Insurance Premium Structure of Reverse Mortgage Loans in Korea*

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Abstract

We analyze the insurance premium structure of reverse mortgage loans in Korea. Our analyses provide a comparison between the reverse mortgage loans structured with constant monthly payments to those structured with graduated monthly payments which are indexed to the growth rate of consumer prices. Using the total annual loan cost measure, we find that, to the relatively younger borrowers, the graduated monthly payments approach is more efficient; while the constant monthly payments approach is more efficient to the older borrowers. Our sensitivity analyses confirm that the younger borrowers are more sensitive to the change of loan terms. Therefore, we propose that insurance premium structure should be more conservative to the relatively younger borrowers group. The results of this study can provide useful guideline to the operation of reverse mortgage system in Korea as well as in other countries.

JEL classification: G21; G22; G28
Keywords: Insurance premium structure; Reverse mortgage system; Graduated monthly payments; Mortgage insurance premium; Total annual loan costs rates

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1. Introduction

Korea is moving rapidly into an aging society. However, social security systems for the elderly in Korea are lagged behind. Reverse mortgage system is recently recognized in Korea as an important financial vehicle to supplement current social security systems for elderly homeowners. A government-insured reverse mortgage program is under consideration by the Korean government.

A reverse mortgage allows the senior homeowner to take out a loan against the equity from house that the borrower does not have to pay back during the lifetime as long as he (she) lives there. With a reverse mortgage, the lender makes payments to the borrower (hence the payment stream is reversed comparing to those in the regular mortgage) based on a percentage of the value of the house. When the borrower no longer occupies the house, the lender takes over the property. Reverse mortgage therefore allows equity rich but cash poor senior homeowners to convert part of their home equity into tax-free cashes without having to sell the house. It gives the seniors financial stability and independence while remain controls of the houses they stay.

Reverse mortgages in the United States can be traced back to 1960's. The most popular reverse mortgage program in the U.S. is the Home Equity Conversion Mortgage (HECM) program, which is the only reverse mortgage insured by the U.S. federal government. HECM was developed by the Department of Housing and Urban Development (HUD) in 1987 to accomplish three broad objects: (1) to permit the conversion of home equity into liquid assets to meet the special needs of elderly homeowners; (2) to encourage and to increase the participation of the primary and secondary mortgage markets in converting home equity into liquid assets; and (3) to determine the extent of demand for home equity conversion and the types of home equity conversion mortgages that best serve the needs of elderly households (Szymanoski, 1994). Although numerous reverse mortgage products have been developed since then, there are three major products in today's market, i.e., HUD's HECM, Fannie Mae's proprietary Home Keeper Mortgage, and Financial Freedom's proprietary Cash Account. Among these three major products, The HECM program is considered the safest reverse mortgage product current available in the U.S. because it is insured by the U.S. federal government. Over 95 percent of all reverse mortgage borrowers choose the HECM product. Depending on the products borrowers chose, the government or a private entity provides guarantee towards reverse mortgage products. For example, the Federal Housing Administration (FHA), a division of HUD, insures the HECM program; Fannie Mae, the largest non-banking financial services company in the world, guarantees the Home Keeper Mortgages; and Financial Freedom, currently the largest private reverse mortgage lender and servicer in the U.S., guarantees the Cash Account (Ballman, 2004). Mayer and Simons (1994 a, b), Case and Schnare (1994), Merrill, Finkel, and Kutty (1994), and

Fratantoni (1999) provided evidence of strong demand for reverse mortgages among “house-rich, cash-poor” elderly homeowners in the U.S.

In Korea, Cho, Park, and Ma (2004) estimated that the potential demand for the reverse mortgage loans could be well over half a million of senior homeowners of age 60 and over in Korea. Lim and Cho (1999), Cho and Ma (2004), and Cho, et al. (2004) provided evidences of potential demand for reverse mortgage loans to the elderly homeowners in the Korean housing market and asserted that the government-insured reverse mortgage system would perform an important role to supplement current social security system for the elderly in Korea. When introducing the government-insured reverse mortgage program in Korea, it is desirable to adopt a similar system to the HECM program in the U.S. because it has been tested and improved since its inception in 1987.

Reverse mortgage funds can be dispensed in several options. Borrower may receive an up-front lump sum in cash; an annuity of pre-determined amount of monthly cash payments as long as he (she) resides in the house as his (her) primary residence (the tenure plan); an annuity of monthly cash payment for a fixed period of time determined by the borrower (the term plan); a line of credit; or a combination of the above. In this paper, we analyze the methods of two tenure plans: the constant monthly payment plan and the graduated monthly payment plan. Because the reverse mortgage tenure plan provides a fixed amount of monthly payments for as long as the borrower occupying the house as his (her) primary residence, the real value of cash steam might decline over time due to the inflation. Therefore, it is useful to analyze the graduated monthly payments plan where the monthly payments are indexed to the growth rate of consumer prices[1].

The reverse mortgage program presents certain risks to the borrowers and the lenders alike. Under the HECM program, these risks are protected through the FHA mortgage insurance program. Reverse mortgage insurance premiums consist of an up-front insurance premium and monthly mortgage insurance premiums (MIP) collected from the borrowers. For the purpose of stable and continual application of reverse mortgage system, it is important to construct an appropriate insurance premium structure which reflects the expected claims properly. To do this, we develop an actuarial model of pricing reverse mortgage insurance premiums for the government-insured reverse mortgage program in Korea.

Existing literature, including Boehm and Ehrhardt (1992, 1994), Szymanoski (1994), Chinloy and Megbolugbe (1994), Rodda, Herbert, and Lam (2000) and Rodda, Youn, Ly,

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[1] In HECM program, to provide readily available cash for unexpected expenses and give borrowers a hedge against rising prices, it also allows to add a line of credit to a constant monthly advance (The American Association of Retired Person, 2005).

Rodger, and Thompson (2003), and Rodda, Lam, and Youn (2004), provided analysis of the risks associated with reverse mortgage loans and presented pricing models for reverse mortgages. Recently, several empirical studies analyzed reverse mortgage system in Korea. Yoo (2002) analyzed the economic effects of the reverse mortgage system. Ma and Cho (2003) analyzed the methods of long term forecasting of housing values and interest rates for building reverse mortgage models. Ma and Cho (2004) and Cho, et al. (2004) analyzed the payment plans of reverse mortgage and analyzed reverse mortgage related risks. Sung (2005) analyzed life insurer's strategy for operating the reverse mortgage loans in Korea.

The main purpose of this paper is to develop a reasonable insurance premium structure of the reverse mortgage system and to provide some guideline for the implementation of the reverse mortgage system in Korea. Insurance claim losses are expected to occur in the event that the borrower's total outstanding loan balance exceeds the appreciated value of his (her) property at the time the loan is due and payable. However, it has been well documented that the exact timing of a loan becoming due and payable is unknown and is difficult to estimate (Rodda, et al., 2000 and Rodda, et al., 2003). In this study, develop a framework of the actuarial structure of the reverse mortgage program based on forecasted growth rates of future housing values and interest rates, and estimated loan termination rates and costs of reverse mortgage.

Our research strategy is described as follows: we first determine the maximum levels of constant monthly payments and graduated monthly payments using the maximum levels of Loan to Value Ratio (LTV) classified by borrower's ages; secondly, we estimate the present values of expected claim losses and expected reverse mortgage insurance premiums and then, adjust the levels of monthly payments if there are discords with the levels of present values; thirdly, we propose the method of payments that have the minimum levels of Total Annual Loan Costs (TALC) rates such that the values of expected insurance premiums are equal to the values of expected claim losses, and finally we conduct sensitivity analysis of the reverse mortgage pricing models based on a set of scenarios with different house price appreciation rates and interest rates.

The remaining of the paper is organized as follows: section 2 presents a model of reverse mortgage focusing on tenure plans with alternative payment approach, section 3 describes methodology and data, section 4 reports the results of analysis, and the last section draws conclusion.

2. A Model of Reverse Mortgage

2.1. Alternative Payment Plans

The maximum level of lump sum payment

Following the HECM program, cash advances in our reverse mortgage program are limited by the principal limit factor, which is determined when the expected losses from future claims can be covered by the insurance premium (Szymanoski, 1994). This principal limit factor is also known as the maximum level of Loan-to-Value (LTV) ratio of the reverse mortgage. In this paper, we adopt the concept of life expectancy to determine the unique level of maximum LTVs corresponding to borrower cohorts varying by borrower's age, house price appreciation rates and interest rates. Following Ma and Cho (2004), the maximum level of lump sum reverse mortgage payment (LSUM) can be calculated according to the following formula:

$$LSUM = \frac{H_0 \prod_{t=1}^{T_a} \left(1 + g_t\right)}{\prod_{t=1}^{T_a} \left(1 + m_t\right)} \tag{1}$$

where	$LSUM$	=	the lump sum reverse mortgage payment
	H_0	=	the initial housing equity
	T_a	=	the life expectancy of the borrower with initial age a
	g_t	=	the house price appreciation rate at period t
	m_t	=	the market interest rate at period t

In equation (1), the non-linear relationship of house price appreciation and discount factor, $(1 + g_t)/(1 + m_t)$, is called the net discount ratio. If the time series of net discount ratio is stationary, we can use the mean value of net discount ratio, $(1 + g)/(1 + m)$, for calculating the maximum level of the lump sum reverse mortgage payment[2]. In that case, equation (1) can be simplified into following equation[3]:

$$LSUM = H_0 \left(\frac{1 + g}{1 + m}\right)^{T_a} = H_0 \cdot NDR^{T_a} = H_0 \cdot LTV \tag{2}$$

[2] Refer to Haslag, Nieswiadomy, and Slottje (1991) and Ma and Cho (2004).

[3] Mayer and Simon (1994b) used the simplified model similar to the Equation (2), but they did not test the stationary of the net discount ratio series before applying the mean values of the house price appreciation rate and that of the mortgage rate in their analysis.

where NDR^{T_a} = maximum LTV conditioning on the life expectancy of the borrower with initial age a

NDR = $(1+g)/(1+m)$ = the mean value of net discount ratio

In this analysis, we compute LSUM in equation (2) as the original principal limit[4]. The amount of LSUM borrowers can get varies depending on their ages, current interest rates, and their property values in the reverse mortgage program. However, by using equation (2), we can find out the unique level of LTV by borrower's ages regardless of the current interest rates fluctuation because we use the mean value of net discount ratios in equation (2).

With HECM products, borrowers may obtain their reverse mortgage funds as a single lump sum, a tenure plan, a term plan, or a line of credit. In addition, borrowers can choose any combination of these options. In this analysis, we focus on two methods of the tenure plan, the constant monthly payments and the graduated monthly payments.

Maximum level of constant monthly payment

Under the constant monthly payment scheme, the annuity payment is computed such that the lump sum payment after adjusting the equilibrium factor equals the present discounted value of the stream of annuity payments multiplied by the borrower's survival rate[5].

$$LSUM\left(1-\beta\right) = \sum_{t=0}^{T(a)-1}\left[\frac{PMT_C}{\left(1+i\right)^t}\times p_{a,t}\right] \tag{3}$$

[4] Currently, the HECM program uses a different method to determine the level of LTV. Under the single insurance premium structure and arbitrary assumptions of the key variables (i.e., growth rate of housing value, interest rates, loan terminations, loan costs, etc.), the HECM calculates the level of LTV where the present values of expected losses equal the expected insurance premiums using the method of trial and error (Szymanoski, 1990, 1994).

[5] However, in the HECM model, the value of constant monthly payments can be calculated using the formula as follows; $PMT = \mathrm{LSUM}\Big/\sum_{t=0}^{(100-a)\times 12}\left(1+r\right)^{-t}$ (where, a = borrower's age). As we can see in the HECM model, borrowers of the tenure plan in the HECM model were assumed to live until they are 100 years old (Szymanoski,1990, and Rodda, et al., 2000). Therefore, the calculation in HECM is more conservative compared to equation (4) which is based on expected survival rate, ($p_{a,t}$). In this paper, we assume the payments of an annuity are made at the beginning of interest conversion periods (Muksian, 2003). Ma and Cho (2004) used monthly payments model similar to this paper. However, they simply used the concept of life expectancy by borrower's age instead of using borrower's survival rate as we do in this paper.

where β = the equilibrium factor for balancing income and outgo

$T(a)$ = the number of months that borrowers with age "a" will continue to receive the annuity payments until they reach 100 years of age

PMT_C = the annuity payment (constant monthly payment)

i = the annuity rate

$p_{a,t}$ = the probability that a borrower of age a will survive at age $a+t$

In equation (3), the value of the equilibrium factor, β, for balancing the present value of expected claims and that of expected mortgage insurance premium will be changed according to the assumptions of insurance premium structure, the levels of housing price appreciation rates, and expected interest rates in the actuarial model of reverse mortgage. Solving the equation (3) for the monthly annuity payment gives:

$$PMT_C = \frac{LSUM\,(1-\beta)}{\sum_{t=0}^{T(a)-1}\left[\frac{1}{(1+i)^t}\times p_{a,t}\right]} \tag{4}$$

We can calculate the value of equilibrium factor, β, using the trial-and-error approach.

Maximum level of graduated monthly payments

The graduated monthly payments scheme can alleviate the risk of decrease in purchasing power over time. In this paper, we analyze the graduated monthly payments scheme which are indexed to the growth rate of consumer prices. Provided that the time series of growth rate of consumer prices (c_t) is stationary, we can calculate the base starting amounts (PMT_G) of graduated monthly payments using the following relationship.

$$\begin{aligned} LSUM\,(1-\beta) &= \sum_{t=0}^{T(a)-1}\left[\frac{PMT_C}{(1+i)^t}\times p_{a,t}\right] \\ &= PMT_G \cdot \sum_{t=0}^{T(a)-1}\left[\left(\frac{1+c}{1+i}\right)^t\times p_{a,t}\right] \end{aligned} \tag{5}$$

where PMT_G = the base starting amount of graduated monthly payment

c = the mean value of growth rate of consumer prices

Using the above relationship, we can evaluate the maximum level of base starting amount of graduated monthly payments as follows:

$$PMT_G = \frac{LSUM\left(1 - \beta\right)}{\sum_{t=0}^{T(a)-1}\left[\left(\frac{1+c}{1+i}\right)^t \times p_{a,t}\right]} \tag{6}$$

2.2. Insurance Premium Structure

The main purpose of this study is to develop an appropriate insurance premium structure of reverse mortgage system in Korea. To do this, we conduct an analysis based on the actuarial structure of the reverse mortgage. We assume that the combination of up-front cost and monthly mortgage insurance premium (MIP) begins with an up-front cost of 5% of housing values and a monthly MIP according to the annual rate of 0.5% of the loan's outstanding balance[6]. We first evaluate the present values of expected claim losses and expected insurance premiums under predetermined insurance premium structure. Next, we modify the levels of monthly payments if there is a discord with the levels of present values. We then find the methods of payments that have the minimum levels of total annual loan cost (TALC) rates under the present value conditions that the expected insurance premiums are equal to the expected claim losses.

Present Value of Future Premiums and Future Claim Losses

At the time of loan closing, following Rodda, et al. (2000; 2003), present value of total

[6] In the HECM, after loan closing, every borrowers are required to pay 2 percent of the maximum claim amount (adjusted property value) as an up-front (initial) insurance premium and a monthly MIP according to the annual rate of 0.5% of the loan's outstanding balance (Rodda, et al., 2000, 2003). The itemized costs of a HECM loan include an origination fee, third-party closing costs, an up-front mortgage insurance premium, a monthly MIP, a servicing fee, and interest (AAPR, 2005). In 1999, the typical HECM borrowers paid $1,800 in origination fees, $1,500 in closing costs, $2,100 in up-front insurance premium or a total of $5,400 as the initial cost of a HECM (Rodda et al., 2004). In this analysis, we assume that the up-front cost is composed of the origination fee and third-party closing costs (3% of housing values) and up-front insurance premium (2% of housing values). These high initial transaction costs create a large hurdle that has essentially blocked refinancing of reverse mortgages. Therefore, prepayment rates in reverse mortgage loans could be controlled by the up-front costs (Szymanoski, 1994, and Rodda, et al., 2004).

expected claim losses ($PVEC$) can be calculated as follows:

$$PVEC = \sum_{t=1}^{T(a)} \left[\frac{EC_t \times q_{a,t}}{(1+i)^t} \right] \tag{7}$$

where $PVEC$ = present value of total expected claim losses at t=0

EC_t = $max\{0, [(OLB_t - H_t) \cdot q_{a+t}]\}$ = expected claim losses at t

OLB_t = expected outstanding loan balance[7]

H_t = expected house price at t ($H_t = H_0 \cdot (1+g)^t$)[8]

$q_{a,t}$ = probability that the loan will be terminated at age $a+t$

i = discount rate

At the time of loan closing, following Rodda, et al. (2000, 2003), present value of total projected mortgage insurance premium ($PVMIP$) can be calculated according to the following discounting formula.

$$PVMIP = UP_0 + \sum_{t=1}^{T(a)} \left[\frac{MIP_t \times q_{a,t}}{(1+i)^t} \right] \tag{8}$$

where $PVMIP$ = present value of total projected mortgage insurance premiums at t=0

UP_0 = up-front insurance premium at t=0

MIP_t = projected monthly mortgage insurance premiums

Net Expected Insurance Liability

The net expected insurance liability (NEL) is calculated as follows.

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[7] The outstanding loan balance (OLB_t) is estimated as the previous period's loan balance plus the projected amount of cash payments to borrowers, monthly MIP (mortgage insurance premiums) , service fees, and interest charges accrued during that period. The HECM actuarial model assumes that there is no partial prepayment before the loan is due and payable because they do not appear to happen frequently. (Rodda, et al., 2003).

[8] At the time when the loan becomes due and payable, the future value of house price (FV) can be computed according to the following formula, $FV = H_0 \prod_{t=1}^{T} (1 + g_t)$. As we can see equation (2), if the time series of the house price appreciation rate (g_t) is also confirmed stationary, we can simplify formula into the equation which using the mean value of the house price appreciation rate (g).

$$NEL = PVEC - \left(RESV + PVMIP\right) \tag{9}$$

where NEL = net expected insurance liability

$RESV$ = $\sum_{t=1}^{k}\left[\left(TIP_t - TC_t\right)\left(1+i\right)^{n-t}\right]$ = net reserve[9]

TIP_t = total amount of insurance premiums including up-front premium

TC_t = total amount of claim disbursements

k = loan duration

n = total number of months between loan closing and the cutoff date

Under the present conditions that the values of expected premiums are equal to the values of expected claim losses, we finally search for the method of payments that shows the minimum levels of TALC rates.

2.3. Total Annual Loan Costs (TALC) rates

The TALC rate is the annual average rate that includes all the costs of a reverse mortgage but do not considers the survival probabilities of the loan. The advantage of the TALC method is that it presents us the total cost of the loan by a single rate at a specific period ($t = n$) during the borrowers become aged 100 (Scholen, 1996).

Constant Monthly payment

Under the constant monthly payments scheme, the total outstanding loan balance at period $t = n$ can be expressed as follows:

$$OLB_n = \left(PMT_C \times n\right) \times \left(1 + TALCR\right)^n$$

(10)

where $TALCR$ = total annual loan costs (TALC) rates

In equation (10), we can calculate TALC rates at period $t = n$ as follows.

[9] At the time of loan closing, $RESV$ will be only an up-front premium (2% of the house price).

$$TALCR = \left(\frac{OLB_n}{PMT_C \times n} \right)^{\frac{1}{n}} - 1$$

(11)

Graduated Monthly Payment

In the case of graduated monthly payments, the total outstanding loan balance at period $t = n$ can be expressed as follows:

$$OLB_n = \left[PMT_G \sum_{t=1}^{n} (1 + c)^t \right] \times (1 + TALCR)^n \quad (12)$$

In equation (12), we can calculate TALC rates at period $t = n$ as follows.

$$TALCR = \left(\frac{OLB_n}{\left[PMT_G \sum_{t=1}^{n} (1 + c)^t \right]} \right)^{\frac{1}{n}} - 1 \quad (13)$$

3. The Data

House price appreciation, Market interest rates, and Net discount ratios

The time series data used in the analysis include the monthly data of apartment house price index (APT) maintained by Kookmin Bank from January 1986 to December 2004[10], the monthly data of yields on national housing bonds with 5-year maturity (HB5) of Korea National Statistical Office (KNSO), and the consumer price index (CPI) of Korea National Statistical Office. We generate the time series of growth rate of consumer price by log differencing the time series of CPI and the growth rate of APT by log differencing the time series of APT. As discussed in previous section that equation (2) is valid only if the discount ratios series is stationary. A time series is said to be stationary if the generating function for the series does not [11]itself change through time. We conduct the unit root test in order to confirm the stationary of time series. We primarily conduct OLS (ordinary least squares) estimation with DF model and

[10] The apartment housing in Korea is the most popular housing type. In Korea, the apartment housing is similar to the condominium sector of the housing market in the United States.
[11] See Appendix for a discussion of the unit roots test.

modify t-statistics of δ, coefficient from the AR(1) regression, to account the serial correlation in u_t. The time series of the net discount ratio, the growth rate of consumer price are confirmed stationary, respectively. We then conclude that the mean values of the time series can be used on calculating equation (2) to (6) in this research. Following equation (1), we use the net discount ratio (NDR_t) and the borrower's life expectancy for calculating the value of lump sum reverse mortgage payment ($LSUM$). We generate the time series of monthly discount rates (m_t) based on a market interest rate (i.e. HB5). We then generate the time series of the net discount ratio (NDR_t) by using the growth rate of APT and the time series of the market interest rates (m_t). Figure 1 show the net discount ratio (NDR_t) from January 1986 to December 2004.

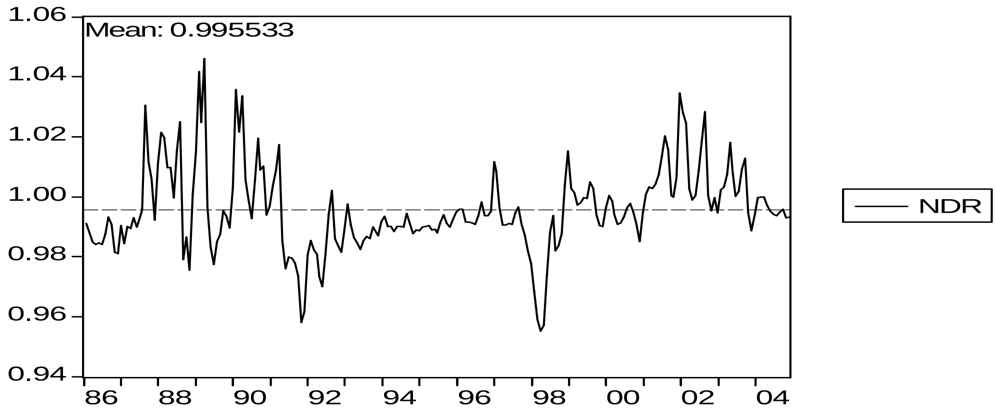

Figure 1. Trend of the net discount ratio (January 1986 to December 2004)

The loan termination rates

Because there was no previous experience on reverse mortgage termination rates (the probability that the loan will become due and payable), U.S. HUD used untested assumptions for termination rates. In HECM termination model, the loan termination probability was assumed to be 1.3 times the mortality rate of the youngest borrower in the family[12]. In HECM termination model, we can find the relationship between monthly loan survival probabilities and that of termination probabilities as below.

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12 HECM loans terminate when the borrower leaves her home permanently, simply chooses to pay off the loan, or borrower dies. However, no termination experience was available when the premiums were originally set, so an assumption of terminations at 1.3 times mortality was made (Rodda et al. (2004)). We assume that the younger co-borrower in the family is a wife (i.e. female). Therefore, instead of using the co-borrower's joint age sex mortality rate, we simply use the female's mortality rate in this analysis. Meanwhile, if considering the single status, it is necessary to use male's mortality rate.

$$d_{a,t} = p_{a.t} \times q_{a,t} = p_{a,t} - p_{a,t+1}$$

(14)

where $d_{a,t}$ = the probability that the loan will be terminated within a month after age $a+t$

$p_{a,t}$ = the probability that a borrower of age a will survive at age $a+t$

$q_{a,t}$ = the probability that the loan will be terminated at age $a+t$

To convert annual borrower survival probabilities, $S_{i,j}$, into monthly loan survival probabilities, $p_{a,t}$, the HECM used the following equation which both interpolated geometrically and adjusted for loan terminations for reasons other than death of the borrower (Szymanoski (1990)).

$$p_{a,t} = \left[S_{i,j} \cdot \left(\frac{S_{i,j+1}}{S_{i,j}} \right)^{\frac{r}{12}} \right]^{1+m} \tag{15}$$

where i = initial age in years = {62, 63, ⋯, 99}

j = attained age in full years = { i , i +1, ⋯, 100}

a = initial age in months = 12 i

t = attained age minus initial age in months = 12(j - 1)+ r

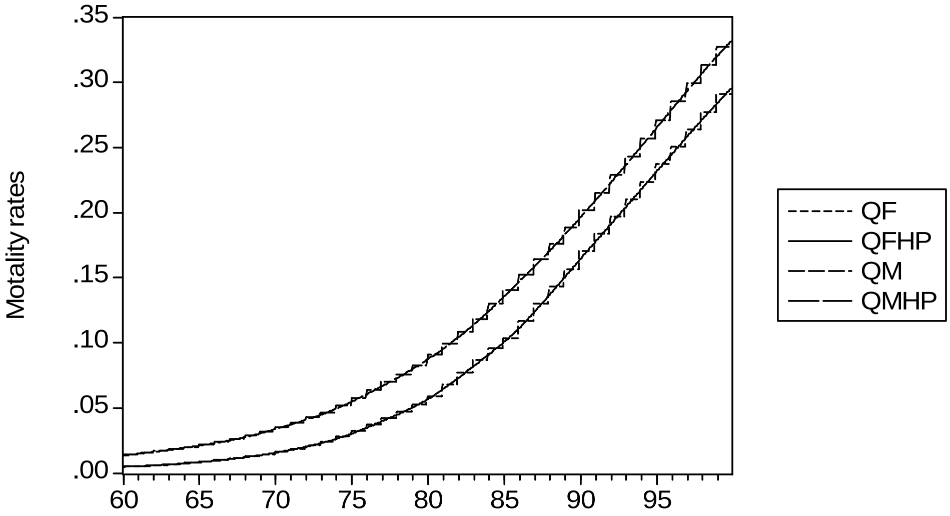
r = months between attained ages j and $j+1$ = {0,1, …, 11}

m = Move-out rate expressed as a decimal = 0.3

But, according to Chow, Szymanoski, and DiVenti (2000) and Rodda, et al. (2003), the 1.3 times mortality assumption under-predicts termination probabilities at young ages, and over-predicts termination probabilities at late ages based on the historical data. To alleviate this problem, we use male's mortality rate as female's termination rate in this analysis.[13] In Korea,

[13] According to this mortality assumption, we use the male's life expectancy from the data of 2002 Complete Life Tables in the Korea National Statistical Office (KNSO) when we calculate the values of LTV in equation (2).

we use the mortality rate (the probability of dying) from the data of 2002 Complete Life Tables in the Korea National Statistical Office (KNSO) and generate monthly mortality rate of aged 60 and above to aged 100[14]. For the purpose of interpolating, we used the smoothed Hodrick-Prescott (HP) trends as follows.[15]



[Figure 2] Smoothed Mortality Rates by Age

In Figure 2, QF is female's mortality rates and QM is male's mortality rates. QFHP is HP trend of female's mortality rates and QMHP is HP trend of male's mortality rates QM. We can see in Figure 2 that both HP trends penetrate the median point of each age interval. This is just the reason why we used HP trends for interpolating the value of mortality rates in this analysis because the annual mortality rates of KNSO represent the median value of each age interval. If we simply follow the method of HECM, the monthly loan survival rates (termination rates) will be a little higher (lower) than that of our analysis[16]. In Figure 3, we compared QFHP, QMHP, and 1.3 times of female's mortality rate (QFHP×1.3).

[14] The KNSO assumes that the mortality rate of aged 100 and above equal to 1.0 (if age$\geq$100 then, q_{a+t} =1.0).

[15] See Appendix for a discussion of the Hodrick-Prescott Filtering approach.

[16] In actual analysis, we divided the values of HP trend by 12 months to generate the monthly mortality rate of aged 60 and above.

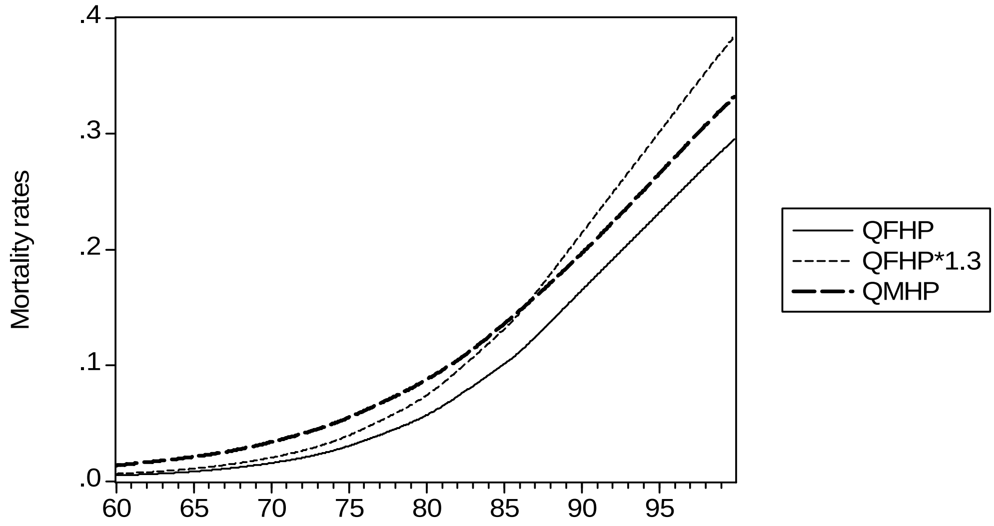


Figure 3. Mortality rates.

The annuity rate, discount rate, expected interest rate

When applying equation (4) to (8), proxy the annuity rate, discount rate, and expected interest rate which adopted to determine the outstanding loan balance by using the mean value of life insurer's ratio of invest assets profit (RIAP)[17] time series from April, 2000 to November, 2004.

4. The Results

The descriptive statistics of each time series in this paper are as follows.

Table 1
The descriptive statistics of each monthly time series (January, 1986 to December, 2004)

[17] Ma and Park (2004) confirmed that there was a structural change in the time series of RIAP before and after the point of April, 2000 and the two sub-period time series of life insurer's RIAP were stationary before and after April, 2001, respectively. Therefore, to alleviate the problem of interest rate risk resulting from the difficulties of forecasting long term interest rates, they suggested that the mean value of RIAP after April, 2000 should be used a reference interest rate to calculate the life insurer's assumed interest rate in Korea. Reverse mortgages have two interest rates, one for determining the annuity and the other for accumulating the loan (i.e. the total outstanding loan balance). In the reverse mortgage program, the fixed interest rate determines the annuity payment to avoid fluctuations in the borrower's cash flow while the adjustable rate compounds the loan (Chinloy and Megbolugbe, 1994).

	growth rate of APT	Market rate (HB5)	growth rate of consumer price	net discount ratio	RIAP
Mean	0.004701	0.009223	0.003893	0.995533	0.006129
Std. Dev.	0.013567	0.002983	0.005288	0.014068	0.000623

Note: The results of RIAP are from April, 2000 to November, 2004.

We conduct unit root test to test the stationary of each time series. Table 2 reports the results of ADF test and PP test.[18]

Table 2
The result of unit root test (01.1986 to 12.2004)

	growth rate of APT	Market rate (HB5)	growth rate of consumer price	Net discount ratio	RIAP
ADF	-4.3484	-2.8543	-10.1871	-4.1572	-5.7686
PP	-6.2546	-2.7042	-10.6108	-5.9801	-5.7686

Note: 1. The results from including both intercept and trend in test equation. 2. The results of RIAP are from April, 2001 to November, 2004. 3. Critical values: Period (January, 1986 – December, 2004): 1%: -3.9991, 5%: -3.4298, 10%: -3.1384; Period (April, 2000 – November, 2004): 1%: -4.1338, 5%: -3.4937, 10%: -3.1757

In Table 2, both ADF and PP tests show that the time series of growth rate of APT, growth rate of consumer price, net discount ratio, and RIAP are stationary at a 1 % level of significance, respectively. But, the market interest rate (HB5) does not reject the null hypothesis that there exists a unit root at a 10 % level of significance. Although the market interest is non-stationary time series, we can still use the mean value of net discount ratio for calculating the lump sum reverse mortgage payment (LSUM) in equation (2) because the time series of net discount ratio is stationary.

The lump sum reverse mortgage payment (LSUM)

Based upon the mean value of net discount ratio (NDR = 0.9955) and male's life expectancy, we can determine LTV and calculate the lump sum reverse mortgage payment (LSUM). We assume that the housing value is 200 million won[19] and the up-front cost is 5% of housing value[20]. The maximum values of LTV and LSUM in equation (2) are reported in Table 3.

[18] See Appendix for a discussion of ADF and PP tests.
[19] USD $1 is about 1,000 won. Therefore, 200million won is about USD $200,000.
[20] As a base case, we assume that the value of up-front cost is 5 % of housing value and the up-front cost involves 2 % of housing value as an up-front insurance premium according to the insurance premium structure of HECM program.

Table 3
Maximum value of LTV and LSUM (unit: Korean 1,000 won)

Borrower's age	60	65	70	75	80	85
Life expectancy	222 month	179 month	140 month	106 month	80 month	59 month
LTV	0.37	0.45	0.53	0.62	0.70	0.77
LSUM	74,000	90,000	106,000	124,000	140,000	154,000

Note: LSUM = 200 million Won * LTV

We focus on two payment methods of the tenure plan in this paper. One is the constant monthly payments and the other is the graduated monthly payments which index to the growth rate of consumer prices.

The constant monthly payments

We determine the maximum level of annuity rate in equation (3) and (4). The monthly CDF (cumulative discount factor), the present values of total loan costs, and the maximum level of constant monthly payments (PMT_C) are reported in Table 4.

Table 4
CDF and maximum value of PMT_C (unit: Korean won)

Borrower's age	60	65	70	75	80	85
CDF_C	114.5557	101.7029	87.4872	72.9795	59.3985	47.4110
β	23.5%	31%	37.5%	44%	48.2%	50.4%
PMT_C	513,616	631,763	779,889	975,555	1,246,561	1,638,812

Note: 1. $CDF_C = \sum_{t=0}^{T(a)-1}\left[(1/1+i)^t \cdot {}_tp_a\right]$ 2. the annuity rate: i = 0.075 per annum (RIAP rate 7% + MIP 0.5%): The mean value of RIAP time series from April, 2000 to November, 2004 was 7.35 % per annum. We assume 7.0 % per annum as the RIAP rate. 3. We can calculate the values of β using trial-and-error approach such that the values of LSUM after adjusting β equals to the present discounted values of annuity payments multiplied by the borrower's survival rate. In this case, the present values of expected claims equal to that of expected mortgage insurance premiums.

The graduated monthly payments

In this paper, we analyze a method of graduated monthly payments which index to the growth rate of consumer prices. Based upon the mean value of monthly growth rate of consumer price (c = 0.003893) and 7.5 % of annuity rate, we can calculate the maximum level of base starting amounts of graduated monthly payments in equation (6).

Table 5

CDF and Maximum base starting amounts (PMT_G) (unit: Korean won)

Borrower's age	60	65	70	75	80	85
CDF_G	174.0165	146.1623	119.1028	94.42	73.387	56.2459
β	23.5%	31%	37.5%	44%	48.2%	50.4%
PMT_G	343,299	445,149	578,823	760,504	1,016,182	1,389,760

Note: 1. $CDF_G = \sum_{t=0}^{T(a)-1}\left[(1+c/1+i)^t \cdot {}_t p_a\right]$ 2. inflation rate: c = 4.67% per annum 3. the annuity rate: i =7.5% per annum. 3. We calculate the values of PMT_G using the same values of β in constant payment method (Table 4).

The present Value of Future Claim Losses and Future Insurance Premiums

We calculate the present value of future claim losses and future insurance premiums using the determined values of monthly payments. After calculating the present values, we evaluate the net expected insurance liability of reverse mortgage loans. We apply several assumptions during the analysis.

Table 6 reports the results of net expected insurance liability of reverse mortgage loans. Under equal insurance premium structure, all the ratios of PVEC to PVMIP of constant payments show similar to 1.0 because there were a pre-adjustment of β in the actuarial model of reverse mortgage. However, the ratios of graduated payments show greater than 1.30 because the loan termination rates show a pattern of exponential increase in the tail period and the magnitude of monthly payments increase by passage of time. We adjust the level of monthly payments of graduated payment methods to improve the ratios of PVEC to PVMIP.

Table 7 reports the results of revised payments plan which represent the ratios of PVEC to PVMIP of graduated payments approach to the value of 1.0.

Evaluating total annual loan costs (TALC) rates

First of all, we evaluate the values of TALC rates under the condition that the values of β are equal to both constant payment and graduated payment methods and then calculate the values of TALC rates under the condition that the ratios of PVEC to PVMIP are equal to 1.0 in the graduated payment method. Table 8 reports the TALC rates evaluated using the results of Table 6 and 7 at various times (t = n) by borrower's age.

Table 6
Net Expected Insurance Liabilities (unit: Korean won)

AGE	Payment method	LSUM	β	LSUM(1- β)	PMT	PVEC	PVMIP	NEL	PVEC/PVMIP
60	constant	74,000,000	23.5%	56,610,000	513,616	8,807,347	8,822,409	-15,062	**0.998**
	graduated				343,299	11,544,074	8,473,348	3,070,726	1.362
65	constant	90,000,000	31%	62,100,000	631,763	8,288,931	8,234,802	54,129	**1.007**
	graduated				445,149	11,165,067	7,975,857	3,189,210	1.400
70	constant	106,000,000	37.5%	66,250,000	779,889	7,551,454	7,573,311	-21,857	**0.997**
	graduated				578,823	10,387,778	7,396,846	2,990,932	1.404
75	constant	124,000,000	44%	69,440,000	975,555	6,864,932	6,927,860	-62,928	**0.991**
	graduated				760,504	9,493,598	6,815,776	2,677,822	1.393
80	constant	140,000,000	48.2%	72,520,000	1,246,561	6,364,146	6,365,416	-1,270	**1.000**
	graduated				1,016,182	8,649,222	6,296,976	2,352,246	1.374
85	constant	154,000,000	50.4%	76,384,000	1,638,812	5,874,415	5,906,753	-32,338	**0.995**
	graduated				1,389,760	7,659,491	5,863,936	1,795,555	1.306

Note: 1. The growth rate of APT is 3/12 % (i.e. $H_t = H_0 \cdot \left(1 + \left(0.03/12\right)\right)^t$: For calculating the present values of future claim losses, we assume that the growth rate of APT is 3 % per annum. U.S. house price appreciation rates based on the OFHEO index have averaged 5.7% since 1975. But, for the conservative assumption, the HECM actuarial model assumed house prices follow a 3 percent annual appreciation rate from the loan origination until loan termination. This assumption about house price appreciation rate has been kept conservative to allow for under-maintenance given the extreme age of many HECM borrowers (Rodda, et al., 2003). In Korea, the mean value of annual growth rate of APT from January, 1986 to December, 2004 was 5.64% (=0.004701*12). 2. The value of discount rate which used on calculating the present values of expected claims and that of MIP, the expected interest rate which adopted to determine the outstanding loan balance (OLB) is 7.5 % per annum including margin and MIP (i.e. 0.5 % per annum) 3. Up-front costs is 5 % of the initial house price (H_0 *5 %) and we assume that up-front costs includes 2 % of up-front insurance premium (i.e. H_0 *2 %) 4. The initial house price is 200 million Won. 5. The probability that the loan will become due and payable is male's mortality rate.

Table 7
Modified Net Expected Insurance Liabilities: Graduated monthly payments (unit: Korean won)

AGE	Payment method	LSUM	β	LSUM(1- β)	PMT	PVEC	PVMIP	NEL	PVEC/PVMIP
60	before	74,000,000	23.5%	56,610,000	343,299	11,544,074	8,473,348	3,070,726	1.362
	after		32.6%	49,876,000	302,463	8,111,320	8,051,544	59,776	**1.007**
65	before	90,000,000	31%	62,100,000	445,149	11,165,067	7,975,857	3,189,210	1.400
	after		39.5%	54,450,000	390,312	7,581,886	7,578,428	3,458	**1.000**
70	before	106,000,000	37.5%	66,250,000	578,823	10,387,778	7,396,846	2,990,932	1.404
	after		44.8%	58,512,000	511,216	7,076,847	7,068,936	7,911	**1.001**
75	before	124,000,000	44%	69,440,000	760,504	9,493,598	6,815,776	2,677,822	1.393
	after		50%	62,000,000	679,021	6,580,341	6,562,552	17,788	**1.003**
80	before	140,000,000	48.2%	72,520,000	1,016,182	8,649,222	6,296,976	2,352,246	1.374
	after		53.2%	65,520,000	918,095	6,121,451	6,108,246	13,206	**1.002**
85	before	154,000,000	50.4%	76,384,000	1,389,760	7,659,491	5,863,936	1,795,555	1.306
	after		54.1%	70,686,000	1,286,089	5,756,549	5,743,958	12,591	**1.002**

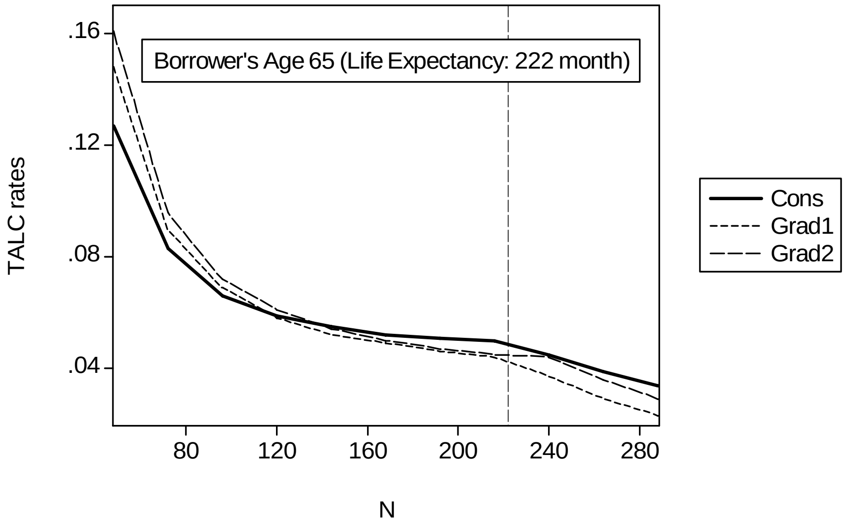
Table 8
Total annual loan costs

	age60			age65			age70			age75			age80			age85		
n	cons	grad1	grad2	cons	grad1	grad2	cons	grad1	grad2	cons	grad1	grad2	cons	grad1	grad2	cons	grad1	grad2
24	0.423	0.558	0.616	0.359	0.456	0.505	0.305	0.371	0.409	0.256	0.300	0.327	0.213	0.239	0.259	0.174	0.189	0.200
48	0.145	0.176	0.191	0.127	0.148	0.161	0.112	0.126	0.136	0.099	0.107	0.114	0.087	0.091	0.096	0.076	0.078	0.080
72	0.091	0.103	0.111	0.083	0.090	0.096	0.075	0.079	0.084	0.069	0.070	0.074	0.063	0.062	0.065	0.058	0.056	0.058
96	0.072	0.077	0.081	0.066	0.069	0.072	0.062	0.062	0.065	0.058	0.057	0.059	0.054	0.052	0.054	0.051	0.048	0.049
120	0.063	0.064	0.067	0.059	0.058	0.061	0.056	0.054	0.056	0.053	0.050	0.052	0.050	0.047	0.048	0.032	0.024	0.032
144	0.057	0.056	0.059	0.055	0.052	0.054	0.052	0.049	0.051	0.050	0.047	0.048	0.040	0.032	0.041	0.016	0.006	0.012
168	0.054	0.052	0.053	0.052	0.049	0.050	0.050	0.046	0.047	0.045	0.038	0.045	0.027	0.017	0.024	0.007	-0.006	0.000
192	0.053	0.049	0.050	0.051	0.046	0.047	0.049	0.043	0.045	0.035	0.025	0.033	0.019	0.007	0.013			
216	0.051	0.046	0.048	0.050	0.044	0.045	0.040	0.032	0.039	0.027	0.016	0.023	0.014	0.000	0.006			
240	0.051	0.045	0.046	0.045	0.037	0.044	0.034	0.023	0.030	0.022	0.010	0.015	0.010	-0.005	0.000			
264	0.049	0.042	0.044	0.039	0.029	0.036	0.029	0.017	0.023	0.019	0.005	0.010						
288	0.043	0.035	0.040	0.034	0.023	0.029	0.025	0.012	0.017	0.016	0.001	0.006						
312	0.039	0.029	0.034	0.031	0.019	0.024	0.023	0.008	0.013									
336	0.036	0.024	0.029	0.028	0.015	0.019	0.021	0.005	0.010									
360	0.033	0.020	0.025	0.026	0.011	0.016	0.019	0.003	0.007									
384	0.031	0.017	0.021	0.024	0.009	0.013												
408	0.029	0.014	0.018	0.023	0.007	0.010												
432	0.027	0.012	0.015															
456	0.026	0.010	0.013															
480	0.025	0.008	0.011															

Note: “cons” represent monthly constant payments, and “grad1” represent monthly graduated payments before adjustment, “grad2” represent monthly graduated payments after adjustment, respectively.

As we can see in Table 8, TALC rates decline over time due to the up-front costs beard by the total debt over time is shrinking, and borrower's total outstanding loan balances at time t= n are limited by home values[21].

Figure 4 shows the results of TALC rates by comparing two monthly payment plans in the case of borrower's age 65 and 80, respectively.



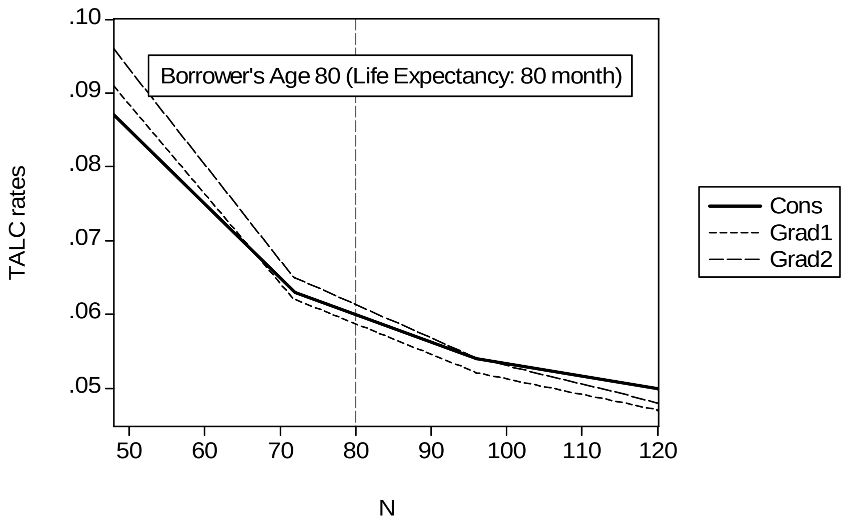


Figure 4. TALC rates (Age 65 and 80)

[21] In HECM program, if borrower's rising loan balance ever grows to equal the value of home, then the total debt is limited by the value of home and this overall cap on borrower's loan balance is called a "non-recourse" limit (AARP, 2005). Non-recourse limit is assumed to be 93% of the home's value because this leaves 7% for the costs of selling the home (Scholen, 1996). In this paper, we simply assume 100% of the home's value as non-recourse limit.

Figure 4 suggests that, from the borrower's perspective, the method of graduated monthly payments (Grad) is more efficient than that of constant monthly payments (Cons) to relatively younger borrowers (age 65). Yet, the method of constant monthly payments (Cons) is more efficient than that of graduated monthly payments (Grad2) to relatively older borrowers (age 80). According to the results of this analysis, we can expect that the borrowers who believe positively that their lifetime would exceed that of general population would select the method of graduated monthly payments.

Sensitivity analysis

In this analysis, our actuarial model assumes that the house price appreciation rate to be 3 % per annum and the expected interest rate to be 7.5 % (including margin and MIP) per annum. In general, the actuarial model results are quite sensitive to changes in the values of future house price appreciation rate and expected interest rates (Rodda, et al., 2000). For sensitivity testing, we assume three values of the annual house price appreciation rate (g = 2%, 3%, 4%) and three values of expected interest rate (i =7.0%, 7.5%, 8.0%). We test on borrower's age groups in 65 and 80. Tables 9 and 10 report the results of sensitivity analyses of the actuarial model by shocking at the house price appreciation rates and expected interest rates for borrower's age 65 (i.e. relatively younger borrowers group) and 80 (i.e. relatively older borrowers group).

In Table 9, 10, and Figure 5, we can see that the variability on the ratios of PVEC to PVMIP is distinctly higher for the relatively younger age group (e.g. age 65) than for the relatively older age group (e.g. age 80) due to the changes of loan terms. Therefore we can conclude that the magnitudes of sensitivity are higher to the relatively younger age group (e.g. age 65) who is more sensible to the shock in house price and interest rates than the relatively older age group (e.g. age 80).

Table 9
Result of Sensitivity Test (Constant monthly payments) (unit: Korean won)

AGE	Assumption	Combination	LSUM	PMT	PVEC	PVMIP	NEL	PVEC/PVMIP
		g=4.0%, i=7.0%	90,000,000	631,763	2,192,484	8,330,330	-6,137,845	0.263
	optimistic	g=4.0%, i=7.5%	90,000,000	631,763	3,412,320	8,234,802	-4,822,482	0.414
		g=4.0%, i=8.0%	90,000,000	631,763	4,754,858	8,143,689	-3,388,831	0.584
		g=3.0%, i=7.0%	90,000,000	631,763	6,789,585	8,330,330	-1,540,745	0.815
65	stable	**g=3.0%, i=7.5%**	**90,000,000**	**631,763**	**8,288,931**	**8,234,802**	**54,129**	**1.007**
		g=3.0%, i=8.0%	90,000,000	631,763	9,751,384	8,143,689	1,607,695	1.197
		g=2.0%, i=7.0%	90,000,000	631,763	12,428,877	8,330,330	4,098,547	1.492
	pessimistic	g=2.0%, i=7.5%	90,000,000	631,763	13,806,947	8,234,802	5,572,145	1.677
		g=2.0%, i=8.0%	90,000,000	631,763	15,090,825	8,143,689	6,947,136	1.853
AGE	Assumption	Combination	LSUM	PMT	PVEC	PVMIP	NEL	PVEC/PVMIP
		g=4.0%, i=7.0%	140,000,000	1,246,561	3,041,895	6,401,256	-3,359,361	0.475
	optimistic	g=4.0%, i=7.5%	140,000,000	1,246,561	3,690,673	6,365,416	-2,674,743	0.580
		g=4.0%, i=8.0%	140,000,000	1,246,561	4,352,486	6,330,669	-1,978,183	0.688
		g=3.0%, i=7.0%	140,000,000	1,246,561	5,670,780	6,401,256	-730,476	0.886
80	stable	**g=3.0%, i=7.5%**	**140,000,000**	**1,246,561**	**6,364,146**	**6,365,416**	**-1,270**	**1.000**
		g=3.0%, i=8.0%	140,000,000	1,246,561	7,047,658	6,330,669	716,989	1.113
		g=2.0%, i=7.0%	140,000,000	1,246,561	8,624,475	6,401,256	2,223,219	1.347
	pessimistic	g=2.0%, i=7.5%	140,000,000	1,246,561	9,292,414	6,365,416	2,926,998	1.460
		g=2.0%, i=8.0%	140,000,000	1,246,561	9,939,751	6,330,669	3,609,082	1.570

Table 10
Result of Sensitivity Test (Graduated monthly payments) (unit: Korean won)

AGE	Assumption	Combination	LSUM	PMT	PVEC	PVMIP	NEL	PVEC/PVMIP
		g=4.0%, i=7.0%	90,000,000	390,312	2,591,048	7,673,625	-5,082,577	0.34
	optimistic	g=4.0%, i=7.5%	90,000,000	390,312	3,456,134	7,578,428	-4,122,293	0.46
		g=4.0%, i=8.0%	90,000,000	390,312	4,370,840	7,488,352	-3,117,512	0.58
		g=3.0%, i=7.0%	90,000,000	390,312	6,606,070	7,673,625	-1,067,555	0.86
65	Stable	**g=3.0%, i=7.5%**	**90,000,000**	**390,312**	**7,581,886**	**7,578,428**	**3,458**	**1.00**
		g=3.0%, i=8.0%	90,000,000	390,312	8,530,505	7,488,352	1,042,153	1.14
		g=2.0%, i=7.0%	90,000,000	390,312	11,418,589	7,673,625	3,744,964	1.49
	pessimistic	g=2.0%, i=7.5%	90,000,000	390,312	12,257,388	7,578,428	4,678,960	1.62
		g=2.0%, i=8.0%	90,000,000	390,312	13,040,169	7,488,352	5,551,817	1.74
AGE	Assumption	Combination	LSUM	PMT	PVEC	PVMIP	NEL	PVEC/PVMIP
		g=4.0%, i=7.0%	140,000,000	918,095	3,276,903	6,143,901	-2,866,998	0.53
	optimistic	g=4.0%, i=7.5%	140,000,000	918,095	3,764,755	6,108,246	-2,343,491	0.62
		g=4.0%, i=8.0%	140,000,000	918,095	4,256,570	6,073,791	-1,817,220	0.70
		g=3.0%, i=7.0%	140,000,000	918,095	5,622,008	6,143,901	-521,893	0.92
80	Stable	**g=3.0%, i=7.5%**	**140,000,000**	**918,095**	**6,121,451**	**6,108,246**	**13,206**	**1.00**
		g=3.0%, i=8.0%	140,000,000	918,095	6,612,861	6,073,791	539,070	1.09
		g=2.0%, i=7.0%	140,000,000	918,095	8,224,866	6,143,901	2,080,965	1.34
	pessimistic	g=2.0%, i=7.5%	140,000,000	918,095	8,689,125	6,108,246	2,580,879	1.42
		g=2.0%, i=8.0%	140,000,000	918,095	9,138,517	6,073,791	3,064,726	1.50

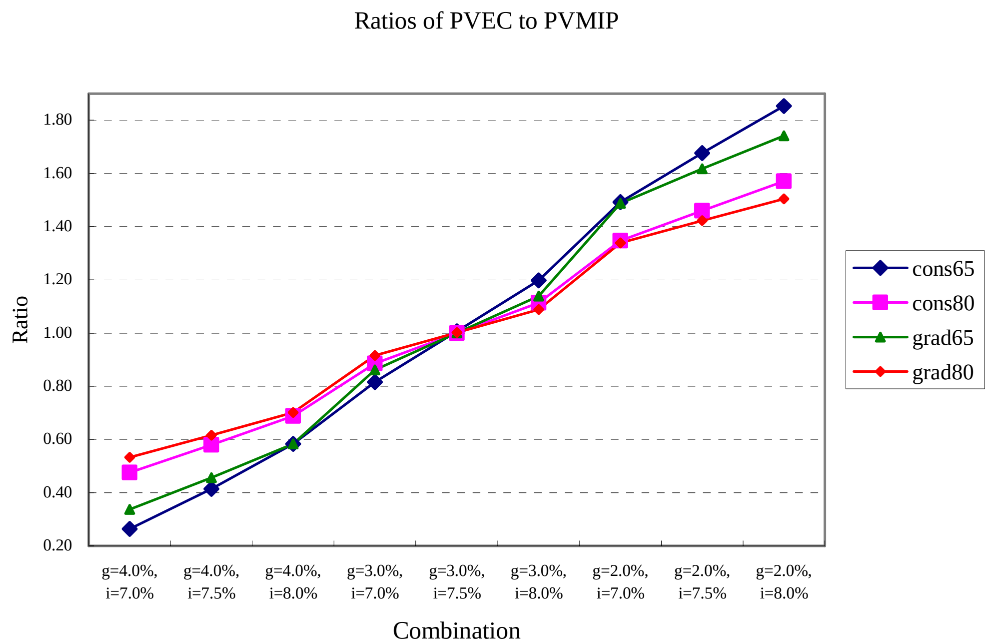


Figure 5. Comparison of Sensitivity (Ratios of PVEC to PVMIP)

Considering the results of sensitivity test in Tables 9 and 10, under the single insurance premium structure as the HECM, we can see that the insurance premium structure should be set up more conservatively for the relatively younger borrower's group than the older borrower's group, because variability of the ratios of PVEC to PVMIP in the relatively younger borrower's group is more sensitive to the shocks in future growth rates of housing price and expected interest rates.

5. Conclusion

Insurance claim losses are expected to occur in the event that the borrower's total outstanding loan balance exceeds the current market value of his (her) property at the time the loan is due and payable. A reasonable insurance premium structure would play a leading role that the lenders could provide borrowers with prearranged monthly payments at a scheduled time, and make sure that the borrower's total outstanding balance is less than the value of the property at the time the loan is due and payable. We analyze the reverse mortgage system focus on two payment methods of the tenure plan in this paper. One is the constant monthly payments and the other is the graduated monthly payments where monthly payments are indexed to the growth rate of consumer prices. We find that, under the equal insurance premium structure, the ratios of PVEC to PVMIP of graduated monthly payments are greater than that of constant monthly payments because the termination rates show a pattern of exponential increase in the tail and the magnitudes of graduated monthly payments are increase over the time. We adjust the level of graduated monthly payments to improve the ratios of PVEC to PVMIP. We then evaluate the values of TALC rates under the condition that the present values of expected premiums are equal to that of expected claim losses. We find that, from borrower's perspective, the graduated monthly payments approach is more efficient than the constant monthly payments approach to the relatively younger borrowers. Yet, the constant monthly payments approach is more efficient than the graduated monthly payments approach to the relatively older borrowers. Finally, we conduct sensitivity analysis and find that the younger age group (e.g. age 65) is more sensitive to the shocks in future house price appreciation rates and interest rates compared to the relatively older age group (e.g. age 80). Therefore, insurance premium structure should be set more conservatively to the relatively younger borrowers than older borrowers. The results of this study offer valuable insight of the insurance premium structure of the reverse mortgage system. They can provide useful guideline in the operation of reverse mortgage system that is under consideration in the Korean housing financial market.

Appendix

The unit root test

This study uses the methods of the ADF test (Augmented Dickey-Fuller test) and PP test (Phillips-Perron test) for testing the stationary of the time series. The original DF test (Dickey-Fuller test) is valid only if the series is an AR(1) process. The ADF and PP tests use different methods to control for higher-order serial correlation in the series. The ADF test makes a parametric correction for higher-order correlation by assuming that the time series follows an AR(p) process and adjusting the test methodology. The ADF approach controls higher-order correlation by adding lagged difference terms of the dependent variable to the regression. Phillips and Perron (1988) propose a nonparametric method of controlling for higher-order serial correlation in a series. PP test is a unit root test method that can be used in a situation that the assumption on error term, u_t, does not meet the condition of $u_t \sim iid(0, \sigma_u^2)$. The test regression for the PP test is the AR(1) process.

The Hodrick-Prescott Filter

The probabilities of survival data used in this study are observed at annual intervals. We adopt the Hodrick-Prescott filter (Hodrick and Prescott, 1997) to obtain monthly survival rate from the annual data. The HP filter is a two-sided linear filter that computes the smoothed series s of y by minimizing the variance of y around s, subject to a penalty that constrains the second difference of s. That is, the Hodrick-Prescott filter chooses s to minimize $\sum_{t=1}^{T}\left(y_t - s_t\right)^2 + \lambda\sum_{t=2}^{T-1}\left[\left(s_{t+1} - s_t\right) - \left(s_t - s_{t-1}\right)\right]^2$. The penalty parameter λ controls the smoothness of the series s. The larger the λ, the smoother the s. As $\lambda \to \infty$, s approaches a linear trend.

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