An Empirical Study of Termination Behavior of Reverse Mortgage

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Abstract

Reverse mortgages generally have open maturity dates. The variability of the exact termination time of a mortgage is one of the most important risks faced by the lenders and mortgage insurers. This paper analyzes the termination experience of the reverse mortgages in the US. We identify that a reverse mortgage can be terminated by three distinct events: refinance, mortality, and mobility. Using FHA insured Home Equity Conversion Mortgage loan level data, we estimated the probabilities of the termination by individual events. The results show that the three termination events are driven by different factors. Refinances are mainly driven by the appreciation of the house value, especially during the first three years. Mortality terminations follow closely the US mortality tables, which are governed by age and gender. Mobility caused terminations are sensitive to borrower's age-gender characteristics as well as housing market conditions. Meanwhile, the initial cash draw pattern has significant but different impact on each of the termination types.

1. Introduction

Reverse mortgages have gained substantial market interest due to the aging populations of the country. Seniors with most wealth in their houses are interested in alternative ways to access this illiquid asset to raise or maintain the living standard. Distinct from a conventional mortgage loan, the borrower of a reverse mortgage periodically borrows principals against the equity in the collateral house and makes no repayment to the lender until the end of the loan. Home Equity Conversion Mortgage (HECM) insured by the Federal Housing Administration (FHA) is the dominant reverse mortgage program in the U.S. market. Under the HECM program, a loan becomes immediately due (terminates) upon the borrower's death, prepayment, or when the borrower has not lived in the collateral house for more than one year. No scheduled termination dates associates with HECM loans.

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As the interest on the debt and other fees accrue, the unpaid principal balance (UPB) of the loan grows. Whether the debt surpasses the equity depends on the property appreciation rate as well. Combining with the uncertainty posed by house price appreciation and interest rates, the nature of the HECM loans raises critical cashflow risks and high cost of securitization for the secondary mortgage market. The purpose of this paper is to provide the analysis of actual program experience on the terminations of HECM loans.

HECM has been the dominant reverse mortgage product in the U.S. market ever since its inception. HECMs started as a pilot program in 1989 and became a permanent program in 1998. Between 2003 and 2008, the number of HECM loans grew steadily because of increased product awareness on the part of potential applicants, lower interest rates, increased home values and higher loan limits. Volume remained steady during the financial crisis with 114,413 endorsements in FY 2009. However, in the aftermath of the house price depreciation in FY 2009, HECM volume started to decline. Combining with the initial disbursement limitation and the reduction of principal limits, the volume further decreased in FY 2014 and returning to 2005 volumes in FY 2016. Despite the reduction in the volumes, HECM is still projected to increase and be salient given the population aging.

The major characteristics of the HECM portfolio are relatively consistent through FY 2016. For instance, the majority of HECM borrowers selected the line of credit payment type; except FY 2010 – FY 2013, the dominating HECM loans are adjustable rate mortgages…etc. Nevertheless, some borrowers' characteristics have been evolving. Single females used to comprise the largest gender cohort before FY 2012. But since FY 2013, couples become the largest gender cohort, and comprise growing proportion up to date. The appraised values of associated properties increased significantly after FY 2009. This is due to the passage of the American Recovery & Reinvestment Act and HERA which increased the HECM loan limit and further accelerated the upward trend[4]. This paper studies these patterns and provide additional evidence that higher termination probabilities are correlated with these characteristics – single male borrowers, younger borrowers, and borrowers with higher property values are more likely to terminate their loans quickly than others. One of the most important contributions of this paper is that we separate the refinance termination from the mortality termination and the moving-out termination. We find that the probability of refinancing increases significantly while housing appreciate fast, and is also heavily affected by other macroeconomic factors. Different from the general termination rate, by investigating the individual termination rate, we could capture effects of borrowers' characteristics and the macro economic environment to different termination type, and precisely forecast the termination behavior in the future.

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[4] IFE Actuarial Review of the Federal Housing Administration Mutual Mortgage Insurance Fund HECM Loans For Fiscal Year 2016.

The rest of paper constructs as following: Section 2 reviews relevant literature in estimating the HECM termination rates; Second 3 presents the multinomial logit framework to estimate the three competing termination types; Section 4 describes the data used in this research and presents some of termination rate drivers; Section 5 presents and discusses the empirical results of the three termination types. Section 6 concludes our findings.

2. Relevant Literature

A HECM loan is terminated as a loan payoff due to borrower death, move-out, or other voluntary payoff such as refinancing. As documented in Szymanoski, Enriquez and DiVenti(2007), the original pricing assumption for HECM insurance was that HECM loans would terminate at a fixed rate which only be determined by the borrower's age at loan origination and gender. Szymanoski, DiVenti, and Chow (2000) note that HUD does not collect complete data on borrowers' deaths, and hence, actual HECM termination experience cannot distinguish between mortality and other termination types. These authors found that for some HECM borrowers—especially for younger borrowers in their 60s at the time of loan origination—HUD's assumptions appeared to be underestimating total terminations and, therefore, overestimating loan (as opposed to borrower) survival rates. Szymanoski, Enriquez, and DiVenti(2007) demonstrates that through 2007, terminations not only exceeded the assumed level, but also exceeded the termination rates for otherwise similar households. The rapid early rate of reverse mortgage terminations was surprising.

Davidoff and Welke (2007) explains the phenomenon that HECM borrowers appear to exit their homes at a faster pace than the general population from the perspective of advantageous selection in the HECM program. In other words, higher discount rate among the borrowers combining with housing price appreciation explains the fact that borrowers intend to terminate their loans quickly. This is also reflected from the strong actuarial performance of FHA's HECM insurance program in the early years, since home prices rose too far, and borrowers terminated their loans too quickly for insurance claims to offset guarantee fee income. From the mid-2000s, declining prices and slow terminations have led to high realized and anticipated losses to FHA.

Szymanoski, DiVenti, and Chow (2000), and Rodda, Lam, and Youn (2004) construct multivariate statistical models of HECM termination probabilities. These studies show that factors such as borrower type, house price appreciation at the metropolitan area level, and interest rates affect termination probabilities. Nevertheless, these studies reply on strong assumptions on the termination types which are lack of the support from the up-to-date data. Our paper provides estimate on discrete-time HECM loan

termination rates for three termination types, and focuses on investigating various factors' impacts on these rates by using detailed and up-to-date HUD HECM data which has not been made public elsewhere.

3. Modeling Framework

This research classifies HECM loans terminate into three different types: borrower mortality (death), loan refinancing or borrower move-outs (mobility). To classify observed terminations among the three possible outcomes, terminations that resulted from refinancing were based on FHA's endorsement records. That is, these refinancing terminations would lead to FHA endorsement of new HECM loans. The remaining terminations were cross-referenced with the Social Security Administration's mortality data provided by FHA. If a loan terminated within one year prior to and two years after the borrower's recorded death date[5], the loan was considered to have terminated due to death. The remaining terminations are classified as mobility terminations.

HECM loans have been endorsed over the past 26 years, but program officially started at the beginning of 2000. Due to the limited number of loan observations in late policy years, the regression sample was restricted to observations that are shorter than policy year 12.

Similar to Szymanoski, DiVenti, and Chow (2000), and Yuen-Reed and Szymanoski (2007), a competing-risk multinomial logistic model is used to estimate the probabilities of HECM loan termination events[6]. Given survival to the beginning of time period t, the conditional probabilities that a loan will terminate due to mortality ($P_D(t)$), refinance ($P_R(t)$) or mobility ($P_M(t)$) are given by:

$$P_D(t) = \frac{e^{\alpha_D + X_D(t)\beta_D}}{1 + e^{\alpha_M + X_M(t)\beta_M} + e^{\alpha_R + X_R(t)\beta_R} + e^{\alpha_D + X_D(t)\beta_D}} \tag{1}$$

$$P_R(t) = \frac{e^{\alpha_R + X_R(t)\beta_R}}{1 + e^{\alpha_M + X_M(t)\beta_M} + e^{\alpha_R + X_R(t)\beta_R} + e^{\alpha_D + X_D(t)\beta_D}} \tag{2}$$

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[5] For loans with multiple borrowers, the date of death of the last surviving borrower is used. The same holds for spouses even if one of them is not a borrower.
[6] Pursuant to Mortgagee Letter 2011-01, HECM loans can be terminated under foreclosure when borrowers fail to pay their real estate taxes and/or property insurance premiums as required by the HECM contract. This paper excludes T&I default terminations from the discussion.

$$P_M(t) = \frac{e^{\alpha_M + X_M(t)\beta_M}}{1 + e^{\alpha_M + X_M(t)\beta_M} + e^{\alpha_R + X_R(t)\beta_R} + e^{\alpha_D + X_D(t)\beta_D}} \tag{3}$$

The probability of remaining active during the period is simply one minus the sum of these three probabilities. The constant terms α_D, α_R and α_M, and the coefficient vectors β_D, β_R and β_M are parameters estimated by the multinomial logistic model. The subscripts D, R and M denote death, refinance and mobility, respectively. The vectors of independent variables for predicting the conditional probability of termination due to mortality, refinance and mobility are represented by $X_D(t)$, $X_R(t)$ and $X_M(t)$, respectively.

Loan and borrower characteristics as well as economic variables are included in each vector to predict HECM terminations. Some of these variables are constant over the life of the loan while others vary over time. Please refer Appendices for variable specifications of regression models.

However, the estimation technique for the multinomial logistic equation system follows Begg and Gray (1984), who showed that it is statistically equivalent to model a multinomial logistic regression model as a special aggregation of individually estimated binomial logistic regression models.

The joint termination hazard rate can be defined as

$$P(t) = \sum_{j=1}^{3} P_j(t) \tag{4}$$

where P_j is defined in Equations (1), (2) and (3), which are estimated from the binomial logistic models and transferred to the competing risk (multinomial) probabilities using the Begg and Gray (1984) methodology. *P(t)* is an augmented joint conditional probability that a HECM loan will terminate due to any one of the three competing risks. These *P(t)* probabilities are calculated at the loan level. Thus, this paper estimates three types of termination rate using binomial logistic models, for better computation efficiency.

4. Data

Historical HECM termination data were used to estimate the base termination model. These data include loans that were endorsed under the General Insurance (GI) Fund between FY 2000 and FY 2008, and loans endorsed under the Mutual Mortgage Insurance (MMI) Fund in FY 2009 through the end of March of 2015.[7] The data come from three sources: the HUD Single Family Data Warehouse, FHA's Single Family Mortgage Asset Recovery Technology (SMART) database and MSA-level, Purchase-Only house price index from FHFA. HUD's Single Family Data Warehouse compiles its HECM data from the primary program source systems: the Computerized Housing Underwriting contains information about HECM cases which have been assigned to HUD. This dataset provides the borrower characteristic, loan characteristic on loan-level basis. SMART dataset provides the loss and termination information of each HECM loans. House price index from FHFA provides the macro information that a HECM property experienced after origination.

Each loan-level record contains fields for the loan origination date and borrower and co-borrower (if applicable) characteristics, including date of birth, gender, date of termination (if applicable), and loan status, all as of the cutoff date of March of 2015. The borrower's age at loan origination was calculated using the loan origination date and the borrower's date-of-birth information. When a co-borrower presents, the age of the borrower is the same as the younger one of the couple. Given the detailed attributes of the data, we are able to construct discrete-time hazard models for borrowers of different types and ages.

In previous years, FHA was able to collect information regarding the death of HECM borrowers from the Social Security Administration. Such information enabled the estimation of separate mortality, refinance and mobility termination models. HECM loans terminate due to borrower mortality (death), loan refinancing or borrower move-outs (mobility). A multinomial logistic model is specified and estimated to capture the loan termination behavior. Even though HECM insurance terminates upon a mortgage note assignment (because then HUD owns the loan), the HECM loan itself does not terminate at this time as the borrower continues to live in the home. Hence, note assignments are not modeled as HECM loan terminations particularly in this paper.

Table 1 shows the descriptive statistics of main variables investigated in this paper. To remove the period with few observations and make the sample consistent across the three termination models, we use the sample from fiscal year 2000 through 2015, and observations with loan ages no larger than 12 years.

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[7] The estimation data is only available through March of 2015 due to the lack of death file and updated refinance information from FY 2016.

Table 1. Descriptive statistics of main variables

Variable	N	Mean	Std Dev	Minimum	Maximum
Borrower Age	841892	72.48	7.48	61	113
Percentage of Cash Draw	841892	0.69	0.31	0	1
Loan Age	841892	5.93	2.84	1	12
Relative House Price	841892	1.09	0.57	0	3
Current Loan to Value	841880	0.69	0.61	-1.67	177.63
Two-years change in house price appreciation	841892	0.14	0.13	-0.51	0.69

Next, we look at the relationship between HECM terminations, and potential drivers, such as borrower gender, borrower age, house price appreciation, first-month cash draw, etc.

Fiscal Year

Table 2 summarizes the percentage of loans originated by fiscal year and by termination status. The active loans strand for the loans which are not terminated until March of Fiscal year 2015.

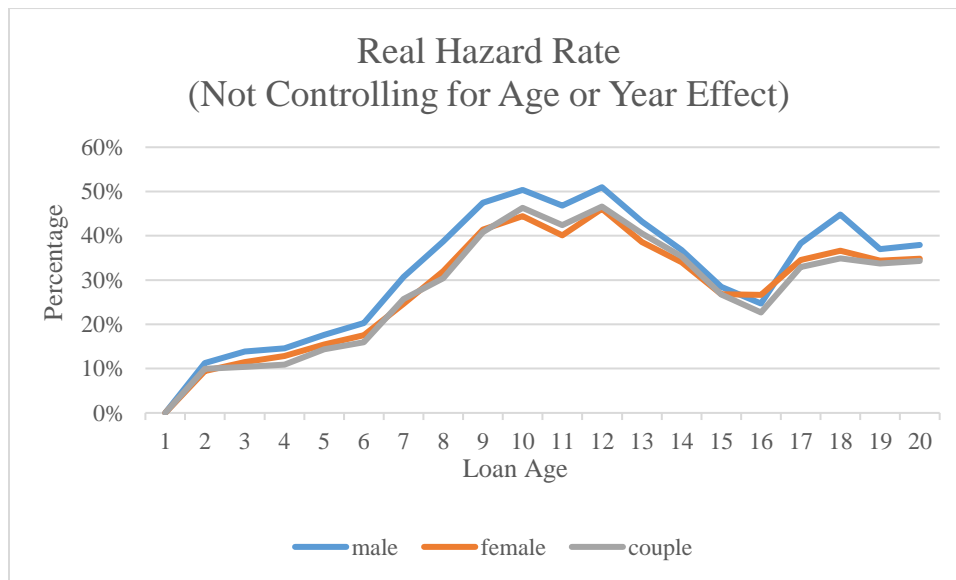## Table 2. Termination Type across Fiscal Years

Originated Fiscal Year	Termination Type			Active
	Mobility	Refinance	Mortality	
2000	41%	24%	35%	0%
2001	40%	27%	33%	0%
2002	39%	30%	31%	0%
2003	17%	12%	13%	58%
2004	20%	15%	14%	50%
2005	12%	8%	9%	71%
2006	12%	5%	8%	75%
2007	12%	4%	8%	76%
2008	10%	3%	7%	80%
2009	14%	4%	7%	74%
2010	11%	2%	5%	81%
2011	13%	3%	4%	80%
2012	8%	2%	2%	88%
2013	6%	2%	1%	91%

2014	4%	3%	1%	92%
2015	0%	0%	0%	100%
TOTAL	12%	5%	7%	76%

Genders

Due to the different life expectancy across genders, we expect that the loan termination rates could be different across groups as well. Figure 1 plots the observed hazard rate with respect to loan ages for single male, single female, and couple borrowers respectively.

Figure 1.

Real Hazard Rate
(Not Controlling for Age or Year Effect)

Most of the time the hazard rate curve of couple borrowers lies slightly under that of single females' which in turn lies under that of single males'. HECM loan behavior indicates that single males tend to terminate their loans the fastest, while couples have the longest loan life. These hazard rates appear to have an inverse-U shape for the loan age under 16 years. In other words, termination hazard is low in years immediately after origination and then increases with time. For loans that have not been terminated within 10 years, termination hazard declines, which suggesting that borrowers who have no died or moved out after 10 years may start to stay for a long time.

The gender distribution of the HECM portfolio has remained steady over time. Single females comprise the largest gender cohort through the FY 2012. In FYs 2013-2015, couples comprise 40.83 percent, surpassing single females to become the largest gender cohort. The single female share fell to around 39 percent while single males remain the lowest at 21 percent, about the same as in prior years.

Table 3. Borrower Gender across Fiscal Years

Originated Fiscal Year	Loan Gender		
	MALE	FEMALE	COUPLE
2000	14.03%	56.69%	29.28%
2001	14.49%	55.38%	30.13%
2002	15.39%	52.39%	32.22%
2003	15.97%	49.89%	34.14%
2004	14.80%	48.08%	37.12%
2005	15.47%	45.43%	39.10%
2006	15.91%	43.70%	40.39%
2007	17.37%	43.89%	38.74%
2008	19.82%	43.20%	36.99%
2009	20.86%	39.72%	39.41%
2010	21.42%	42.01%	36.57%
2011	20.99%	40.61%	38.40%
2012	21.46%	39.68%	38.86%
2013	21.26%	37.91%	40.83%
2014	20.68%	39.01%	40.31%
2015	21.63%	39.24%	39.13%

Age

In FY 2016, 19 percent of the population (approximately 57 million) was 62 or older. HECM borrowers represent about 1 percent of all households with at least one member ages 62 years or older. Starting from August 4, 2014, the HECM program was modified to allow non-borrowing spouses younger than 62 years of age. Due to this modification, the average borrower age has declined over time. But overall, the HECM borrowers tend to be older than the general population of homeowners age 62 and above. In 2016 actuarial report, the average borrower age was 73 compared with an average age of 72 among all elderly homeowners.

Younger non-borrowing spouses get the benefit of staying in the house until deceased or when moves out, and hence they are associated with a higher financial risk exposure for FHA as they have a longer life expectancy. To manage this risk, the principal limit factors (PLFs), which limit the percentage of initial equity available to the borrower, are lower for younger borrowers, limiting their access to a smaller

portion of the equity in the house. The risk of longevity is captured in the mortality variable including in our models.

Figure 2a shows the termination distribution of borrower ages at loan origination across different types. Younger borrower (those in their mid-60s at loan origination) are paying off their HECM loans much faster through moving out of their home and refinancing than older borrowers. As the sample aging, the death accounts for the major reason for the loan termination.

Another important factor which drives the termination rate varying across different termination type is the loan age. As depicted in the Figure 2b, refinance appears in the early years of a loan. Move-out loans distribute uniformly throughout the life length of a loan.
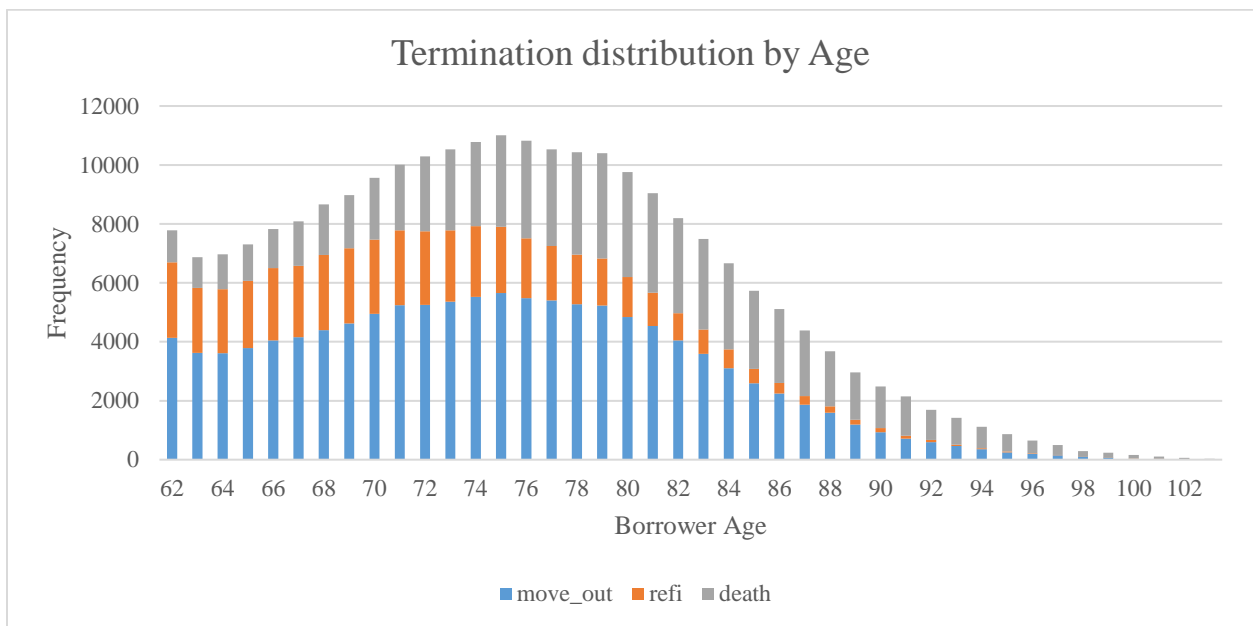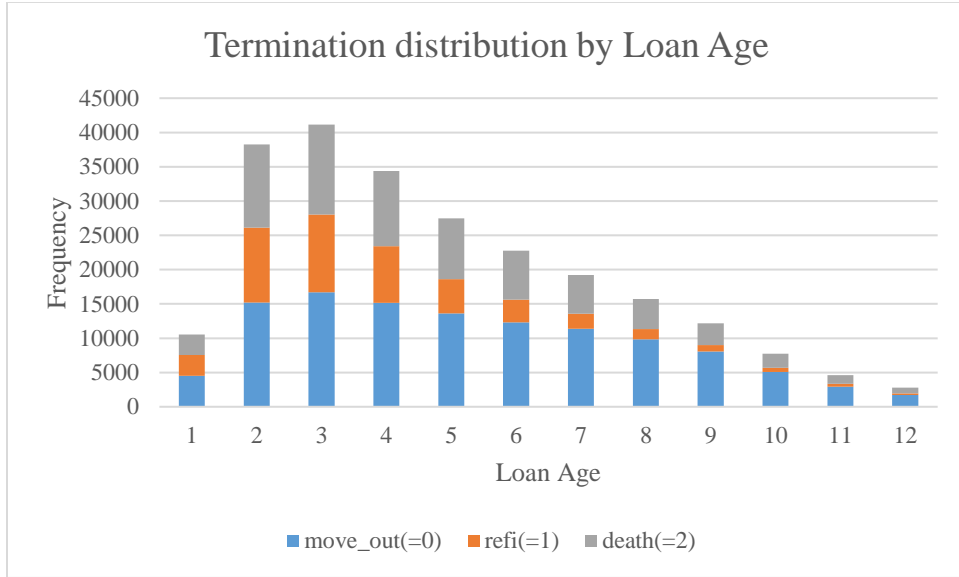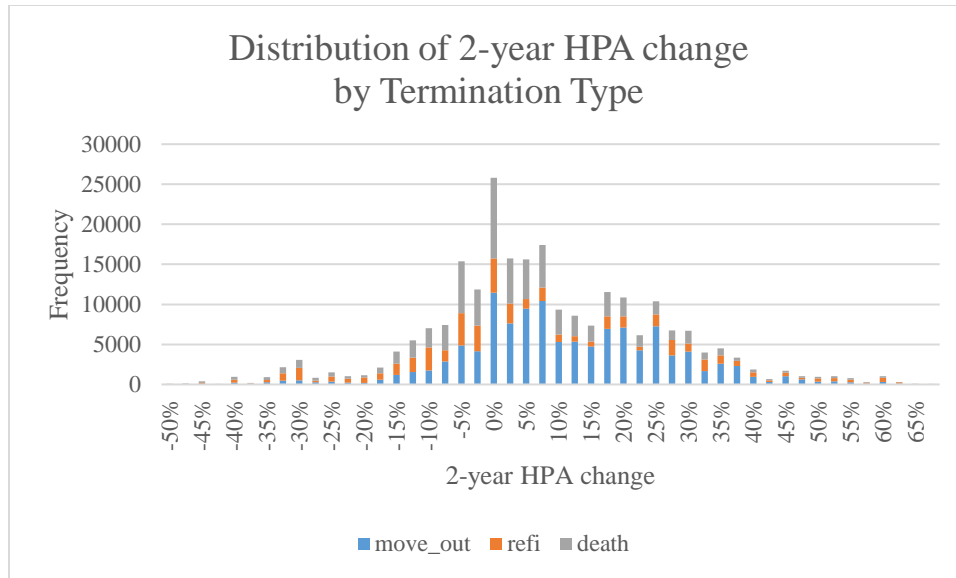
Figure 2a.

Termination distribution by Age

Figure 2b.

Termination distribution by Loan Age

Housing Price Appreciation

HECM borrowers' mobility was significantly affected by home price appreciation (Davidoff and Welke (2007)). When home prices decrease, borrowers who expect to exact equity have less incentive to move out due to the high propensity that the home values could fall below the loan. Figure 3 indicates that as the housing price increasing, the frequency of the move-out termination rises significantly.

Figure 3.

Distribution of 2-year HPA change by Termination Type

Besides, the fact documented in Szymanoski, Enriquez, and DiVenti(2007) shows that the initial high mobility of HECM borrowers was concentrated among relatively young borrowers. The differential sensitivity by age suggests a rationalization for HECM borrowers' rapid mobility with rising prices: borrows are a highly selected sample with strong liquidity needs (Davidoff(2014), Haurin et al. (2014)).
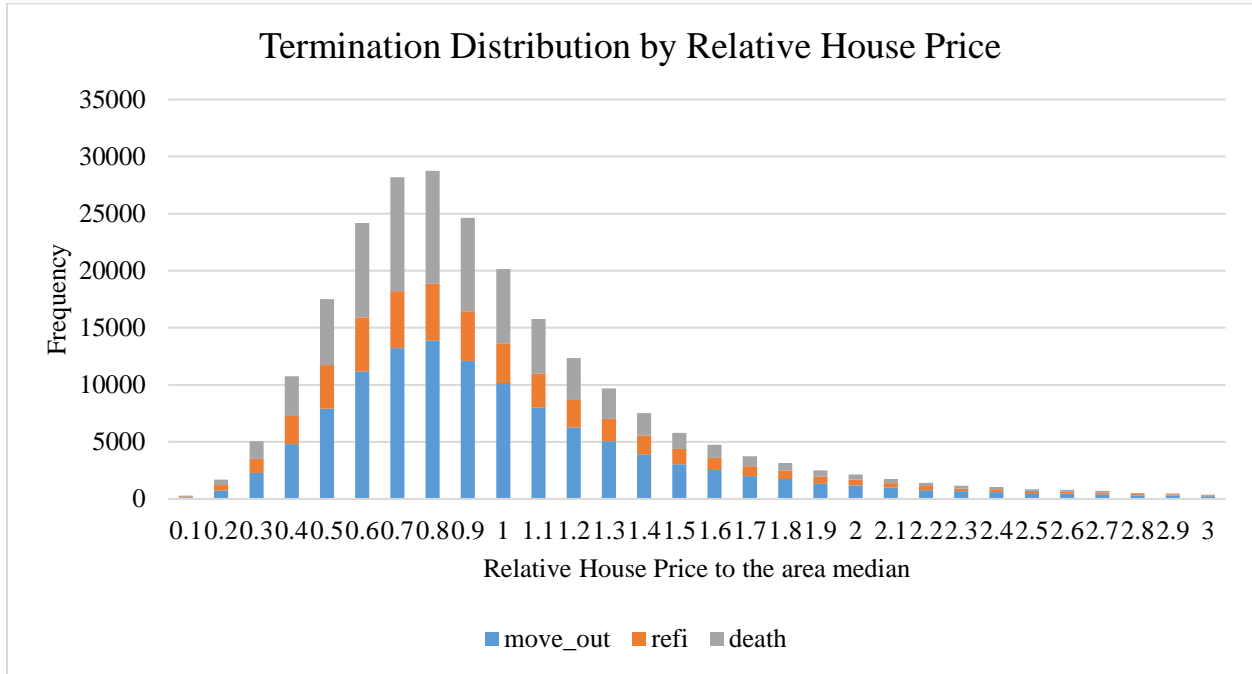
Other factors

The majority of HECM borrowers selected monthly or annually adjustable rate mortgages in FY 2009. However, the percentage of fixed-rate endorsements increased sharply from 12 percent in FY 2009 to 72 percent of endorsements in the first three quarters of FY 2013, and by FY 2016, it had dropped down to 11 percent. The LIBOR-indexed loans increased to an all-time high at 89 percent in FY2016.

In FY2016, loans with the maximum claim amount (MCA), the minimum of the FHA HECM loan limit and the appraised value, less than $300,000 accounts for 59 percent in FY 2016. 17 percent of the loans were made up of loans with an MCA between $300,000 and $417,000, and the rest of loans were with an MCA greater than $417,000. FHA research has found, and our empirical findings reinforce, that loans associated with properties with an appraised value at origination greater than their area median tend to be maintained better than those with appraised value below the area median. Starting with the FY 2005 book of business, there has been an upward trend in the ratio of appraised values to the area medians. The passage of the American Recovery & Reinvestment Act and HERA increased the HECM loan limit and further accelerated the upward trend. Figure 4 shows that as the ratio increasing to 1, the termination frequency becomes higher. When the real house price index exceeds 1, the frequency drops as well. When the house price is close to the area median level, the property is usually easier to be sold on the market

which offers large liquidity to borrowers. And hence the loan terminated as refinance or moveout happen more often to properties with median values.
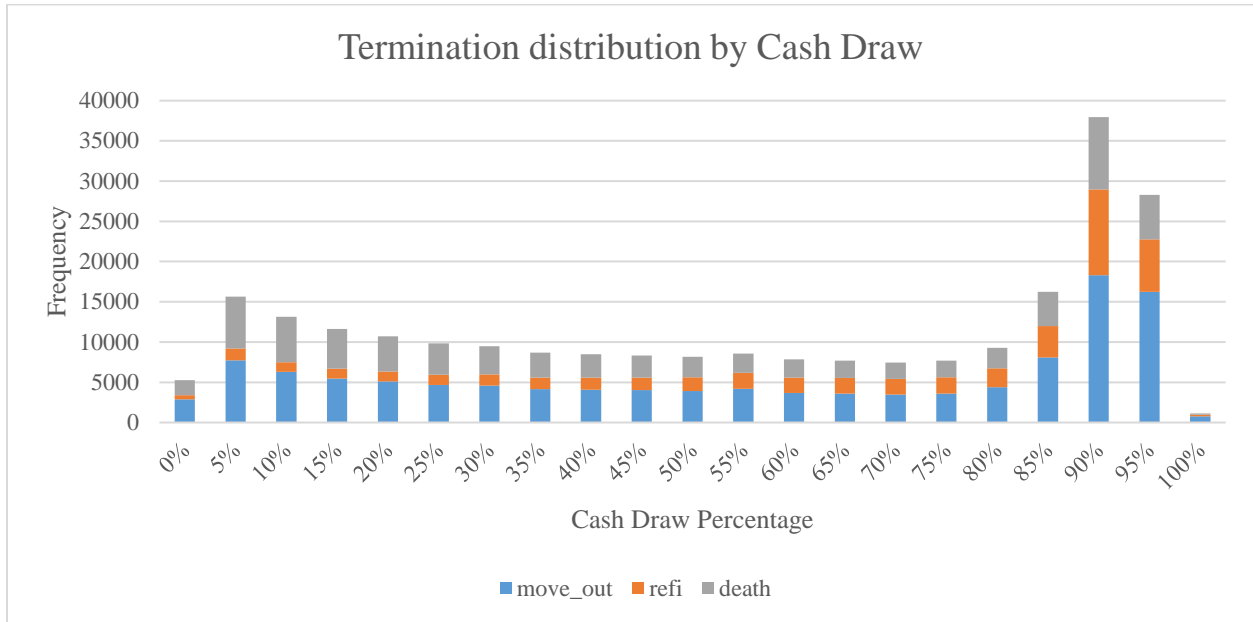
Figure 4.

Termination Distribution by Relative House Price

As indicated in Figure 5, loans which have drawn a higher percentage of the initial amount of equity available tend to have high termination frequency. The explanation for this phenomenon is twofold. The first one is an age effect. Since the Principal Limit Factors (PLFs) limit the percentage of initial equity available to younger borrowers at a lower level relative to elder borrowers, the higher percentage cash draw for elder individuals accounts for the high death termination incidents. Another reason for the high termination frequency at large percentage cash draw is that withdrawing more equity at the beginning gives borrowers strong incentive to refinance the loan when the house appreciates[8].

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[8] There were disproportionally high initial draws incurred by most fixed-rate HECMs during FYs 2010-2013. In 2014 HUD limited the insurability of fixed interest rate mortgages under the HECM program to mortgages with the Single Disbursement Lump Sum payment option. Also in the same year, HUD introduced a higher mortgage insurance premium charge of 2.50 percent if the initial draw amount exceeds 60 percent of the available principal limit, as compared to the 0.50 percent MIP if the initial draw amount is less than or equal to 60 percent of the available principal limit.

Figure 5.

Termination distribution by Cash Draw

move_out refi death

5. Empirical Result

This section presents the results of three types of termination models from the binomial logistic regression discussed above.

Mortality termination

The mortality model estimates the probability that a HECM loan terminates due to the death of the borrower. Social Security Administration mortality data obtained by FHA indicates the date of death of HECM borrowers. The most updated mortality data available are up to March of 2015.

As we see from previous section Figure 2a and 2b, mortality termination is the major type for elder HECM borrowers or a seasoned loan. Key variables used in this model are: mortality rates from actuarial mortality tables, borrower's gender, the percent of the available cash draw taken in the first month, and the product type. The regression result is presented in Table 4.

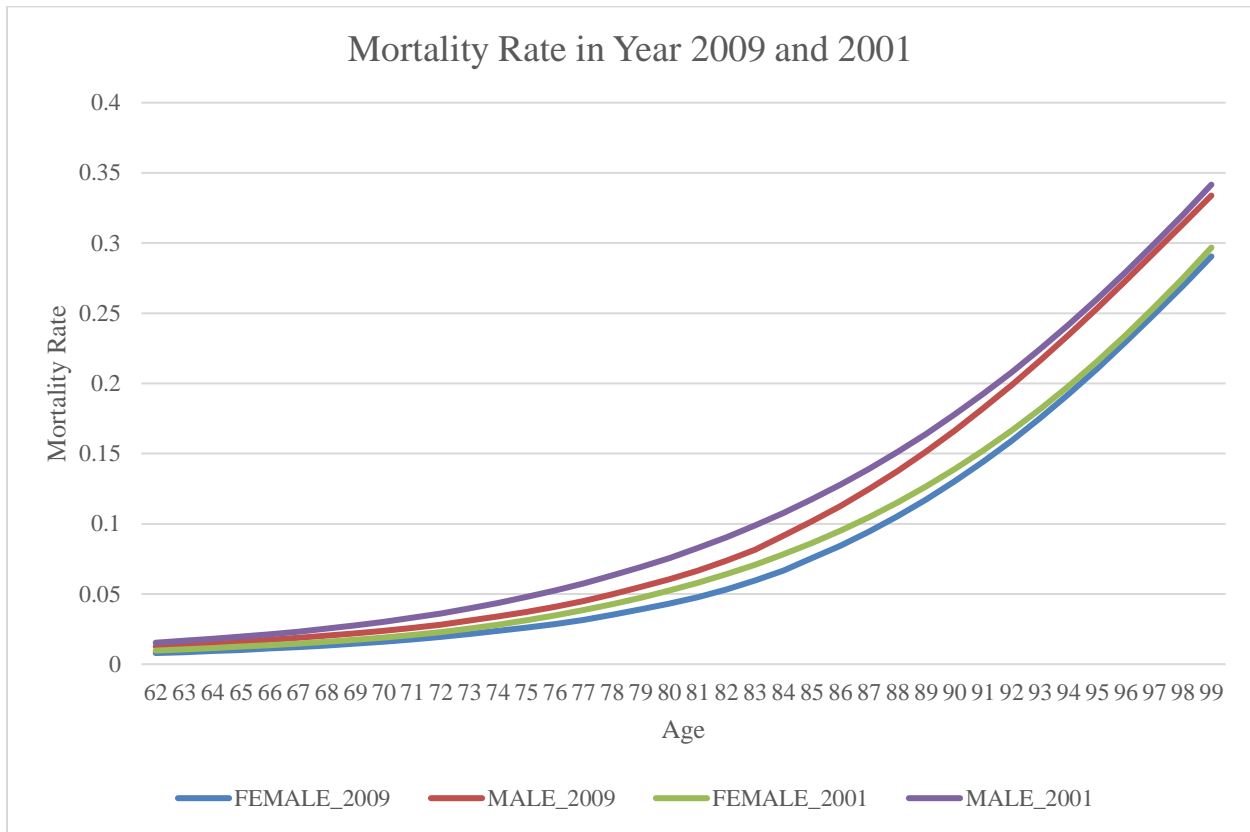**Table 4. Mortality Termination Model Estimation Results**

Description	Estimate	Standard Error	Wald Chi-Square
Intercept	-0.6672	0.0171	1522.93
If Borrower is Couple	-0.3622	0.0133	736.55
Transformed Mortality Rate	0.9008	0.0049	34077.16
Cash Drawdown Percentage	-1.1268	0.0143	6203.78
Line of Credit	0.0916	0.0139	43.47
Term Product with Line of Credit	0.2020	0.0185	118.92
Number of Observations			4424800
-2 Log L			538317.03
Somers' D			0.586

*All coefficients are significant at 99.99% level.

First, we see mortality rates from actuarial mortality tables contribute the most exoplanetary power to HECM loan mortality termination. The Figure 6 shows general population mortality rates for males and females as determined by the National Center for Health Statistics[9] and the ratios of the observed HECM loan hazard rates to the corresponding imputed males and females mortality rates is 0.9. In another word, given same gender and age, a HECM loan borrower survives longer than typical American person. This supports the self-selection issue in HECM programs (Davidoff and Welke (2007)) , as HECM borrowers know their health condition better than lenders, and people who tend to have long longevity are more likely to apply for HECM loans. Szymanoski, Enriquez, and DiVenti (2007) documents that HECM borrowers are terminating their loans more quickly than general population mortality rates for their age-groups would predict. Our result suggests that the this is true for alternative terminations but the opposite for the mortality termination.

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[9] U.S. Decennial Life Tables for 1999-2001, From the Centers for Disease Control and Prevention/National Center for Health Statistics. https://www.cdc.gov/nchs/fastats/life-expectancy.htm
Revised United States Life Tables, 2001-2011, the Centers for Disease Control and Prevention. https://www.cdc.gov/nchs/nvss/mortality/lewk3.htm

Figure 6.

Second, a couple HECM borrower tends to have lower mortality termination than a single borrower, from two evidences. For couple borrowers, the transferred mortality rate we calculated from joint table is lower than that of single borrower as explained in Appendix equation (5) the second part, which is the calculated mortality rate for couple borrowers and accounts for the last borrower survivor dies. Moreover, the couple borrower indicator shows negative coefficient, -0.3622, suggesting the same story.

Third, historical HECM data also suggest that borrowers who experience heavier mortality than the baseline actuarial table seem to have a propensity to have a higher first month draw-down of their total eligible draw amount. Therefore, the variable CashDraw captures this self-selection of borrowers within the HECM program. However, conditional on the same level mortality among the senior population, people who are in the HECM program and have higher percentage of the cash draw tend to use the funding as a one-time subsidy which can help them improve the living condition, and hence have lower possibility of terminating the loan as death.

Last, two dummy variables were included: one for the Line of credit and the other for the Term product with a Line of Credit feature, to reflect additional self-selection effects and higher mortality termination.

Refinance Termination

Although refinance termination is not the major termination type, it's very important to model, especially during house price rising environment. Unlike the traditional mortgage where refinance activity is driven by low rate, HECM refinance termination is driven by large house price appreciation, where borrowers can draw more cash amount from a larger HECM loan. To model refinance termination, we consider three types of explanatory variables: loan age, borrower-related characteristics, and economic variables. Table 5 presents the regression results.

Table 5. Refinance Termination Model Estimation Results

Description	Boundary Values	Estimate	Standard Error	Wald Chi-Square
Intercept		-7.9757	0.0654	14865.07
Policy Year	[1,3]	0.8509	0.0087	9594.25
	(3,74]	-0.1785	0.0039	2073.78
Borrower Age		0.0041	0.0008	28.44
Home Value above Area Median		0.2269	0.0110	424.97
Refinance Incentives	(-∞,0]	0.0951	0.0021	2128.71
	(0,+∞)	0.2038	0.0034	3591.27
Area Median House Price to Origination Loan Limit		2.2313	0.0207	11666.18
Cash Drawdown Percentage		2.5005	0.0280	7955.32
If Borrower is Couple		-0.0978	0.0113	74.75
If Borrower is Male		0.1243	0.0138	81.42
Line of Credit		-0.0898	0.0178	25.42
TERM		0.3247	0.0463	49.09
Indicator for fixed-rate		-0.9662	0.0185	2718.76
Current LTV		-2.4926	0.0402	3840.78
Number of Observations				4409945
-2 Log L				418592.05
Somers' D				0.611

*All coefficients are significant at 99.99% level.

Unsurprised, house price appreciation related variables are the important drivers of refinance terminations. There are three house price appreciation related variables in the equation: refinance incentive, home value above area median, and current LTV. As discussed, when house price rises after HECM loan origination, borrowers can refinance to a new loan with larger loan amount and can draw more cash from the property. Refinance incentive measures how much additional cash draw can a borrower make, if refinance the current HECM loan. From Table 5, we can see that generally higher incentives encourage individuals to refinance. As the incentive approaching to zero, the cost of refinancing is decreasing, which drive people to refinance anyway. Furthermore, at loan origination, the relative value of the property affects the future house price appreciation. In the HECM program, properties with relatively higher values tend to have a larger appreciation and therefore lead to a higher probability of refinance. Also, the result suggests lower current LTV, which related to rising house price, demonstrates higher possibility to refinance. Overall, we see strong evidence of house price appreciation contributing to refinance activity .

Another important driver is the borrower's cash draw pattern. We measure it by first-month initial cash draw percentage. An analysis of the data suggests that the high utilization at the front is a positive predictor of the likelihood of future refinances. This is probably a behavior explanatory. High utilization at beginning is a sign for borrowers who prefer to seek opportunities to get additional draws through refinancing when house price rising.

Another interesting driver is loan age. Prior HECM experience shows that most refinances occur after the first few years of the loan origination. To capture this experience, a piece-wise linear spline function of the time-dependent variable *PolicyYear* was used to capture variations in the trend. The results from Table 5 suggest that the propensity of refinancing increases in the first three years, but the increasing rate starts to drop aftermath.

The ratio of local area median house price to national loan limit at HECM origination is used to capture how expensive a house is compared to the national average. A high ratio indicates a larger dollar amount of benefits if the borrower choses to refinance, thus implying a higher probability of refinance.

The rest of variables add some explanatory power to refinance termination, for example, the variables *borrower's age* and *Gender*. Historical experience suggests that older borrowers are less likely to refinance. However, if we keep all the other factors constant, older people show higher possibility to refinance due to the higher needs for savings. Similarly, borrowers of different genders also refinance at differing rates. Indicators for the gender of borrowers are included in this model. Comparing with the base female group, male is more likely to refinance, as suggested by the historical experience.

Mobility Termination

The mobility model estimates the probability that a HECM loan terminates due to the borrower moving out of the HECM property. Factors representing borrower characteristics, economic conditions, and loan-specific variables were used as explanatory variables. Table 6 presents the results.

Table 6. Mobility Termination Model Estimation Results

Description	Estimate	Standard Error	Wald Chi-Square
Intercept	-2.4831	0.0199	15518.68
If Borrower is Couple	0.3696	0.0093	1581.34
If Borrower is Male	-0.1421	0.0100	200.92
Transformed Mortality Rates	0.4667	0.0038	14963.57
Cash Drawdown Percentage	0.8723	0.0165	2795.20
Appraised Value to Area Median House Price	0.1803	0.0065	760.71
Current LTV	-2.6996	0.0207	16950.89
House Price Volatility	8.0602	0.0681	14005.20
Line of Credit	0.1158	0.0112	107.03
TERM	0.3015	0.0296	103.83
Number of Observations			4410489
-2 Log L			769859.24
Somers' D			0.426

*All coefficients are significant at 99.99% level.

From Figure 2b, move-out termination can occur in the both early years and later years of a loan. There are mainly two considerations during move-out termination: whether houses experience favorable market so that borrowers could sell off the HECM property and move out. Whether borrowers are too aged to manage the property and want to move to nursing homes or with children.

There are three variables related to easy-to-sell house factors: *current LTV*, *house price volatility*, and *home value to area median*. Low LTV, indicting small loan or increase in property value, suggests easy to pay off loan through selling off the house. Additionally, the house price dispersion parameter estimated by FHFA was used to capture the variability among local house price appreciation rates. The higher

volatility drives people sell off their home quicker. Also, properties with relatively higher values tend to have a larger appreciation and therefore the higher propensity to sell off house.

Borrower-specific characteristics are key drivers of the likelihood of moving out at later years. Historical experience suggests that compared with younger borrowers, older borrowers are more likely to move out, such as moving to a nursing home or an assisted-living facility, or to live with their children. We include *transformed mortality rates* to capture the age-related issues in the ongoing years. As indicates in Table 6, the heavier mortality rate leads to a higher rate of moving out.

An interesting observation here is the effect of cash draw pattern. The data suggest that high utilization at the beginning predicts higher move-out termination. High cash draw probably indicates more needs of money to pay expenses like medical expenses. And those types of people are more likely be taken care by nursing homes, instead of self-manage at home.

The rest of variables add some explanatory power to move-out termination. For example, *Gender_Couple*, *gender_male*. Results show that couples are more likely to move out compared with single female borrowers who are treated as the base group. Two loan-type dummy variables are included: Term HECMs and loans with Line of Credit (LOC). The pure Term loans seem to have mobility rates greater than for the loans with a LOC, which may indicate a self-selection effect for borrowers with different mobility preferences.

6. Conclusion

This paper classifies the reverse mortgage terminations into three types according to borrowers' different behaviors. Competing risk models are estimated to investigate main driving factors in each of the termination types. Loan level data of the FHA insured HECM loans originated since year 2000 with observed termination experiences up to 2015 are used to empirically estimate these termination rates and identify their main driving factors. The results show that mortality termination is largely explained by borrowers' age-gender- characters. HECM borrowers are found to survive longer than average American population. This is consistent with the hypothesis of the self-selection where borrowers in better health condition are more likely to take out reverse mortgages. Refinance termination is mostly house price appreciation driven. Data also show borrowers are more likely to refinance during in the first few years after origination. Larger utilization at the front signals how closely a borrower watches for opportunities to increase the amount available to draw. Such a borrower would be more likely to take advantage the rising house price through refinancing. Mobility termination captures the phenomena whether a borrower is no longer able to manage the house and chooses to live with family members or in a nursing home.

Such a decision tends to differ by borrower age, amount of equity in house, and volatility of the housing market.

These results show that terminations of reverse mortgages are driven by borrower's life, financial, and the living style choices. These choices are competing with one another. Each choice is governed by different driving factors. There are different factors driving each of the three types of terminations. For the same driving factors, the impact can be very different among the three termination types, sometimes even in opposite directions. As a result, it will be difficult to achieve high accuracy if one attempts to estimate the termination speed of reverse mortgages by combining these three distinct termination types. Modeling the termination rates in the competing risk framework will improve the accuracy in pricing and analyzing risks of reverse mortgages and their derivative securities.

7. Appendices

Here list out the variable specification used the regressions.

<u>Transformed mortality rate</u>

We use a gender- and age- specific mortality rate $m_g(t)$ in the life tables from the Center for Disease Control and Prevention (CDC). For loans with co-borrowers or couples, the joint mortality table represents the likelihood of both borrowers or spouses not surviving to the end of a period. Equation (5) below defines the Mortality (M(t)) calculation.

$$M(t) \begin{cases} m_g(t) & if\ single \\ m_b(t)|\ D_{co}(t-1)S_b(t-1) + m_{co}(t)|\ D_b(t-1)S_{co}(t-1) + m_b(t) * m_{co}(t)\ |S(t-1) & if\ couple \end{cases}$$

$$(5)$$

where M(t) represents the mortality rate at t ;

$m_g(t)$ represents the conditional mortality rate (gender and age specific) for a borrower dying at time t based on the U.S. Census Decennial Life Table;

$m_i(t)|\ D_j(t-1)S_i(t-1)$ represents the mortality rate of borrower i at time t conditional on borrower j dying before time t-1 and borrower i surviving up to time t-1. The notation here is that i=b

(borrower), j=co (co-borrower), or i=co, j=b; $m_b(t) * m_{co}(t) \,|S(t-1)$ represents the probability that both borrower and co-borrower die at time t conditional that both survived to t-1.

Next, equation (6) transforms M(t) into xbetaM(t), which is one of explanatory variables that used in our model:

$$xbetaM(t) = ln(\frac{M(t)}{1-M(t)}) \tag{6}$$

The transformed mortality rate accounts for expected mortality rates of the population. In previous studies, the most recent mortality table is often used to model the HECM termination model. However, the mortality calculated in such table uses data cross more than two decades since 1990. Historical data suggest that the mortality rate of the same age group decreases across year. The decreasing rate varies with age groups as well. Older people demonstrate lower death rate as time passed by at a faster rate than younger individuals. Using the single mortality table directly negatively affect the accuracy of the model. To solve this issue, the most straightforward way is to use specific mortality rates for each cohort from various tables. However, two problems are raised in the meanwhile. First, this makes programs very complicated and not practically useful. Second, the requirement "one table for each cohort" can rarely be met.

In order to capture this trend, we build a model to calculate the corresponding mortalities for each cohort. Using the transformed mortality rate from equation (6), we fit a linear regression on age and its quadratic term as follow:

$$xbetaM(t) = \alpha + \beta * age + \gamma * age^2 + \varepsilon \tag{7}$$

The life tables include the U.S. Life Table from the Center for Disease Control and Prevention (CDC) 1999-2001, and 2001-2009. We use the mortality rate for these specific years and the estimated parameters to interpolate rates for the years in between and to extrapolate the mortality rate from 2009 to the end of the estimation dataset in 2013. For forecasts after 2014, mortality rates are constant at the 2013 level for each given age.

Couple borrower Indicator

The dummy variable Gender(Couple), which equals 1 if a couple and 0 otherwise.

Policy Year

A piece-wise linear spline function of the time-dependent variable *PolicyYear* was used to capture variations in the trend. The series of piece-wise linear spline functions for loan age are defined as follows:

$$Pol_{yr1} = \begin{cases} loan\ age & if\ loan\ age \leq k_1 \\ k_1 & if\ loan\ age > k_1 \end{cases}$$

$$(8)$$

$$Pol_{yr2} = \begin{cases} 0 & if\ loan\ age \leq k_1 \\ loan\ age - k_1 & if\ loan\ age > k_1 \end{cases}$$

where $k_1 = 3$.

$$(9)$$

Coefficient estimates for each variable are the slopes of the line segments between individual knot points. The overall generic PolicyYear function for the four Pol_yr segments is given by:

$$PolicyYear\ function = \beta_1 * Pol\_yr1 + \beta_2 * Pol\_yr2$$

$$(10)$$

Refinance Incentive

The refinance incentive variable was designed to model HECM borrowers' potential benefit of refinancing a loan. The refinance incentive variable represents the net increase in the principal limit for a borrower upon refinancing relative to refinance costs. Equation 10 defines the refinance incentive variable:

$$rfi_t\_new = \frac{\min(MCA_0 \times \Delta H, LoanLimit_t) \times PLF_t - C - PL_t}{C}$$

$$(11)$$

where MCA_0 = Original maximum claim amount for loan at time 0

$\Delta H = \dfrac{HPI_t}{HPI_0}$, HPI is the FHFA house price index per MSA (or state if loans are located outside of an MSA)

$LoanLimit_t$ = FHA loan limit for time t

PLF_t = New principal limit factor for the borrower's age and the current interest rate at time t

C = Transaction cost to originate the refinanced loan

PL_t = Gross principal limit on the original HECM loan at time t

Home Value to Area Median

It measures the ratio of appraised property value at origination to median value in the local (MSA or state) area. The local median house price data was obtained from the Census at the MSA and state levels, with the most granular level available being used for each property.

House Price Volatility

The house price dispersion parameter estimated by FHFA was used to capture the variability among local house price appreciation rates.

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