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Termination Risk of Reverse Mortgages

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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 reverse mortgages in the United States (US). We find that reverse mortgages can be terminated by three distinct events: refinancing, mortality and mobility. Using the Federal Housing Administration (FHA) insured Home Equity Conversion Mortgage (HECM) loan data, we estimate the probability of the termination through individual events. The results show that refinance termination and other termination events are driven by different factors. Refinances are mainly driven by macroeconomic conditions, such as the appreciation of the house value and decline in interest rate, and usually done in the beginning years of the loan origination. Mortality terminations follow closely the US mortality tables, which are governed by age and gender. Mobility termination shares a similar pattern with mortality termination, especially in the later years of the loan life. Meanwhile, the initial cash drawdown pattern has significant but different impacts on each type of termination. By separating refinance termination from the two other types of terminations, we show that refinance termination slows down when the interest rate starts to rise. Without separating refinance termination, HECM investors could over-project the number of future HECM terminations in a rising interest rate scenario and result in loss of funds.

Keywords

Reverse Mortgage, HECM, Competing Risk, Refinance, Mortality, Mobility Termination

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1. Introduction

Reverse mortgages have gained substantial market interest due to the aging populations worldwide. Seniors with the most housing wealth are interested in alternative ways to access this illiquid asset to improve or maintain their living standards. Unlike conventional mortgage loans, the borrower of a reverse mortgage periodically borrows on the principal against the equity of the collateral house and makes no repayment to the lender until the end of the loan. The 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 death of the borrower, or prepayment, or when the borrower has not lived in the collateral house for more than one year. HECM loans have no scheduled termination date.

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. Combined with the uncertainty posed by house price appreciation and interest rates, the nature of HECM loans increases cash flow risks and the cost of securitization in the secondary mortgage market. The purpose of this paper is to provide an analysis of actual program experience on the terminations of HECM loans.

HECMs have been the dominant reverse mortgage product in the U.S. market ever since their inception in 1989 as a pilot program. In 2003, the amount of HECM loans started to grow persistently, which was the result of the combination of lower interest rates, higher house values, and the growing acceptance of HECM products. However, in the aftermath of the house price depreciation in fiscal year (FY) 2009, the HECM volume started to decline. Along with the initial disbursement limits and the reduction of principal limits, the volume further decreased in FY 2014 and returned to the volume in 2005 in FY 2016. Despite the reduction in volume, HECMs are still projected to increase and remain salient given the aging population.

The major characteristics of the HECM portfolio have been relatively consistent through to FY 2016. For instance, the majority of HECM borrowers choose the line of credit (LOC) payment option, and with the exception of FY 2010 – FY 2013, adjustable rate mortgages have been the dominant type of HECM loan. Nevertheless, the characteristics of some of the borrowers have been changing. Single females used to comprise the largest gender cohort before FY 2012. However, since FY 2013, couples have become the largest gender cohort, and to date, continue to grow in proportion to other borrowers. The appraised values of the associated properties have increased significantly after FY 2009 due to the enactment of the American Recovery & Reinvestment Act and Housing and Economic Recovery Act (HERA) which increased the HECM loan limits and further accelerated the trend of increase in the use of

HECMs[1]. This paper studies these patterns and provides additional evidence that higher termination probability is correlated with the following individuals who are more likely to terminate their loans more quickly than others – single male borrowers, younger borrowers, and borrowers who have property with a higher value.

One of the most important contributions of this paper is that we make a distinction between refinance termination and mortality and mobility terminations, by identifying refinance termination and the passing of borrowers. We use a multinomial logistic model for competing-risks to predict the rate of termination, respectively. We define mortality termination as a loan not terminated through refinancing but within one year prior to the recorded date of death of the borrower or non-borrowing spouse to two years after their recorded date of death. We define mobility termination as a loan terminated not due to identified refinancing or mortality records[2]. Under these definitions, the independence of irrelevant alternatives (IIA) imposed by the multinomial logistic model is satisfied.

We find that the probability of refinancing increases significantly when housing appreciates quickly and interest rate declines and is also heavily affected by other macroeconomic factors. Unlike the general rate of termination, we can capture the effects of the characteristics of borrowers and the macro economic environment on the different type of termination by investigating the individual rate of termination and precisely predict future termination behavior. The existing historical data from a period of declining interest rate shows a great tendency towards refinancing. However, refinance termination should slow down when interest rate starts to increase in the future. Without separating refinance termination, investors could over-project the overall HECM terminations in a rising interest rate scenario, which leads to the overvaluation of HECMs and loss of money.

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

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

[2] There could be loans terminated because they were voluntarily paid off even if the individual is still residing in the house or has moved out. However, we lack the data to confirm this phenomenon. Therefore, we group the residuals into the 3rd group or mobility termination which is the majority of the remaining types of termination.

2. Relevant Literature

An HECM loan is terminated as a loan paid off due to the death of the borrower, if the borrower moves out of the house, or voluntarily pays off the loan such as through refinancing. As documented in Szymanoski et al. (2007), the original pricing assumption for HECM insurance was that HECM loans would terminate at a fixed rate which can only be determined by the age of the borrower at loan origination and gender. Szymanoski et al. (2000) note that the United States Department of Housing and Urban Development (HUD) does not collect complete data on the death of borrowers, and hence, the actual HECM termination experience cannot differentiate between mortality and other types of termination. Szymanoski et al. (2000) find that for some HECM borrowers—especially for borrowers in their 60s at the time of loan origination— the assumptions of the HUD appear to underestimate the total terminations and, therefore, overestimate the loan (as opposed to borrower) survival rates. Szymanoski et al. (2007) demonstrate that through to 2007, terminations not only exceeded the assumed level, but also the rate of terminations for otherwise similar households. The rapid rate of early reverse mortgage terminations was surprising.

Davidoff and Welke (2007) explain for this phenomenon by stating that HECM borrowers tend to move out of their homes more quickly than the general population due to advantageous selection in the HECM program. In other words, a higher discount rate along with appreciation in house price explains why borrowers tend to terminate their loans more quickly. This is also reflected by the HECM insurance program under the FHA which was actuarially strong in the early years since housing prices increased exponentially and borrowers in response rapidly terminated their loans to claim insurance and offset the guarantee fee income. In the mid-2000s, housing price declines and fewer terminations resulted in both anticipated and actual exorbitant losses to the FHA.

Szymanoski et al. (2000), and Rodda et al. (2004) construct multivariate statistical models to determine the probability of HECM termination. They show that factors such as type of borrower, house price appreciation at the metropolitan area level, and interest rates affect termination probabilities. Nevertheless, they rely on strong assumptions about the type of termination which lacks support from the data of current studies. Our paper provides an estimate for the discrete-time rates of HECM loan termination for different types of terminations, and focuses on investigating the impacts of various factors on these rates by using detailed and the most recent HUD HECM data which have not been made public elsewhere.

3. Modeling Framework

This research study classifies the termination of HECM loans into three different types of termination: the mortality (death), of the borrower, loan refinancing or borrower move-outs (mobility). In terms of group observed terminations under the three possible types of terminations, those that result due to refinancing are based on the endorsement records of the FHA. That is, these refinance terminations lead to the FHA endorsement of new HECM loans. The remaining terminations are cross-referenced with the mortality data from the Social Security Administration provided by the FHA. If a loan is terminated within one year prior to the recorded date of death of the borrower[3] and two years after the death, the loan is considered to have terminated due to death. The remaining terminations are grouped as mobility terminations.

HECM loans could be terminated due to foreclosure if borrowers miss their tax and/or insurance premium payments for a certain period of time[4]. However, in our data[5], we do not observe any loans that were terminated under foreclosure due to tax and insurance (T&I) default. The fact is that as the borrower continues to live in the home, the loan itself will not be terminated based on T&I default[6]. Therefore, our estimation sample includes T&I default loans which follow the same classification as described above and are not grouped separately.

Similar to Szymanoski et al. (2000), and Yuen-Reed and Szymanoski (2007), we use a competing-risk model to estimate the probability of the three types of terminations. For a more efficient estimation, we estimated three binomial logistic regression models, which are defined in Equations (1), (2), and (3), respectively, and then transformed into a multinomial probability following Begg and Gray (1984), which shows that the technique is statistically equivalent to a multinomial logistic regression.

The conditional probability that a loan will terminate due to mortality ($P_D(t)$), refinancing ($P_R(t)$) or mobility ($P_M(t)$) is estimated by using:

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

[3] For loans with multiple borrowers or non-borrowing spouses, the mortality date of the last survivor is used.
[4] Mortgagee Letter 2011-01.
[5] Our sample is from FY 2000 to 2015, which restricts observations to a loan age no longer than 16 years.
[6] HECM insurance could be terminated due to T&I default and create the burden of extra cashout flow for the FHA.

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

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

where 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 separate binomial logistic models, and the variables used to predict the conditional probability are $X_D(t)$, $X_R(t)$and $X_M(t)$, for mortality, refinancing, and mobility, respectively. There are both time variant and invariant variables which could reflect the characteristics of the loans and borrowers and capture the economic conditions. In our empirical models, we carefully tested all potential explanatory variables for each binomial regression, checked the in-sample fit of each explanatory variable, and removed the variables that are insignificant, or have counter-intuitive signs.

Given the classification of types of termination, the definition of mortality termination is not subject to the presence of other choices. Conversely, borrowers who terminate their loans through refinancing simply use the HECM as a means of financing. Therefore, the independence of irrelevant alternatives (IIA) imposed by the multinomial logistic model is satisfied under this definition.

4. Data

The basic termination model includes historical HECM terminated loans that were endorsed under the General Insurance (GI) Fund before FY 2008 and under the Mutual Mortgage Insurance (MMI) Fund after FY 2008[7]. The data originate from three sources: the Single Family Data Warehouse of the HUD, Single Family Mortgage Asset Recovery Technology (SMART) system of the FHA and purchase-only House Price Index at the MSA-level from the Federal Housing Finance Agency (FHFA). The Single Family Data Warehouse of the HUD compiles its HECM data primarily from the program's source system: The Computerized Housing Underwriting Management System which contains information about HECM cases that have been assigned to the HUD. This dataset provides the borrower and loan characteristics on a loan-level basis. The SMART dataset provides the loss and termination information of each HECM loan. The FHFA House Price Index provides the macro information on average price changes that an HECM property is subjected to after loan origination.

[7] The estimation sample is through March of FY 2015, due to the availability of mortality data and refinancing information.

Each loan-level record contains fields of the loan origination date and characteristics of the borrower and co-borrower (if applicable), including date of birth, gender, date of termination (if applicable), and loan status, which all have a cutoff date of March 2015. The age of the borrower at loan origination was calculated by using the loan origination date and the date of birth of the borrower. When a co-borrower is involved, the age of the borrower used is the younger of the couple. Since August 4, 2014, the HECM program has permitted the age of non-borrowing spouses to be younger than 62. The non-borrowing spouse could still remain in the house after the borrower passes away, until his/her death or he/she decides to permanently move out. Statistically, the Principal Limit Factors (PLFs) are designed to capture the longevity risk of borrowing by considering the age of the younger spouse regardless whether s/he is a borrower. In our model, we capture the longevity risk in the mortality variable by using the constructed age of the borrower.

As discussed in Clapp et al. (2006), any unobserved changes in borrower characteristics or economic conditions could impact decisions to refinance or move. In our work, we include time variant variables to reduce unobserved heterogeneity. We created refinancing cost as a variable to capture the time varying opportunity cost of refinancing a loan. The FHA House Price Index at the MSA-level can be used to build the appraisal values of properties with time. To accommodate other possible changes in the characteristics of borrowers, i.e., age, time of death, and time of death of spouse (marital status), we calculate the specified mortality rate transferred from gender and marital status as aging of the borrowers, and use the date of death of the last surviving spouse regardless whether she/he is a borrower given the available mortality data from the Social Security Administration. Since HECM borrowers are the aging population who are reaching retirement, they often do not have any major changes in employment, which is the key factor that could vitally affect their financial decisions in forward mortgages, and therefore not crucial in this context.

Given the detailed attributes of the data, we are able to construct discrete-time hazard models for borrowers with different demographics as well as their economic conditions. The household characteristics and the time-varying economic conditions in turn inform how they make their termination decisions.

Table 1 shows the descriptive statistics of the main variables investigated in this paper. To remove the period that has few observations and provide a consistent sample across the three models of termination, we use the sample from FY 2000 through to 2015, and observations with a loan age that does not exceed 16 years.

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

Table 1 Descriptive Statistics of Main Variables

Variable	N	Mean	Std Dev	1st percentile	99th percentile
Borrower Age	841880	72.48	7.48	62.00	92.00
Percentage of Cash Drawdown	841880	0.69	0.31	0.04	1.00
Loan Age	841880	5.93	2.84	1.00	16.00
Relative House Price	841880	1.09	0.57	0.30	3.87
Current Loan to Value	841880	0.69	0.61	0.07	1.41
Two-year change in house price appreciation	841880	0.14	0.13	(0.28)	0.46

Fiscal Year

Table 2 summarizes the percentage of loans by fiscal year of origination and termination status. Active loans denote loans which were not terminated by March of FY 2015. In the sample period, mobility termination dominates the type of termination across the origination years. Prior to FY 2012, mortality termination was more prevalent than refinance termination, whereas in the years after, the pattern is reversed. This observation is consistent with one of our findings that refinance loans tend to terminate earlier. Therefore, there are more refinance loans in loans of recent origination.

Table 2 Termination Type across Fiscal Years

Fiscal Year of Origination	Termination Type			Active
	Mobility	Refinancing	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%

Gender

The gender distribution of HECM portfolios has been consistent over time. Single female borrowers comprise the largest gender cohort up to FY 2012. From FY 2013 to FY 2015, couple borrowers comprise 40.83 percent, which exceeded single female borrowers and made up the largest gender cohort. In FY 2015, the proportion of single female borrowers dropped to around 39 percent, and that of single male borrowers remained at 21 percent, which has been at the same level since FY 2009.

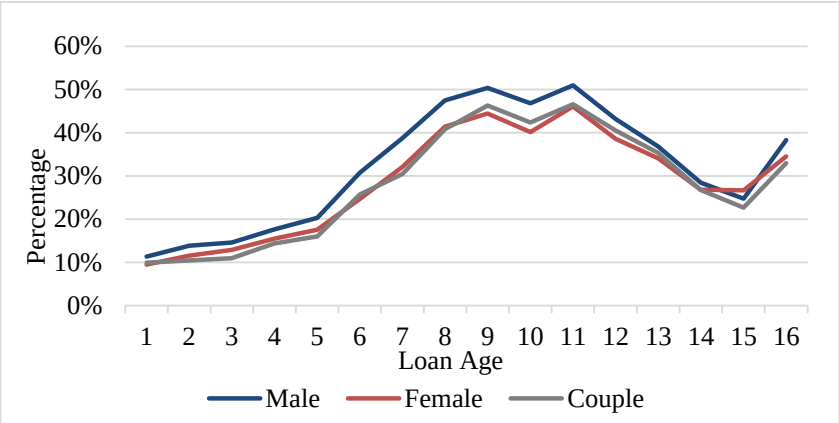
Table 3 Borrower Gender across Fiscal Years

Fiscal Year of Origination	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%

Due to the different life expectancy across the genders, we expect that the rates of terminating loans could also differ across the gender groups. Figure 1 plots the observed hazard rate with respect to loan age for single males, single females, and couple borrowers, respectively.

The hazard rate curve of couple borrowers converges to that of the single female borrowers which is lower than that of the single male borrowers. Among the three cohorts, single male borrowers terminate their mortgage the earliest. These hazard rates present an inverse-U shape for a loan age that is less than 15 years, thus indicating that the termination hazard is low in the early years since origination begins to increase rapidly after five years. For loans that reach the 10 year mark, the termination hazard declines, which suggests that borrowers who have not passed away, paid off the loan, or moved out permanently after 10 years might stay in their home for a long time.

Figure 1 Real Hazard Rate



Note: Not controlled for age or year effect

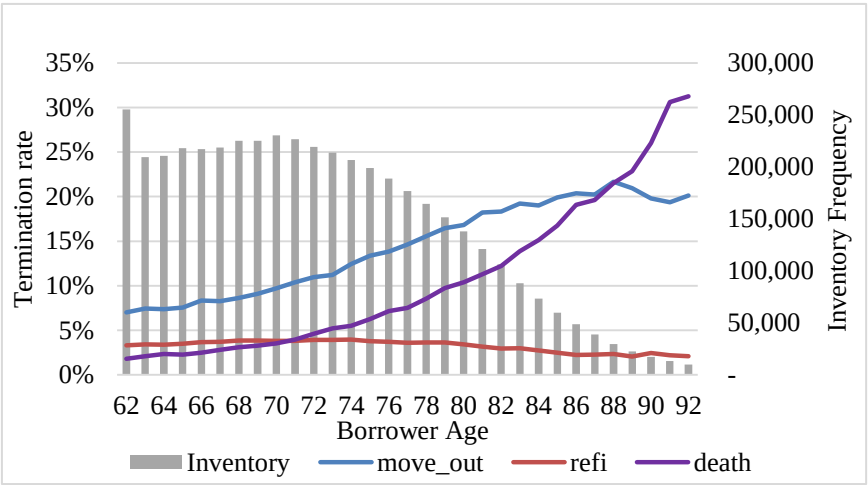
Age

As reported by the AARP, HECM borrowers amount to 1 percent of all households with at least one family member who is 62 years old or older. Assuming that the rate is consistent, the senior population will grow substantially as the overall population ages, which would also hold true for the number of HECM borrowers. Since August 4, 2014, the HECM program has included non-borrowing spouses who are younger than 62 years old. This change means that the average age of borrowers has declined over time. However, overall, the HECM borrowers tend to be older than the general population of homeowners who are 62 and older. In an actuarial report conducted in 2016, the average borrower age was 73 compared to the average age of 72 of all older homeowners.

Non-borrowing spouses are still allowed to stay in the house until they pass away or permanently move out if their borrowing spouse passes away before they do so. As a result, younger non-borrowing spouses could pose as a higher financial risk for the FHA due to their longer life expectancy. In order to reduce this risk, the initial equity available to borrowers is associated with the borrower age: younger borrowers will draw on a smaller portion of the equity available. The risk of longevity is captured in the mortality variable included in our models.

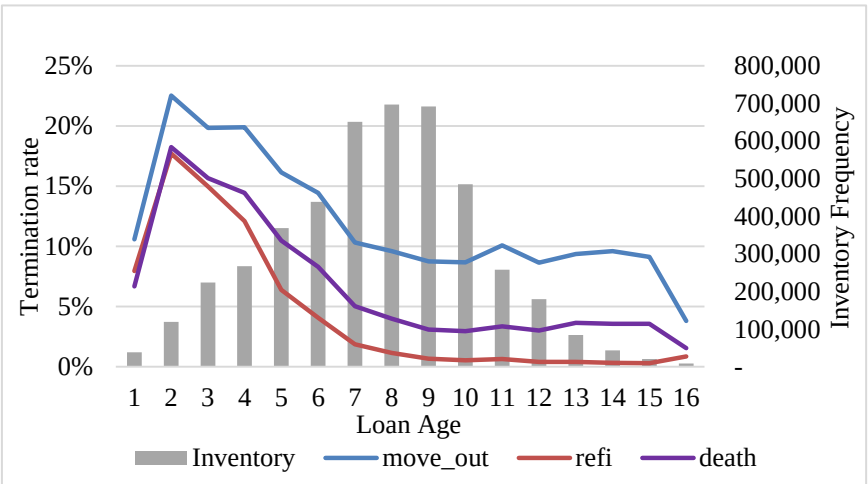
Figure 2a shows the termination distribution of borrower age at loan origination across different types of termination. Relative to mortality and mobility terminations, younger borrowers (those in their mid-60s at loan origination) are paying off their HECM loans much faster through refinancing than older borrowers. As the sample ages, death is the primary reason for loan termination.

Figure 2a Termination Distribution by Age



Another important factor which drives the variation in the rate of termination across the different types of termination is the loan age. As shown in Figure 2b, refinancing appears in the early years of a loan. From the 3rd to 7th year of a loan, the rate of termination for all types of termination shows significant declines, among which refinance termination declines the most rapidly. After the seventh year of a loan, the rate of terminations declines at a slower rate, and then remain linear over the life of the loan.

Figure 2b Termination Distribution by Loan Age

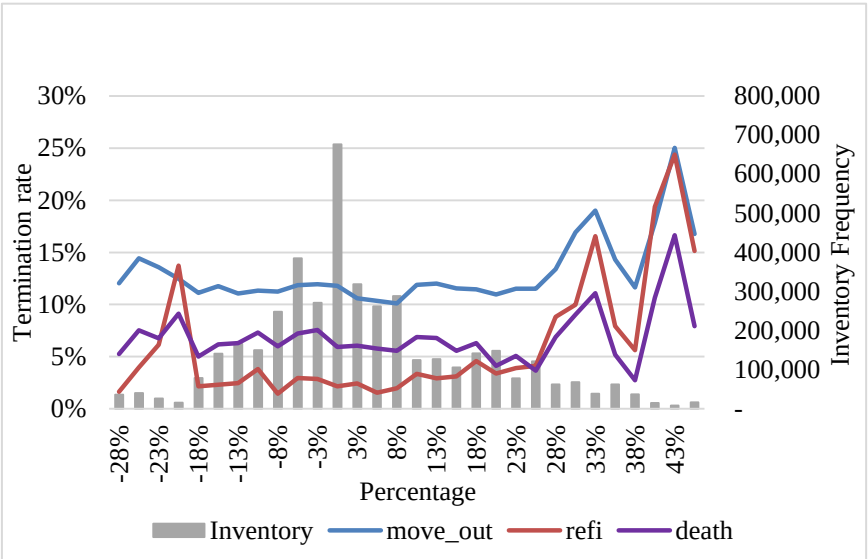


Housing Price Appreciation

The mobility of HECM borrowers is significantly affected by home price appreciation (Davidoff and Welke, 2007). When house prices drop, borrowers who expect exact equity have less incentive to move out due to the likelihood that home values could fall below the loan amount. Figure 3 shows that as the housing price increases (particularly after an 8% increment increase of a 2-year house price appreciation rate), not only does the rate of move-out termination increase, but the refinance rates also increase which balances the decline in mortality termination.

As noted earlier, younger borrowers tend to pay off their HECM loans sooner by moving-out or refinancing as opposed to older borrowers. Young borrowers may therefore show rapid mobility with rising prices. In fact, Szymanoski et al. (2007), Davidoff (2014) and Haurin et al. (2016) conclude that HECM borrowers are a highly selected sample with high liquidity needs.

Figure 3 Distribution of 2-Year HPA Changes by Termination Type



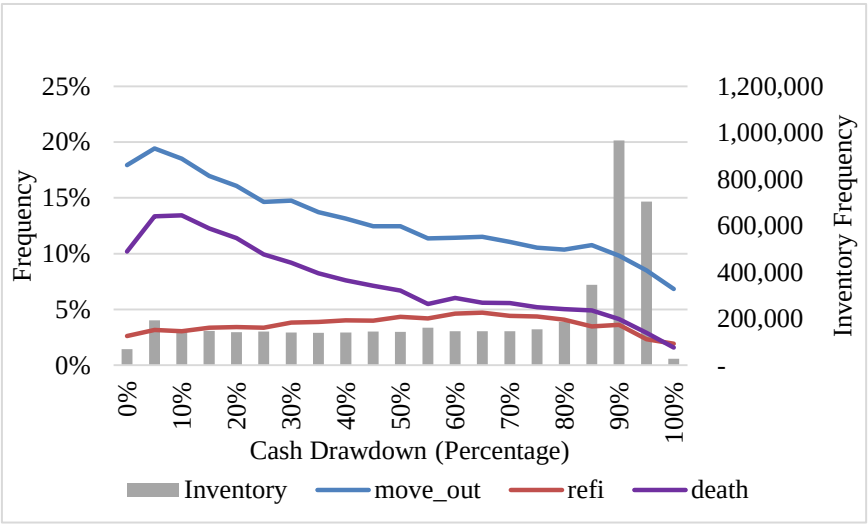
Other Factors

Since FY 2009, the share of fixed-rate mortgages has substantially increased from 12 percent to 72 percent of the total endorsements in the 3rd quarter of FY 2013. The primary outcome driven by most fixed-rate HECMs during FYs 2010-2013 is disproportional loans which have high initial cash drawdowns over the limit: over 80 percent of the borrowers across all ages drew 60 percent above the initial principal limit. Our study shows that a higher percentage of the initial cash drawdown tends to result in a greater likelihood of refinancing. In 2014, the FHA limited the insurability of fixed-rate mortgages with the

Single Disbursement Lump Sum payment option[8]. Therefore, the percentage of fixed-rate loans started to drop in FY 2014 and declined to 11 percent in FY 2016. The London Inter-Bank Offered Rate (LIBOR)-indexed loans increased to an all-time high of 89 percent in FY 2016.

Loans which have a larger initial cash drawdown (percentage) of equity available are more likely to terminate through refinance as shown in Figure 4. There are two factors that explain for this phenomenon. The first factor is the age effect. Since PLFs limit the percentage of initial equity available to younger borrowers at a lower rate relative to older borrowers, the larger cash drawdown (percentage) of the latter accounts for the high death termination rates. Another reason for the high frequency of termination with large cash drawdowns is that withdrawing more equity at the beginning gives borrowers greater incentive to refinance the loan when the house appreciates[9].

Figure 4 Termination Distribution by Cash Drawdown



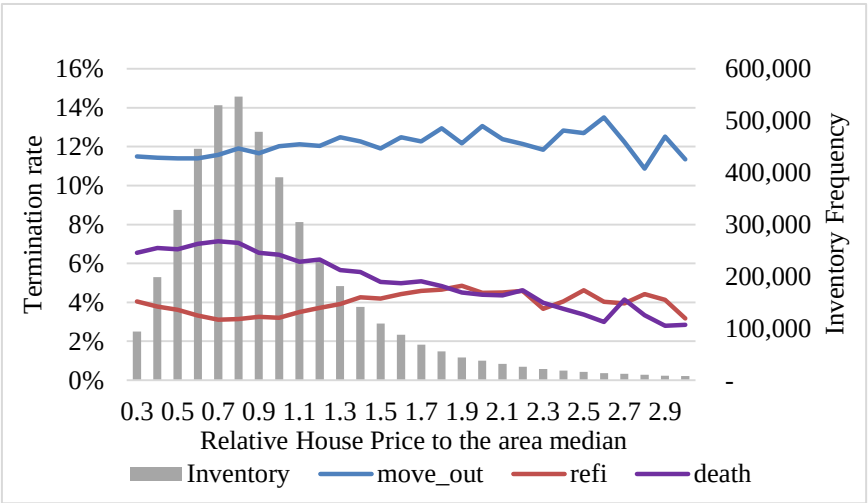
In FY 2016, loans with a maximum claim amount (MCA), or the lowest limit of an HECM loan estimated by appraised value, less than $300,000 accounted for 59 percent of the loans. Loans with an MCA between $300,000 and $417,000 made up 17 percent of the loans, and the rest had an MCA higher than $417,000. The ratio of the appraised values to the area median house prices has been found to indicate the effort that owners put into ongoing maintenance of

[8] Mortgagee Letter 2014-11, June 18, 2014

[9] The policy limited the insurability of HECM loans with a fixed interest rate and lowered the percentage of loans with high initial cash drawdown since 2014. Besides, in the same year, the HUD introduced a higher mortgage insurance premium charge if the initial drawdown amount exceeded 60 percent of the available principal limit.

their house. As our empirical finding confirms, properties with a higher appraised value relative to their area median house prices tend to be in better condition. Since FY 2005, the ratio of appraised value to the area median house price has been increasing. The American Recovery & Reinvestment Act and HERA increased the HECM loan limit and therefore accelerated the trend of the increase. Figure 5 shows that as the ratio increases to 1, the frequency of termination also increases. When the real house price index exceeds 1, the frequency of termination decreases. The move-out rates are consistent with the relative changes in house price. However, the refinance rate increases when relative house prices increase more than the area median house prices. When the house price is close to the area median house prices, it is usually easier to sell the property on the market because the property would offer large liquidity to borrowers. Hence, loans terminated through refinancing or moving were more often found with median value properties.

Figure 5 Termination Distribution by Relative House Price



5. Empirical Result

5.1 Estimation Result

This section presents the results of a termination model regardless of the type of termination, as well as an individual termination model identified by mortality and refinance events, which applies the logistic regression discussed earlier. This section presents the results of a termination model regardless of the type of termination, as well as an individual termination model identified by mortality, refinancing, and mobility events, which applies the logistic regression discussed earlier.

Mortality Termination

The mortality model estimates the probability that am HECM loan terminates due to the death of the borrower. We use the mortality data provided by the Social Security Administration to indicate the date of death of HECM borrowers. The most updated available data on mortality is March 2015.

As evident in Figures 2a and 2b, mortality termination is the primary type of termination found for older HECM borrowers or a seasoned loan. Key variables used in this model are: transformed mortality rates from actuarial mortality tables and interactions of borrower's gender with transformed mortality rates.

The regression result is presented in Table 4[10]. For loans with multiple borrowers, the date of death of the last surviving borrower is used to determine the date of the mortality termination. The same holds for spouses even if one of them is not a borrower. Since the mortality rates for couples are not available from a public source, we determined the mortality rates by utilizing a gender- and age- specific mortality rate $m_g(t)$ in the life tables obtained from the Center for Disease Control and Prevention (CDC). The constructed mortality rates represent the population mortality rates given the policy requirement of HECM loans. For loans with co-borrowers or couples, the joint mortality table represents the likelihood that both borrowers and their spouse will not survive to the end of period *j*. Equations (4) and (5) present the mortality (*M*(*t*)) calculations.

$$M(t)\begin{cases} m_g(t) & \textit{if single} \quad (4) \\ m_b(t) \mid D_{co}(t-1)S_b(t-1) & \\ \quad + m_{co}(t) \mid D_b(t-1)S_{co}(t-1) & \textit{if couple} \quad (5) \\ \quad + m_b(t) * m_{co}(t) \mid S(t-1) & \end{cases}$$

where *M*(*t*) represents the mortality rate at the end of period *t*;

$m_g(t)$ represents the conditional mortality rate of a borrower who passes at time *t* based on the U.S. Census Decennial Life Table. The conditional mortality rate is also gender and age specific. The notation here is *g*= gender.

$m_i(t) \mid D_j(t-1)S_i(t-1)$ represents the mortality rate of borrower *i* at time *t* conditional upon his/her survival up to time *t*-1, and co-borrower *j* passing away before time *t*-1. The notation here is *i=b* (borrower), *j=co* (co-borrower), or *i=co*, *j=b*; and

$m_b(t) * m_{co}(t) \mid S(t-1)$ represents the mortality rate of both the borrower *i* and co-borrower *j* who pass away at time *t* conditional upon the survival of both borrowers to time *t*-1.

[10] As long as more data are available, out-of-sample tests will be conducted.

Table 4 Mortality Termination Model Estimation Results

Description	Boundary Value	Mortality Termination			Refinance Termination			All Terminations		
		Estimate	Standard Error	Wald Chi-Square	Estimate	Standard Error	Wald Chi-Square	Estimate	Standard Error	Wald Chi-Square
Intercept		-0.63*	0.02	1691.81	-7.46*	0.03	66583.57	-5.50*	0.03	37776.25
Loan age								0.04*	0.00	184.68
	[1,3]				0.83*	0.01	9187.10			
	(3,74]				-0.17*	0.00	1987.28			
Refinancing Incentives	(-∞,0]				0.09*	0.00	1756.22	0.05*	0.00	579.47
	(0,+∞)				0.23*	0.00	4551.46	0.30*	0.00	8683.63
Transformed Mortality Rate		0.85*	0.02	7301.81				0.10*	0.00	682.81
Male _Transformed Mortality Rate		0.03***	0.02	2.36						
Female_Transformed Mortality Rate		0.03***	0.02	2.71						
Couple_Transformed Mortality Rate		0.13*	0.02	46.92						
Cash Drawdown (Percentage)_		-1.14*	0.01	1985.52	2.44*	0.03	9053.24	2.46*	0.03	8908.17
Home Value above Area Median Price		0.04*	0.01	16.95	0.21*	0.01	364.40	0.25*	0.01	511.06
Term or Tenure Product		-0.21*	0.02	95.58	0.37*	0.03	204.81	0.38*	0.03	214.44

(*Continued*…)

(Table 4 Continued)

Description	Boundary Value	Mortality Termination			Refinance Termination			All Terminations		
		Estimate	Standard Error	Wald Chi-Square	Estimate	Standard Error	Wald Chi-Square	Estimate	Standard Error	Wald Chi-Square
Area Median House Price to Origination Loan Limit					1.56*	0.01	11493.34	1.47*	0.01	10277.94
Current LTV					-2.33*	0.04	3896.73	-2.30*	0.04	3859.26
Indicator of Fixed-rate					-1.03*	0.02	3136.09	-0.85*	0.02	2162.38
One Year Change in 10-Year Treasury Rate					-0.20*	0.02	78.19	-0.31*	0.02	200.28
Pseudo R^2		0.1183			0.1216			0.1017		
Somers' D		0.586			0.611			0.572		
Number of Observations		4,424,800			4,409,945			4,424,800		

Note: * p<0.001, ** p<0.01, p<0.05***.

Equation (6) presents the transformation of the odds ratio $M(t)$ into $xbetaM(t)$:

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

The transformed mortality rate accounts for the expected mortality rates of the population[11]. In previous studies, the most recent mortality table is often used to model the HECM termination model. However, the mortality calculated in the table uses data since 1990 that span more than two decades and neglects the diminishing trend in mortality rates annually. Figure 6 shows mortality rates of the general population for males and females as determined by the National Center for Health Statistics[12]. The historical data suggest that the mortality rate of the same age group decreases by year. The decrease in the rate varies with age group as well. Older people have a lower death rate which declines at a faster rate with time than younger individuals. The direct use of the single mortality table could negatively affect the accuracy of the model. To address this issue, the most straightforward way is to use specific mortality rates for each cohort from multiple tables. However, two problems arise from this so-called solution. First, the programming is very complicated and not practically useful. Second, the requirement of "one table for each cohort" is challenging to carry out.

In order to capture this trend, we build a model to determine the corresponding mortalities for each cohort, which are used in our estimation models. Using the transformed mortality rate from Equation (6), we fit a linear regression on age and its quadratic term as follows:

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

The life tables include the United States Life Tables from the Centers 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 extrapolate the mortality rate from 2009 to the end of the estimation dataset in 2013. For forecasts after 2014, the mortality rates are constant at the 2013 level for each given age.

[11] Since the mortality rate is an independent variable in the logistic regression, the mortality rate needs to be transformed into a log-odds ratio, to the same scale as the termination rates for a convincing interpretation of the coefficient.

[12] 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 Mortality Rates for 2001 and 2009

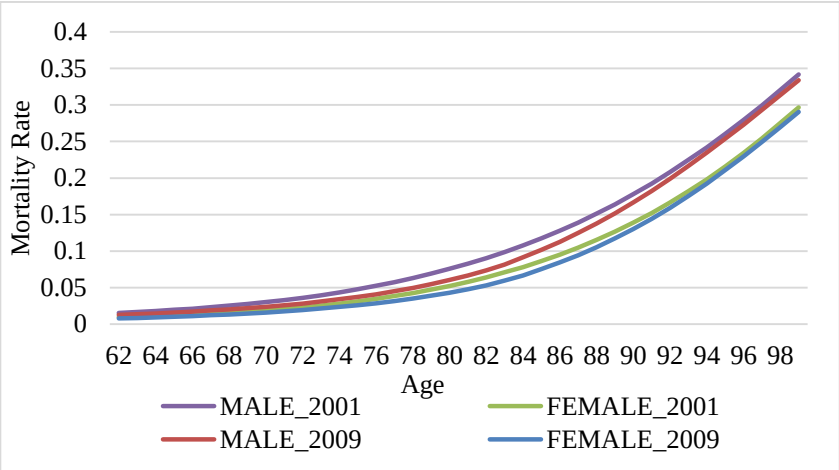


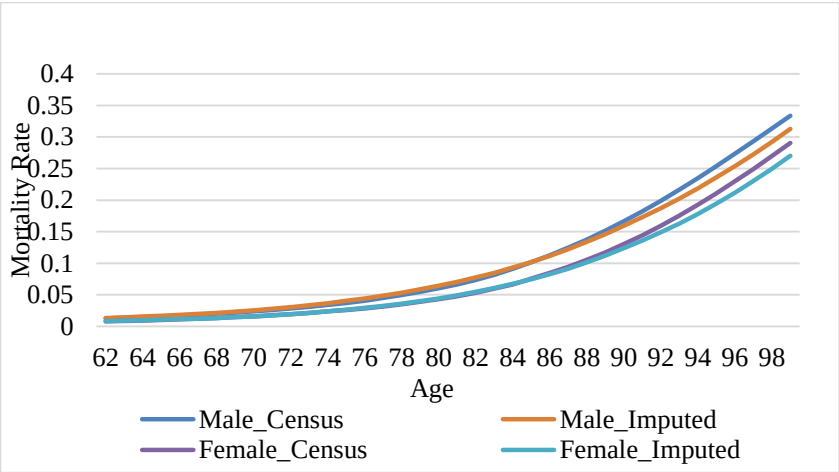
Figure 7 compares the mortality rates from the census table (National Center for Health Statistics) and imputed mortality that considers marital status by using Equations (6) and (7). For HECM borrowers, the average observed ratio of hazard rates to the corresponding imputed male and female mortality rates is 0.85. In other words, given the same gender and age, an HECM loan borrower lives longer than a typical American person. This supports the self-selection issue in HECM programs (Davidoff and Welke, 2007), as HECM borrowers know more about their health conditions than lenders, and people who tend to have longevity are more likely to apply for HECM loans. Szymanoski et al. (2007) state that HECM borrowers terminate their loans more quickly than the general population mortality rates for their age-groups would predict. Our result suggests that this is true for the other types of terminations but the opposite for mortality termination. Mortality rates from the actuarial mortality tables have the highest explanatory power for the mortality termination of HECM loans.

Second, for couple borrowers, the transferred mortality rate that we have calculated jointly from the tables is lower than that of single borrowers as discussed for the second part of Equation (5), which is the calculated mortality rate for couple borrowers and accounts for the death of the remaining borrower. However, the regression result suggests that both single male or female borrowers have slightly higher mortality rates than the average person as denoted by the transformed mortality rates.

Third, the historical HECM data also indicate that borrowers who have a higher mortality rate than that of the baseline actuarial table tend to drawdown more of their total eligible drawdown amount in the first month. Therefore, the variable CashDraw captures this self-selection of the borrowers in the HECM program. However, conditional on the same level of mortality among the senior

population, people who are in the HECM program and have a higher cash drawdown tend to use the funds as a one-time subsidy which can help them to improve their living conditions, and hence it is not as likely that they would constitute as mortality terminations.

Figure 7 Mortality Rate in 2009



Finally, two dummy variables are included: one for the home value and the other for the term or tenure product to reflect additional self-selection effects.

Refinance Termination

In previous research, refinance information is often absent. Some papers match the street address of the collateral with the one in the transaction data to identify move-out termination, and then assign the rest as refinance termination. In this paper, since we are able to identify refinanced loans, the measurement errors found in the previous literature can be eliminated. When the options theory is applied to mortgage refinancing, this means that borrowers should exercise the option to call the debt when the market value of the mortgage exceeds the current balance. Intuitively, refinance termination of an HECM is mainly driven by high house price appreciation, in which borrowers can draw more cash from a larger HECM loan. To model refinance termination, we consider three different explanatory variables: loan age, borrower-related characteristics, and economic variables. Table 4 presents the regression results.

It is not surprising that 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 price, and current loan to value (LTV). The refinance incentive variable was used to capture the potential benefits for HECM borrowers if they refinanced a loan. The refinance incentive variable measures

the net increase in the principal limit relative to refinancing cost, if the borrower chooses to refinance an HECM loan at time t . The variable is constructed as follows:

$$rfi_{t}\_new = \frac{min(MCA_0 \times \Delta H, LoanLimit_t) * PLF_t - C - PL_t}{C} \quad (8)$$

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

$\Delta H = \frac{HPI_t}{HPI_0}$, 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*

The PLF is determined by the expected mortgage interest rate, borrower age at origination, and programs (for instance, the Saver program). We observe the borrower age and the type of loan at time *t*, and use the prevailing expected mortgage interest rate at time *t*. The PLF could be found correspondingly from HUD public information. Following the same process, the transaction cost could be calculated as well.

As discussed, when house price increases after the origination of an HECM loan, borrowers can refinance a new loan with a larger amount and draw more cash from the property. Refinance incentive measures how much additional cash drawdown can be made, if the current HECM loan is refinanced. In Table 4, it can be observed that as the incentive approaches to zero from a negative value, the cost of refinancing declines, which provides more incentive to refinance. As the incentive increases from 0 to a positive value, much more could be gained by refinancing and hence the borrower would be even more likely to terminate the loan through refinancing Furthermore, the relative property value at loan origination affects future house price appreciation. In the HECM program, properties with relatively higher values seem to appreciate more and therefore results in a greater likelihood of refinancing. Also, the result suggests that a lower current LTV, which is related to rising house prices, shows a greater likelihood of refinancing. In addition, when the interest rate is declining, borrowers could refinance for a new HECM with a higher PLF and draw more cash from their property, thus also indicating greater likelihood of refinancing. Overall, we see strong evidence that house price appreciation and interest rate decline contribute to refinancing.

Another important driver is the cash drawdown pattern of the borrower. We measure the pattern by using the first-month initial cash drawdown (percentage). An analysis of the data suggests that frequent drawdowns in the beginning is a positive predictor of the likelihood of refinancing. This is probably a behavior

explanatory variable. Frequent drawdowns at the beginning of an HECM loan is a sign that borrowers who seek opportunities would tend to make more additional drawdowns through refinancing when house prices increase.

Another interesting driver is loan age. Previous HECM experiences show that most refinances occur after the first few years of the loan origination. We use a piece-wise linear spline function of the variable *PolicyYear* to capture the variations in this trend. The results in Table 4 suggest that the propensity to refinance increases during the first three years, but rate of increase starts to decline after that.

The ratio of the local area median house price to national loan limit at the origination of an HECM is used to measure the cost of a house relative to the national average. A high ratio suggests a larger dollar amount for use if the borrower choses to refinance, therefore indicating a greater likelihood to refinance.

Mobility Termination

The mobility model estimates the probability that an HECM loan terminates mainly due to moving out. The explanatory variables include borrower characteristics, economic conditions, and loan-specific variables. Table 5 presents the results.

Table 5 Mobility Termination Model Estimation Results

Description	Estimate	Standard Error	Wald Chi-Square
Intercept	-2.48*	0.02	15518.68
If Borrower is Couple	0.37*	0.01	1581.34
If Borrower is Male	-0.14*	0.01	200.92
Transformed Mortality Rates	0.47*	0.00	14963.57
Cash Drawdown (Percentage)	0.87*	0.02	2795.20
Appraised Value to Area Median House Price	0.18*	0.01	760.71
Current LTV	-2.70*	0.02	16950.89
House Price Volatility	8.06*	0.07	14005.20
Line of Credit	0.12*	0.01	107.03
TERM	0.30*	0.03	103.83
Pseudo R^2		0.0602	
Somers' D		0.426	
Number of Observations		4,410,489	

Note: *All coefficients are significant at $p<0.001$.

Figure 2b shows that move-out termination can occur in both the early and later years of a loan. There are mainly two considerations during move-out

termination; that is, whether there is a favorable market so borrowers could sell their HECM property and move out, and whether borrowers are too advanced in age to manage the property and wish to move to a nursing home or live with their children.

There are three variables related to the factors that facilitate the selling of a house with ease: *current LTV*, *house price volatility*, and *home value to area median value*. A low LTV, which indicates a small loan or increase in property value, suggests that it is easier to pay off the loan by selling the house. Additionally, the dispersion parameter of house price estimated by the FHFA is used to capture the variability among local house price appreciation rates. Higher volatility drives people to sell off their home more quickly. The home value to area median value measures the ratio of the appraised property value at origination to the local median area value of house price at the MSA or state level. Similarly, properties with relatively higher values tend to appreciate more and therefore there is a greater propensity to sell off the house.

Borrower-specific characteristics are key drivers of the likelihood of moving out in the later years of an HECM loan. Historical data indicate that older borrowers are more likely to move out, such as moving to an assisted-living facility or a nursing home. We include *transformed mortality rates* to capture the age-related issues in the later years. As indicated in Table 5, a higher mortality rate leads to a greater likelihood of moving out.

An interesting observation here is the effect of the cash drawdown pattern. The data suggest that frequent drawdowns at the beginning predicts a greater likelihood of move-out termination. Frequent cash drawdown probably indicates that money is needed to pay expenses like medical bills. Moreover, those who tend to more frequently draw cash are more likely to receive nursing home care, instead of self-managing themselves at home.

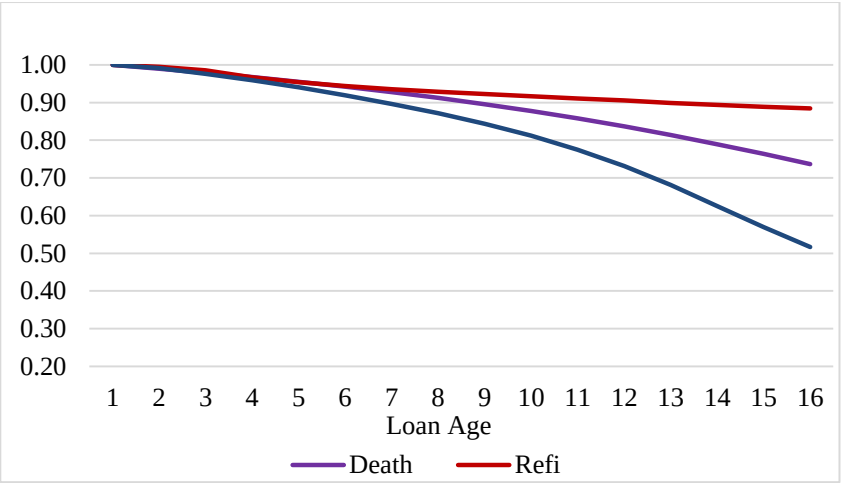
The rest of the variables add some explanatory power to move-out termination. For example, *Gender_Couple*, and *gender_male*. The results show that couples are more likely to move out compared to single female borrowers who are treated as the base group. Two loan-type dummy variables are included: term HECMs and loans with an LOC. The pure term loans seem to have higher mobility rates than the loans with an LOC, thus indicating the self-selection effect of borrowers with different mobility preferences.

We also present the results under the column “All Terminations” in Table 4 from a binary model without particularly considering the type of termination. It is obvious that the key drivers have changed, and the corresponding magnitude of the marginal effects has changed as well. The results will be further discussed in the next section to predict survival rates.

5.2 Predicted Survival Rates

Using the predictions of our model, we calculate the survival rates[13] for refinance, move-out, and mortality terminations, as shown in Figure 8a. Overall, the survival rates for refinance termination are higher than the others. However, as the loans mature, the survival rates of refinance termination become linear, thus indicating refinance terminations would probably not occur. Similar to Figure 2b, refinance termination happens more frequently in the beginning years of the origination of the loan. For loans terminated by death, the survival rate declines uniformly as the loan age increases. Since moving-out terminations are most frequently found among all types of terminations, the lowest predicted survival rate at each loan age suggests the greatest possibility for loans to terminate as a mobility termination relative to the others. To better illustrate the effect of the loan age across the different types of termination, the predicted survival rates are calculated for three distinct termination groups. Without the influence of the competing risk, Figure 8b provides the relative tendency for termination: loans are more likely to terminate through mortality and refinancing in the early stages of the loan, whereas there is an increasing rate that borrowers terminate their loans by moving out of their property 10 years after origination.

Figure 8a Predicted Survival Rates of Entire Sample



[13] Predicted survival rates are aggregated over the sample loans. The survival rate represents the average behavior of the sample loan over its lifetime. Unless a significant regime shift happens and results have quite a different impact on the loan performance than the impact that our models have captured on our sample loans, the predicted survival rate should remain relatively constant over time.

Figure 8b Relative Tendency for Termination

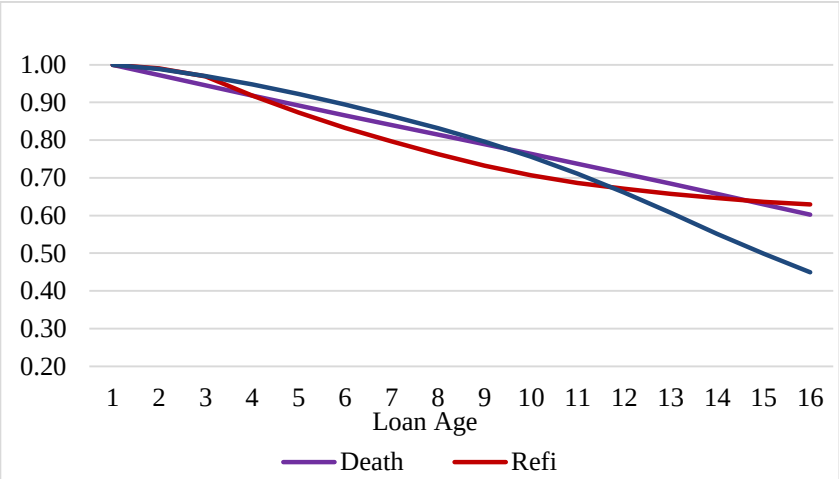
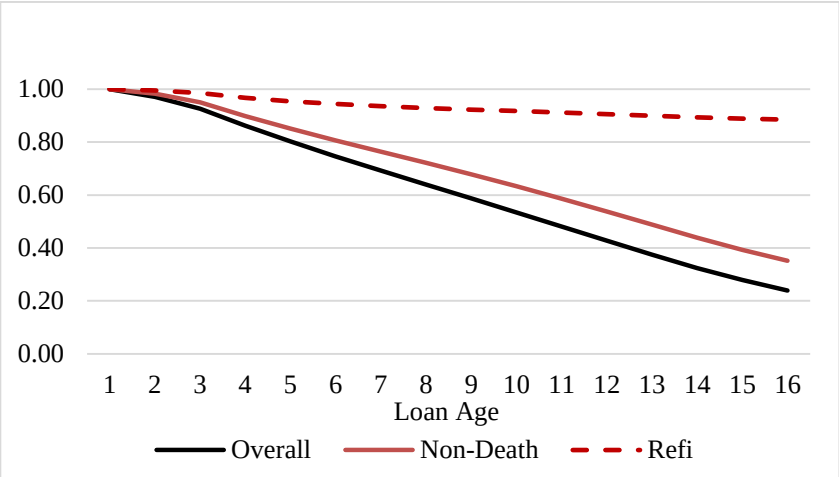


Figure 9 shows the survival rates for refinance terminations, terminations that are not related to death (that is, refinance combined with mobility terminations), and the overall survival rates (predicted by using the all termination model). The overall survival rate represents all terminations for each loan age and hence is always lower than the survival rate for one type of termination. Since the majority of the loans terminate with moving out, the survival curve for terminations that are not related to death more resembles that of move-out termination and more approximates the overall termination curve. However, the use of the survival rate predicted by terminations that are not related to death could underestimate the life expectancy of loans terminated through either refinancing or moving out. In particular, when interest rates fall, borrowers tend to refinance and terminate their loans at a faster rate in the early days of the loan but retain the loan with time. The survival curve predicted by terminations that are not related to death does not truly reflect the historical termination rates at the later stages of a loan by significantly underestimating the life time of the remaining loans, which are the remaining and would have been refinanced loans in a portfolio. This also implies that if the interest rate increases in the future, the survival curve predicted by terminations that are not related to death could overproject the terminations, overestimate loans that terminate through refinancing, and thus overestimate the HECM value.

Additionally, we predicted the count-weighted average life expectancy of loans terminated in different ways. We find that loans terminated by refinancing have the longest life span of 12.71 years, followed by those terminated by death at 11.48 years and finally, those terminated by moving out at 9.96 years. Overall, a loan is expected to be terminated in its 8.62nd year if the type of termination is neglected.

Figure 9 Predicted Survival Rates Overall vs. Non-Death



6. Conclusion

This paper categorizes reverse mortgage terminations into three types based on the different behavior of the borrowers. Competing risk models are estimated to investigate the primary driving factors of each type of termination. Data from FHA insured HECM loans that have originated since 2000 with observed termination experiences up to 2015 are used to empirically estimate these termination rates and identify their primary driving factors. The results show that mortality termination is largely explained by the age-gender-characteristics of the borrowers. HECM borrowers are found to live longer than the average American population. This is consistent with the hypothesis of self-selection in which borrowers in better health are more likely to take out reverse mortgages. Refinance termination is mostly macroeconomically driven, such as house price appreciation and interest rate decline. The data also show borrowers are more likely to refinance in the first few years after origination. More frequent cash drawdowns signal how closely a borrower watches for opportunities to increase the amount available to use. This type of borrower would be more likely to take advantage of rising house prices through refinancing. Mobility termination captures the phenomenon in which a borrower is no longer able to manage his/her house and chooses to live with family members or move to a nursing home. This decision tends to differ based on borrower age, amount of equity left in the house, and volatility of the housing market.

The results in this study show that termination of reverse mortgages is driven by the life, financial, and lifestyle choices of the borrower. These choices compete with one another. Refinance termination is driven by very different

factors from the two other types of terminations and very much macroeconomically driven. By separating the refinance termination from two other types of terminations, we show that refinance terminations are reduced when the interest rate starts to increase. Since the beginning of the HECM program in 1989, the interest rate has steadily declined. As a result, if the probability of refinancing is not separately estimated, the terminations would have been falsely attributed to the other types of terminations and upward biased the projected probability of the other types of terminations. When the interest rate stops declining, refinancing would not take place, thus causing the early total termination rate to be much lower than that observed in the historical data. As a result, more HECM loans would stay active for a longer period of time, the probability that the UPB exceeds the house value at the time of termination would also increase in likelihood. Thus, investors who hold HECM loans (i.e. buyers in the mortgage backed security (MBS) market, loan servicers who are not eligible to file claims to the FHA, or the FHA if HECM loans are conveyed to the FHA) would not be able to recover the full UPB indicated by the contract interest rate and result in a loss of money.

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