Received 31 May 2022
Revised 4 July 2022
17 August 2022
Accepted 23 August 2022

A comparative study on determinants of housing mortgage prepayment of individual borrowers

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Abstract

This paper examines how the macroeconomic environment affects the determinants of prepayment of mortgage loans from October 2004 to February 2020. For more accurate analysis, the authors define the timing of prepayment not only before the loan maturity but also at the time when 50% or more of the loan principal is repaid. The results show that, during the global financial crisis as well as the recent period of low interest rates, macroeconomic variables such as interest rate spreads and housing prices have a different effect compared to the normal situation. Also, significant explanatory variables, such as debt to income (DTI) ratio, loan amount ratio and poor credit score, have different effects depending on the macroenvironment. On the other hand, in all periods, the possibility of prepayment increases as comprehensive loan to value (CLTV) increases, and the younger the age, the shorter the loan maturity. The results suggest that, in the case of ultralong (40 years) mortgage loans recently introduced to support young people purchasing houses, the prepayment risk can be, at least partially, migrated by offsetting the increase in prepayment by young people and the decrease in prepayment due to long loan maturity. In addition, this study confirms that the accelerated time failure model compared to the logit model and COX proportional risk model has the potential to be more appropriate as a prepayment model for individual borrower analysis in terms of the explanatory power.

Keywords Mortgage, Prepayment, Individual borrowers, MBS pool, Bogeumjari loan

Paper type Research paper

1. Introduction

The continuous upward trend of the real estate market in Korea has caused the rapid increase in the size of the home equity loan market of domestic banks up to 679.6 tn won as of December 2020. Since such growth is expected to continue in the future, it will be more difficult for people to purchase a house. Founded in 2004 for the purpose of stabilizing the housing and revitalizing the long-term housing finance market, the Korea Housing Finance Corporation (HF) contributes to the revitalization of the secondary market by issuing Mortgage Backed Securities (MBS) based on mortgage loans as underlying assets. MBS is created by a financial company directly based on securitizing a mortgage loan or selling it to HF. Generally, MBS in Korea is issued in trenches of eight maturities. Among those, five-year MBSs tend to include a call option clause that can be purchased before maturity.

Journal of Derivatives and Quantitative Studies: 선물연구
Vol. 30 No. 4, 2022
pp. 278-295
Emerald Publishing Limited
e-ISSN: 2713-6647
p-ISSN: 1229-988X
DOI 10.1108/JDQS-05-2022-0013

There are two kinds of risk, namely the default risk and the prepayment risk, in MBS investment. The default risk is very low because the HF guarantees the principal payment. However, the risk of prepayment which refers to the borrower repaying all or part of a loan before a preagreed period always exists and, thus, requires special attention. The cash flow of an MBS is affected by the cash flow of the mortgage loan, and borrowers decide whether to prepay their loans. Thus, it is most important to analyze and predict the prepayment of the mortgage loan, the underlying asset, when estimating the cash flow of MBS.

Due to limitations in access to the data, however, only a few studies have been examining the prepayment of MBS in Korea, while many research studies have been done in developed markets. Existing studies mainly have analyzed factors affecting the probability of prepayment by examining the unit of MBS pools, not the unit of borrowers, due to the difficulty in obtaining information on the characteristics of individual borrowers. This is a limitation of existing research which our study attempts to incorporate.

It has been documented that the key factors that affect the probability of prepayment include the interest rate spread, housing price, delinquency rate and prepayment fees. The interest rate spread is defined as the difference between the loan interest rate and the market rate at the time of prepayment. If the market interest rate is lower than the loan rate, borrowers have the higher incentive for prepayment by refinancing with a lower interest rate. Regarding housing prices, borrowers are more likely to prepay their loans in the situation that they can move to a cheaper house, realize profits by selling an existing house or procure additional loan amount due to an increase in the value of collateral. As far as the delinquency rate is concerned, an increase in the delinquency rate tends to reduce the incentive for prepayment by decreasing the borrower's ability to repay the loan. On the other hand, if delinquency leads to default, prepayment may increase because the house is more likely to be auctioned off. Therefore, it is important to distinguish between simple prepayment and prepayment due to default. When the prepayment fee decreases, the probability of prepayment will increase.

In this paper, we examine how the macroeconomic environment affects the determinants of prepayment of mortgage loans, discussed above, using the sample from October 2004 to February 2020. For more accurate analysis, we define the timing of prepayment not only before the loan maturity but also at the time when 50% or more of the loan principal is repaid. Our results show that during the global financial crisis as well as the recent low interest rate situation, macroeconomic variables such as the interest rate spread and housing prices known to be significant for prepayment in previous studies have a different effect from the normal situation. Also, significant explanatory variables such as debt to income (DTI), loan amount ratio and significance rating ratio have different effects depending on the macroenvironment.

On the other hand, in all periods, the probability of prepayment increases as comprehensive loan to value (CLTV) increases, and the younger the age, the shorter the loan maturity. The results imply that in the case of ultra-long (40 years) mortgage loans recently introduced to support young people purchasing houses in Korea, the risk of prepayment will be, at least partially, migrated by offsetting the increase in prepayment by young people and the decrease in prepayment due to long loan-maturity. In addition, this study confirms that the accelerated time-failure (ATF) model applied to pool unit analysis compared to the existing logit model and COX proportional risk model has the potential to be more appropriate to measure the probability of prepayment by individual borrowers in terms of the explanatory power of the model.

The paper is organized as follows. In Section 2, we introduce the previous literature on MBS prepayment. Section 3 describes our sample, and Section 4 provides research design and summary statistics. Section 5 analyzes the probability of prepayment, and Section 6 concludes.

2. Literature review

2.1 Global studies

Many previous researchers have been investigating the mortgage prepayment since it is the one of key risks of MBS. Richard and Roll (1989) presented a prepayment model and explained the factors affecting prepayment through the interest rate effect, the maturation effect and the exhaustion effect. Schorin (1992) estimated the prepayment rate of the 30-year MBS mortgage loan pool for the period from 1973 to 1989 based on the age of the mortgage loan, the interest rate spreads and the seasonality. Matty and Wallace (2001) showed that the investment opportunity cost and the expected housing price affect the prepayment rate, and Chinloy (1993) reported that the interest rate spreads (the difference between the interest rate and the market rate at the loan contract), elapsed time and seasonality significantly affect the prepayment while the effects of macroeconomic variables are insignificant.

Archer *et al.* (1996) examined mortgage loan data from 1985 to 1987 and showed that when the collateralized loan ratio is high, economic benefits are large and, thus, the incentive for prepayment becomes strong with low interest rates. Deng *et al.* (2000) analyzed the prepayment risk and default risk through a competitive risk model and designed a model with risk factors which the call option value by interest rate change and the put option value by housing price change affect. Deng and Liu (2009) reported that not only the repayment factors of borrowers but also the stock index, unemployment rate and inherent variables of borrowers affect prepayment in the Chinese market. LaCour-Little *et al.* (2010), using the loan data from 2000 to 2006, showed that when the collateral value increases, the probability of prepayment of borrowers with liquidity restrictions increases. Beltratti *et al.* (2017) investigated the effect of the policy of prepayment fees and found that the prepayment rate increases after the abolition of the prepayment fee. Steinbuks (2015) analyzed prepayment behavior before and after the ban on prepayment penalty in the US market and concluded that the prepayment is higher in the period after the ban than before.

2.2 Domestic studies

Research in the Korean market has also been investigating verification on factors affecting prepayment using MBS pool data or borrower-level mortgage loan data. Bang *et al.* (2010) analyzed the determinants of prepayment based on borrower characteristics data. They showed that as the loan balance increases due to the low market interest rate and high LTV, the probability of prepayment increases. The effect, however, of overheating or cooling of the real estate market is limited. Jeon and Kim (2011) estimated the prepayment model considering the US PSA (Public Securities Assoication) model and the linear and nonlinear models for MBS pool. They reported that the prepayment rate increases 1% per month to stable 19% and increases rapidly from 58 months. Bang and Park (2011) analyzed the factors affecting prepayment through panel regression analysis using pool-scale time series data. They showed that the interest rate spread, loan period (age by pool), house price increase rate and transaction volume have a positive effect on the prepayment rate. The effects of refinancing incentives or house market related factors stay significant after controlling the time series characteristics for each pool.

Choi and Kim (2011) found that the interest rate has a negative effect on the prepayment rate, while the house price and default rate have a positive (+) effect. Kim and Tongkyu (2017) analyzed the effect of the investor sentiment index of the real estate market on the prepayment rate applied to MBS. They reported that loan interest rates and real estate investor sentiment have a negative effect, while interest rate spreads and apartment sale price indexes have a positive effect. The result suggests that with the expectation of an increase in housing prices borrowers are less likely to prepay their loans.

Kim *et al.* (2018) used Schwartz and Torous (1989)'s prepayment model in the pool-level prepayment analysis following the implementation of the safe conversion loan supply policy.

They mentioned that prepayment increases in the short term due to borrowers who want to refinance with a loan with a lower interest rate. Lee *et al.* (2019) showed that the correlation between borrowers residing in the same places affects the prepayment. Also, the prepayment option value, LTV, DTI, loan maturity, borrower's age, income and credit rating influence the prepayment risk. Lee and Lee (2020) stated that the construction industry has a positive effect and inflation has a negative effect on prepayment. They argue that if an abnormality occurs in the MBS price or the market, the interest rate policy should be effective in the short term, while the construction policy are more effective in the mid to long term. Kim and Bungkwon (2020) analyzed the effect of the prepayment fee of a mortgage loan on the MBS prepayment rate and borrowers' prepayment using 245 MBSs issued by the HF and showed that the levy system has a significant effect on prepayment.

3. Sample descriptions

3.1 Data

This study empirically investigates how macroenvironment and characteristics of individual borrowers affect the prepayment of mortgage loans. To do so, from October 2004 to February 2020, we obtain all the transaction data of Bogeumjari from HF loans with equal principal payment and equal principal and interest payment. We exclude loans with options that artificially limit artificial cash flows. Also, transaction data of the borrowers who have been delinquent for more than 91 days are excluded from the sample since they might have an effect of credit risk.

Comprehensive data include all the information on the transaction details of prepayment such as borrower characteristics (e.g. loan amount, interest rate, loan maturity, gender, age, collateral value, LTV, DTI, credit rating, etc.) as well as information on delinquency and overdue payment by more than 90 days at the end of each month and prepayment at the end of the month after loan contracts. In addition, in order to consider the effect of changes in interest rates and real estate prices on prepayment, we use the monthly interest rate of three-year treasury bonds, the average mortgage interest rate of commercial banks, the HF Bogeumjari loan (20 years) interest rate, KB housing price index by housing type and region (metropolitan city/Provincial unit) and the housing transaction volume maintained by the Korea Real Estate Agency.

Prior to empirical analysis, we divide the analysis periods considering macroeconomic trends as well as changes in the policy of the Bogeumjari loan including prepayment fee policy. Figure 1 shows the trends of three-year treasury bonds, mortgage interest rates and KB housing price index from January 2004 to April 2021. The interest rates on treasury bonds and mortgage loans rose until October 2008 due to the global financial crisis and then rebounded for some periods until April 2021 while they show a continuous downward trend. For the entire period, however, the housing price index shows a continuous upward trend. In addition, the prepayment fee policy, which is an important variable affecting prepayment, has changed two times since the establishment of HF as presented in Table 1.

We divide the sample periods into six sections by two years considering interest rate patterns, interest rate levels and changes in prepayment fee policy. Table 2 shows the characteristics of each section related to the change in prepayment fee policy, interest rate pattern and interest rate level for the Bogeumjari loans implemented for two years in each section. We set 3~5 years as tracking periods for each loan. That is, for example, the final tracking month of Period 6 is February 2020, which indicates a tracking period of five years for loans made in the first month (March 2015) and three years for the last month (February 2017) of the period.

A few papers have studied the characteristics of borrowers who prepaid their loans. Bang *et al.* (2010) analyze data from 2004 to 2007 without a follow-up period. Lee *et al.* (2019) follows

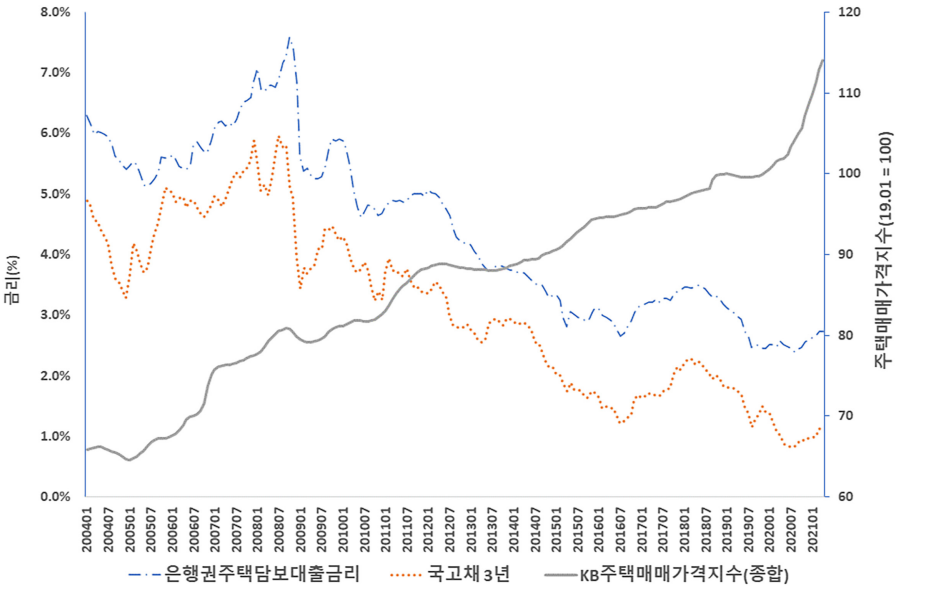

Figure 1.
Korea treasure bond (three years), mortgage interest rates and KB housing price index (2004.01~2021.04)

	Prepayment fee
(Case 1) ~ 2012.10	1 yr or less: Loan balance * 2% 1 yr~3 yr: Loan balance * 1.5% 3 yr~5 yr: Loan balance * 1%
(Case 2) ~ 2015.02	Loan balance * (3 yr – No. of elapsed days)/(3 yr) * 1.5%
(Case 3) 2015.03 ~	Loan balance * (3 yr – No. of elapsed days)/(3 yr) * 1.2%

Note(s): See HF Bylaws

Table 1.
HF prepayment fee policy

Period	Loan term	Final tracking month	Fee policy	Interest rate	Loan rate
1	2004. 10~2006. 09	2009. 09	Case 1	Up	High (≈6%)
2	2006. 10~2008. 09	2011. 09	Case 1	Up → Down	High (≈6%)
3	2008. 10~2010. 09	2013. 09	Case 1	Down	High (≈6%)
4	2010. 10~2012. 09	2015. 09	Case 1	Down	Medium (≈5%)
5	2013. 03~2015. 02	2018. 02	Case 2	Down	Low (≈3%)
6	2015. 03~2017. 02	2020. 02	Case 3	Up → Down	Low (≈2%)

Table 2.
Fee policy, interest rate and loan rate by subperiods

2–4 years for borrowers in the metropolitan area from 2013. However, due to insufficient data, these studies set only a single period for their analysis or did not have a sufficient follow-up period after the loan contract. Also, they fail to incorporate the effect of artificially affecting cash flow such as the effect of prepayment due to default, lump-sum repayment and deferral period [1].

Figures 2 and 3 present the interest rate spread between HF's Bogeumjari loan (maturity 20 years) and commercial bank mortgage rates and KB housing price index and the trends of housing transaction volume by the Korea Appraisal Board, respectively. The reason for setting the maturity of the Bogeumjari loan to 20 years to compare the interest rate spread is that the average maturity of the Bogeumjari loan during the sample period is 18.99 years. Also we consider that the borrowers are able to replace their Bogeumjari loan prepaid due to low interest rates with a loan in commercial banks.

In Figure 2, the interest rate spread between bank mortgage loans and the Bogeumjari loan (20 years) decreases after the establishment of the HF. In the low interest rate period since 2016, negative spreads appear for a certain period of time. In this period, the interest rate competitiveness of Bogeumjari loans compared to commercial banks' collateralized loans has increased due to the decline in MBS interest rates followed by low interest rates and improved HF credit. Thus, from the borrower's point of view, the incentive for prepayment to switch to commercial banks' loans might decrease during this period.

Figure 3 presents the trend of KB housing prices and the housing transaction volume. It shows that the increase in housing prices did not lead to an increase in the housing transaction volume from 2007 to 2011 mainly due to the effect of global financial crisis. Therefore, in Section 2 (06.10~11.09), the effect of an increase in housing sales price on prepayment might be different compared to other sections. In addition, we consider housing transaction volume as explanatory variables in the pool unit analysis while it is difficult to be included in the prepayment model for individual borrowers.

One of the key contributions of this study is that, by using big data of borrowers, we define the time point of prepayment as the point at which 50% or more of the principal is repaid. The main reason of our assumption regarding prepayment is because, in the case of two or more early repayments, the largest amount is usually repaid at the point of repayment over 50% of the loan. Also, since the sum of normal repayment and 50% more prepayment accounts take more than 80% of the total account, by doing so we are able to consider the characteristics of the entire account. Most of previous studies use the point of prepayment time when the loan

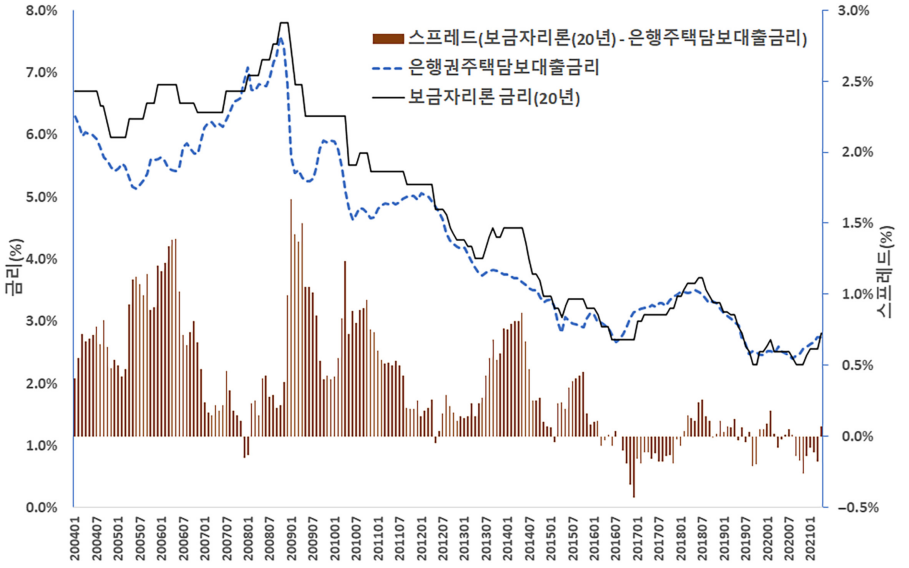

Figure 2.
Interest rate spread between bank mortgage loans and the Bogeumjari loan (20 years) (04.01~21.04)

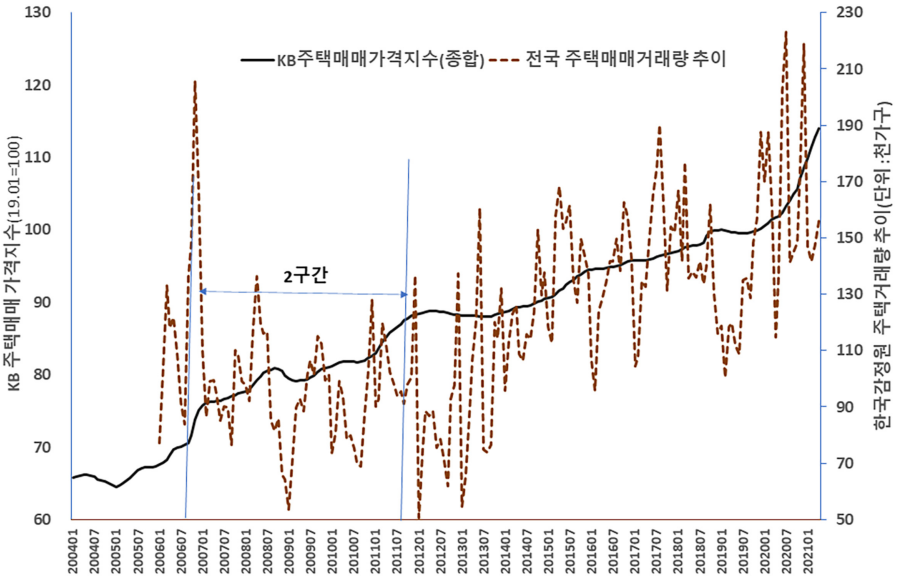

Figure 3.
KB housing prices and the housing transaction volume

balance reaches zero before maturity. Since the prepayment transaction information is huge data, it takes a considerable effort to find the time when the total amount of account has been repaid in excess of 50% during the monthly transaction time. Determining when 50% or more of the loan balance is repaid using population data on borrowers' transactions is a remarkable improvement in this study.

4. Methodology and summary statistics

4.1 Research design

4.1.1 Explanatory variables. Researchers estimate the prepayment model based on each pool or borrower, which affects the significance of the explanatory variables. In the case of pool-level analysis, Chinloy (1993), Schorin (1992), and Richard and Roll (1989), etc., employ the refinancing factors including the interest rate spread and the contract rate ratio based on the interest rate difference, the exhaustion factors such as the mortgage elapsed months, the maturity effect such as the loan balance ratio and the seasonal factor related to the moving season. Domestic studies including Kim *et al.* (2018) provide the similar while they report the different effects of macroeconomic variables.

On the other hand, in the OFHEO (Office of Federal Housing Enterprise Oversight) model, which is representative of the analysis by the borrower, collateral-related data such as LTV are included instead of excluding seasonal factors. In this regard, Lee *et al.* (2019) additionally include the characteristic individual borrowers such as region, LTV, DTI, age, gender and delinquency, the interest rate spread, credit spread, the month-average change rate of house prices and the expected house price change rate as macroeconomic variables.

In this study, we include the interest rate spread defined by the difference in interest rates between at the contract of the Bogeumjari loan and on collateralized loans at commercial banks. The variable serves as the measure of refinancing incentives. The interest rate is based on the monthly average rate divided by the months elapsed after the loan contract. For macrovariables related to housing prices, we include for the change rate of the average monthly house price by dividing the rate of return of the house sale price index at the time of the

contract as well as the end of the contract. Those macrodata are obtained from the database maintained by Korea Real Estate Board (REB). Also, the expected house price change rate reflecting the housing outlook used in the study of Lee *et al.* (2019) is employed. Regarding the characteristics of individual borrowers, we employ CLTV, DTI, loan amount ratio, low credit rating (grade 7 or higher), loan maturity and the borrower's age. CLTV ratio is the mortgage loan plus rental deposit divided by rental housing price, while DTI ratio is the amount of principal and interest repayment divided by the annual income of borrowers. Instead of including the loan amount, we include the collateralized loan ratio (the ratio of the loan amount divided by the average value) used in LaCour-Little *et al.* (2002). Low credit rating is a dummy variable that takes a value of 1 if a borrower's credit rating is higher than 7. Loan maturity is the logarithm of the number of months to the maturity. We also take the logarithm for borrowers' age. 30 year maturity is a dummy variable which takes a value of 1 if the maturity of the loan is 30 years. Young borrower is a dummy for the borrowers whose ages are between 26 and 35 [2].

Previous studies report the sign of each explanatory variable that we employ in this study. Deep and Domanski (2002) and LaCour-Little *et al.* (2010) show that the monthly average house price increases the collateral value, which causes the positive effect on prepayment. Stanton (1995), Green and LaCour-Little (1999), and Kim *et al.* (2018) report the positive relationship between loan amount and prepayment, assuming that refinancing costs are fixed. Lee *et al.* (2019) show the negative relationship between age and prepayment suggesting that the older the borrower, the more stable the life and the lower the probability of moving. Regarding loan maturity and credit ratings, Lee *et al.* (2019) document that the incentive for prepayment is greater for normal borrowers (grade 6 or lower) compared to borrowers with a long maturity and low credit rating (grade 7 or higher). Several papers investigate the effect of LTV and DTI on prepayment. Archer *et al.* (1996), LaCour-Little (2000) and Bang *et al.* (2010) report the positive effect of LTV since with the greater LTV, the economic benefit becomes larger when the interest rate is lowered. Bang *et al.* (2010) argue that a high DTI ratio represents a large loan amount, suggesting the positive relationship between repayment and DTI. Kim *et al.* (2018) also report the positive effect of DTI.

4.1.2 Prepayment model. In this study, we employ the OFHEO model, logit model and Cox proportional hazard model to estimate the prepayment model. Among the proportional hazards models, we also estimate the accelerated time-failure (ATF) model applied by Schwartz and Torous (1989) as a pool-level analysis.

As the prepayment function, the Cox proportional hazard model is a semi-parametric estimation method that estimates both a parametric part affected by explanatory variables and a nonparametric part affected by time t as the baseline hazard as Equation (1).

$$h_T(t;\, x) = h_0(t)\exp\left(\sum_{t=1}^{P}\beta_t x_t\right) \tag{1}$$

On the other hand, the prepayment model assuming proportional hazards used in Schwartz and Torous (1989) is basically similar to Cox's proportional hazards model, while it takes a parametric approach to estimating the baseline hazard (see Equation (2)) that does not require a parametric assumption in Cox model. The model is called the accelerated failure time model.

$$h_T(t;\, x, \theta) = h_0(t;\, \alpha, \tau)\exp\left(\sum_{t=1}^{P}\beta_t x_t\right),\ h_0(t;\, \alpha, \tau) = \frac{\alpha\tau(\alpha t)^{\tau-1}}{1+(\alpha t)^{\tau}} \tag{2}$$

This model is more efficient than Cox model, when the survival distribution is known and specified. However, if the survival distribution is significantly different from the distribution assumed in the acceleration failure model, estimation may lead to inefficient results. Schwartz

and Torous (1989) assumes a logit distribution as well as a Weibull distribution when the sample period is short. In this study, we compare the AIC values for the exponential distribution, the logit distribution, the Weibull distribution and Gaussian distribution and apply the distribution with the lowest AIC value.

4.2 Summary statistics

Table 3 reports the summary statistics on explanatory variables related to borrowers who have experienced prepayment and borrowers who are making normal repayment for the all

Variables		All Mean	All SD	Prepayment Mean	Prepayment SD	Normal repayment Mean	Normal repayment SD
All periods							
Monthly averaged spread (%)		0.0112	0.0546	0.0136	0.0656	0.0065	0.0177
Monthly average Δhouse price (%)		0.2176	0.3386	0.2450	0.3562	0.1633	0.2931
ΔExpected house price (%)		1.9438	4.0311	2.6486	3.9767	0.5465	3.7652
CLTV (%)		44.7445	16.7248	45.5131	16.8517	43.2207	16.3641
DTI (%)		26.7467	16.3552	27.0846	16.5202	26.0770	16.0020
Relative loan amount ratio		1.0000	0.6765	0.9646	0.6474	1.0701	0.7257
Loan maturity (year)		18.8893	7.4118	18.4790	7.3128	19.7028	7.5386
Borrower age		38.8667	7.7728	38.4254	7.6105	39.7415	8.0136
Grade 7 or higher		0.0438	0.2045	0.0452	0.2078	0.0408	0.1979
Elapsed months		31.4801	15.3799	24.6403	13.7755	45.0408	7.2552
Prepayer (%)		0.6647	0.4721	–	–	–	–
No. of observations		341,280		226,857		114,423	
Etc	Loan rate	3.7229	1.4071	3.8589	1.3869	3.4532	1.4081
	Spread	0.3559	0.7939	0.3771	0.8316	0.3138	0.7112
	LTV (%)	54.3513	15.9500	51.1752	15.9706	54.7005	15.9035
Period 5							
Monthly averaged spread (%)		0.0084	0.0562	0.0129	0.0631	−0.0067	0.0111
Monthly average Δhouse price (%)		0.2310	0.1932	0.2506	0.1987	0.1656	0.1566
ΔExpected house price (%)		2.0715	2.6334	2.5106	2.5846	0.6042	2.2336
CLTV (%)		47.6207	15.9336	48.6223	15.4418	44.2739	15.4418
DTI (%)		26.2615	15.9331	26.2371	15.8048	26.3434	16.3548
Relative loan amount ratio		1.0000	0.6475	0.9973	0.6494	1.0092	0.6409
Loan maturity (year)		18.0005	7.2993	17.8855	7.2591	18.3846	7.4196
Borrower age		26.2615	15.9331	26.2371	15.8048	26.3434	16.3548
Grade 7 or higher		0.0391	0.1938	0.0367	0.1880	0.0471	0.2119
Elapsed months		26.6231	14.0419	21.8413	12.0246	42.6014	6.4165
Prepayer (%)		0.7697	0.4211	–	–	–	–
No. of observations		71,665		55,158		16,507	
Etc.	Loan rate	3.4343	0.5364	3.5001	0.5350	3.2143	0.4792
	Spread	0.2400	0.6369	0.3852	0.6055	−0.2453	0.4794
	LTV (%)	56.3947	15.2453	56.3816	15.2698	56.4383	15.1636

Table 3.
Summary statistics (All periods and period 5)

Note(s): The table reports the mean and standard deviations of key variables of prepaid and normal repaid loans. The data of loan and borrower characteristics are obtained from HF and the data of house prices are obtained from REB

period as well as 5th period. The monthly average interest rate spread, monthly average house price change rate and expected house price change rate of prepayers are higher than those of borrowers in normal repayment in all period and 5th period. The higher spread in monthly average interest rates indicates that prepayers experience a larger drop in interest rates during the loan period and have higher loan interest rates than borrowers with normal repayment. The high rate of change in house price and expected change in house price represent that prepayers are considered to be borrowers who have experienced a steeper rise in house prices as well as who predicted that house prices would rise more compared to the past 12 months.

The average value of CLTV is higher for prepayers in all period and 5th period, contrary to the result of simple LTV which is not adjusted through the house price sale price index at the time of prepayment. While the difference of DTI and credit significance rating (grade 7 or higher) is generally insignificant, they are higher for prepayers in the whole period and higher for normal payers in the 5th period. Relative loan amount ratio, loan maturity and borrower age are higher for normal payers.

Figures 4 and 5 show the trend of spreads between the loan interest rate and the monthly average interest rate, the average monthly house price change rate and the expected house price change rate for each period. In Figure 4, loan interest rates for prepayers were higher than normal payer in all periods, and the monthly average interest rate difference shows the same result except for Period 6. In Figure 5, the average monthly house price change rate and the expected house price change rate are higher for prepayers except for Period 2.

The reason that Period 6 shows the different result from the other periods might be that, due to the ultra-low interest rate, there would be no difference in the spread between the 20-year Bogeumjari loan and the interest rate on bank mortgages; thus, the incentive for interest rate refinancing was small in. In addition, due to the global financial crisis, the result in Period 2 is also different from other periods when the transaction volume decreased despite the rising pattern of housing prices.

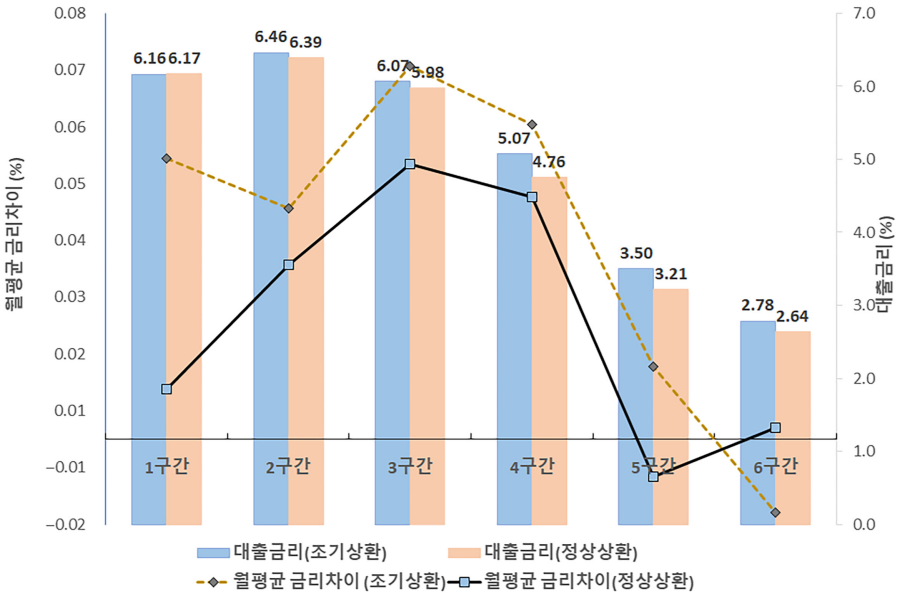

Figure 4.
Loan interest rates and monthly average rate spread by subperiods

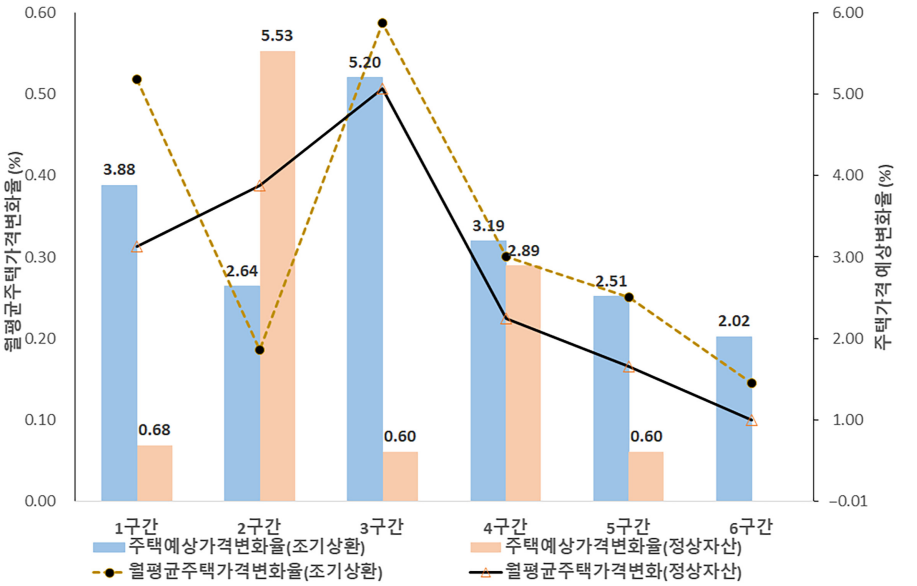

Figure 5.
Average monthly house price change rate and the expected house price change

5. Empirical results

In this section, we analyze the probability of prepayment by estimating Cox proportional hazard model and ATF model which requires the distribution for the basic function.

5.1 Determining the distribution for the AFT model

In order to determine the distribution for the basic function of the AFT model that assumes a specific distribution, the AIC values for the exponential distribution, log-logic distribution, Weibull distribution, logistic distribution and Gaussian distribution are calculated for each period. Table 4 shows that the AIC value of the basic function using the Weibull distribution is the lowest. Therefore, we measure the AFT model assuming the Weibull distribution in this study.

5.2 Estimation results

Tables 5–7 show estimation results the logit model, the Cox proportional risk model and the ATF model, respectively, on the monthly average house price change rate and the expected house price change rate for each period. The dependent variables in each model are a dummy for the presence of prepayment in the logit model and the elapsed period until prepayment for the Cox model and in ATF model.

Table 4.
AIC values of the basic function

Period	Exponential dist.	Log-logic dist.	Weibull dist.	Logistic dis.	Gaussian dist.
1	130,367 (3)*	130,087 (2)	129,781 (1)	135,367 (5)	134,263 (4)
2	120,540 (5)	116,734 (2)	116,357 (1)	118,558 (4)	117,870 (3)
3	156,134 (5)	146,108 (4)	144,465 (1)	145,443 (3)	144,936 (2)
4	247,595 (5)	232,303 (2)	230,284 (1)	233,276 (4)	232,324 (3)
5	502,232 (3)	493,462 (2)	490,916 (1)	506,699 (5)	504,352 (4)
6	1,036,095 (3)	1,029,530 (2)	1,026,271 (1)	1,067,512 (5)	1,058,807 (4)

Note(s): The value in () is ranked with the lowest AIC value among the five distributions

Table 5. Results of logit regressions by periods

Period	1	2	3	4	5	6 (A)	6 (B)
Model A: monthly average Δhouse price (%)							
Intercept	0.358**	1.870***	0.738***	0.543***	0.401***	0.407***	−2.803***
Loan rate	–	–	–	–	–	–	1.518***
Monthly averaged spread (%)	15.044***	3.448***	25.606***	39.754***	6.582***	−18.933***	–
Monthly average Δhouse price (%)	1.956***	−1.301***	0.604***	0.624***	3.107***	1.487***	1.271***
CLTV	0.026***	0.009***	0.003**	0.000	0.029***	0.019***	0.019***
DTI	0.008***	0.001	0.003***	0.006***	−0.001**	−0.002***	−0.001*
Relative loan amount ratio	−0.331***	−0.024	0.669***	0.460***	−0.138***	−0.363***	−0.390***
Grade 7 or higher (%)	0.152***	0.151**	−0.262***	−0.313***	−0.374***	0.077	−0.151***
Loan maturity	−0.021***	−0.017***	−0.023***	−0.033***	−0.037***	−0.020***	−0.041***
Borrower age	−0.019***	−0.029***	−0.038***	−0.031***	−0.008***	−0.008***	−0.019***
LR	13,388	11,084	8,960	14,084	35,495	110,231	109,994
30 yr Maturity(D)	−1.020***	−0.143**	−0.335***	−0.482***	−0.496***	−0.285***	−0.519***
Young borrower (D)	0.277***	0.358***	0.510***	0.454***	0.117***	0.106***	0.339***
Model B: Δexpected house price (%)							
Intercept	0.326*	1.791***	0.027	0.793***	0.526***	0.403***	−2.559***
Loan rate	–	–	–	–	–	–	1.428***
Monthly averaged spread (%)	16.941***	3.300***	30.274***	38.896***	5.425***	−21.362***	–
ΔExpected house price (%)	26.919***	−4.897***	18.148***	1.984***	35.671***	24.549***	22.937***
CLTV	0.010***	0.011***	0.004**	0.001	0.030***	0.025***	0.025***
DTI	0.008***	0.000	0.004***	0.006***	−0.001*	−0.005***	−0.001*
Relative loan amount ratio	0.010	−0.036	0.981***	0.404***	−0.219***	−0.473***	−0.509***
Grade 7 or higher (%)	0.099*	0.147***	−0.464***	−0.255***	−0.397***	0.065	−0.164***
Loan maturity	−0.376***	−0.018***	−0.031***	−0.030***	−0.036***	−0.023***	−0.043***
Borrower age	−0.027***	−0.029***	−0.035***	−0.032***	−0.009***	−0.010***	−0.021***
LR	12,319	11,133	7,829	14,206	33,265	101,047	101,787
30 yr Maturity(D)	−0.763***	−0.148**	−0.397***	−0.441***	−0.477***	−0.320***	−0.551***
Young borrower (D)	0.360***	0.354***	0.487***	0.468***	0.139***	0.143***	0.371***

Note(s): The table reports the results of logit regressions of six subperiods. The dependent variable is a dummy for prepayment. All variables are described in Section 4.1. Key variables in Model A and Model B are Monthly average Δhouse price (%) and ΔExpected house price (%), both of which are obtained from the REB database. The data of loan and borrower characteristics are obtained from HF. The z-statistics not reported are adjusted for heteroskedasticity. ***, ** and * denote statistical significance at the 1, 5 and 10% levels, respectively

Table 6.
Results of cox proportional hazard regressions by periods

	1	2	3	4	5	6 (A)	6 (B)
Model A: Monthly average Δhouse price (%)							
Loan rate	–	–	–	–	–	–	0.576***
Monthly averaged spread (%)	9.011***	11.331***	18.119***	34.288***	5.610***	−14.790***	–
Monthly average Δhouse price (%)	1.432***	−0.954***	0.515***	0.345***	1.673***	1.006***	0.949***
CLTV	0.051***	0.008***	0.014***	0.009***	0.025***	0.018***	0.019***
DTI	0.008***	0.002**	0.002***	0.003***	−0.002***	−0.004***	−0.002***
Relative loan amount ratio	−0.186***	−0.052***	0.212***	0.108***	−0.053***	−0.188***	−0.184***
Grade 7 or higher (%)	0.040	0.101	−0.112***	−0.248***	−0.171***	0.017	−0.069**
Loan maturity	−0.065***	−0.019***	−0.023***	−0.032***	−0.021***	−0.016***	−0.025***
Borrower age	−0.009***	−0.015***	−0.013***	−0.014***	−0.000	0.000	−0.004***
LR	114,971	111,572	151,996	255,204	575,333	1,170,863	1,180,556
30 yr Maturity(D)	−0.724***	−0.152***	−0.237***	−0.380***	−0.257***	−0.186***	−0.305***
Young borrower (D)	0.098***	0.178***	0.183***	0.205***	0.003	−0.016*	0.084***
Model B: Δexpected house price (%)							
Loan rate	–	–	–	–	–	–	0.464***
Monthly averaged spread (%)	8.624***	11.713***	17.976***	33.999***	3.507***	−13.916***	–
ΔExpected house price (%)	13.972***	−4.266***	7.310***	6.440***	15.720***	17.867***	17.709***
CLTV	0.034***	0.010***	0.014***	0.009***	0.025***	0.025***	0.026****
DTI	0.007***	0.002***	0.003***	0.003***	−0.002***	−0.006***	−0.005***
Relative loan amount ratio	0.019	−0.046**	0.253***	0.113***	−0.092***	−0.258***	−0.255***
Grade 7 or higher (%)	0.039	0.087**	−0.138***	−0.240***	−0.176***	0.021	−0.055*
Loan maturity	−0.478***	−0.021***	−0.025***	−0.033***	−0.019***	−0.019***	−0.028***
Borrower age	−0.013***	−0.015***	−0.010***	−0.015***	−0.000	0.001*	−0.003***
LR	114,637	111,813	150,928	254,760	573,912	1,157,622	1,166,898
30 yr Maturity (D)	−0.478***	−0.160***	−0.232***	−0.397***	−0.228***	−0.227***	−0.335***
Young borrower (D)	0.145***	0.181***	0.151***	0.208***	0.004	−0.029***	0.060***

Note(s): The table reports the results of Cox proportional hazard regressions of six subperiods. The dependent variable is the elapsed period until prepayment. All variables are described in Section 4. 1. Key variables in Model A and Model B are Monthly average Δhouse price (%) and ΔExpected house price (%), both of which are obtained from the REB database. The data of loan and borrower characteristics are obtained from HF. The z-statistics not reported are adjusted for heteroskedasticity. ***, ** and * denote statistical significance at the 1, 5 and 10% levels, respectively

Table 7. Results of ATF (accelerated time failure) regressions by periods

	1	2	3	4	5	6 (A)	6 (B)
Model A: Monthly average Δhouse price (%)							
Intercept	4.945***	3.649***	3.999***	3.920***	4.200***	4.160***	5.252***
Loan rate	–	–	–	–	–	–	−0.471***
Monthly averaged spread (%)	−3.668***	−5.892***	−5.997***	−8.273***	−3.081***	8.940***	–
Monthly average Δhouse price (%)	−0.863***	0.464***	−0.146***	−0.165***	−1.000***	−0.689***	−0.719***
CLTV	−0.028***	−0.004***	−0.003***	−0.005***	−0.015***	−0.012***	−0.014***
DTI	−0.005***	−0.001**	−0.001***	−0.001***	0.001***	0.002***	0.002***
Relative loan amount ratio	0.128**	0.026***	−0.070***	−0.044***	0.037***	0.136***	0.139***
Grade 7 or higher (%)	−0.042**	−0.048***	0.025**	0.055***	0.101***	−0.015	0.053**
Loan maturity	0.033***	0.010***	0.007***	0.011***	0.013***	0.011***	0.020***
Borrower age	0.006***	0.00***	0.004***	0.005***	0.000	0.000	0.003***
LR	60,181	56,692	71,040	112,047	239,755	495,129	505,288
Weib scale	1.623	2.015	3.401	2.505	1.644	1.521	1.358
Weib shape	140.510	38.422	54.570	50.416	66.756	64.279	190.875
30 yr maturity (D)	0.397***	0.077***	0.053***	0.132***	0.152***	0.137***	0.241***
Young borrower (D)	−0.072***	−0.088***	−0.060***	−0.069***	−0.001	−0.001	−0.059***
Model B: Δexpected house price (%)							
Intercept	4.456***	3.732***	4.051***	3.941***	4.140***	4.290***	5.180***
Loan rate	–	–	–	–	–	–	−0.375***
Monthly averaged spread (%)	−4.437***	−6.350***	−6.323***	−8.350***	−1.760***	8.180***	–
ΔExpected house price (%)	−8.349***	2.108***	−2.393***	−2.924***	−9.180***	−11.2***	−12.3***
CLTV	−0.016***	−0.005***	−0.004***	−0.005***	−0.015***	−0.016***	−0.018***
DTI	−0.004***	−0.001***	−0.001***	−0.001***	0.001***	0.003***	0.003***
Relative loan amount ratio	0.002	0.023**	−0.086***	−0.043***	0.059***	0.171***	0.179***
Grade 7 or higher (%)	−0.033*	−0.041**	0.039****	0.051***	0.102***	−0.016	0.042*
Loan maturity	0.021***	0.010***	0.008***	0.011***	0.011***	0.012***	0.020***
Borrower age	0.008***	0.007***	0.004***	0.005***	0.000	−0.001**	0.002***
LR	59,583	56,911	69,459	111,507	238,423	481,839	491,522
Weib scale	1.667	1.999	2.909	2.571	1.665	1.600	1.443
Weib shape	86.179	41.769	57.438	51.479	62.806	73.078	177.277
30 yr Maturity(D)	0.208***	0.082***	0.088***	0.133***	0.132***	0.155***	0.251***
Young borrower(D)	−0.118***	−0.090***	−0.053***	−0.074***	−0.001	0.011**	−0.037***

Note(s): The table reports the results of ATF regressions of six subperiods. The dependent variable is the elapsed period until prepayment. All variables are described in Section 4. 1. Key variables in Model A and Model B are Monthly average Δhouse Price (%) and ΔExpected house price (%), both of which are obtained from the REB database. The data of loan and borrower characteristics are obtained from HF. The z-statistics not reported are adjusted for heteroskedasticity. ***, ** and * denote statistical significance at the 1, 5 and 10% levels, respectively

The monthly average interest rate difference significantly increases the probability of prepayment in all three regression models except for Period 6. The different result in Period 6 could be explained by the lower refinancing incentive during the period due to the low interest rate of 2% and the absence of the spread between the bank's mortgage loan and the market interest rate. When the loan interest rate is used as an explanatory variable instead of the monthly average loan interest rate difference during Period 6, the results are similar to those in other periods.

Model A and Model B where the monthly average house price change rate and the expected house price change rate are included, respectively, show that house prices, in general, significantly increase the probability of prepayment except for Period 2. Note that the global financial crisis occurred during Period 2 where the increase in housing price did not lead to an increase in transaction volume. The results suggest that it is necessary to refer to the pool unit analysis where the housing transaction volume is included as an explanatory variable.

Next, we test which the monthly average house price change rate and the expected house price change rate representing the expected house price is more suitable as an explanatory variable in the prepayment model. The result shows that the likelihood function value is slightly smaller when the expected house price change rate is used. That is, when the expected change rate of house price is used as an explanatory variable, the problem of a decrease in the incentive for prepayment due to a decrease in transaction volume even when the house price rises as in Period 2 cannot be fundamentally solved. CLTV representing the characteristics of each borrower plays a significant role in prepayment in all periods, while statistical significances are slightly different across the models.

Also, in all estimation results, the shorter the loan maturity and the younger the age, the greater the incentive for prepayment. The results are more robust when the 30-year loan maturity dummy and the youth group (26–35 years old) dummy are included as explanatory variables. The results provide an important implication on the housing policy. Recently, the government launched the 40-year super long-term Bogeumjari loan to support the housing purchase of young people including newlyweds. This contract is expected to have the effect of, at least partially, offsetting liquidity-related risks in financing mortgage loans by combining the incentive to decrease prepayment due to long-term loan maturity and the incentive to increase prepayment by young borrowers.

Consistent with Bang *et al.* (2010), as the DTI ratio increases in Period 1 to 4, the incentive for prepayment tend to be greater while, Period 5 and 6 where the average loan interest rates are low, the probability of prepayment decreases as the DTI increases. This is plausible in that the increase in interest cost caused by the increase in DTI (i.e. increase in loan amount) in Period 5 and 6 is sufficiently offset by the lower loan interest rate. At the same time, as the regulation on DTI ratio became strengthened, the average DTI ratio continued to decrease from 43% in Period 1–27.1 and 25.8% in Period 5 and 6, respectively.

Previous studies report that borrowers with the grade 7 or higher (i.e. cautious level) or the lower the credit rating are less likely to prepay their loans. In our results excluding accounts in bankruptcy and overdue for more than 91 days, Period 1 and 2 where the proportion of borrowers with grade 7 or higher exceeds 10%, borrowers in the cautious level are more likely to repay their loans. During these periods immediately before or affected by the global financial crisis, macrofactors such as credit risk to the overall economy might affect prepayment. From Period 3, however, the results are consistent with previous studies.

Regarding the loan amount, previous studies report that borrowers with larger loans have the incentive to make prepayment due to the interest burden. The results in Period 4 and 5 are consistent with previous studies. However, in Period 1 and 2 as well as Period 5 and 6, borrowers with lower loan amounts are more likely to repay their loans. In Period and 2, the average loan amounts are relatively small. In Period 5 and 6, the interest rate has greatly decreased to 3.43 and 2.73%, respectively, of which effect might overwhelms the effect of loan size. This suggests that

the borrower's incentive of prepayment is affected not only by the loan size but also to some extent by the loan interest.

Across the estimation results of each model, there was no significant difference in the significance and sign of the explanatory variables, which suggests that each explanatory variable has a significant effect on the prepayment. Also, we confirm that the effect of each explanatory variable may vary depending on the period of analysis. Also, in the analysis for the individual borrower unit, the ATF model used in the pool unit analysis by Schwartz and Torous (1989) and Kim *et al.* (2018) shows explanatory power, compared with the estimated results of the logit model and the COX proportional risk model. Therefore, we conclude that the ATF model has the potential to be appropriate as a prepayment model for individual borrower analysis.

6. Conclusion

This study investigates the determinants of individual borrowers' prepayment on mortgage loans, the underlying assets of MBS issued by HF since 2004. To do so, we divide the sample period into six subperiods and set 3–5 years as the tracking period for two-year loans. This is the unique study in the Korean market that analyzes the prepayment by individual borrowers by reflecting macro-environmental changes over more than ten years. In addition, our study is different from previous literature in that we set the time of prepayment as the time when borrowers repay 50% or more of the loan principal, not time of the early termination of the loan. As far as methodology is concerned, we confirm the possibility of using the ATF model, which is mainly used for pool unit prepayment analysis where the logit model and Cox proportional risk model are frequently employed.

We summarize the main findings as follows. First, we show that the effect of the monthly average interest rate difference suggested as a determinant on loan refinancing for prepayment in the existing literature becomes insignificant during the recent low interest rate situation. Also, at the time of the financial crisis when a rise in house prices did not lead to an increase in transaction volume, a rise in house prices did not cause prepayment. In particular, the spread between HF's 20-year fixed-rate Bogeumjari loan and commercial banks' housing mortgage loan which is, in general, a strong variable rate has almost disappeared. Thus, the preference for the Bogeumjari loan increases over commercial banks' home mortgage loans, which result in reducing the incentive for prepayment. These results suggest that although the existing literature mainly analyzes the determinants of prepayment in a normal macroenvironment, an analysis considering exceptional macroeconomic conditions is also necessary.

Second, as the CLTV which adjusted the LTV ratio to the housing price index at the time of prepayment increases, the inducement for prepayment increases for the entire sample period. The result is more significant than the case of using LTV at the time of loan. Also, in all periods, the longer the loan maturity and the older the borrower, the lower the incentive for prepayment. In particular, the younger the borrowers, the greater the incentive for prepayment, while the 30-year maturity loan leads to the less incentive. The result implies that for ultralong (40 years) mortgage loans, recently introduced to raise housing for young people, the risk of prepayment will be, at least partially, migrated by offsetting the increase in prepayment by young people and the decrease in prepayment due to long loan maturity.

Third, unlike previous studies reporting the greater incentives for prepayment of borrowers with lower credit ratings, we show that the credit rating itself has little effect on prepayment when the default rate or the proportion of grade 7 or higher decreases significantly. The larger the loan amount and DTI, the greater the incentive for prepayment. However, the incentive can be reduced due to a large reduction in interest expenses in the recent low interest rate economy. In addition, in the analysis for the individual borrower unit, the ATF model used in the pool unit analysis shows as strong explanatory power as the logit model and the COX proportional risk model. Taking into account that the dependent variable of the ATF is the elapsed period until the time of prepayment, the ATF models may provide a more accurate estimation on the determinants of prepayment.

In short, on the one hand, explanatory variables that are not affected by macroeconomic variables such as loan maturity and age exist. However, during the financial crisis or during the period with a low interest rate of 2–3% due to economic stabilization, the influence of macroeconomic variables such as the monthly average interest rate difference and the housing sales index disappears. The main contribution of our study is to show that, using the unique data of individual borrowers, the influence of key determinants on prepayment can vary depending on macroenvironment, while the previous study focuses on only a single period.

We present the limitations of the study and further research challenges in the future as follows. First, this paper analyzes the determinants of prepayment for individual borrowers. Additional research is necessary to complement the results by using explanatory variables, which are difficult to be considered in our data. Those may include housing transaction volume, real estate investment sentiment index and construction industry BSI. Second, in this study, we exclude individual default data. Thus, it is necessary to consider and analyze the prepayment model including borrower default like the OFHEO study.

Second, an empirical analysis that takes into account interest rates and the level of prepayment fees due to the cut in prepayment fees and the spread between the interest rates of collateralized loans in commercial banks seems to be a necessary study in the future.

Third, future studies can be conducted to establish an estimation model by determining the optimal variables for each of the three models employed in this study and, then, to test the adequacy of the model . One may use backtesting to understand which model better predicts the probability of prepayment and estimates the elapsed time to early repayment.

Notes

1. Lee *et al.* (2019) employ a dummy variable to control for the effect of artificial cash flow due to existence of the deferral period.
2. According to the Basic Act for Young People in Korea, young people are defined as citizens between the ages of 19 and 34. We exclude borrowers under the age of 25 since the number of observations is small and consider the Korean age system.

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Further reading

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