

A Comparison of Option-Theoretic and Choice-Theoretic Approaches to Evaluating Alternative Financial Technologies for Mortgage Loans to Low-Income Households*

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Abstract: This paper evaluates the efficacy of two alternative lending technologies – the traditional banking technology and a cash flow based counseling program - by using competing risks (option-based) and choice theoretic approaches. We find evidence to support the notion that low-income borrowers have some degree of financial sophistication, as they prepay the mortgage loan by considering the current value of the call option. The evidence also suggests that borrower heterogeneity and insolvency affect mortgage termination.

Keywords: credit counseling, competing risks, low-income mortgage loans.

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I. Introduction¹

Access to housing financing by low-income households has been an important issue in public policy at least since the Community Reinvestment Act of 1977. Mortgage loans to low-income households as riskier and/or costlier than housing loans to wealthier clients. Financial institutions must address these challenges and still reach low-income clients in a profitable manner. Typically, banks and other financial institutions attempt to assess the risks of housing loans by using a traditional lending technology, based on a consideration of loan features (namely, term to maturity, interest rate, downpayment), some financial characteristics of the borrower (income levels, total debt), and the value of property pledged as collateral.²

Banks, furthermore, seek to attract low-income borrowers by reducing downpayment and other cash contribution requirements, extending closing cost assistance, and accepting lower qualifying incomes and non-traditional credit histories. These actions do not necessarily represent genuine innovations in lending technologies and often are simply in response to regulatory requirements. Standard banking practices do not sufficiently reduce a generalized reluctance to lend to this segment of the population. Dealing with these risks more effectively will require innovative screening and monitoring tools.

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² We use the term *lending technology* to denote the set of criteria, steps and procedures used by a lender to overcome the typical information, incentive, and contract enforcement problems that constrain the emergence of credit transactions. The elements of the technology allow the lender to assess the probability of default and to include incentives (such as collateral), among the terms and conditions of the loan contract, in order to encourage repayment. When the lending technology does not closely match the

In recent years, financial institutions have begun collaborating with third parties in their attempt to design a better screening mechanism for low-income mortgage loans. This collaboration involves the third party setting up a credit counseling program to evaluate more precisely the optimal amount of mortgage loan that a low-income household can sustain. While numerous programs offer such homeownership counseling, little is known about their effectiveness. Further understanding of what works and what does not work in this area can help focus additional attention on promising practices that increase access to mortgage loans by low-income households.

Credit counseling is an innovation designed to help low-income households to estimate the amount of debt they can afford and thus prevent default. By learning more about mortgage loans, however, low-income borrowers may also learn to behave strategically and may prepay (refinance) their mortgages more often when the interest rates fall. If that is the case, counseling may be more beneficial than previously thought. Costly practices, such as lower down payment, higher housing expense to income, and total monthly liabilities to income ratios, designed to attract low-income borrowers, may be less appropriate than credit counseling and lower prepayment penalties.

An important impediment to the evaluation of the effectiveness of alternative lending practices is the lack of agreement among researchers on how to study mortgage termination by low-income households. The option theoretic and the choice theoretic approaches are the two alternative approaches to mortgage termination. While the option theoretic approach has ruled the research on mortgage termination in the past two decades, very few studies have been successful in demonstrating that low-income households behave strategically when acting on their mortgage obligations. On the other

features of a particular set of potential clients, these clients may be excluded from access to loans, despite

hand, the choice theoretic approach has dealt primarily with explaining default as a result of borrower heterogeneity and insolvency and does not deal with prepayment behavior.

This paper evaluates empirically what determines low-income households mortgage termination and compares the effectiveness of the traditional banking screening mechanism to the screening as a result of a particular counseling program. Part II describes standard mortgage lending and lending with counseling. Part III briefly reviews the relevant literature and describes the competing risks and choice theoretic approaches to mortgage termination. Part IV presents the empirical analysis. Conclusions are offered in Part V.

II. Alternative Technologies for Lending to Low-income Households

Traditional banking technology relies mainly on underwriting standards to determine whether a potential borrower will be able to service the mortgage loan. These underwriting standards require that the ratio of total (monthly) housing expense to pretax income does not exceed 28 percent and that the ratio of total (monthly) obligations to income does not exceed 36 percent. To estimate these ratios banks engage in expensive and time consuming collection and verification of data on household income, liabilities and assets. Most of the information on the loan application form is verifiable but some (for example, the value of miscellaneous assets) is not. The lack of knowledge on low-income households circumstances impede banks abilities to screen good borrowers and precisely determine the optimal level of sustainable debt.³

their underlying creditworthiness.

³ Credit scoring, considered by many the most important innovation in mortgage lending was not used for the whole period for which we have data, and given the small size sample of the data, we can not use it to evaluate its effectiveness.

The Community Mortgage Loan Program studied here was initiated by (Paul Taylor & Associates Community Development Consulting, Huntington Bank, and Fannie Mae) in 1992. The objective of the program was to provide cost efficient mortgage loans to low-income households, in a fashion profitable for the bank.

Prior to 1995, only the bank was involved in the screening of potential borrowers. In 1995, the counsel provider introduced its counseling program. All potential low-income borrowers go through a counseling process prior to their application at the bank. To address the specific needs of each borrower, the amount of counseling is individually determined. Potential borrowers participate in group sessions, where they learn how to keep track of their living expenses, measure their level of debt, and calculate whether the expected mortgage loan can be sustainable.

Graduation, (which is a prerequisite for loan application) is granted only to those participants who, given an interest rate and a loan amount, can generate zero or *positive cash flow*, based on a thorough verification and calculation of their actual living expenses and debt. Loan amounts adjusted by these criteria do not always correspond to those resulting from the standard financial ratios that banks use as a screening device.

Granting a loan, furthermore, requires that the borrower contribute a five-percent downpayment. The program combines counseling with financial assistance. If the borrower cannot provide the five-percent downpayment, she is granted a consumer loan to make it possible.

A potential advantage of the Community Mortgage Loan program is that the counsel provider is a third party, with superior knowledge of the circumstances of low-income households (that is, the provider of counseling possesses information advantages

over the bank). This expertise, combined with a conservative approach to maximum sustainable debt estimation, improves the chances of success of the loan.

III. Discussion of the Literature

To study the effectiveness of the alternative lending technologies we first estimate an *option-based* model of competing risks of mortgage termination, in a Cox proportional hazards context. We then introduce the influence of trigger events. Finally, we estimate a simple, choice theoretic model and compare the results of the two approaches.

According to an option-based theory of mortgage termination, a borrower faces several choices when deciding how to act on her loan obligation. She has the option to (1) make the payment on the loan and continue in good standing as a debtor, (2) pay in full the remaining balance on the loan, by refinancing (prepayment), or (3) surrender the house to the lender, in exchange for cancellation of the debt. Prepayment and default are just two actions that borrowers undertake in order to increase their wealth, and therefore are driven by the value of the underlying prepayment (call) and default (put) options (Foster and van Order, 1984).

The call option is-in-the money (prepayment is profitable) when the net present value of the outstanding loan balance is lower at market rates than at contract rates. The put option is in-the-money (default is wealth increasing) when the present value of the outstanding loan balance and the market is higher than the contemporaneous value of the house (Quigley and van Order, 1991). Default and prepayment, from this theoretical perspective, are purely a financial matter.

While earlier models of mortgage terminations have studied the prepayment and default options separately (Quigley and van Order, 1992, Capozza *et al.*, 1998). The

main concern of the literature was to correct for overestimation of the default hazard and prepayment rates by attempting to measure the transaction costs and trigger events (**ref**). A series of papers by Kau, Keen and Muller, Kau and Keenan (1996), Epperson (1992, 1995), provide theoretical work that emphasizes the importance of the jointness of prepayment and default options. Most generally, the framework accounts for the fact that by exercising his option to default today a borrower gives up his option to default in the future but also his option to prepay in the future. Deng, Quigley and VanOrder (1996), and Deng 1997 estimate empirically the joint choices of individuals in deterministic competing risks model. Deng, Quigley and VanOrder (2000) also estimate competing risks model of mortgage termination by accounting for borrower heterogeneity. This empirical approach estimates prepayment and default as competing risks simultaneously, accounting for the fact that risks may be correlated, and for the fact that covariates may be time related.

The proportional hazard model introduced by Cox (Cox and Oakes, 1984) provides the convenient framework for evaluating the options empirically and the importance of trigger events. This approach is also ideal for dealing with time censored (seasoned) data. This is critical, as empirical information is often available for only several years since loan origination, for loans still outstanding.

Following Deng et. al. (2000) let T_p and T_d be the discrete random variables representing the duration of a mortgage until it is terminated by the mortgage holder in the form of prepayment or default. There is no restriction on the functional form of the baseline hazard. The joint survivor function conditional on n_p , n_d , r , H , Y and X can be expressed in the following form:

$$S(t_p, t_d | r, H, Y, X, n_p, n_d) = \exp(-n_p \sum_{k=1}^{t_p} \exp(\gamma_{pk} + g_{pk}(r, H, Y) + \beta'_p X)) \quad (1)$$

$$\exp(-n_d \sum_{k=1}^{t_d} \exp(\gamma_{dk} + g_{dk}(r, H, Y) + \beta'_d X))$$

where $g_{pk}(r, H, Y)$ and $g_{dk}(r, H, Y)$ are the time-varying functions of option-related variables, r and H are the relevant interest rates and property values, respectively; Y is a vector of other variables that will be used together with r and H to estimate the market values of the options empirically; X is a vector of non-option related variables that indicate borrower financial strength or financial risk, as well as trigger events as unemployment and divorce; γ_{pk} , γ_{dk} are parameters of the baseline function that are not estimated empirically (nonrestricted baseline hazard) and n_p , n_d are unobserved heterogeneity associated with the hazard functions for prepayment and default. The model is estimated by the Maximum Likelihood Method.

The choice theoretic approach incorporates option values commonly stressed by the option-based model but in a more general, consumer choice framework. In fact, adherents argue that the option-based model can be viewed as a nested model within the broader consumer choice model and can be qualified by the consumer choice paradigm. This approach integrates all wealth related variables. The importance of insolvency for default is introduced as a separate motivation for default. That is, the approach deals with the *ability to pay*, as different to the *willingness to pay* (strategic default) implicit in the option models.

The two approaches disagree, on the role of mortgage value effect as the choice theoretic approach argues that it is insolvency, not changes in interest rates that trigger default. The option-based approach views default as a substitute for prepayment and

therefore, falling interest rates will create the same incentives for default and prepayment. The choice theoretic approach recognizes only a secondary role for the interest rates because they do not directly cause insolvency and because prepayment will dominate default as a strategy to claiming wealth gained from a drop in rates. The choice theoretic approach emphasis on income and debt is consistent with widespread use of payment and debt-to-income ratios as standard underwriting criteria. (Elmer and Seelig, 1999)

In terms of prepayment, there are no major differences between the two approaches, as prepayment is not explicitly addressed by the choice theoretic approach.

Yang *et al.* (1998) found evidence about the presence of consumer-choice determinants of mortgage termination, mainly through the influence of household income. LaCour-Little (1999) shows that borrower characteristics influence mortgage termination, especially when the option does not have value (that is, the option is *at-the-money*, rather than *in-the-money*, in the terminology of option theory). In these cases, other factors, different from financial calculation, influence default.

The major difficulty in testing the choice theoretical approach is that it is not possible to observe household solvency in time. The role of trigger events is highly consistent with the role ascribed to solvency, however. Foster and van Order (1984), Lekkas, Quigley and van Order (1993), Quigley and van Order (1995), and Vandell (1998) provide evidence on the importance of trigger events and the role of transaction costs.

The greater importance of ability to pay, particularly for poorer households with volatile incomes, provides additional reasons to study the role of income levels and variability and of debt-to-income ratios in establishing creditworthiness and predicting default. As empirical result from option based models on mortgage termination by low-

income households are mixed, critics of the option-based theory of mortgage default also contend that borrowers may not understand how mortgage markets function. Counseling, usually introduces concepts such as the present value of money, annualized interest rates, and the true value of a mortgage loan. When interest rates and property values change, borrowers who have undergone counseling will have a better understanding of how these changes affect the value of their loan obligations. Therefore, counseling may actually improve the predictive power of the option-based approach.

In the next section we put both these approaches to the test.

IV. The Empirical Analysis

The data consist of information from a *random sample* of 394 loan folders, drawn from the database of 1,338 mortgage loans, originated between 1992 and 2000, under the auspices of the program (Table 1 in the Statistical Annex). Counseled loans represent 63 percent (294 loans) and non-counseled loans 37 percent (100 loans) of the total number of loans in the sample. The population includes mortgages from Florida, Indiana, Kentucky, Michigan, Ohio, and West Virginia.

Counseled and non-counseled borrowers differ in income and net assets (Table 1). Primary monthly income and total borrower monthly income are significantly higher for the counseled loans (\$1,808 and \$1,928 respectively) than for the non-counseled loans (\$1,657 and \$1,756 respectively). Counseled borrowers also paid higher rent prior to the purchase and have higher housing expenses after the purchase of the house. The relative increase in housing expenses is not significantly different, however.

The data suggest that non-counseled borrowers may have misrepresented their financial situation in order to get the mortgage loan. Non-counseled borrowers report

miscellaneous assets (\$18,008) that are almost twice the miscellaneous assets reported by counseled borrowers (\$10,979). Since the value of most other itemized assets (*i.e.*, deposits, car value, real estate owned, savings for retirement) must be confirmed, declaring higher value of miscellaneous assets increases the net worth and therefore the chances of getting the loan. Savings for retirement, on the other hand, are three times higher for the counseled borrowers than the saving of non-counseled. These results may suggest that non-counseled borrowers have lower degree of financial sophistication and made the decision to buy a house without properly evaluating their own repayment capacity.

Prime housing expenses to income and total monthly obligations to income ratios are important because financial institutions use them heavily to screen potential borrowers. These ratios do not statistically differ for counseled and non-counseled borrowers, in spite of the fact that the difference between the total monthly obligations for the counseled loans (\$748) and the total monthly obligations for the non-counseled loans (\$641) is statistically significant. Counseling seem to improve the chances of people with past financial problems to obtain house mortgage loans. The rate of declared personal bankruptcy during the previous seven years is twice as high for the counseled (14 percent) than for non-counseled borrowers (7 percent), and the difference is statistically significant.

Data associated with the financial contract show that there is no statistically significant difference in purchasing price of the house for the two groups (\$43,840 and \$45,834). Counseled borrowers received higher loan amount (\$43,061 and \$40,880 respectively), and higher consumer loan credit to pay the down payment (\$3,231 and

\$1,040 respectively), while the amount of real down payment – cash from the borrower - was practically the same for the two groups.

The data are observed at specific points in time, and since the mortgage loans are for 30 years, all observations are truncated. Repayment records in the sample expand up to nine years, with most loans still outstanding (Table 2). Non-parametric duration analysis shows that the incidence of default among non-counseled borrowers is higher than the incidence of default among counseled borrowers, while prepayment is higher for counseled borrowers.

The key variables, according to the option theoretic approach, are those measuring the extent to which the put and call options are in-the-money. To establish the effect of counseling on default, the current mortgage (Fannie Mae 30years) interest rate and the initial contract terms are sufficient. The “*Call_Option*” variable measures the ratio of the present discounted value of unpaid mortgage balance at current quarterly mortgage rate relative to the value discounted at contact interest rate (Appendix B).

To value the put option, we need to measure the market value of each house quarterly and compute homeowner equity quarterly. Since we cannot observe the individual variations in houses in the sample, we use estimates of the means and variances from repeat (paired) sales provided by the Office of Federal Housing Oversight (OFHEO) to impute the value of the individual house prices in the sample. The variable “*Put_Option*” measures the probability that homeowner equity is negative, i.e. that the put option is in the money (Appendix B).

As proxies for “trigger events” we use monthly unemployment rate by county and the annual divorce rate by state.

The variables that would affect mortgage termination according to the choice theoretic approach are *Income* (total household monthly income), *Housing Expense to Income Ratio*, and *Downpayment*.

The results regarding the effectiveness of alternative lending mechanisms vary depending on the approach used. Default and prepayment hazard rates, estimated in a competing risks framework, as prescribed by the option are shown in Table 4, Model 1. According to these results, mortgage termination by low-income households is not driven by the value of the put option but only by the value of the call option. Moreover, counseling does not decrease the hazard rate of default, and therefore, may not be an improvement in the screening mechanisms of traditional mortgage lending.

From an option theory perspective, these results seem disappointing. Some measurement error may, however, contribute to this result. The median and variance values that are used to impute the changes of house price in time come from housing price indexes computed by the Office of Federal Housing Oversight (OFHEO). The indexes are calculated from repeated sales of single-family, detached properties, using data on conventional conforming mortgage transactions obtained by Freddie Mac and Fannie Mae. These estimates of the fluctuation around the mean are much higher for conventional houses due to the higher degree of heterogeneity of the underlining population. Houses owned by low-income households are more homogeneous and their fluctuations around the mean vary less. Moreover, the mean values of the houses used in OFHEO indexes may be quite different from the values of the houses in low-income neighborhoods in our sample.

The explanatory power of the competing risks model improves, however, when variables that account for the trigger events are included. Surprisingly, it is divorce, not

unemployment that seems to influence default and in unexpected direction - for each one 1 percent increase in the national divorce rate, default hazard decrease by 0.001. Prepayment, on the other hand is positively affected by the local unemployment rate; as unemployment increases by 1 percent the prepayment hazard rate increases by 0.003 percent. Again in Model 2 (Table 4) the put option is not significant while the prepayment option is. Counseling affects prepayment but not default.

When the competing risks framework is extended to include variables that capture borrower heterogeneity at time of loan origination (Model 3), the explanatory power of the model increases even further. Default hazard again is not affected by the value of the value of the put option but it is affected by the divorce rate, income and housing expense to income ratios. Here again counseling does not affect default but affects prepayment. If default and prepayment are interdependent risks, then the influence of counseling is on prepayment, not on default.

Estimates from consumer choice specifications, when default hazard is estimated independently (Table 4) show that counseling is only marginally effective, at 10 percent level of significance. Moreover, this result is not robust. Even with consumer choice specifications, counseling significantly affects prepayment.

Our results shed some light on the theoretical debate. Low-income borrowers may consider home ownership a financial investment, and act on it as predicted by the option-based theory of mortgage termination. Other variables, however, such as income and personal circumstances also affect the borrower's behavior, and render even more credibility to the consumer choice approach.

V. Conclusions

The purpose of this study was to evaluate the efficacy of two alternative lending technologies – traditional banking technology and a cash-flow based counseling program by using innovative competing risks (option-based) and choice theoretic approaches.

If mortgage termination by low-income households is driven by the consumer choice considerations, and default is not a strategic action but is driven by ability to pay, then the screening technology of the counsel provider is only marginally better than traditional banking practices. Indeed, we find evidence that the choice theoretic approach is an appropriate approach to study low-income households' mortgage termination.

The competing risks model of mortgage termination may not be out of place either. We find evidence that low-income households possess some degree of financial sophistication as they act on their call option. Limitations in data quality may be behind problematic explanation of default hazard within the competing risks framework. Although in this approach counseling does not directly affect default hazard, results still indicate that counseled borrowers may learn to behave more strategically and may be more inclined to default or prepay when the put and the call options are in-the-money.

Overall, we find evidence to support the notion that low-income borrowers have some degree of financial sophistication, as they repay, default or prepay on their mortgages by considering the current value of their put option. The evidence also suggests that borrower heterogeneity and insolvency affect mortgage termination. While both approaches agree that counseling influences prepayment, the two approaches do not show similar results regarding default. To clarify this ambiguity more disaggregated price indexes should be used but this data is currently unavailable. Therefore, the jury on what technology better identifies potential borrowers is still out.

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Appendix A

Table 1. Borrower and Financial Contract Characteristics

Variable	Non-Counseled (Mean/\$*)	Counseled (Mean/\$*)	Z-Value
Borrower age	37.4	35.4	0.68
Monthly income (borrower)	1,756	1,928	-2.04
Monthly income (family)	2,030	2,339	-3.07
Income previous year	17,576	23,818	-4.22
Monthly housing expense to income	0.21	0.23	-1.33
Monthly total obligations to income	0.33	0.33	-0.25
Rent payment prior to loan	269	309	-1.79
Housing expense after mortgage	375	458	-6.64
Increase in housing costs	0.8	0.5	1.10
Total declared assets	28,221	19,988	2.97
Miscellaneous	18,008	10,979	3.97
Savings for retirement	2,060	6,939	-2.17
Total liability (stock)	8,240	11,333	-2.48
Down payment	2,439	2,606	-0.60
Consumer loan and credits	1,040	3,231	-3.24
Loan amount	40,880	43,061	-1.73
Property value	44,914	47,538	-2.00
Purchasing price	43,840	45,834	1.55

* in 1992 price equivalent

Table 2. Portfolio Status

Loan Status	Non-Counseled		Counseled		Total	
	%	Number	%	Number	%	Number
In Default	17.6	18	6.1	16	10.3	34
Prepaid	5.9	5	3.8	12	4.5	17
Current	76.6	77	90.2	266	85.2	343
Total	37.3	100	63.3	294	100	394

Table 3. Portfolio Characteristics – Non-Parametric Duration Analysis

Type of Loans	Time at Risk (portfolio days)	Incidence Rate (portfolio days)
Default (Portfolio)	604,246	0.0000671
Counseled	312,921	0.0000485
Non-Counseled	291,324	0.0000871
Prepayment (Portfolio)	637,115	0.0000283
Counseled	312,388	0.0000204
Non-Counseled	324,727	0.000036

Table 4. Estimates of Competing Risk Model

Variables	Model 1		Model 2		Model 3	
	Default	Prepayment	Default	Prepayment	Default	Prepayment
Call Option	-0.930 (-0.37)	-4.078 (-2.36)	1.452 (0.58)	-0.519 (-3.44)	1.138 (0.62)	-9.699 (-2.82)
Put Option	-0.191 (-0.44)	-0.177 (-0.39)	-0.244 (-0.44)	-7.027 (-1.12)	0.281 (0.47)	-0.472 (-0.66)
EQR					-0.870 (-0.31)	
Unemployment			-0.203 -1.01	0.305 2.06	-0.033 (-0.15)	0.255 (1.53)
Divorce			-0.463 -1.72	0.028 0.14	-0.495 -1.68	0.067 0.31
Income					0.0004 -2.31	0.000 -1.29
Housing Expense to Income					3.289 2.06	-4.371 -2.10
Downpayment					0.001 0.24	0.000 -1.44
Counseling	-0.317 (-0.74)	0.530 (2.16)	-0.540 -1.31	0.739 2.32	-0.106 -0.25	0.894 3.56
Log Likelihood	-287.15		-283.63		-223.35	
P> z	0.05		0.009		0.000	

Table 5. Default and Prepayment as Independent Hazards

Variables	Default	Prepayment
Call Option	1.486 (0.48)	0.000 (-2.67)
Put Option	-0.752 (-0.71)	0.416 (-0.59)
EQR	-3.964 (-0.93)	
Unemployment	-0.075 (-0.32)	1.549 (1.19)
Divorce	-0.561 (-2.02)	1.372 (0.68)
Income	-0.001 (-2.29)	0.966 (-1.25)
Housing Expense to Income Ratio	3.864 (2.20)	
Downpayment	0.000 (2.01)	0.966 (-1.42)
Counseling	-0.8730 (-1.68)	3.073 (2.22)
Log Likelihood	-144.97	-65.01
$P > z $	0.015	0.0018

Appendix B

The variables measuring the value of the put and call options are defined by the initial terms of the mortgage and current conditions. For fixed-rate level-payment mortgage i with an original amount of O_i , a mortgage rate of r_i , and a monthly payment of P_i , in principal and interest, the mortgage term in quarters, TM_i , is

$$\begin{aligned}
 Call_Option_{i,k_i} &= \frac{\sum_{t=1}^{TM_i-k_i} \frac{P_i}{(1+m_{j,\tau_i+k_i})^t} - \sum_{t=1}^{TM_i-k_i} \frac{P_i}{(1+r_j)^t}}{\sum_{t=1}^{TM_i-k_i} \frac{P_i}{(1+m_{j,\tau_i+k_i})^t}} \\
 &= \frac{V_{i,m_{j,\tau_i+k_i}} - V_{i,r_i}^*}{V_{i,m_{j,\tau_i+k_i}}}
 \end{aligned} \tag{1}$$

The market value M_i of property i , purchased at cost C_i at time τ_i and evaluated k_i months thereafter is

$$M_{i,k_i} = C_i \left(\frac{I_{j,\tau_i+k_i}}{I_{j,\tau_i}} \right) \tag{2}$$

where the term in parentheses follows a log-normal distribution.

The ratio of equity to market value, E , of the property i is

$$E_{i,k_i} = \frac{M_{i,k_i} - V_{i,m_{j,\tau_i+k_i}}}{M_{i,k_i}} \tag{3}$$

The “*Put_Option*” variable is defined as the probability that equity is negative:

$$Put_Option_{i,k_i} = prob(E_{i,k_i} < 0) = \Phi \left(\frac{\log V_{i,m_{j,\tau_i+k_i}} - \log M_{i,k_i}}{\sqrt{w^2}} \right) \tag{4}$$

where $\Phi(\cdot)$ is cumulative standard normal distribution function, and w^2 is an estimated variance is estimated using OHEO estimates of housing prices volatility as of the last quarter of 2000.