasoning Comparison – 1994-95, 2000, 2006, and Sep 2013



Source: CPR&CDR, Citi

Recent speeds, labeled "Sep 2013" in Figure 29, show a pattern that resembles year 2000 data initially, but later moves closer to the1994-95 seasoning curve. Strong HPA (home price appreciation) over the past year or two may have accelerated the initial rate of seasoning for recent issuance, but speeds subsequently decelerate to levels more consistent with our long-run assumption of overall housing turnover being around 1994-95 levels. As we mentioned earlier, it may be that high unemployment and demographic shifts have lowered the "fully seasoned" baseline versus what it was in 2000, resulting in recent seasoning curves moving toward the 1994-95 "fully seasoned" baseline. For example, as we mentioned, the aging of the baby boomer generation may mean a lower "fully seasoned" turnover baseline, all other things being equal.

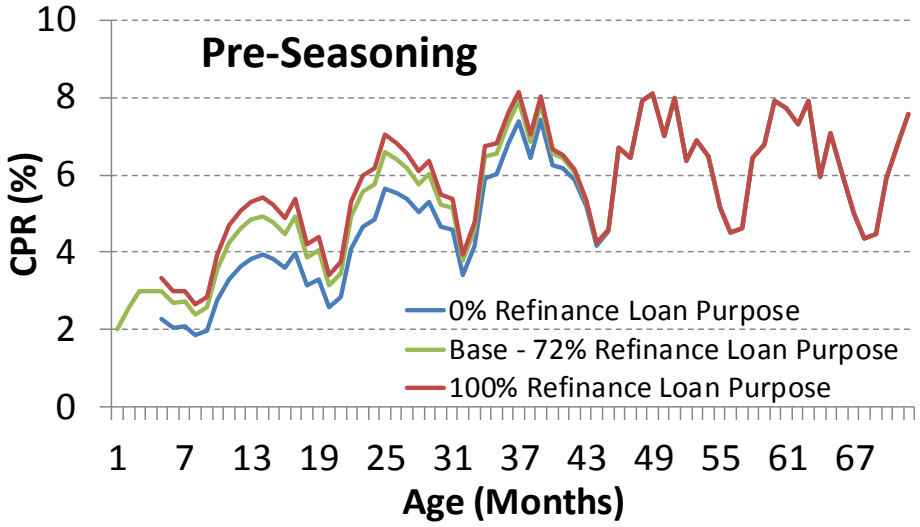
We note that these seasoning curves may contain significant components of prepayments that are not home sales; for example, the 2006 curve would reflects above-normal cash-out refinances initially and above-normal defaults later on; while the 2000 seasoning ramp likely contains some cash-out refinances as the housing boom was reaching its peak.

The new prepayment model assumes refinance loans season slightly faster than purchase.

Pre-Seasoning – Loan purpose also impacts seasoning. Pre-seasoning refers to refinance loans seasoning more quickly, because the borrower may have already lived in the current residence for a substantial amount of time (so the borrower is "pre-seasoned"). This dynamic is more complex now, because many recently refinanced loans (including non-MHA collateral) have refinanced through the streamlined HARP program. These, as mentioned above, may have a pent-up desire to move, but not the ability. The new purchase would

require a full underwriting, which could be difficult for some HARPed borrowers whose refinance underwriting was abbreviated (for example, HARP requires only a verbal verification of employment and not a new debt-to-income ratio). [42] All things considered, Model v20 assumes a slightly faster turnover seasoning ramp-up for refinance loans than for purchase loans – see Figure 30.

Figure 30. FNMA 30 Year 3s of 2013 Projected CPRs As Function of Age, With Different Refi% By Modifying Collateral



Source: Citi, The Yield Book

Home Price Appreciation Adjustment

High HPA along with the associated build-up in home equity make it more likely that the borrower has not only the *desire* to move, but also a greater *ability* to move (since higher equity allows the homeowner to trade up to a larger house). Some homeowners may also be motivated by the profit or loss they would take on a sale; there is likely some pent-up demand that is currently accelerating turnover for borrowers that have been underwater for a while, even for newer loans that may have been refinanced through HARP (despite the headwinds they might face from a full underwriting). Models v20 and v19.1 consider high **home-price appreciation momentum** (in addition to the HPA itself) as an important and separate driver. This could be seen at its extreme in 2004-2006, when it was necessary to add extra "flipping" parameters to the model (which were later discontinued) to capture the magnitude of the effect at that time.

[42] Because re-HARPing is not permitted, refinance loans have at times also been observed to be slower from a refinancing perspective, due to the borrowers having trouble with making it through a full refinance underwriting.

Lock-In and Assumability

The impact of interest rates on **Housing Turnover** primarily comes from **Lock-In** and **Assumability**.[43] Lock-in in particular refers to collateral with a below prevailing market mortgage rate resulting in borrowers having a disincentive to move (and prepay their existing mortgage). In most cases, this means borrowers may delay a move in order to keep their advantageous below-market-rate mortgage (Figure 31 shows that the greater the disincentive, the slower the speed). FHA/VA mortgages additionally have an assumability option allowing the mortgage to be transferred to the new owner of the home, which probably makes this effect a bit stronger for GNMA collateral.

Figure 31. Conventional 30-Yr Out-of-the-Money 12-Month CPRs by Coupon – in 1995 (Top) and in 2000 (Bottom)

Last 12 Month Average of Mortgage Rates as of March 1995 = 9.19					
Coupon	5.5	6	6.5	7	7.5
Incentive	-2.7	-2.2	-1.7	-1.2	-0.7
12-M CPR as of May 1995	2.5	3.1	3.9	4.8	6.2

Last 12 Month Average of Mortgage Rates as of September 2000 = 8.36					
Coupon	5.5	6	6.5	7	7.5
Incentive	-2.4	-1.9	-1.4	-0.9	-0.4
12-M CPR as of Nov 2000	4.8	6.1	7.7	9.6	12.6

Source: Citi

Factors Impacting Lock-In – The size of the rate increase that the borrower would incur as a result of moving is not the only factor impacting the degree of lock-in.

1) **Rate Differential** = New Mortgage Rate – Old Mortgage Rate. While the primary reason for a lock-in effect is to model slower turnover when borrowers would incur a rate increase to move, we also assume a modest increase in turnover if the borrower would be able to obtain a lower rate on the new purchase loan than on their current mortgage.

2) **Amortization** – The more principal the borrower has already paid off, the less disincentive the borrower will have to move.

3) **Home Price Appreciation** (HPA) – The more home prices rise, the

[43] Model v19.1 had an affordability term correlated with rates, removed in Model v20; economic and housing conditions cloud the relationship of affordability with rates.

larger the new mortgage on the new house will need to be and the less the mortgage on the old house matters. This suggests that the size of cumulative HPA may be inversely related to the degree of lock-in.

4) **Loan Size** – The prepayment model assumes that smaller loan sizes experience a smaller lock-in effect consistent with their smaller absolute dollar disincentive. The smaller lock-in (and hence reduced extension risk) is an additional benefit of loan balance collateral.

The new model accounts for mortgage insurance in determining the degree of lock-in.

5) **Mortgage Insurance –** In computing the financial value of the lock-in effect, the new model accounts for mortgage insurance (MI) in determining the degree of lock-in (similar to the role mortgage insurance plays in the refinancing incentive discussed earlier). In other words, after accounting for mortgage insurance on the old mortgage (by adding the MI to the rate on the old mortgage), a borrower who (a) is essentially paying the same rate as current prevailing mortgage rates, and (b) has already amortized down to below 80 LTV, should not experience any lock-in effect. But a FHA borrower who would obtain the same rate, but incur a substantial MIP increase on the loan for the new home, may have some lock-in, which would be captured in Model v20.

Using the Lock-in Effect to Model Assumable Mortgages -- If a home seller is financing a house with an assumable mortgage, the new buyer can "assume" the obligations of the existing mortgage, thereby not triggering a prepayment. In general, whenever the current market rate exceeds the contract rate on the assumable mortgage, the home seller can pass on the below-market rate loan to the buyer and capture the value of the assumability option through a higher selling price. Thus, the seller and the buyer both benefit at the expense of the lender or investor, which continues to carry a low-rate loan in a period of high market rates.

FHA and VA loans have always been assumable, although the FHA has periodically tightened the requirements for making an assumption. Until the 1970s, most conventional loans were assumable but this began to change in the 1980s. In the high-rate environment of the early 1980s lenders became increasingly aware of the value of the assumability option and began to remove it for conventional mortgages through a due-on-sale clause. Essentially, a due-on-sale clause stipulates that the entire amount of the remaining loan balance is due to the lender in the event of a sale of the property. By the 1990s, virtually all conventional mortgages had this clause.

In practice, the assumability of FHA and VA loans can be modeled by assuming that these loans experience an enhanced lock-in effect. Although having an assumable mortgage has little additional bearing on a borrower's economic disincentive to move, the value of the assumability option is very similar to the lock-in effect and depends on the same factors. For example, the greater the rate differential between the existing below-market loan rate and the market rate, the more attractive the existing loan is as a candidate for assumption. And the smaller the current loan balance as a proportion of the likely amount of a new loan the less attractive the existing loan is as a candidate for assumption. Thus, the more locked-in a borrower is, the more likely it is that his mortgage is an attractive candidate for assumption, and vice versa. This explains why prepayment rates on FHA/VA discount loans can appear as if the borrower were experiencing a strong lock-in effect. We discuss the expected impact of assumability on prepayments further when we cover the GNMA model.

Mobility

Mobility refers to the likelihood of a move due to self-selection.[44] For example, borrowers in fixed-rates loans tend to have lower mobility rates than ARM borrowers (who may select a hybrid ARM for the express reason that they plan to move before the fixed period expires, as discussed further in the ARM model section of the paper). And homeowners with a mortgage generally tend to be more mobile than those that own their home free and clear, so the long-term turnover rate in the model is higher than the rate implied by the comparison of existing home sales to housing stock.

In addition, the probability of a move declines when mortgages become very seasoned, since older people generally move less often than younger people; for that matter, the simple fact that the borrower has not moved for a very long time may indicate a lower mobility for that borrower.[45] (The decline in mobility as collateral gets very seasoned could also have been implemented into the seasoning curve, but for clarity we limit our definition of seasoning to the ramping up of housing turnover.)

[44] "Expected Mobility: Part of the Prepayment Puzzle," John Clapp, John Harding, and Michael LaCour-Little, *Journal of Fixed Income*, June 2000.

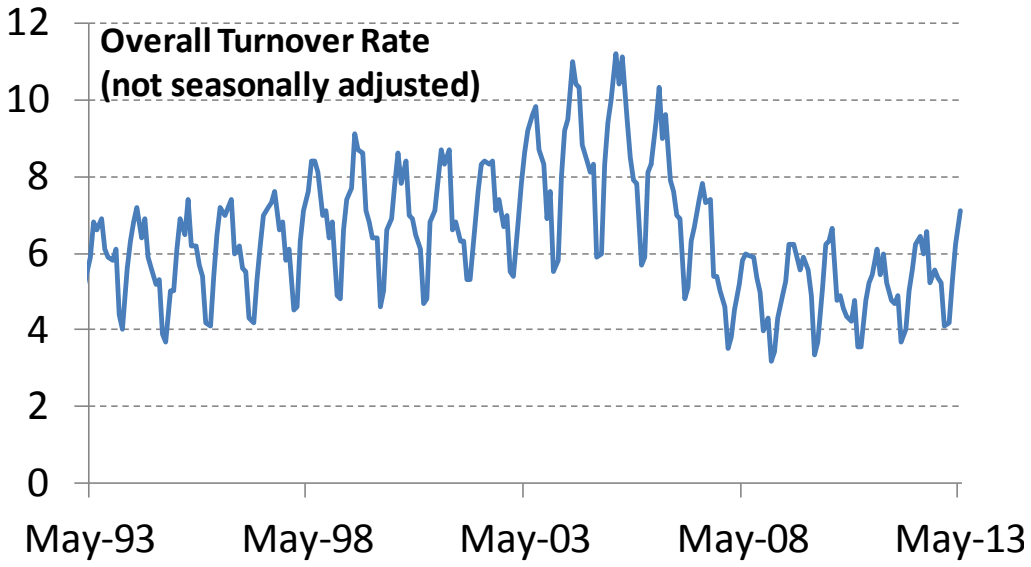
[45] "Citicorp Mortgage Prepayment Research Review," Michael LaCour-Little and Michael Jacobson, Internal Presentation, March 2000. By matching paid-off borrower information with the National Change of Address database, borrowers who moved could be distinguished from borrowers who refinanced.

Seasonality

Seasonality refers to calendar month oscillations of housing turnover, which can be observed in Figure 32 (a non-seasonally adjusted version of Figure 28). This is due in large part to parents with children preferring to move during the summer when school is not in session, as well as the impact of weather. While fairly straightforward from a modeling perspective, seasonality can have a substantial impact – for example Figure 33 shows a +42% increase in housing turnover from February to March.

Related to seasonal factors are calendar month **day counts**, which impact month-to-month speed changes for both housing turnover and refinancings. Simply put, more business days in a month means more days for originators to process refinancing applications and close home purchases. Generally, the number of business days and prepayment speeds are roughly directly proportional to one another.

Figure 32. U.S. Overall Housing Turnover Rate – Not Seasonally Adjusted



Source: Citi.

Figure 33. Sales of Existing Homes – Estimated Seasonal Adjustments and Month-to-Month Percent Change

Month	Seasonal Adjustment	Percent Chg From Prev Month
Jan	0.66	-21
Feb	0.72	+10
Mar	1.01	+42
Apr	1.07	+5
May	1.18	+11
Jun	1.22	+2
Jul	1.14	-7
Aug	1.19	+3
Sep	0.99	-16
Oct	1.07	+8
Nov	0.92	-13
Dec	0.83	-9

Source: Citi.

Additional Considerations

Points paid can be an indicator of borrower mobility, since a decision to pay points likely indicates that at the time the loan was closed, the borrower expected to keep the loan outstanding for a number of years. The model uses highly negative SATOs as a proxy for points paid (less negative SATOs may simply indicate a below market rate), and reduces turnover slightly as SATO becomes more negative than about 25 basis points.

Investor property loans are likely to have different turnover dynamics than owner-occupied properties, as the motivation for ownership may be different. Turnover on these loans may be driven more by home-price appreciation and the ratio of home prices to rents than by the typical considerations for owner-occupied properties discussed above. Neither Model v20 nor Model v19.1 apply different turnover models to investor properties than owner occupied ones; but we do expect, after further research, to consider such a change for future models.

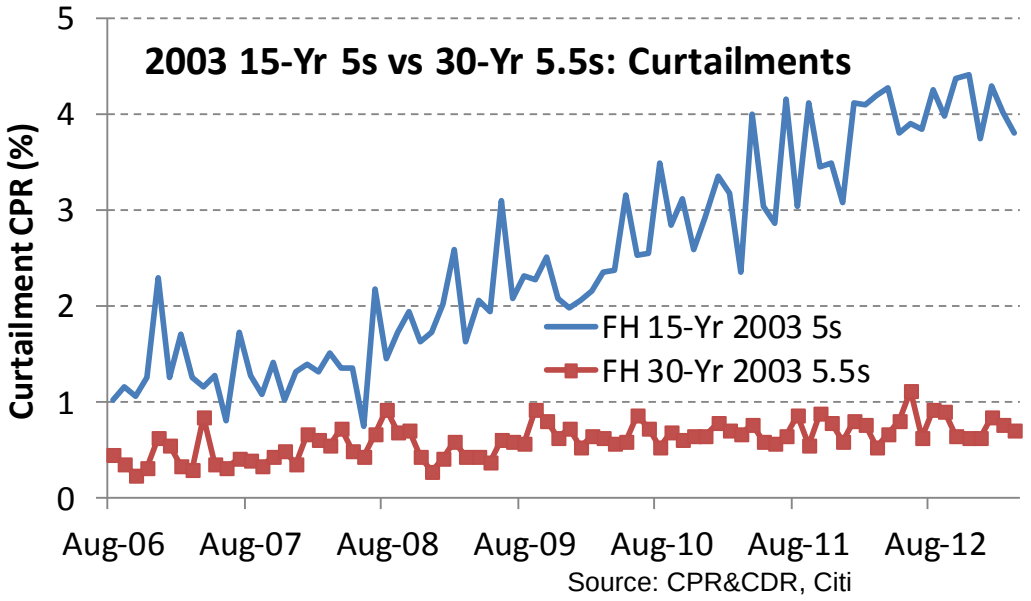
Relocation loans are loans facilitated by corporations to ease the move of employees who are being relocated. These borrowers tend to be highly mobile, so the model applies an especially high mobility factor to these loans.

Partial Prepayments/Full Payoffs Model

Partial Prepayments, also known as **Curtailments**, are extra payments of principal beyond scheduled principal – for example, some borrowers send in more than the scheduled payment each month, as a form of forced savings and to build equity in their homes faster.[46] Because the monthly payment due on a level payment mortgage is fixed regardless of the amount of outstanding balance prepaid, when a borrower sends in a larger monthly payment than the one due, *the borrower is effectively shortening the remaining term of the mortgage*.[47]

The primary driver of **Curtailments** is ***product*** since borrowers who go into a shorter mortgage like a 15-year term are a self-selected population inclined to pay off their mortgage sooner rather than later. As a result, these shorter maturity mortgage borrowers are more likely to both (i) *desire* and (ii) *be able* to include extra principal in their monthly payment. – see Figure 34.

Figure 34. 15-Yr Curtailments Much Higher than Corresponding 30-Yr Curtailments – 2003 Orig Yr 15-Yr 5s vs 30-Yr 5.5s



Source: CPR&CDR, Citi

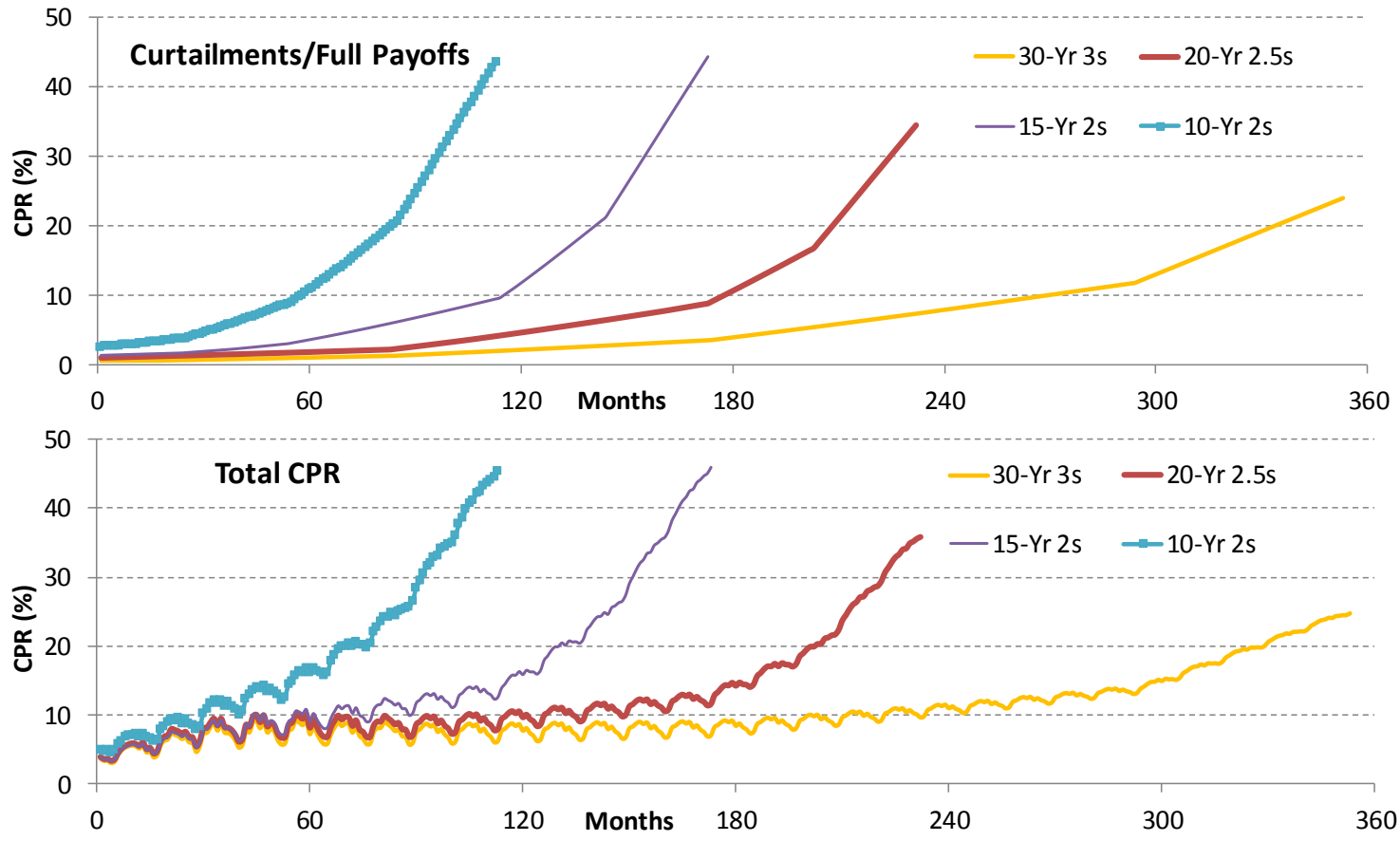
[46] Early work was done in "Partial and Full Prepayments and the Modeling of Mortgage Cash Flows," Lakhbir Hayre and Kenneth Lauterbach, *Journal of Fixed Income*, Volume 1, Number 2, September 1991.

[47] Extra principal payments on a fixed-rate mortgage shorten the term without changing the monthly payment. In contrast, extra principal payments on an ARM reduce the payment on rate adjustment dates, but do not change the term.

Partial Prepayments/Full Payoffs plays an especially prominent role in the newly added 10-Yr Prepayment Model.

Full Payoffs refer to complete repayments on mortgages that are typically very seasoned with a low remaining balance. As an example, a **Full Payoff** could result from a borrower using some of their savings to pay off a mortgage early to save on the interest costs, especially if the borrower does not itemize deductions and does not make use of the mortgage interest rate tax deduction. Full payoffs can also occur from an insurance recovery on a home destroyed by fire or natural disaster. ***The combination of* Curtailments and Full Payoffs *can be a large fraction of prepayments, especially for discount shorter maturity mortgage collateral.*** This component of the model has been recalibrated and plays an especially prominent role in the newly added 10-year prepayment model. Although important, a quick comparison of the top (**Curtailments/Full Payoffs**) and bottom (Total CPR) charts in Figure 35 may make it appear that curtailments and full payoffs are by far the largest and most important component of out-of-the-money collateral prepayments.

Figure 35. Curtailments/Full Payoffs (Top Chart) Can Be Large Fraction of Total CPR (Bottom Chart), Especially for Short Maturity Mortgages



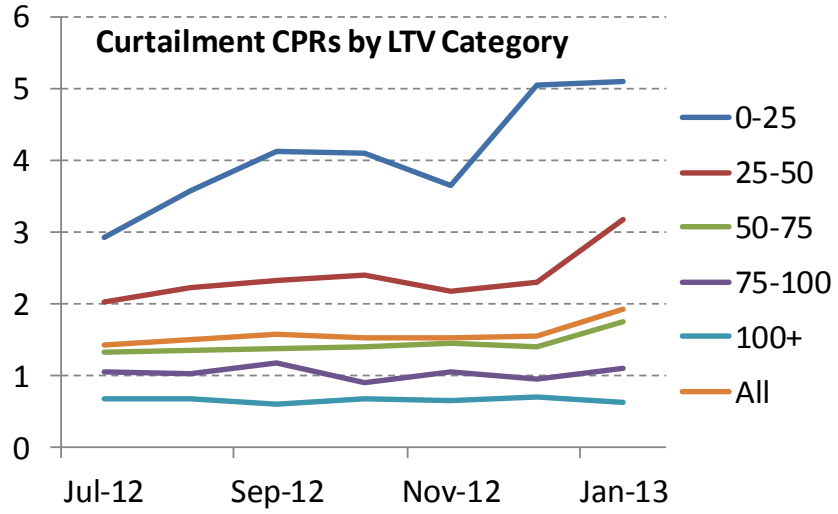
New model projections for 2013 Orig Yr 30-Yr 3s, 20-Yr 2.5s, 15-Yr 2s, and 10-Yr 2s shown. Source: Yield Book, Citi.

While certainly important, *Figure 35 exaggerates the impact since this component is low early in the life of the mortgage* (e.g., ramping to around one CPR for 30-year collateral at an age of 60 months). Even a short maturity borrower is unlikely to start off with a high level of curtailments since the borrower could have simply financed a lower principal balance if extra cash was on hand. As a result, on a present value basis, housing turnover is usually just as important or more important (as in the case of 30-year collateral) for discount coupon collateral valuation (this is discussed in greater detail later).

The impact of LTV and FICO, as well as curtailments for 15-year borrowers, has been strengthened in the curtailment component of the new prepay model.

LTV and FICO Impact – It should not be surprising that partial prepayments are modeled not only as a function of age, but LTV and FICO as well. The impact of LTV and FICO, as well as the propensity of shorter-maturity borrowers to pay off debt, has been strengthened in Model v20. It is natural that the ability and/or desire to pay off one's mortgage would be dependent on these attributes – for example, as a borrower's income grows over time, the ability to make extra payments toward one's principal balance would grow. Figure 36 shows the effect of LTV and that the super-low sub-25 LTV category exhibits substantially higher curtailment speeds. At the other end of the LTV spectrum, super high LTV CQ/CR/U6/U9 borrowers,[48] who default at a higher than average rate, have low curtailments consistent with underwater borrowers either experiencing economic distress or considering defaulting on the mortgage.

Figure 36. Curtailments Also Depend on LTV – Curtailment CPRs of 2012 Orig Yr 15-Yr and 10-Yr 3s by LTV Category



Source: CPR&CDR, Citi

[48] CQ and U6 borrowers have original LTVs 105< OLTV <=125, while CR and U9 have LTVs >125. CQ/CR are Fannie pool prefixes, while U6/U9 are 30-year Freddie codes.

Default/Buyout Model

Default occurs when a borrower stops making monthly payments on their mortgage. Reasons are typically related to loss of income (or the ability to make the monthly payment) and negative equity, which means the borrower has an economic incentive to default (if defaulting despite having the ability to pay the monthly payments, this is referred to as a "strategic default").[49] Figure 37 gives a list of typical reasons for default.

Figure 37. Trigger Events: Reasons for Mortgage Delinquencies (%)

Unemployment or Loss of Income	36.3
Illness in the Family	21.1
Excessive Obligation	13.6
Maritial Difficulties	6.0
Death in the Family	3.9
Property Problems or Casualty Loss	2.8
Extreme Hardship	0.9
Inability to Sell or Rent Property	1.4
Employment Transfer or Military Service	0.6
All Other Reasons	13.3

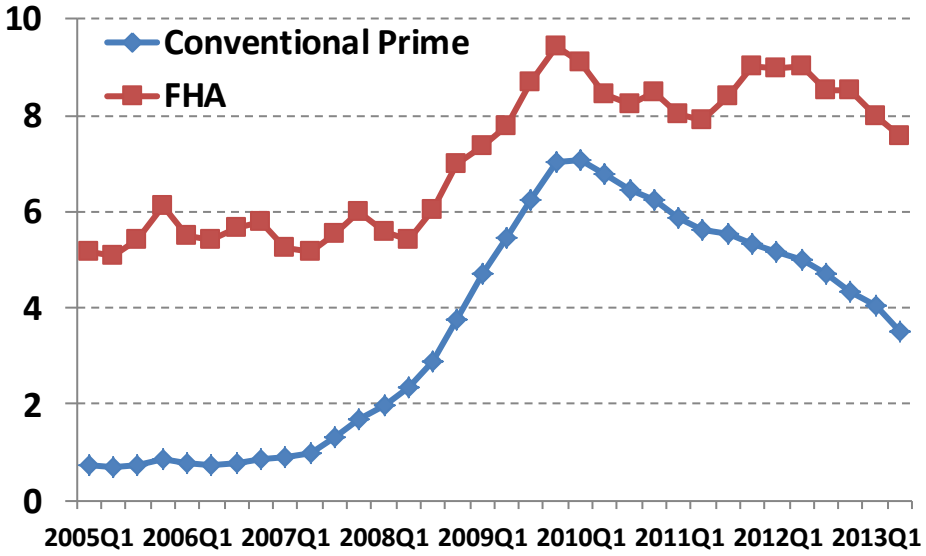
See Modeling of Mortgage Defaults, Citigroup, Jan 22, 2008 (republished Nov 9, 2010). Taken from 2006 Freddie Mac data. Source: Freddie Mac, Citi.

For agency MBS, a default normally results in a full prepayment of the outstanding balance of the loan because of the agency guarantee, and normally occurs through a **Buyout** of the loan from the pool. General expectations of default have varied over a very large range over the past decade – from extremely low levels during the housing bubble years 2006 and earlier, to super-high in the aftermath of the subsequent crash and financial panic in 2008-2009, back down to lower levels as home prices have rebounded and the economy and unemployment continue to recover (Figure 38).

Default projections for agency MBS collateral have recently increased in importance with (a) the issuance of very high LTV pools like CR and U9 by Fannie Mae and Freddie Mac, respectively, (see earlier Figure 6), and (b) GSE "risk-sharing" credit deals designed to sell off some of the default risk of GSE residential mortgage holdings to private investors. The default model component of Model v20 incorporates the information from recent data issued by the GSEs in preparation for these deals.

[49] "Interventions in Mortgage Default: Policies and Practices to Prevent Home Loss and Lower Costs", Amy Crews Cutts and William A. Merrill, Freddie Mac, March 2008.

Figure 38. Seriously Delinquent Percentage Rose Dramatically and Subsequently Dropped with Recovery in Home Prices



Seriously Delinquent % = % Past Due 90+Days + % in Foreclosure

Source: Mortgage Bankers Association, Moody's Economy.com, Citi.

Defaults Versus Buyouts. Although default occurs when a borrower stops making monthly payments on their mortgage, for agency MBS pools, a prepayment occurs when the loan is bought out of the pool. Fannie Mae and Freddie Mac have the option of purchasing any seriously delinquent loan from their mortgage pools at par, and can do this no later than when the loan becomes 24 months past due. In recent years, the GSEs have for the most part been buying out delinquent loans when they reach 120 days delinquent (delinquent for four consecutive monthly payments). As a result the buyout prepayment component of Fannie Mae and Freddie Mac pools has become fairly stable. GNMA buyouts have been more sporadic and are discussed more fully in the GNMA section of this paper.

Modeling Defaults/Buyouts. Modeling defaults begins with a baseline default seasoning function: F(Age). The seasoning curve peaks around 4 years after origination.[50] It is further modified by several other variables:

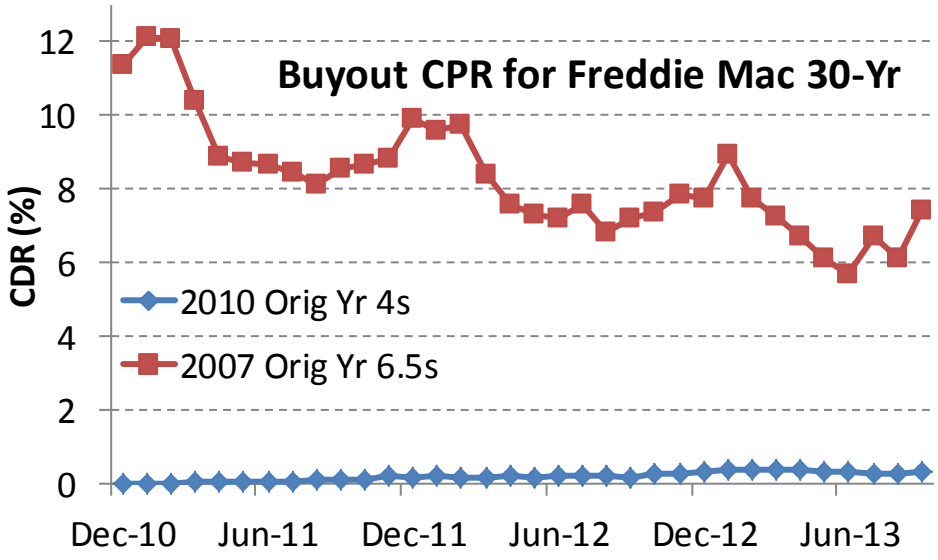
Projected Defaults/Buyouts = F(Age) * G(SATO) * H(FICO)

*** I(Unemployment) * K(LTV) * S(WAC – CC)**

[50] "Introduction to the Home Equity Loan Market", Citigroup Fixed Income Research, 2005.

This relationship describes the most important variables used in the model; additional minor adjustments are made that will be discussed briefly later. The importance of credit characteristics is illustrated by the wide difference in buyouts between poor credit 6.5s of 2007 and very good credit 4s of 2010.

Figure 39. Buyout CPR (CDR) for Credit Impaired 6.5s of 2007 vs Very Good Credit 4s of 2010



Source: Freddie Mac, CPR&CDR, Citi.

Defaults are generally lower in the new model.

With the new model incorporating updated higher HPA assumptions and a more optimistic economic outlook, new prepay model default projections are generally lower except for a few very seasoned and higher credit quality cohorts.[51] The new model also incorporates, as mentioned, additional insights related to the recent GSE credit data releases, as well as longer available histories for high-LTV cohorts such as CQ/U6 and CR/U9 pools.

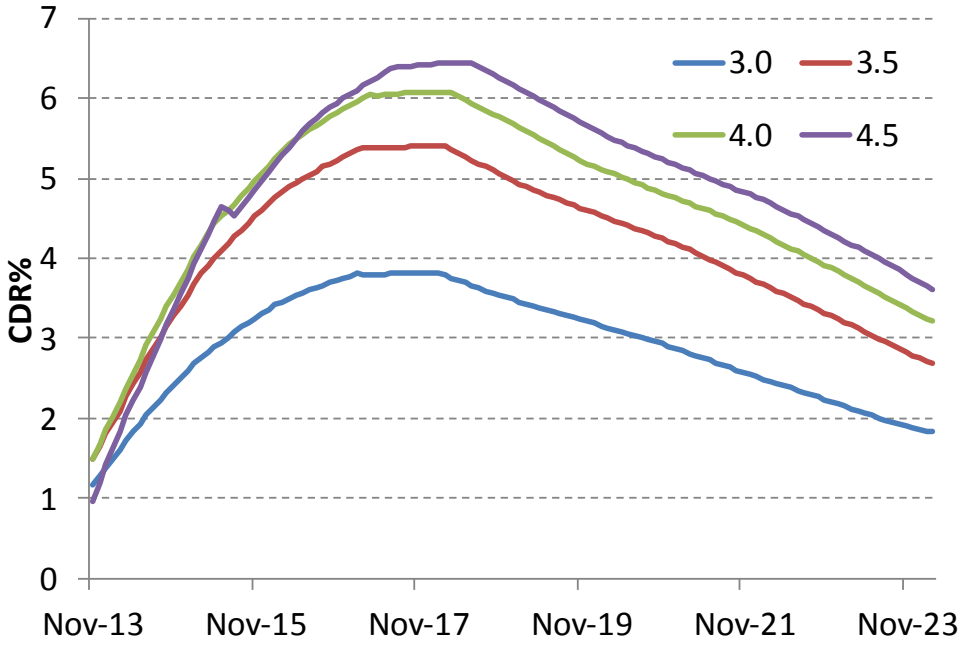
Furthermore, projected unemployment rates and related sensitivities are included for the first time (previously, unemployment was only used in the non-agency models). Including the unemployment rate in the model aligns base case default projections with reasonable future unemployment projections and allows for improved on-the-fly adjustments as economic conditions change.

[51] The most significant changes in the default model can be observed in impaired cohorts that have multiple strikes against them…e.g. high SATO, low FICO and high LTV. Some of these cohorts show reductions of as much as 3 to 5 CDR. There are slightly lower default projections for the seasoned HARP-able universe.

Defaults on very high LTV collateral in particular have been lowered significantly.

As a specific example, consider CR/U9 collateral. The new model continues to project defaults as the primary driver of prepayments in this cohort. Figure 40 shows the new model's projected default curve over a range of coupons for 2013 CR collateral. As a result of an improved economic environment and higher HPA, new model peak default rates have been lowered substantially compared to the old model, especially for credit impaired collateral (such as the 4% and 4.5% coupons in Figure 40 that have higher SATOs and lower credit scores). The rate of decline is also faster after the peak due to the lower unemployment rates now included in the model.

Figure 40. New Model Default Rate Projections for 2013 Origination Fannie Mae CR (LTV > 125) Collateral By Coupon

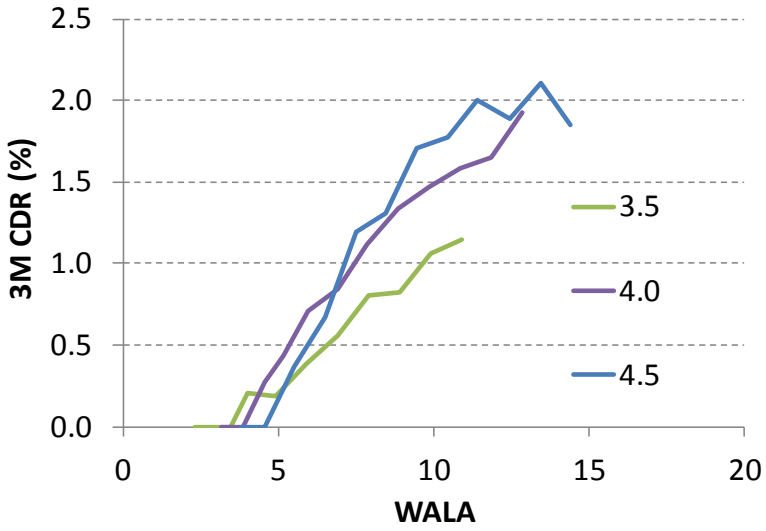


Source: Citi, Yield Book

Comparing historical CDRs for 4.5s of 2012 U9 collateral shown in Figure 41 we can see that buyouts reached about 2 CDR after a year, which is consistent with new model projections (the new model projects 2.1 CDR for Oct 2013 on 2012 U9 4s, for example).[52]

[52] The kink that can be observed in 2015 for the default curve on 4.5s is related to the planned expiration of the FHFA streamlined loan modification program announced in early 2013, discussed further later.

Figure 41. 3-Month Historical Default Rates by WALA for 2012 Vintage Freddie Mac U9 Collateral



Source: CPR&CDR, Citi

The new model accounts for initial clean pay history of pools of modified loans and begins to cover the conventional modified loan sector.

Modified Loans. Additional adjustments are made by the new model that account for the fact that modified loans may suffer high re-default rates; this may be moderated in the model by the origination year (more recent modifications tend to do better than earlier ones) and the initial clean payment history between modification and issuance of the pool. There is little history to review for conventional modified loans, and after additional research we expect to refine model parameters for modified loans. More history is available for GNMAs and there is further discussion in that section of the paper. Finally, a related issue is the potential effects of moral hazard from FHFA's recently announced streamlined modification program. Some impact from this program is included in the new model as well (discussed further in Appendix I).

The **incentive term** in the default model exists primarily to distinguish buyouts from defaults. Buyouts must be done at par; thus one would expect more aggressive buyouts on higher coupon collateral and less aggressive buyouts on lower coupon collateral. This effect is visible for GNMAs where the buyout decision is made by the servicer, but less evident for conventionals where the decision is made by the GSEs and must in any event occur within 24 months.[53]

[53] The new prepay model eliminates the distinction within the model between buyouts and defaults. In addition to reflecting the recent reality that the GSEs have not been highly selective by coupon, this has the potential to make the new model more useful for GSE risk-sharing deals such as the Freddie STACR (Structured Agency Credit Risk) deals, as defaults (rather than buyouts) are relevant for these deals.

Other Default Model Drivers – The default model considers a number of other variables that are generally less important than the above. A few that are worthy of mention are the following:

Default sensitivities to loan size have been reduced.

Loan Size – Default rates have not appeared to be as sensitive to loan size in agency conforming space as Model v19.1 implied; we have thus reduced the sensitivity in Model 20, retaining slightly lower default rates for lower loan balance collateral.

No separate default model adjustment made for investor loans in the new model.

Occupancy Type – Investors may be more likely to default than owners due to a lower vested interest, as reflected by rate premiums on investor loans. But perhaps that is offset by more rigorous underwriting focus on investors. Model v20, in contrast to Model v19.1, does not make a separate adjustment except for what is implied by the higher average SATO on these borrowers.

Origination Period – Originations during the crisis period are modeled for higher defaults than recent originations that have endured a much stricter underwriting regime, or have indicated an ability and willingness to pay by refinancing through the HARP program.

Burnout – Collateral burned out after heavy refinancing is modeled for higher defaults, as lower-quality borrowers typically remain in the pool.

Finally, It is important to note that **there is much uncertainty regarding default rates going forward** (for example, regarding how rapidly and by how much the housing recovery lowers defaults). Leading indicator 30-day and 60-day delinquency levels appear to be starting to stabilize, suggesting defaults/buyouts may peak earlier than historical data suggests. There are reasons to believe that defaults could be on the low side for the current mortgage universe going forward. New purchase and non-HARP refinance loans have faced very stringent underwriting over the past few years. While loans refinanced through the HARP program were not subject to full underwriting, this collateral was required to have six months of clean payment history with only one 30-day late allowed in the preceding six months prior to the refinance. As mentioned above, this seems to indicate that a willingness and ability to pay were present. Finally, recent sharp increases in home prices could result in faster-than-normal equity buildup on homes purchased after the crisis. Despite these positive signs, we have been conservative about reducing default projections. High default rates persist in many cohorts, and the ultimate impact of Fed tapering and inevitable monetary tightening is uncertain.

Ginnie Mae Prepayment Model

Ginnie Mae speeds historically are the most leveraged to the housing cycle given borrowers are often less affluent and as a result tend to both:

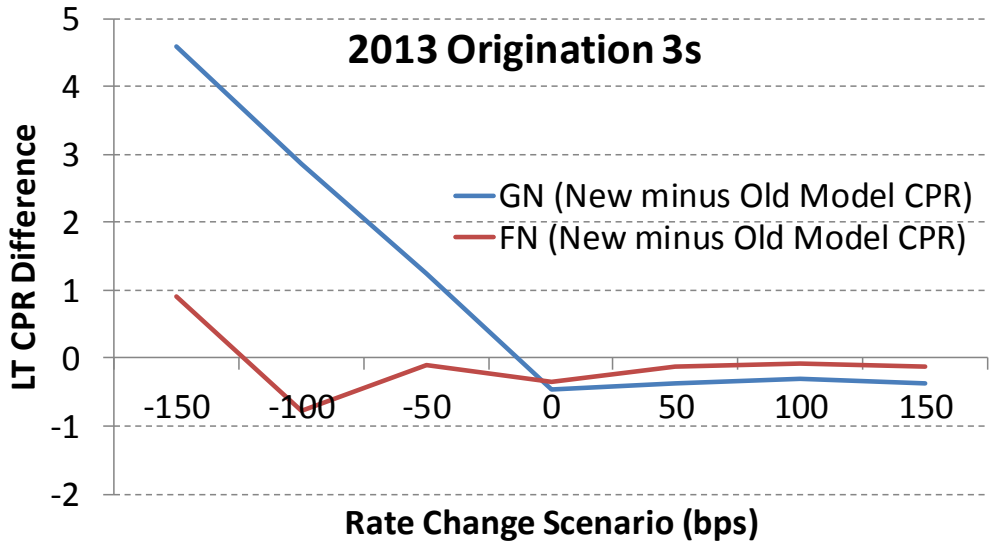
a. have the greatest desire to (i) trade up and (ii) take out equity (even if a lack of financial resources/equity prevents them from doing so), and

b. to be in a position of greatest sensitivity to home price movements given small to zero down payments of most FHA/VA mortgages.

The new prepay model assumes Ginnie Mae collateral to be more callable both on an absolute and relative basis.

As a result of the above, it should not be surprising that the new Ginnie Mae prepayment model is not only more callable, but has also increased in callability more relative to the conventional prepayment model (Figure 42). The increased GNMA responsiveness in a rally is primarily due to higher FHA speeds, as we assume an increasing number of borrowers can obtain conventional loans and avoid high FHA MIPs. Additionally VA speeds continue to be extremely high, and RHS speeds are stronger, particularly on higher coupons due to a refinance pilot program launched by USDA in 2012.

Figure 42. New Ginnie Prepay Model Exhibits Greater Increase in Callability vs Old Model Than Chg in Conventional Model



Source: Citi

GNMA Refinancings

GNMA Guarantor Matters -- The GNMA universe may in reality be viewed as four separate collateral types, one for each U.S. government entity that guarantees the loans backing GNMA securities. The prepayment patterns on loans from each guarantor differ primarily due to borrower type, streamlined refinancing programs offered by each guarantor, and insurance premiums required. The four entities are briefly compared in Figure 43; only the first three are significant.

Figure 43. Comparison of the Four GNMA Guarantors

	FHA (Federal Housing Administration, HUD); provides low down payment loans for less affluent homebuyers with lower credit scores.	**VA** (Veterans Administration); provides low down payment loans for veterans.	**RHS** (Rural Housing Service, USDA); provides low down payment loans for residents of rural areas.	**PIH** (Public and Indian Housing, HUD); supports loans for Native American and certain very low income buyers.
Estimated fraction of GNMA universe (October 2013)	71%	23%	6%	<1%
Mortgage Insurance Premium (% of Loan Amount) for Refinanced Loans	Currently 1.75% upfront and 1.35% annually for most loans endorsed after May 31, 2009, 0.01% upfront and 0.55% annual if endorsed prior to May 31, 2009; see subsequent table for more detail.	0.5% upfront, no annual premium.	2.0% upfront and 0.4% annual (up from 1.5% upfront and 0.3% annual in 2012, and 1.0% upfront and no annual premium in 2011).	1.0% upfront.
Streamlined refinance program	No appraisal required; Need 12 months of clean payment history (one 30-day late allowed 6-12 months ago) closing costs may not be included in loan balance (although may be rolled into the rate).	No appraisal required; Some delinquent borrowers may be able to refinance, and closing costs may be rolled into the new loan balance.	No appraisal required; pilot program: closing costs may be included in loan balance, no credit report or property inspection if last 12 payments made timely and rate declines by at least a point.	

Source: Citi, HUD, VA, USDA, CPR&CDR.

The new prepay model accounts for increased refinancing of FHA into conventional loans driven by high HPA and higher MIP requirements from FHA.

Recent FHA Loans Increasingly Refinancing into Conventionals -- FHA is the largest guarantor, and higher projected FHA refinancings are the primary driver behind the faster GNMA speeds in Model v20 vs. Model v19. The older model assumed that FHA-to-conventional speeds would not be material. But due to strong HPA, higher credit quality on GNMA loans originated over the past few years, and sharp increases in FHA Mortgage Insurance Premiums (MIPs)

relative to private mortgage insurance (PMI) premiums,[54] FHA-to-conventional speeds have picked up recently.[55] Although FHA rates have generally been lower than conventional rates over the past few years (due primarily to the favorable secondary market for GNMA securities, backed by the full faith and credit of the U.S. government), this is more than offset by the much higher MIPs now charged by the FHA. See Figure 44 for the substantial increases over the past few years, in response to the impact of the housing crisis on FHA's insurance reserves.

Figure 44. Recent Changes in FHA MIPs

FHA MIPs in Basis Points for Various Periods		Upfront		Annual					
		P	SL	15 Year Term			30 Year Term		
					Base ≤ 625.5K	Base > 625.5K		Base ≤ 625.5K	Base > 625.5K
Before 4/5/10		175	150	LTV ≤ 90	0		LTV ≤ 95	50	
				LTV > 90	25		LTV > 95	55	
4/5/10 - 10/3/10		225		LTV ≤ 90	0		LTV ≤ 95	50	
				LTV > 90	25		LTV > 95	55	
10/4/10 - 4/17/11		100		LTV ≤ 90	0		LTV ≤ 95	85	
				LTV > 90	25		LTV > 95	90	
4/18/11 - 4/8/12		100		LTV ≤ 78	0		LTV ≤ 95	110	
				78 < LTV ≤ 90	25		LTV > 95	115	
				LTV > 90	50				
4/9/12 - 6/10/12		175		LTV ≤ 78	0		LTV ≤ 95	120	
				78 < LTV ≤ 90	35		LTV > 95	125	
				LTV > 90	60				
6/11/12-3/31/13	HARP	1		55					
	Non-HARP	175		LTV ≤ 78	0		LTV ≤ 95	120	145
				78 < LTV ≤ 90	35	60	LTV > 95	125	150
				LTV > 90	60	85			
4/1/13-6/2/13	HARP	1		55					
	Non-HARP	175		LTV ≤ 78	0		LTV ≤ 95	130	150
				78 < LTV ≤ 90	45	70	LTV > 95	135	155
				LTV > 90	70	95			
After 6/3/13	HARP	1		55					
	Non-HARP	175		LTV ≤ 90	45	70	LTV ≤ 95	130	150
				LTV > 90	70	95	LTV > 95	135	155

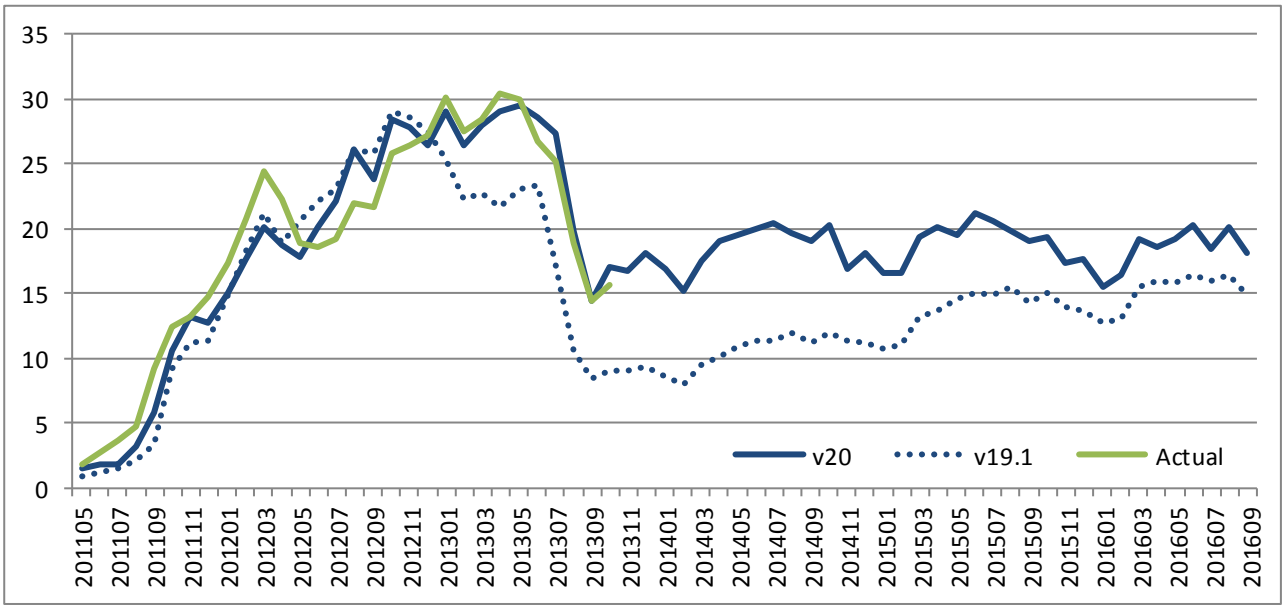
P = Purchase, SL = Streamline Refi, Base = Base Loan Amount. Source: FHA

[54] Ginnie refinancings into conventional mortgages have the most significant relative impact on triple MIP protected collateral (referring to collateral originated at 50-55 bps annual MIP and which now after three major MIP increases would face a premium of 130-135 bps on an FHA-to-FHA refinance).

[55] Agency MBS Weekly, Citi Research, Ankur Mehta et al., September 20, 2013

Significant Hidden Incentives for Better FHA Borrowers -- Many FHA borrowers cannot qualify under a conventional underwriting due to high LTVs, low FICO scores and high debt-to-income ratios. These would continue to rely on the FHA streamlined refinance program and pay the higher MIPs. But the net benefit for those that can refinance into a conventional loan as opposed to another FHA loan is substantial when the LTV is below 90 (and especially when below 80). Figure 45 compares the projections on GNMA II 4.5s of 2011 between Model v20 and Model v19, showing the impact of adding FHA-to-conventional refinances. Borrowers in this cohort would be roughly at-the-money for a new FHA loan, but might have 50-100 basis points of incentive for a conventional loan, depending primarily on FICO and LTV.

Figure 45. Major Model v20 Adjustment for GNMAs: FHA-to-Conventional Refinancings



Source: Citi, eMBS

The new model incorporates faster FHA HARP projections.

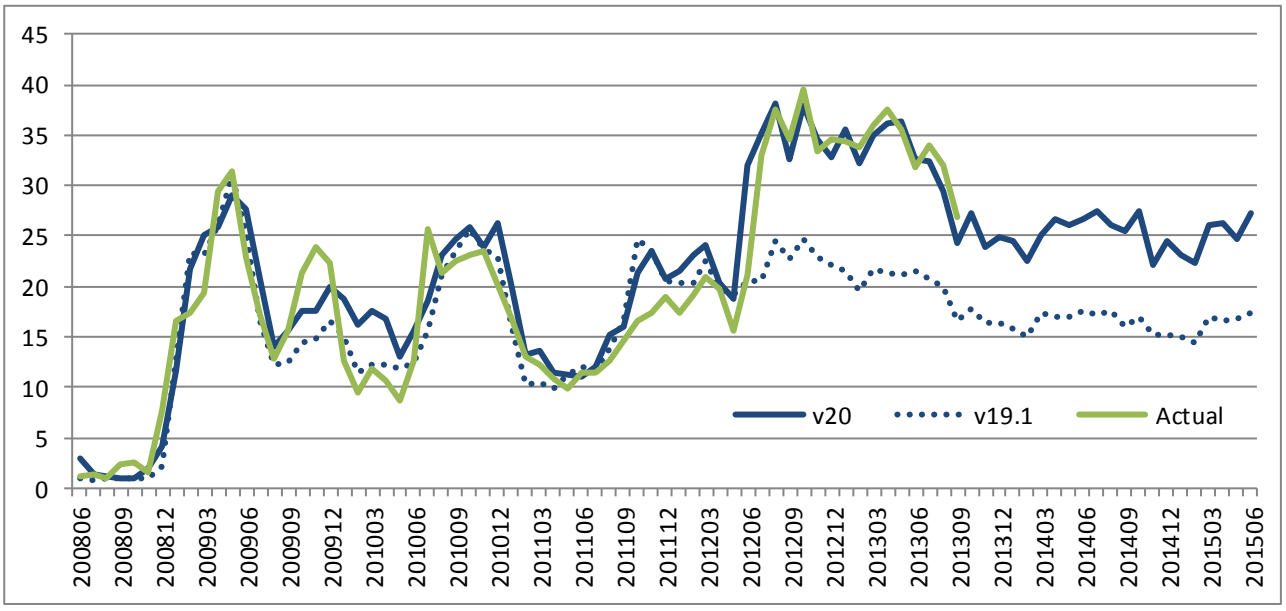
FHA "HARP" Very Successful – In March 2012, FHA announced that loans endorsed by the FHA for insurance prior to May 31, 2009 (the same date as applies to the HARP program for conventionals[56]) would, upon a refinance, have their annual MIPs essentially grandfathered at 55 basis points and avoid a new upfront MIP (nominal charge of one basis point). This roughly corresponded to the grandfathering of PMI for conventional HARP refis, but

[56] For conventional HARP, the May 31, 2009 date now refers to the "note" date (previously, it referred to the GSE acquisition date).

affected almost the entire FHA universe as most of these loans carry high LTVs. The FHA HARP program, in addition to being very attractive to borrowers, is very attractive to originators due to its simplicity (same rules as for existing FHA streamlined refis, but significantly lower MIPs) and profitability.[57]

Figure 46 shows the dramatic response for a sample cohort (5.5s of 2008) and compares voluntary speeds projected by Model v20 vs. Model v19. With the benefit of hindsight, Model v20 incorporates the dramatic response of eligible collateral, the magnitude of which surprised most market participants (Model v19 was released before any actual speeds were observed). Speeds have been declining due to higher rates, but remain substantially above levels prior to when the FHA "HARP" policy took effect.

Figure 46. Dramatic Increases in Speeds for FHA "HARP"-Eligible Borrowers Captured by Model v20



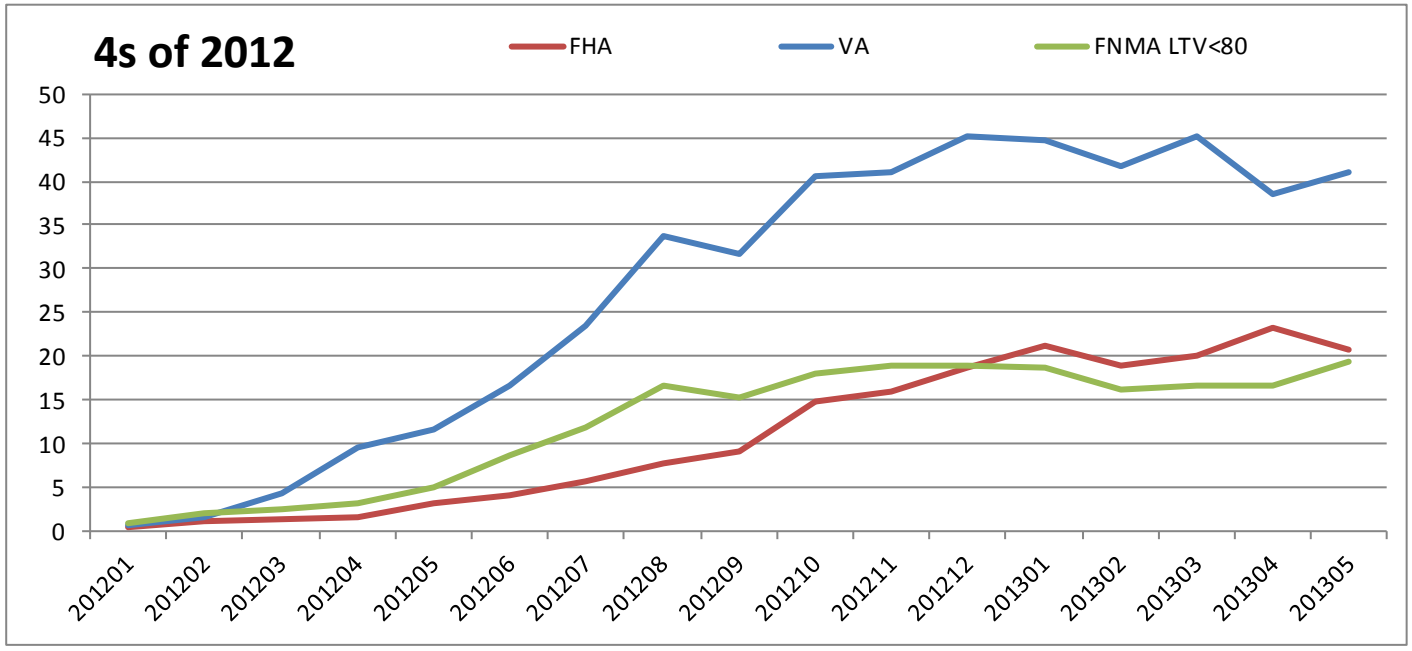
Source: Citi, eMBS

VA Speeds Continue To Be Very Fast – VA speeds remain extremely fast and appear to occur even with relatively little incentive. Figure 47 shows speeds on GNMA 4s of 2012 separately for FHA and VA, and also shows conventional FNMA speeds for comparison. Both Model v20 and Model v19 project very high VA refinances due to the highly streamlined process with essentially no

[57] In addition to the premium price on GNMA collateral, an additional premium developed because the "GNMA MHA" collateral resulting from these refis have a significant elbow shift to overcome for a second FHA-to-FHA refinance.

constraints on participation. There are no annual MIPs, veterans are likely to be served first and given the most favorable interest rates due to a broad appreciation of their service, and we believe VA permits refinances even on delinquent loans under certain circumstances. The refinancing rates are therefore much faster than those for both FHA and conventional loans.

Figure 47. VA Speeds Often Significantly Exceed FHA and Conventional Speeds



Source: Citi, CPR&CDR

The new model incorporates the Rural Housing Refinance Pilot Program, resulting in faster projections.

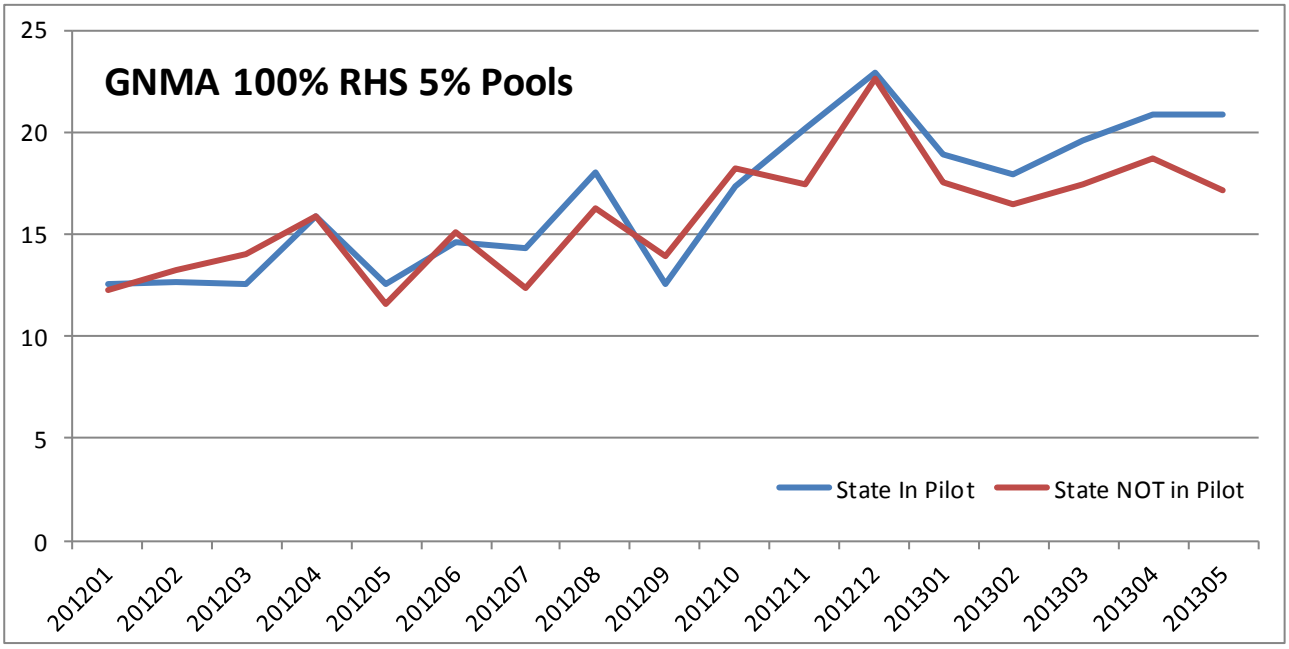
Rural Housing Pilot Program Results in Faster Speeds -- The new Ginnie Mae Prepayment Model increases the refinancibility of the Rural Housing (RH) sector due to the refinance pilot program announced by RH in early 2012 and expanded in early 2013.[58] The program is currently effective in 35 states. If the loan coupon is lowered at least one point and timely payments have been made for 12 months, closing costs may be rolled into the balance and the borrower may avoid the appraisal, credit report and property inspection. Chase services most of the 100% RH specified pools and has embraced the program.[59] Figure 48 shows the increase in speeds on RH collateral into early 2013, especially for

[58] Program Information: http://www.rurdev.usda.gov/SupportDocuments/RefinanceFacts.pdf

[59] "Chase Stands By RHS Refi Pilot Program, Others Say No", National Mortgage News, June 27th, 2012

the states where the pilot program is in effect.

Figure 48. RHS Speeds Increase, Especially for Pilot Program States



Source: Citi, CPR&CDR

GNMA Turnover, Buyouts and Curtailments

Out-of-the-money GNMA speeds will vary from conventional speeds in three major ways: (1) **less turnover in lower-coupon loans**, due to loan assumptions when market rates are significantly above the loan coupon, (2) **higher and more volatile defaults**, due to poorer credit quality, a significant loss-mitigation component to many pools, and differing buyout practices (GNMA buyout decisions are made by servicers as opposed to the GSEs for conventionals), and (3) **lower curtailments**, since borrowers are generally of lesser financial means than conventional borrowers. The third issue is not very significant for recently issued pools, but we discuss the first two issues in more detail below.

The new model incorporates a modest assumability impact for GNMAs.

Will Assumability Matter for GNMAs? -- FHA and VA allows a prior owner's loan to be assumed by the new owner of a home. While in theory the assumption benefit may be significant for both buyer and seller, there are headwinds to this in practice:

- An assumable loan will often have a materially lower balance than the value of the home. This would require the new owner to get piggyback financing.
- The initiative is taken by the seller, who may attempt to extract a higher price in exchange for offering an assumption of the loan, reducing the benefit for the buyer and the likelihood that an assumption would take place.
- Lenders, who are limited regarding the assumption fee they may charge and would forego origination profit, would not be inclined to promote assumptions.

The Model v20 GNMA prepayment model begins to incorporate loan assumptions when loan coupons reach one point below market, and increases the impact as the gap widens.[60] An upper bound on the impact of assumability might be speeds on 1993 production in 1995 (see Figure 49). Speeds on GNMAs originated during a period of low rates in 1993 fell to about half those on FNMAs as some loan coupons fell almost three points below market. Note that these speeds occurred for modestly seasoned loans during a period of muted home price appreciation. We expect a less dramatic impact on the current GNMA universe, due to higher expected home price appreciation.

Figure 49. GNMA and FNMA Speed Comparisons in 1995: Presumed Impact of Assumability

For 1993 Production (Market rates over 9%)	6s	6.5s	7s	7.5s
GNMA 6m CPR May 1995	1.3	2.1	3.2	4.7
FNMA 6m CPR May 1995	2.5	3.0	3.6	4.2

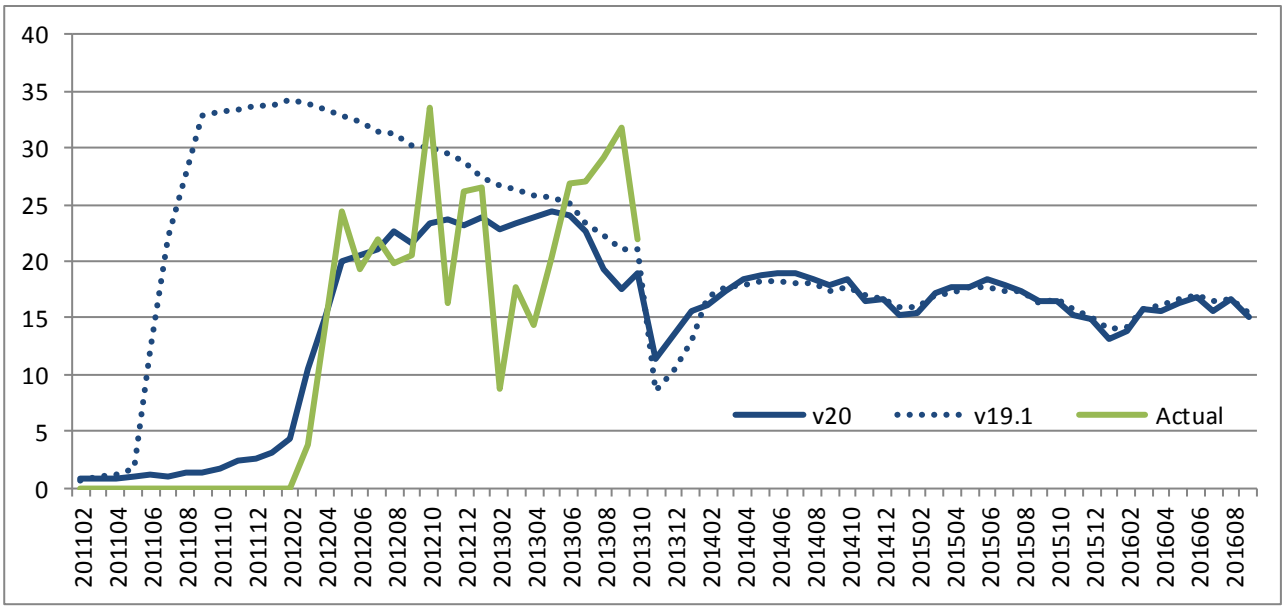
The new model incorporates somewhat lower defaults for GNMAs and refines projections for loss mitigation collateral.

GNMA Default Projections Reduced – GNMA default projections are generally lower in Model v20, based on the same drivers (lower unemployment, higher HPA, better quality originations) for conventional loans. The defaults portion of the agency prepayment model is discussed elsewhere, but GNMA loan defaults are much higher in magnitude than conventional loan defaults, and are driven by other GNMA-specific issues as discussed below.

[60] Assumability could play a larger role in a depressed HPA area. Also, the lack of alternative refinancing options that were available during the housing bubble years may make any assumption related slowing more important for valuation now vs. then.

GNMA Loss Mitigation Collateral: Pay History and Origination Year Important – Modeling for GNMA loss mitigation collateral was introduced in Model v19, but did not account for the period during which the collateral paid clean prior to securitization. Loans pooled immediately after modification tend to show very high re-default rates, but as might be expected, those that pay for a number of months after modification do much better once securitized. Figure 50 shows projections for Model v20 vs. Model v19 on GNMA 2012-12 KN, a CMO tranche backed by loss mitigation collateral that was current at the time of securitization (9 months after modification). It defaulted at a very high but lower rate than Model v19's prediction, which was applicable to collateral securitized immediately after modification. The new model also considers modification date; recent modifications have done better than earlier ones done shortly after the post-crisis modification programs were initiated.

Figure 50. Loss Mitigation Collateral Defaults – Pay History and Modification Period Matter



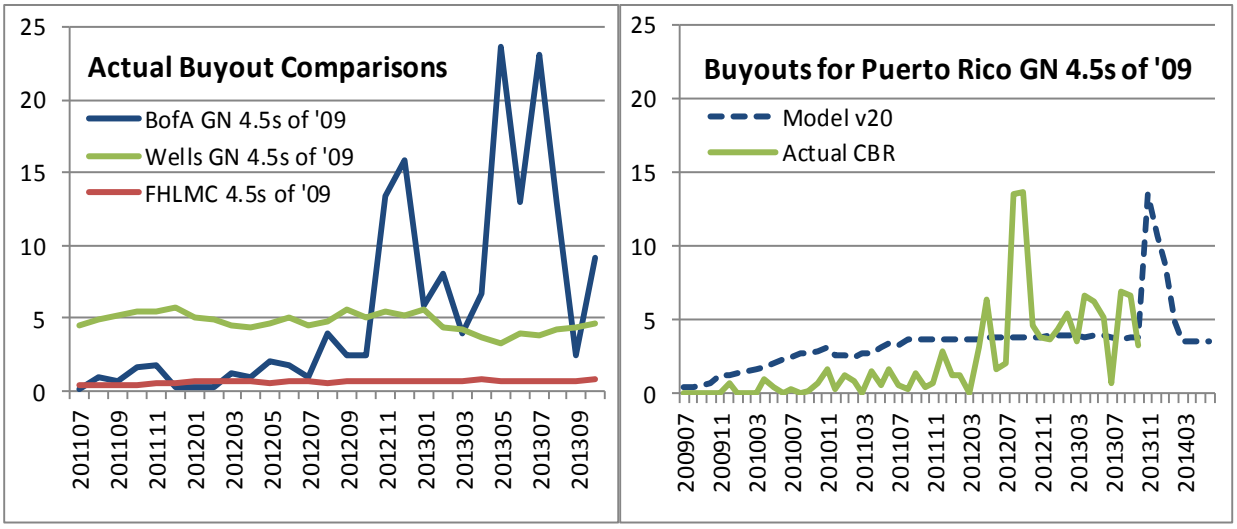
Source: Citi, eMBS

GNMA Model Flushes Out Built-up Delinquencies – Model v20 retains this feature from Model v19, which flags collateral with 90+ day delinquencies that are higher or lower than normal. The prepayment model flushes out the excessive accumulated 90+ day delinquencies that are not expected to cure, and then returns to the original default model projection. It is typically advantageous for a servicer to buy out delinquent loans quickly, because FHA

does not reimburse the full advanced coupon, and servicers must remain below certain delinquency threshholds. Thus, while capital constraints can hinder buyouts, the model assumes buyout of the excess 90+ delinquencies over the next few months.[61]

Buyout practices vary significantly by servicer. For example, Bank of America buyouts have typically been done in large, irregular chunks over recent years, while Wells Fargo tends to buy out loans as soon as permitted. The result is GNMA defaults are more volatile as well as being higher than those on conventionals. The left panel of Figure 51 contrasts Bank of America and Wells Fargo buyouts on 4.5s of 2009, and show defaults on similar FHLMC collateral. The right panel shows actual and Model v20 projected buyouts for GNMA collateral from Puerto Rico, where servicers have generally been slow to buy out delinquent loans; thus a large default spike is generated.

Figure 51. GNMA Buyout Policies Are Servicer Specific – Accumulated 90+ Delinquencies Flushed Out



[61] This feature may be turned off in YieldBook by setting the DQ Resol Prd dial to zero, and may be extended over a longer period by setting the dial to a longer number of months over which 90+ loans that don't cure are assumed to be bought out.

Hybrid ARM Prepayment Model

ARMs have been a fairly small segment of the market since the financial crisis, and currently represent approximately 10% of mortgage originations. But hybrid ARM loans are still attractive to some borrowers, especially more mobile ones, because of their lower rates. Hybrids (i.e., mix of fixed and ARMs) have a fixed rate for an initial term (typically three, five, seven or ten years), after which the rate and payment reset annually based on one-year Treasury or LIBOR rates.

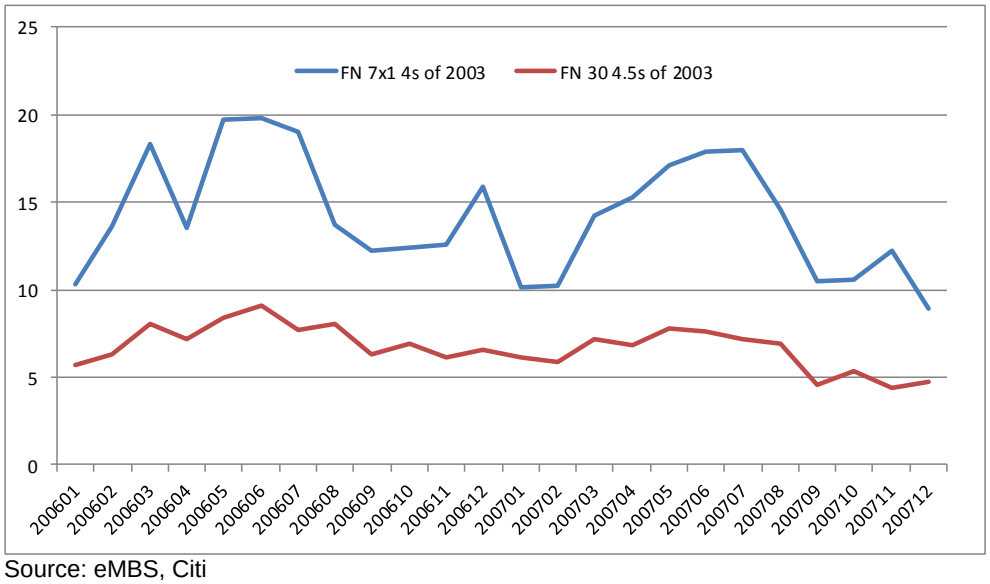
ARM and Fixed-Rate Borrower Similarities – ARM prepayment patterns share common drivers with fixed-rate collateral, and the new Citi hybrid ARM prepayment model (version 20) starts with our 30-year fixed-rate model as the template. Thus many of the new features of the fixed-rate model (improved housing environment, looser underwriting standards, and efficient capacity allocation, as discussed elsewhere) are also new features of the ARM model.

The new ARM model has been restructured using the new fixed-rate model as template.

How ARM Borrowers Are Different – However, as mentioned earlier in the Housing Turnover section, ARM borrowers tend to be more mobile than fixed-rate borrowers; many are motivated to select a hybrid ARM because they expect to move before the initial fixed-rate period expires. Other hybrid ARM borrowers select the product because they expect to refinance the loan prior to the first reset date, so they take the lower rate in exchange for the risk that rates rise in the interim. Thus they tend to be aggressive refinancers when hybrid rates drop (in order to extend their fixed period at a lower rate), when fixed rates become especially attractive (to lock in a favorable rate for the long term), and when the first reset date approaches (in order to reduce future uncertainty about their monthly payment).

Mobility of ARM borrowers – While ARM borrowers are clearly more mobile than fixed borrowers, the multiplier is difficult to determine because turnover cannot easily be separated from refis when examining historical speeds. One comparison that may be informative is the performance of the lowest-coupon 2003 issuance during 2006 and 2007. See Figure 52, in which we compare speeds on hybrid ARMs with a seven-year initial fixed period ("7x1 ARMs") to speeds on 30-year loans. Given that the coupon rates are well below market during this period and defaults were very low, most of the speeds should be turnover. Figure 52 appears to show that ARM borrowers were about twice as mobile during this period.

Figure 52. Relative Mobility of ARM vs. Fixed Borrowers – CPRs for Lower Coupon 2003s in 2006 and 2007



Source: eMBS, Citi

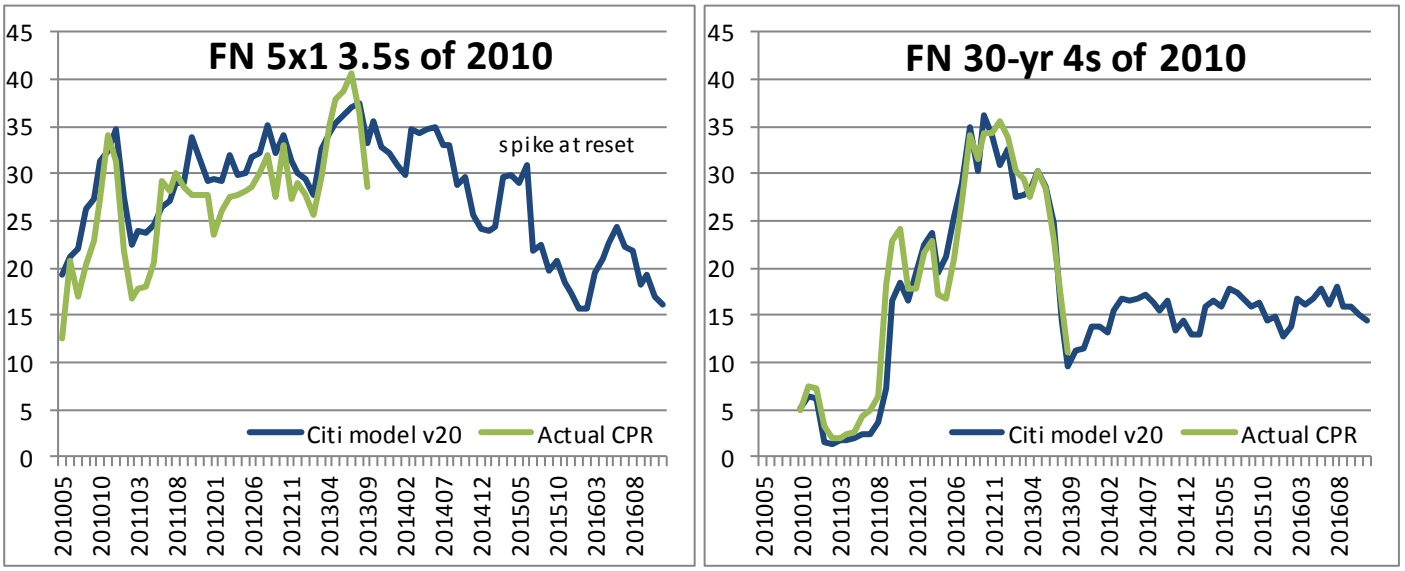
Mobility has been reduced somewhat from the prior model.

In the Citi hybrid model version 20, we have elected to use a mobility multiplier less than twice the value used for fixed-rate collateral, more conservative than what is implied by Figure 52. Strong housing conditions that prevailed during that period likely exaggerate the difference in mobility. Furthermore, even for the relatively high-quality, locked-in collateral shown, a greater portion of the ARM speeds (relative to the fixed-rate speeds) are likely refinancings and defaults.

Capturing Refinancing Patterns for Hybrid Borrowers – Reflecting the discussion above, the new Citi hybrid model has a high baseline level of speeds relative to the fixed-rate model, particularly for shorter initial-period hybrids. But the hybrid model is somewhat less responsive immediately following a rate rally, especially when capacity is constrained, as long-term savings tend to be lower and originators focus on refinancing the more straightforward, highly profitable fixed-to-fixed sector. Finally, the new model reflects the fact that ARM speeds may spike just prior to the first reset and when fixed-to-ARM mortgage rate spreads widen.

Figure 53 compares actual and projected speeds for major 2010 5x1 ARM and fixed cohorts assuming rates unchanged, illustrating these features. Note that the prior hybrid model showed a dramatic spike at first reset (reduced in the new model), but was not sensitive to the fixed-to-ARM mortgage rate spread.

Figure 53. ARM Refinancing Patterns as Compared to Fixed Mortgages



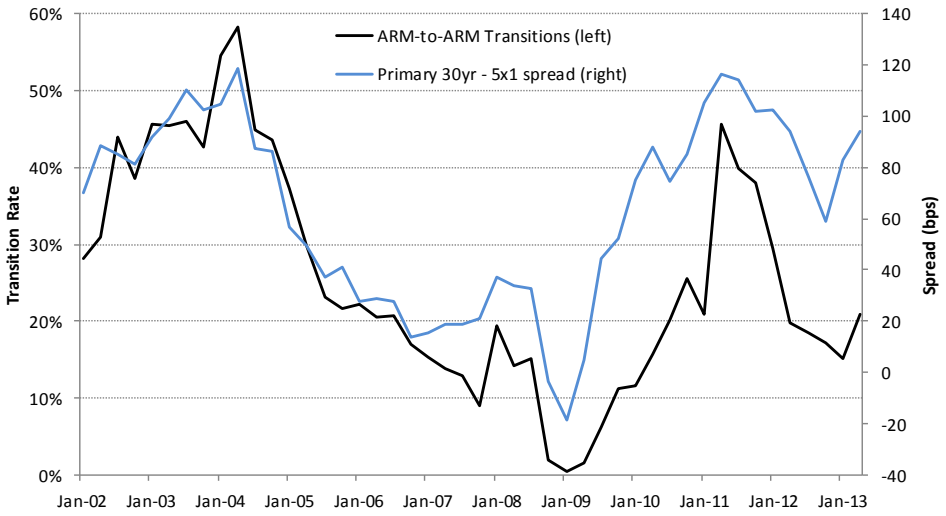
Source: eMBS, Citi

The new model captures the changing relative importance of 30-year and hybrid borrowers as mortgage rate levels and spreads vary.

As mentioned, the new model (in contrast to prior models) is sensitive to the spread between 30-year mortgage rates and hybrid rates, as well as the level of 30-year rates relative to the recent past. This reflects our expectation that when the spread is narrow and fixed rates are low, hybrid ARM borrowers would tend to focus on their opportunity to lock in a low long-term fixed rate. In contrast, when fixed rates are unremarkable and the fixed-to-ARM spread is wide, hybrid borrowers would tend to focus on opportunities to refinance into a lower-rate hybrid. Figure 53 shows that in the second quarter of 2013, ARM speeds increased fairly sharply. This likely reflects, at least in part, the widening spreads between fixed rates and ARM rates during the first half of 2013.

A comparison of the 30-year/5x1 mortgage rate spread to ARM-to-ARM refinancing transitions, shown in Figure 54, provides further evidence along the same lines; the correlation is quite high (although absolute ARM-to-ARM transitions were lower recently amid record low fixed rates and higher risk-aversion). The new Citi hybrid model captures this effect by shifting borrower incentives between the 30-year rate and 5x1 mortgage rates, based on the mortgage rate environment.

Figure 54. ARM-to-ARM Transition Rates Versus 30-year / 5x1 Mortgage Rates

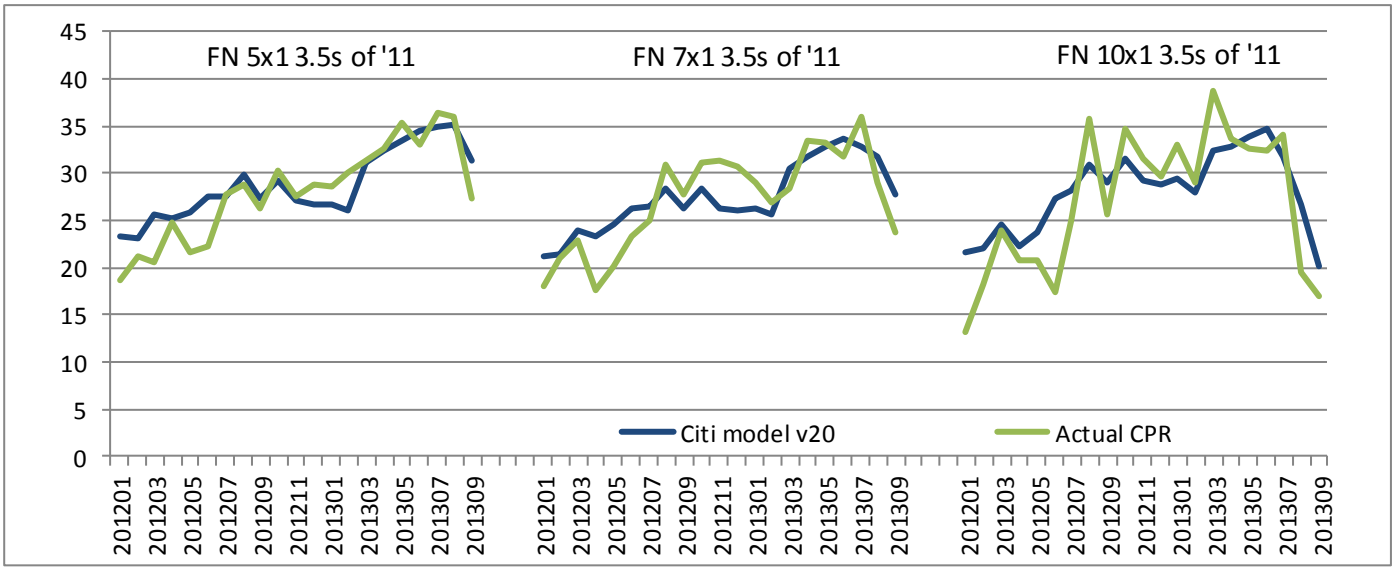


Source: FHLMC, Citi

Influence of Initial Fixed Period Length on Prepayments – Baseline refinancing speeds tend to be higher the shorter the initial period. For example, when comparing 5x1 ARM borrowers to 10x1 borrowers it seems likely that more of the former are consciously taking a rate risk in exchange for a lower rate, and therefore more likely to mitigate the risk by refinancing when their means allow or opportunities present themselves. On the other hand, 10x1 borrowers have a long time to first reset, and to a greater extent than 5x1 borrowers, their refinancing is driven by economic gain rather than risk mitigation. Thus their refinancing pattern will look closer to that of a 30-year borrower.

Figure 55 shows how the pattern of the refinancing response to rate changes differed among 5x1, 7x1 and 10x1 borrowers in 2012, illustrating the patterns just discussed and the efforts of Citi's model to capture them. While noisy, the data seem to justify the model assumptions. The shorter hybrid models generate significant refis even at negative incentives (reflecting the risk mitigation just discussed), are relatively less responsive in a rally, and have a material sensitivity to spreads between fixed and hybrid mortgage rates. All of these effects become less and less important as the initial hybrid term increases, until the pattern begins to resemble 30-year collateral.

Figure 55. Hybrid ARM Refinancing Becomes More Reactive to Rates as Initial Fixed-Rate Period Increases



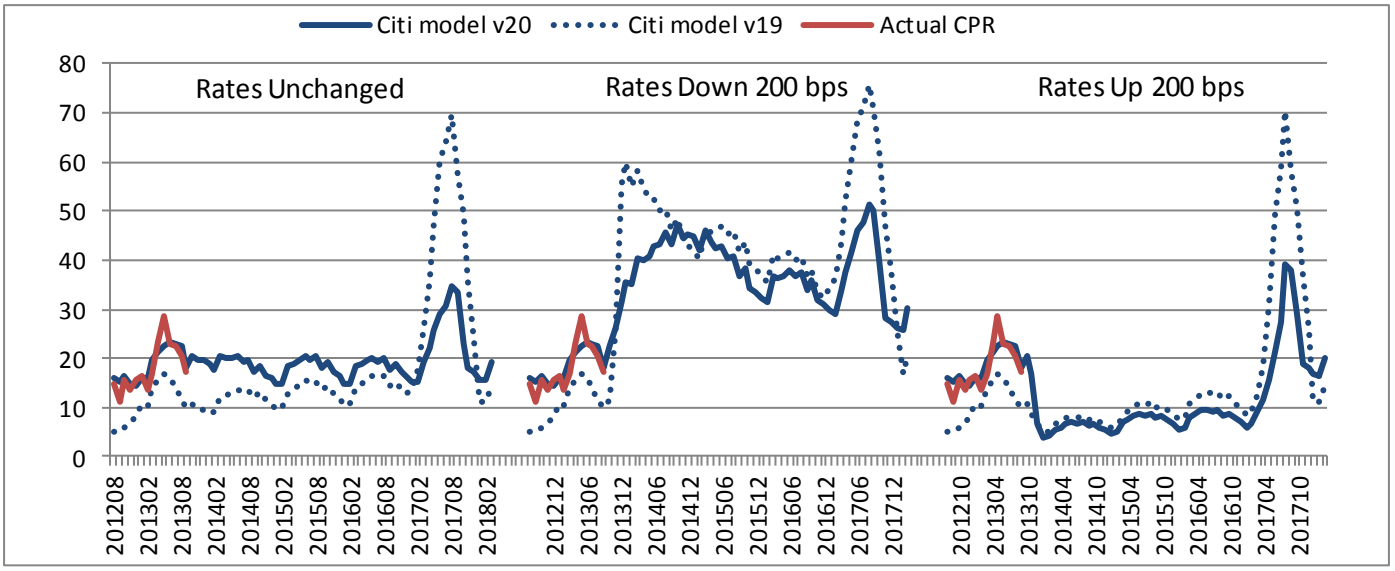
Source: eMBS, Citi

The new model reduces the spike at reset and makes it more sensitive to rate levels.

Speeds at Reset – Historically, hybrid ARMs have been associated with a spike in speeds at reset, based on the assumption that ARM borrowers who do not otherwise move or refinance hang onto their low rate as long as possible, and then refinance in large numbers before their interest rate begins to float. The new model assumes a smaller and more interest-rate sensitive spike than the older model. The magnitudes of recent spikes at reset are difficult to evaluate, due to the influence of HARP and the long period of very low short interest rates. In any event, we do not believe that the spikes will reach 70 CPR regardless of interest rates, as the old model assumed (some of this was influenced by low teaser rates available in the past). Rather, the spike will be more modest overall, and be larger relative to baseline speeds levels if the borrower's WAC is increasing, as opposed to if it is remaining about the same or decreasing.

Figure 56 shows prepayment projections on recently issue 5x1s for different interest-rate scenarios for both the new (v20) and the old (v19) models. In addition to illustrating the changes in the spike at reset, the chart illustrates the higher baseline speeds in the new model, the slightly lower mobility, and the impact of efficient originator capacity utilization during a rally, as discussed earlier.

Figure 56. Refinancing Spikes at Reset for Recent FNMA 5x1 Issuance (2s of 2012) Under Different Rate Scenarios



Source: eMBS, Citi

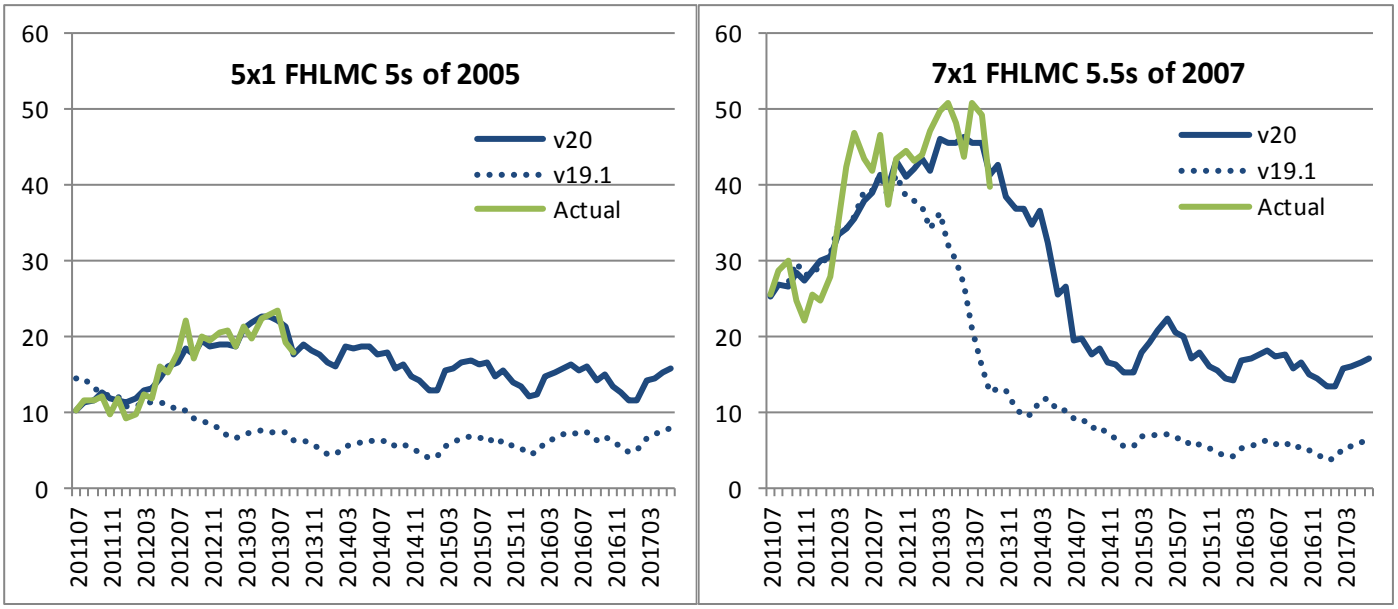
The new model increases speeds sharply on seasoned ARMs, both pre- and post-reset, due to both HARP and a smaller drop in turnover after reset.

Speeds on Seasoned and Post-Reset Borrowers – Seasoned ARM speeds, both pre- and post-reset, have been relatively fast on hybrids. We believe this has resulted both from the HARP program, which encourages refinances into more stable products, and record low interest rates. Seasoned ARM borrowers can refinance into a fixed-rate loan, eliminating payment risk from rising rates. With respect to monthly payment, the resulting increase from the currently very low fully-indexed ARM rates to higher fixed rates is offset, at least in part, by the extension of their term for those refinancing into 30-year fixed loans.

Figure 57 shows the sharply higher seasoned speeds in the new model (v20) in comparison to the older (v19) model. As for the fixed-rate model, the ARM model assumes a more significant HARP response for a given interest-rate incentive. So while HARP speeds have declined due to higher rates, the intensity of the response to a given incentive is higher. Burnout in some "early adopters" like Chase and Wells are offset by higher speeds from other servicers, particularly relatively new servicers that have purchased servicing from Bank of America and others. The high-coupon pre-reset cohorts were and continue to be very responsive to HARP, with speeds in the 40s and 50s like HARP-able fixed rate loans.

Note that the increase in prepayment projections for seasoned ARMs also includes higher turnover, which does not drop as quickly after reset in the new model as compared to the old.

Figure 57. Seasoned Conventional ARMs – Responding to HARP



Source: eMBS, Citi

GNMA ARMs are generally much faster in the new model.

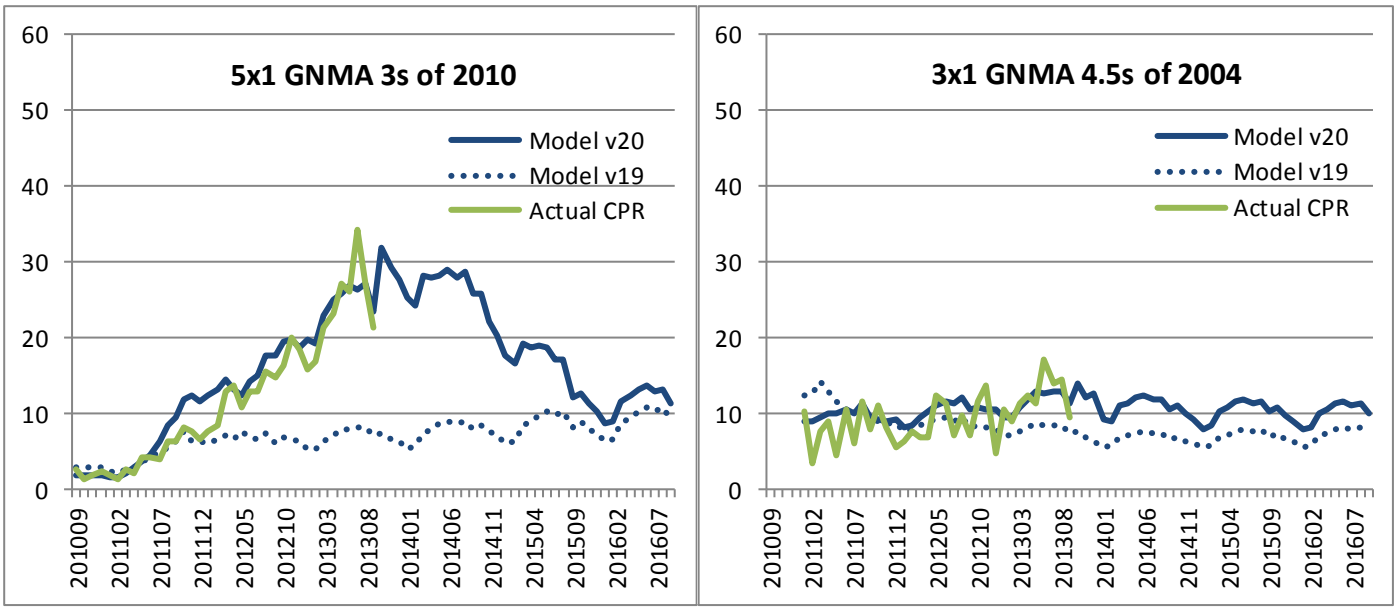
GNMA ARMs -- GNMA ARMs differ from conventionals in many of the ways fixed GNMA loans differ from conventionals (higher LTVs, lower FICOs, availability of streamlined refinance options to most borrowers, mortgage insurance premiums paid to one of the four guarantors, higher and more volatile buyout component to speeds); these are discussed in more detail earlier in the GNMA fixed-rate prepayment section. Relative to conventionals, we assume that GNMA ARM borrowers tend to select hybrids more for their lower initial payments than because of a short tenure horizon. This results in faster speeds pre-reset, as borrowers aggressively mitigate their risk when they have an opportunity to refinance into an affordable fixed-rate loan. Conversely, however, GNMA speeds post-reset seem to be slower than conventionals. We believe this results from lower mobility of GNMA relative to conventional ARM borrowers, lower periodic caps and a residual of borrowers that wish to hang onto the lower payment offered by the ARM.

The new ARM model considers delinquency data when projecting short-term GNMA buyouts.

As mentioned, buyouts are a larger and more important component of speeds for GNMAs; this is true for both ARMs and conventionals. Many servicers are aggressive in buying out delinquent high coupon fixed-rate loans, but as might be expected, less so for lower-coupon and lower-duration ARMs. This may result in periodic sharp spikes in GNMA ARM speeds if 90+ loans accumulate and lenders later buy out in bulk. The new ARM model considers delinquency data and projects a short-term spike in speeds if 90+ delinquencies are high.

Figure 58 shows actual and both new (v20) and old (v19) model speeds for both a pre- and post-reset GNMA ARM cohort, illustrating the points discussed above.

Figure 58. GNMA ARM Pre- and Post-Reset Speeds: Actual vs. Projected



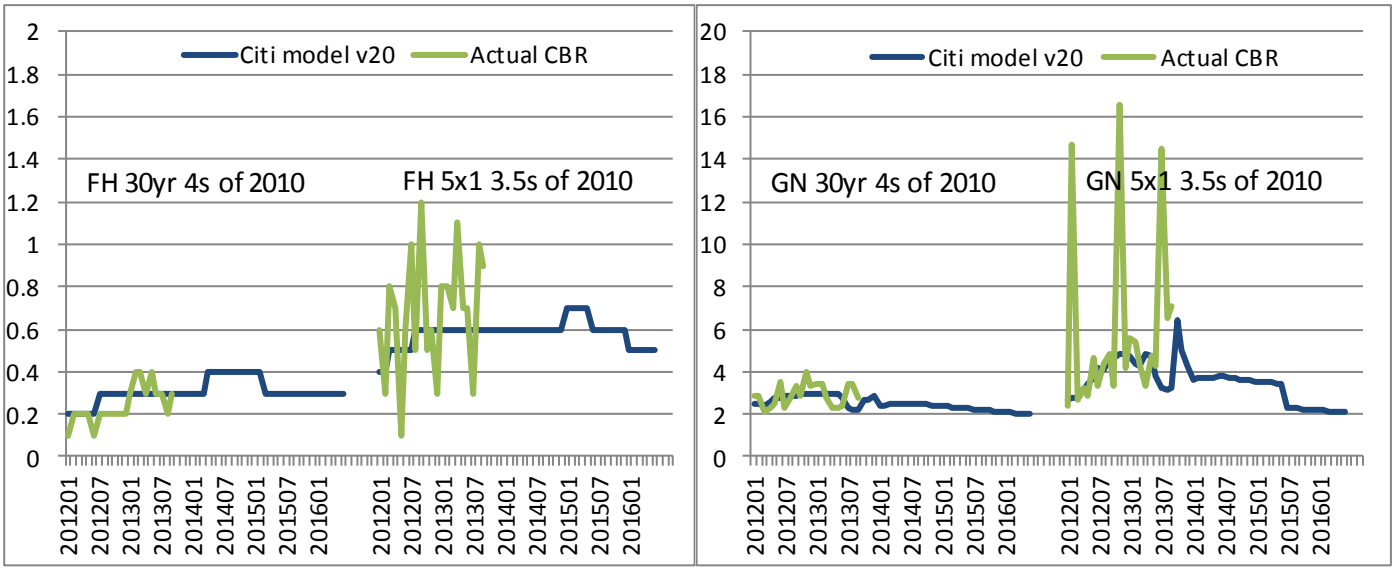
Source: eMBS, Citi

Buyout projections are higher in the new ARM model, particularly for GNMAs.

Buyouts/Defaults for ARMs – All else being equal, buyouts for ARMs are somewhat higher than on fixed-rate collateral. This may not be surprising, as ARM borrowers are likely less risk-averse than fixed-rate borrowers, and may use the product as a means to stretch their resources. In general, buyout projections have been increased for ARMs in the new model, in contrast to fixed-rate collateral for which defaults were decreased (as discussed elsewhere). While more important for GNMAs than conventionals, this increase is part of the explanation for higher ARM projections in the new model.

Figure 59 compares actual buyouts versus model v20 projected buyouts for fixed and ARM collateral, for both FHLMC and GNMA. Defaults / buyouts are running about twice as high for 2010 originations for the ARM cohorts as opposed to fixed. Both the old and new ARM models adjust defaults after reset based on the change in rate and payment; a modest drop can be seen in the charts at reset, since the rate and payment will drop in the static interest rate scenario.

Figure 59. ARM Buyout Rates as Compared to Fixed



Source: eMBS, Citi

New vs. old ARM model valuations: OASs wider and duration longer for new longer-dated ARMs; OASs tighter and durations shorter for seasoned ARMs.

Valuation implications for ARMs – Figure 60 compares valuations for several ARM pools, showing valuation differences. New, longer hybrid conventional production has wider OASs and longer durations due to lower turnover, a smaller spike at reset, and lower rate sensitivity. This is offset by higher baseline refis and defaults for more seasoned, higher-coupon collateral. Post-reset conventional ARM OASs are tighter and durations shorter, due to both higher turnover and higher refis (driven in part by HARP). For GNMAs, higher pre-reset refis and defaults are offset from the valuation perspective by lower rate sensitivity and lower turnover.

Figure 60. Valuation changes (model v19 to model v20) for selected ARM pools

Pool	Description	Price	LT CPR	Change	OAS	Change	Spread Dur	Change
FH 849147	2.8% '13 10x1	101-12	8.9	-4.8	10.6	+9.4	6.4	+1.4
FH 2B0913	2.7% '12 10x1	101-09	9.1	-3.5	18.7	+10.9	6.2	+0.9
FN AL4270	2.3% '13 7x1	101-09	11.8	-1.7	15.3	+7.2	5.5	+0.5
FH 849145	3.8% '10 7x1	106-10	21.7	+4.3	37.9	-18.4	3.5	-0.5
FN AL4267	2.4% '12 5x1	104-11	20.0	+2.9	12.6	-5.9	3.7	-0.2
FN 922680	'04 post-reset	106-24	15.8	+8.2	32.9	-49.7	4.1	-1.9
G2 MA0100	2.5% '12 5x1	103-21	16.5	+3.7	14.8	+1.2	5.5	0.2
G2 82889	3.5% '11 5x1	105-30	19.1	+6.2	38.2	-5.2	4.8	-0.2

As of October 18, 2013 close. Source: YieldBook, Citi

Drivers of Discount Coupon Valuation

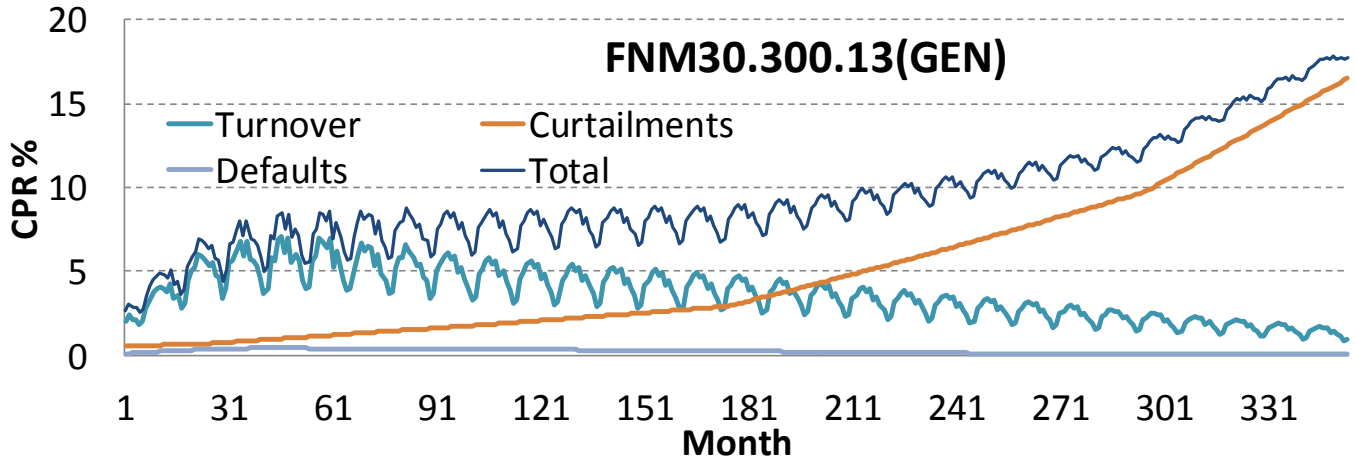
The May to August 2013 back-up in rates resulted in a large portion of the mortgage universe moving out-of-the-money for refinancing. While it is well known that housing turnover is an important driver of out-of-the-money prepayments and discount coupon valuation, the importance of defaults and curtailments/full payoffs are less well known. Figure 61 breaks down projected prepayments for different collateral types into these three components, showing that housing turnover is indeed the most important component for generic 30-year out-of-the-money collateral like new 30-year 3s (top chart). However, this is either not the case or true to a lesser degree for 15-year, high LTV, and seasoned collateral:

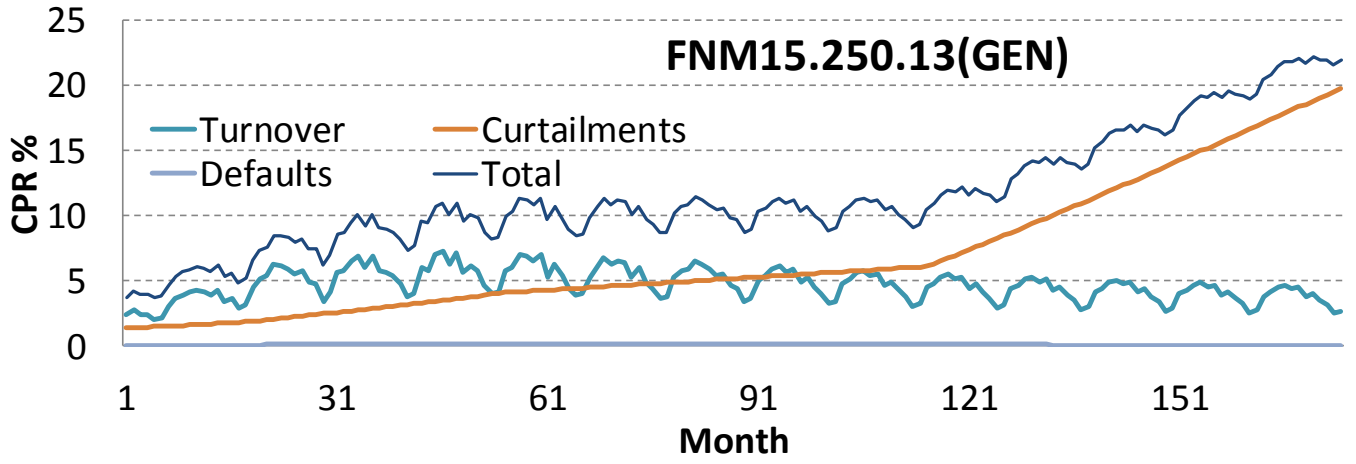
1) **15-Year** – As discussed earlier, 15-year collateral has relatively high levels of curtailments since these borrowers tend to dislike debt and desire being out of debt as quickly as possible. Unlike 30-year collateral in the top chart whose curtailments ramp up more slowly, 15-year curtailments shown in the middle chart of Figure 61 surpass turnover around the seventh year.

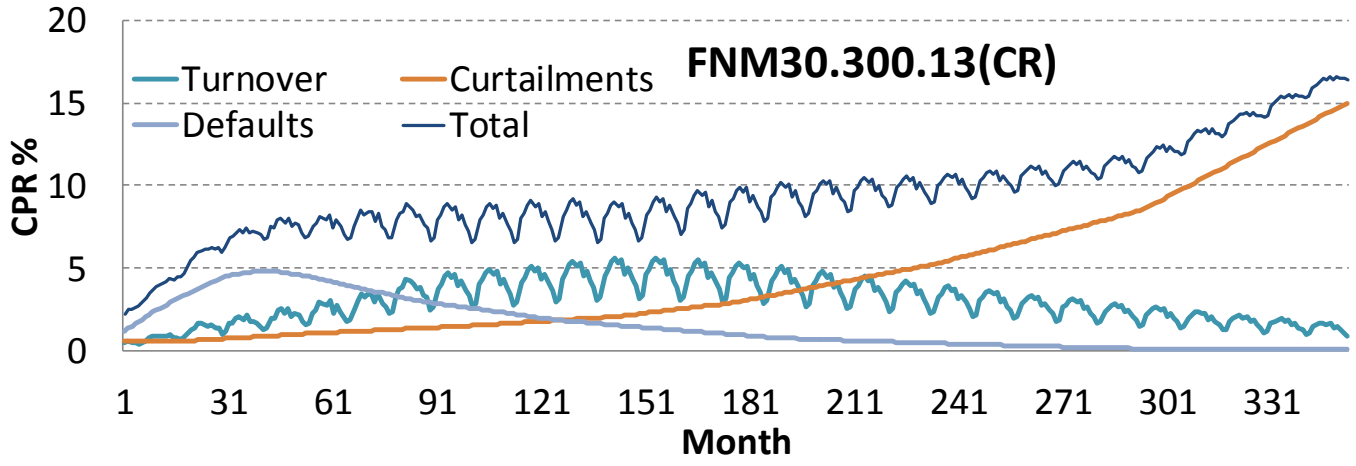
2) **High LTV** – The aftermath of the housing bubble created a large pool of borrowers who are either underwater or nearly underwater on their mortgages. Not only are defaults a larger component of their prepayment speeds, but turnover and curtailments are also smaller when compared against the corresponding components for lower LTV collateral since it is only natural that the stresses that lead to default would also make it difficult to move and/or pay more than one's scheduled monthly mortgage payment. As a result, defaults are the largest component of CR speeds for the first several years – for example, the default component of the prepayment model for very high LTV 3% coupon CR pools shown in the bottom chart in Figure 61 can be seen to be the largest component for the first seven years.

3) **Super Seasoned Collateral** – Curtailments and full payoffs can ramp up dramatically for very old collateral nearing maturity as seen from the right parts of the charts in Figure 61. As discussed earlier, full payoffs tend to occur for super-seasoned collateral nearing maturity.

Figure 61. Model Components Breakdown – 2013 Orig Yr 30-Yr 3s, 15-Yr 2.5s and 30-Yr CR 3s Monthly Projections







Source: Yield Book, Citi

Quantifying Relative Importance of Each Component – For OAS analysis, the importance of turnover, defaults/buyouts, and curtailments/full payoffs is even greater when the yield curve is steep and the forward path of interest rates implies rising rates. One way we can attempt to quantify the importance of each component is by computing the constant OAS impact of each component on price (for example, the price impact of reducing that component by say 10% at constant OAS) and then expressing the price change due to each component as a percentage of the total impact.

Turnover % Impact = Turnover Price Impact / [Turnover Price Impact

+ Default/Buyout Price Impact + Curtailment/Full Payoff Price Impact

+ Refinancing Price Impact]

This approach is used for discount/low coupons in Figure 62, which shows in the last four columns that:

1) Turnover is generally the most important component – for example, turnover represents 60% of the constant OAS price impact resulting from slowing the model by 10% for generic 30-year 3s.

2) Defaults are most important for 30-year CR 3s, representing 52% of the constant OAS price impact (vs a 28% contribution from turnover).

3) Curtailments/Full Payoffs, while not as important as housing turnover for 30-year collateral, are still a substantial fraction of the constant OAS price impact, generally contributing about 30% or more of the total price impact.

4) For 15-Yr collateral, curtailments are generally the largest contributor to the constant OAS price impact.

Figure 62. Model Component Contribution (Last 4 Columns) to Total Price Impact Due to 10% Mdl Slowdown (Const OAS)

	Class	Out Amt ($b)	WAC	WAM	Age	Payup	Price	OAS	Eff Dur	Eff Conv	Turnover %	Refi %	Default %	Curt %
30YR 3.0	TBA	-	3.75	358	2		96-15:0	13	8.0	0.0	61%	-11%	7%	42%
	GEN	202.1	3.59	352	5		96-15:0	18	8.0	0.0	60%	-9%	7%	41%
	LLB	2.0	3.55	351	6	0-01	96-16:0	30	8.0	0.4	63%	-4%	6%	35%
	MLB	3.8	3.56	352	5	0-00+	96-15:4	27	8.0	0.3	62%	-5%	6%	36%
	HLB	8.7	3.57	352	6	0-00	96-15:0	25	8.0	0.3	61%	-6%	7%	38%
	INV100	1.4	3.70	352	7	0-00	96-15:0	19	7.9	0.0	61%	-8%	4%	42%
	MHA90C	2.2	3.67	349	7	0-00	96-15:0	24	7.8	0.1	57%	-7%	14%	36%
	MHA95	1.3	3.65	350	6	0-00+	96-15:4	23	7.9	0.1	55%	-7%	16%	36%
	MHA100	1.0	3.65	350	6	0-00+	96-15:4	25	7.9	0.2	53%	-6%	20%	33%
	MHA105	0.8	3.65	349	6	0-01	96-16:0	26	7.9	0.3	50%	-6%	24%	31%
	CQ	3.6	3.71	323	6	-1-00	95-15:0	55	7.5	0.4	45%	-4%	30%	29%
	CR	3.0	3.76	333	6	-1-08	95-07:0	64	7.3	0.6	28%	-3%	52%	22%
30YR 3.5	TBA	-	4.25	356	4		100-22:6	8	7.3	-0.5	68%	-31%	9%	54%
	GEN	94.1	4.01	354	4		100-22:6	17	7.4	0.0	56%	-19%	20%	42%
	LLB	3.0	3.96	351	5	0-05	100-27:6	26	7.5	0.3	59%	-9%	15%	36%
	MLB	4.5	3.96	352	5	0-03	100-25:6	25	7.5	0.2	58%	-11%	16%	37%
	HLB	9.1	3.98	352	4	0-01+	100-24:2	23	7.5	0.1	56%	-12%	18%	38%
	INV100	4.7	4.09	353	6	0-01	100-23:6	14	7.4	-0.2	61%	-21%	10%	51%
	MHA90C	2.5	4.07	349	5	0-00+	100-23:2	20	7.2	0.0	53%	-16%	27%	36%
	MHA95	2.4	4.01	351	5	0-00+	100-23:2	22	7.3	0.1	50%	-14%	31%	34%
	MHA100	2.7	4.00	350	5	0-01	100-23:6	24	7.3	0.1	47%	-13%	35%	31%
	MHA105	2.8	3.99	350	5	0-02	100-24:6	24	7.3	0.2	45%	-12%	37%	30%
	CQ	10.2	4.09	343	5	-0-28	99-26:6	44	7.2	0.3	40%	-8%	44%	25%
	CR	10.7	4.13	343	5	-1-04	99-18:6	61	6.8	0.5	22%	-5%	66%	16%
15YR 2.5	TBA	-	3.00	178	2		99-17:4	15	5.2	0.1	46%	-6%	1%	60%
	GEN	66.9	2.94	174	5		99-17:4	20	5.0	0.1	45%	-6%	2%	59%
	LLB	2.4	2.96	171	5	0-00+	99-18:0	27	5.0	0.2	49%	-1%	2%	50%
	MLB	3.2	2.95	172	5	0-00+	99-18:0	26	5.0	0.2	49%	-2%	2%	51%
	HLB	6.5	2.94	173	5	0-00	99-17:4	24	5.0	0.2	47%	-3%	2%	53%
	INV100	0.2	3.19	174	6	0-00	99-17:4	21	5.0	0.1	45%	-5%	2%	58%
	MHA90C	0.8	2.99	173	6	0-00	99-17:4	21	5.0	0.2	45%	-5%	4%	55%
	MHA95	0.4	3.01	174	6	0-00	99-17:4	21	5.1	0.2	45%	-4%	5%	54%
	MHA100	0.2	2.99	174	6	0-00+	99-18:0	21	5.1	0.2	45%	-4%	6%	52%
	MHA105	0.3	3.00	174	5	0-01	99-18:4	20	5.1	0.3	45%	-3%	7%	51%
	CV	0.7	3.02	173	5	-1-24	97-25:4	57	5.2	0.3	46%	-2%	8%	48%
	CW	0.4	3.06	173	5	-1-24	97-25:4	55	5.3	0.4	39%	-1%	13%	49%
15YR 3.0	TBA	-	3.50	158	22		102-21:4	10	3.9	-0.7	53%	-66%	2%	111%
	GEN	13.5	3.49	174	3		102-21:4	7	4.8	0.0	42%	-17%	6%	70%
	LLB	1.8	3.52	170	4	0-02	102-23:4	13	4.8	0.2	43%	-5%	5%	56%
	MLB	1.5	3.49	172	4	0-01+	102-23:0	12	4.8	0.2	44%	-7%	5%	58%
	HLB	2.1	3.49	173	4	0-00+	102-22:0	10	4.8	0.1	43%	-10%	6%	61%
	INV100	0.3	3.57	175	4	0-00+	102-22:0	5	4.8	0.0	40%	-20%	4%	76%
	MHA90C	0.1	3.55	175	4	0-00+	102-22:0	7	4.9	0.0	41%	-13%	11%	62%
	MHA95	0.1	3.51	173	5	0-00+	102-22:0	9	4.9	0.1	41%	-11%	11%	59%
	MHA100	0.1	3.49	174	4	0-01	102-22:4	8	4.9	0.1	42%	-12%	12%	58%
	MHA105	0.2	3.46	174	5	0-02	102-23:4	9	5.0	0.1	42%	-9%	10%	57%
	CV	0.7	3.48	174	5	-1-16	101-05:4	41	5.0	0.2	44%	-5%	13%	48%
	CW	0.6	3.50	174	5	-1-16	101-05:4	41	5.2	0.3	37%	-3%	18%	47%

2013 Origination Collateral As of Sep 2013 shown. Source: Yield Book, Citi

Mortgage Index Impact – More Callable

The updated Citigroup Prepayment Model[62] on Yield Book generally assumes greater callability due to rising home prices, looser underwriting, and greater refinancing efficiency.[63] As seen in Figure 63, the Mortgage Index tightens around 10 bp relative to the old Yield Book production model. Durations shorten, more so in a large rally.

Figure 63. Citi Mortgage Index Valuation Measures in Base Case Scenario (top), Up 100 bps (middle), Down 100 bps (bottom) – Yield Book New Model Version V20 and Change from Current Production Model V19.1 – Close of Nov 12, 2013

Base Case	LTCPR	Chg	OAS	Chg	Edur	Chg	Ecvx	Chg	VolDur	Chg
Mortgage Index	14.4	1.9	16	-10	5.0	-0.3	-1.1	-0.1	0.11	0.01
FNMA 30 & 15 Year	14.3	1.7	19	-9	5.0	-0.2	-1.0	0.0	0.10	0.00
GNMA 30 & 15 Year	13.6	1.7	2	-13	5.4	-0.3	-1.4	-0.4	0.15	0.02

Up 100 bps	LTCPR	Chg	OAS	Chg	Edur	Chg	Ecvx	Chg	VolDur	Chg
Mortgage Index	9.5	0.7	16	-10	6.0	-0.1	-0.4	-0.3	0.11	0.01
FNMA 30 & 15 Year	9.6	0.8	19	-9	5.9	-0.2	-0.4	-0.2	0.10	0.01
GNMA 30 & 15 Year	8.9	0.3	2	-13	6.5	0.0	-0.5	-0.4	0.15	0.03

Down 100 bps	LTCPR	Chg	OAS	Chg	Edur	Chg	Ecvx	Chg	VolDur	Chg
Mortgage Index	23.4	3.0	16	-10	3.5	-0.5	-1.3	-0.7	0.08	0.00
FNMA 30 & 15 Year	22.8	2.1	19	-9	3.6	-0.4	-1.3	-0.8	0.08	0.00
GNMA 30 & 15 Year	23.9	4.5	2	-13	3.6	-0.7	-1.6	-0.7	0.11	0.00

Note: Rate shifts are immediate. Source: Yield Book, Citi

Ginnie Mae Impacted More – The tightening in OAS and shortening in duration is greater for the Ginnie Mae sector, reflecting how FHA/VA borrowers are more leveraged to HPA and loosening underwriting. The new prepayment model assumes that rising borrower equity in combination with terms for Private Mortgage Insurance being more advantageous relative to FHA Mortgage Insurance is causing FHA to conventional refinancings to increase.

Greater Reactivity In Large Rally – As discussed earlier, the impact of TPO has been enhanced, which results in the new model being more reactive to rates and exhibiting worse convexity in a large rally like down 100 bps in Figure 63, a rally which would bring mortgage rates back to around historic lows.

[62] We previewed the new model for clients on July 18, 2013.

[63] There are two notable exceptions to the new model being more callable: 15-year and low loan balance collateral. We discuss this earlier in this paper.

Appendix I – Additional New Model Features

Convergence to Current Loan Size: In model v19.1, the current loan size evolved from the original loan size within the model, based on model projected prepayments and amortization. The model current loan size is an internal parameter in that model, is not directly accessible by the user or modifiable through *Modify Collateral*. Moreover, for seasoned collateral it was quite possible that model-estimated current loan size could deviate substantially from the actual current loan size. In the new model the current loan size is now a direct input. As a result, changing either original or current weighted average loan sizes within *Modify Collateral* will impact the new model. In the new model original loan size will only affect past projections and burnout, as it now amortizes to the explicitly provided current loan size.

Power Decay Weighted Average Loan Size Methodology: The weighted average loan size is a very important input parameter within the prepay model. In cases where this number is provided by the agency or the data to compute it exactly is provided (such as loan level data) the exact value is used. However, in many cases, the agencies do not provide either the weighted average loan size or the data elements necessary to compute it. In these cases, the loan size quartiles are used to estimate this value. This method was found to place too much weight on the extreme values; pools with extreme maximum or minimum loan sizes (for example, GNMA II pools that can have loans ranging from $10,000 to the $1 million plus loans allowed by VA in some counties) can have skewed estimates. The new model employs a power decay methodology which shifts weight away from the minimum and maximum values. The resulting methodology, when applied to FHLMC pools, produces an extremely good fit to actual weighted average loan sizes computed from loan level data.

Figure 64. New Power Decay Method Loan Size vs Old Prepay Model Loan Size for GN II Cohorts and CMOs

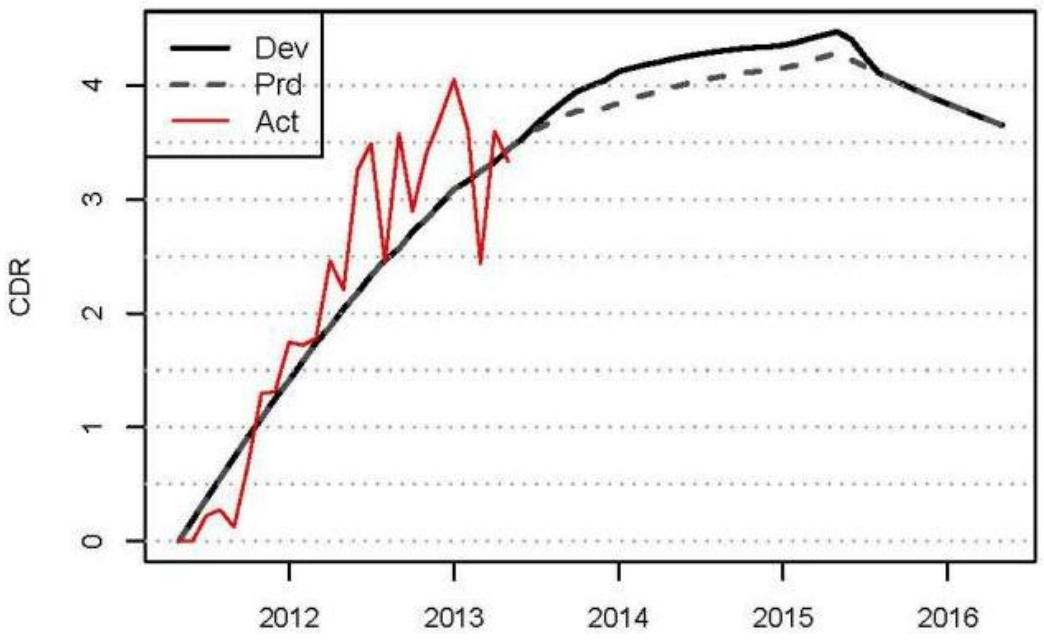
Ginnie Mae II Cohort/ CMO	Old Loan Size	Power Decay Loan Size
3.5s of 2012	270K	248K
4s of 11	263K	237K
GNR 10-26 QE	272K	239K
GNR 10-20 SE	254K	227K

Source: Citi

FHFA Streamlined Modification Program: The FHFA announced its Streamlined Modification Initiative on March 27, 2013 allowing eligible borrowers who are at least 90 days delinquent with LTVs above 80 to bypass the requirement to document financial hardship before receiving a streamlined modification. Certain underwater borrowers with LTVs would also be eligible for principal forbearance. The program was to expire in August 2015, but was later extended (along with the older Home Affordable Modification Program, or HAMP) until year-end 2015.

While the GSEs indicated that they would be screening for strategic defaults, this program nonetheless raises the possibility that borrowers may use strategic defaults in order to gain significant rate and/or payment reduction benefits, as well as possible forbearance. Figure 65 is a snapshot from the when the model adjustment was first made, showing the increase in defaults that might occur as a result of "moral hazard." Our new model initially assumed that defaults could increase 1-2 CDR in certain cases as a result; but with rates higher now and LTVs lower, we now assume the impact would be more modest.

Figure 65. Streamlined Modification Program – Freddie U6 5s of 2011 ("Dev" Shows Model Impact of Streamlined Mods)



Source: Citi.

Appendix II – Coming Attractions

We have a number of additional improvements in the pipeline to supplement the advances already made from Model v19 to Model v20.

Subordinated Financing – Second lien and combined LTV information will be added as drivers to the refinancing component of the model. While captured to some extent by other variables in the current model, subordinated financing appears to slow down post-HARP refinancings to the point that a separate driver may be needed.

Defaults/Buyouts -- We expect to further enhance the default component of the agency model in light of the increasing importance of agency risk-sharing deals. Default projections from the agency prepayment model have historically been used for what is generally a minor component of agency prepayments, but now are being used to evaluate tranches subject to credit losses. The credit data provided by the GSEs in preparation for their initial deals was used in the fitting of Model v20, but we intend to further upgrade the model to a non-agency model standard by adding or using existing parameters related to HPA, DTI and subordinated financing, among others, followed by an extensive re-fitting.

Smaller Servicer Adjustments -- The existing model has servicer adjustments for four of the largest historical servicers (Wells Fargo, JP Morgan Chase, CitiMortgage and Bank of America/Countrywide), primarily used to differentiate HARP response. Given the changes in the marketplace and the increasing importance of some smaller servicers, especially in the context of multiple-issuer "cash-window" pools, we are planning to expand our servicer coverage.

Loss Mitigation Collateral / Re-performers – While making up a small portion of the universe, these pools have become more important in recent months. FHLMC has begun to pool modified loans, and synthetic securities have been tied to the FHLMC "R" re-performer pools. Model v20 has parameters to capture higher involuntary and lower voluntary prepayments for these pools. But a limited data history and missing data elements dictate caution when using the model output for these pools. GNMA projections are the most reliable, as we began to cover GNMA loss mitigation collateral in Model v19 and made further improvements (discussed in the body of the paper) for Model v20.

Short-Term Adjustments – Recent Citi agency prepayment models (including Model v20) have not made short-term adjustments to near-term projections (based on information such as the MBA refinancing index, short-term market

conditions, mortgage industry employment levels, and abnormal day-count expectations) . We tried to incorporate such a feature in earlier models with mixed results; we are considering another attempt (as an option, likely not the default), given the importance of short-term projections to many users.

Accelerated burnout – Early evidence following the sharp rate backup in mid-2013 suggests a sudden drop in solicitation for several collateral categories, since it is no longer possible to offer deals comparable or better to prior offers. There is likely also some disruption from rapid capacity reduction. These factors could cause especially sharp drops in speeds for partially burned-out, cuspier collateral that relies heavily on lender solicitation to drive speeds. Cohorts that appear to be affected the most are lower-coupon HARP-eligible collateral and post-HARP 4.5s and 5s.

Rate Adjustments -- The existing agency model incorporates a single rate adjustment that includes GSE LLPAs (based on original FICO, current LTV and occupancy status), underwriter overlays and changes in collateral attributes over time. We expect to separate the rate adjustment into two components. The first will be computed solely from the LLPA matrices (despite the drawbacks of using the inexact inputs available), including other relevant factors besides credit score, LTV and occupancy status (e.g., cash-out refis, presence of subordinated financing). The remainder will represent other factors.

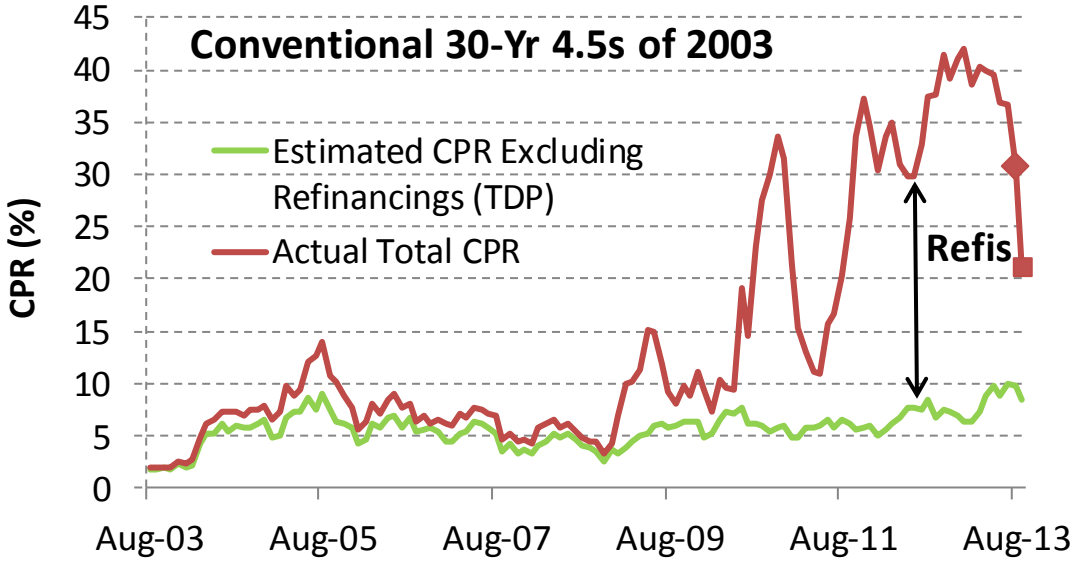
Collateral-Specific Dispersion – Model v20, like prior Citi agency prepayment models, has assumed that dispersion of variables such as WAC, LTV, FICO and WALA does not vary enough from pool to pool to significantly affect relative speeds. (The model does account for loan size dispersion based on either loan-level data or disclosed quartile information, and incorporates WALA dispersion when estimating variables such as SATO and eligibility for HARP.) While it is clear that this assumption will occasionally be false, in practice this issue has rarely come up; and the purest solution (breaking up collateral into multiple buckets and running the prepayment model on each separately, then aggregating the projections) would dramatically increase model runtimes. But with the advent of GSE risk-sharing deals and increasing availability of loan-level data, we intend to explore this issue further. A shorter-term effort to address the matter would be to compute or estimate measures of variance on individual pools (based on loan-level data or pool-level quartile information) and use results to drive model parameters. An additional, more robust and longer-term effort would be to develop algorithms to optimally bucket pools and further improve the model's computational performance.

Appendix III – Answer to Quiz on Prepayments Given Earlier

Quiz on Prepayments (see page 17) – Given that the collateral 30-year 4.5s of 2003 in Figure 2 consists of borrowers paying on average a rate of 5.07%, and given the 100 bp back-up in mortgage rates to the 4.50%-4.75% area also shown (the bulk of the back-up occurred in May-June 2013), what will the next (total) prepayment speed be (in Sep 2013, in the top chart of Figure 2)?

Answer with Explanation: 21 CPR (a drop of 10 CPR from 31 CPR in Aug 2013 to 21 CPR in Sep 2013, shown in Figure 66). TDP, dominated by seasonal factors, is estimated to have dropped from 9.7 to 8.2 (September has fewer business days than August), so most of the 10 CPR drop can be attributed to lower refinancings. While refinancings are also impacted by September being a short month, the bulk of the drop can naturally be attributed to rising mortgage rates, up about 100 bps from April to August with the bulk occurring in May-June. Seasoned collateral likely has longer lags, so the June rise in rates may have at least partly impacted September speeds (a three-month lag). The other important consideration is that 4.5s, with borrowers paying 5.07%, are a cuspy coupon, meaning they are more sensitive to rates because their incentive to refinance (5.07 – 4.66 = about 40 bp) is not large.[64]

Figure 66. Answer to Quiz – Speeds for 4.5s of 2003 Fell 10 CPR From 31 CPR (Diamond) to 21 CPR (Square)



Source: Citi.

[64] Mortgage rates (no point rates) reached about 4.66% at the end of June 2013.

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