Determinants of the Closing Probability of Residential Mortgage Applications

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Abstract. After allowing applicants to "lock" the interest rate, mortgage originators are concerned with protecting themselves from adverse outcomes due to interest-rate changes. One may expect applicants would strive to close applications when rates rose, while letting themselves fall out when rates decline. Our results show that applicant response to interest-rate changes and volatility are modest. The most important predictor of closing probability is the length of the lock period, with shorter locks being more likely to close. Applications for single-family are more likely to close than are those for multiunit dwellings. Applications for owner-occupied properties are more likely to close than are those for investment properties. Applicant characteristics such as loan affordability, education and age have a small influence on closing rate. Gender has an effect for some loan programs, and marital status appears to be irrelevant. Discount points affect refinance mortgages more than purchase mortgages. Conventional applications are more likely to close than FHA and VA, and applications for refinance, in general, are less likely to close. Results are mixed for ARM and fifteen-year applications, as well as for whether it was the original application, or a relock.

Introduction

Upon application for a residential mortgage the potential borrower is typically offered the opportunity to lock in a current interest rate for the proposed loan. While this lock opportunity may be deferred, all applications must lock before closing as the paper work has to be prepared for a known loan contract. Loan lock periods vary, with forty-five and sixty days being the most common, though shorter locks may be used if the application process is nearly complete (i.e., the applicant allowed the interest rate to float during the application processing period). After locking, the application becomes part of the "mortgage pipeline". The mortgage originator then pursues a hedging strategy (which may be no hedging) to protect itself from the adverse effects of interest-rate changes between the date of the loan lock, and the date at which the closed loan will be sold into the secondary markets.

There are several reasons for a locked application to not close including: (i) the applicant may not qualify for the mortgage; (ii) the requisite underwriting package is not completed; (iii) defects in title or property; or (iv) interest rates decline and it is no longer in the applicants best interest to close. If the probability of a locked application becoming a closed one can be related to applicant characteristics, loan type and interest-rate

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movements, a mortgage originator can better manage the pipeline interest-rate risk it faces.

The importance of hedging the mortgage pipeline has been noted (McMurray, 1993; Scrowcroft, Davidson and Bhattacharya, 1988; Goodman and Jonson, 1987) but these studies do not attempt to measure the probability of a locked application closing. Rosenblatt and Vanderhoff (1992) pioneered closing probability research by directly assessing the probability of a locked application closing. A subset of their data is presented in a hazards context in Hakim, Rashidian and Rosenblatt (1995). This study extends the work of Rosenblatt and Vanderhoff (1992) by analyzing a more complete data set. The data set is more recent (1990–95 versus 1988–89), larger (about 55,000 locks versus 25,000), and it includes FHA and VA applications in addition to conventional applications. It contains information not present in Rosenblatt and Vanderhoff (1992) including interest-rate commitment on each application, measures of applicant characteristics, amortization period, reason for refinance (to tap equity or to capture a lower interest rate), and interest-rate volatility (an important options pricing variable). The data set is unique in that the information is recorded by the application lock being considered. McMurray (1994) notes that one must hedge applications by lock, not by whether the applicant ultimately closes a loan, indicating the need for a study based on application locks. The purpose of this study is to empirically analyze determinants of mortgage closing probability, which is an important first step in determining how best to hedge the mortgage pipeline. We present an overview of the data, details about the empirical model variables, an econometric analysis, and summary of our findings.

The Data

Our data is for applications made to a nationally oriented mortgage originator during the January 1990 to January 1995 period, which includes periods of both rising and falling interest rates. The data set includes FHA, VA and conventional applications for fixed- and variable-rate mortgages with fifteen- and thirty-year amortization periods. From about 44,000 loan applications, there are in excess of 55,000 interest-rate locks.

Most applications locked once, but about 9,000 experienced multiple locks. The original number of lock days varied from 1–600 days, with an average of 46 days. About 43% of the locks were for 45 days, and 38% for 60 days. Less than 0.2% are for locks greater than 90 days. For applications that experienced one relock, the average relock period was 20.4 days. For those that relocked a second, third, fourth, or fifth time, the average lock period was for 23, 25, 43, and 48 days, respectively.

Because of the cost of processing applicants, funding during the original lock is the goal of mortgage originators. Two thirds (more precisely 66.54%) funded during the original lock period. About 11% of the applicants terminated their application in this period,[1] and the remaining 22% went on to the next phase, either by allowing the interest rate to float for some period (i.e., allowed lock to expire), or by securing a new lock, prior to the expiration of the initial lock (9.5% of applicants). Cross-tabbing of this data set shows that as the number of locks increases, a somewhat greater proportion funds, but through relock 3, there is not much change in the terminal outcome of a lock. An econometric analysis is needed, however, to understand the relationship among loan program, applicant characteristics and relock behavior that may affect loan closing probability.

Empirical Model Variables

The variables hypothesized to influence the closing outcome are provided in the following table. Most variables describe details of the mortgage applied for or applicant characteristics.

Variables	Hypothesized Sign	Description
CLOSE	N/A	The dependent variable. An indicator variable that takes the value 1 if the application closed, and 0 otherwise.
DISCPOINT	−	Discount points. Amount of discount points an applicant pays. Higher discount points may erode the applicant's ability to close the loan, and an applicant may have a distaste for paying points, even though they may be fairly priced, given the note rate.
DELPRICE	−	Change in price of the ten-year Treasury note futures (as reported by the Chicago Board of Trade) between application lock and termination. While either points or note rates may change in response to interest-rate movements, the net effect of these changes is captured by using the price of a Treasury future.
VOLATILITY	−	The implied volatility of the reference instrument computed by using the price of the reference instrument and the price of CBOT options on the reference instrument. The higher the volatility of an option, the more likely its exercise; similarly, higher volatility increases the likelihood that interest rates will decline to where fall-out will be desirable. If interest rates move little, we expect loan closure as the applicant wants a loan.
LOCKDAYS	−	The number of days the interest-rate lock is in effect. Because short locks only make sense if the application process is nearing the end and the applicant has chosen to proceed with the lock, short lock periods should indicate a higher closing probability.
QRATIO	−	Qualifying ratio. The monthly family income divided by the monthly mortgage payment, assuming the loan is amortized over thirty years. It measures affordability by capturing the relationship among income, loan amount and interest rate. As this ratio rises, affordability falls leading to lower projected closings.
SCHOOL	+	The maximum years of schooling of the applicant or coapplicant. We hypothesize more educated applicants to have higher closing rates as they can better navigate the loan closing process.
AGE	+	Applicant age. We expect that older applicants will be more likely to successfully bring a loan to closure due to having had more experience in completing major financial transactions.
MULTIUNIT	−	Indicator of a mortgage for a two–four-unit building. It may be harder to qualify for multi-unit mortgages and the investor may be more willing to fall out if the deal does not seem financially advantageous.
RENTAL	−	Indicator of a rental unit. Applicant is expected to be less likely to close as less personal disruption occurs from not closing and applicants are expected to be more financially motivated to fall out if interest rates fall.

Table *(Continued)*

Variables	Hypothesized Sign	Description
WOMAN	?	Indicator that the applicant is a woman (which does not prevent a man from being coapplicant).
SINGLE	−	Indicator that the applicant is single. Singles probably have a lower opportunity cost in not having a loan close as it may disrupt only one person.
SHORTLOCK	+	Indicator of a short lock period (fourteen or fewer days). This variable, combined with lockdays allows for nonlinearity in the effect of lock days.
SHORTRELOCK	+	Indicator of a short relock period (fourteen or fewer days).
*RELOCK*1	?	Indictor variable for first relock. There is no a priori reason to assume there is a difference in closing behavior among locks.
*RELOCK*2	?	Indictor variable for second relock.
*RELOCK*3	?	Indictor variable third or greater relock.
15-*YEAR*	+	Indicator variable for a fifteen-year amortization period. Those who apply for a fifteen-year loan are probably more likely to qualify for a loan and thus will be more likely to close.
ARM	−	Indicator variable for an adjustable-rate mortgage. Those who apply for an ARM may be doing so due to a weak financial position and thus are less likely to close.
NORTHEAST	?	Indicator for properties located in the Northeast.
MIDWEST	?	Indicator for properties located in the Midwest.
WEST	?	Indicator for properties located in the West.
SOUTH	?	Indicator variable for properties located in the South.
RATE	−	Indicator variable that the reason for a refinance was to obtain a better interest rate. Hypothesized sign is negative as if rates fall further, or are volatile, these applicants may fall out as they assess whether their decision should be delayed. Applicants who refinance to tap their home equity are probably more constrained in their need to refinance and thus more likely to close their application.

Exhibit 1 presents descriptive statistics for these covariates.

Logistic Regression Modeling Results

Because differences may exist among mortgage programs and uses, the empirical models are disaggregated by loan program and purchase versus refinance. We chose logistic regression as the tool of analysis due to the desirable properties of regression analysis and the reasonable restriction to model closing probabilities in the [0,1] interval.

Exhibits 2–4 present the regression results. For each model, the first column presents the parameter estimate, followed by the estimated *p*-value, which in turn is followed with

Exhibit 1
Descriptive Statistics for the Covariates
(No. of Observations: 55608)

Variable	Mean	Std Dev.	Min.	Max.
RELOCK	0.29	0.65	0.00	9.00
DISCPOINT	0.57	1.29	−4.25	9.50
DELPRICE	−0.03	1.75	−9.75	6.91
VOLATILITY	0.07	0.01	0.05	0.11
LOCKDAYS	45.49	17.02	0.00	600.00
QRATIO	0.16	0.07	0.00	3.42
SCHOOL	15.05	2.69	5.00	30.00
AGE	38.03	10.67	18.00	91.00
MULTIUNIT	0.02	0.14	0	1
RENTAL	0.03	0.18	0	1
WOMAN	0.19	0.39	0	1
SINGLE	0.32	0.46	0	1
SHORTLOCK	0.05	0.22	0	1
SHORTRELOCK	0.03	0.16	0	1
RELOCK1	0.16	0.37	0	1
RELOCK2	0.04	0.20	0	1
RELOCK3	0.01	0.12	0	1
15-YEAR	0.13	0.33	0	1
ARM	0.18	0.38	0	1
NORTHEAST	0.06	0.24	0	1
MIDWEST	0.15	0.35	0	1
WEST	0.28	0.45	0	1
SOUTH	0.51	.50	0	1
RATE	0.21	0.40	0	1

a measure of the impact this variable exerts on the probability of closing. The base probability, from which impact is measured, is the predicted closing probability when each continuous covariate is set to its average value (as shown in Exhibit 1), and the dummy variables are set to zero. This means it is the predicted closing probability of the original lock for an application from the South for a thirty-year, fixed-rate mortgage by a married man for an owner-occupied single-family dwelling. The impact measure shows the percent change (from the baseline probability) in the estimated closing probability as each continuous covariate value is individually increased by one standard deviation. For binary variables, the impact measure shows the effect of the variable taking the value 1. Because some variables that may be statistically significant may not be economically significant it is helpful to provide an impact measure for easy assessment of the economic significance of each covariate in a nonlinear regression model. Exhibits 2–4 also show, for each model, the number of applications in the sample and the overall closing percentage for that sample. Because an *R*-squared measure does not exist for logistic regression, this study presents the square of the correlation between the predicted and actual outcomes, corrsq, which is analogous to the *R*-squared of linear regression (Maddala, 1988).

The first set of results in Exhibit 2 are for conventional mortgages for home purchase. The largest positive impact on closing is the length of the lock period or relock period, as demonstrated by the 11.9% impact displayed by the *SHORTLOCK* variable and 14.9%

Exhibit 2
Logistic Regression Estimates for Conventional Mortgages

	Mortgages for Purchase			Mortgages for Refinance		
	Coeff.	p-Value	Impact (%)	Coeff.	p-Value	Impact (%)
Intercept	0.826	**		0.390	0.12	
DISCPOINT	0.008	0.61	0.2	−0.051	0.01	−2.4
DELPRICE	−0.087	**	−3.6	−0.092	**	−5.9
VOLATILITY	3.129	0.09	0.6	12.714	**	4.1
LOCKDAYS	−0.007	**	−2.9	−0.016	**	−10.4
QRATIO	−1.352	**	−2.4	−1.948	**	−5.3
SCHOOL	0.049	**	2.9	0.024	*	2.3
AGE	−0.001	0.68	−0.2	0.001	0.56	0.5
MULTIUNIT	−0.479	**	−12.4	−0.383	0.01	−14.4
RENTAL	−0.276	*	−6.8	−0.610	**	−23.3
WOMAN	−0.126	0.01	−3.0	−0.056	0.42	−2.1
SINGLE	−0.011	0.79	−0.2	−0.042	0.50	−1.5
SHORTLOCK	0.392	*	11.9	0.084	0.51	19.4
SHORTRELOCK	0.597	**	14.9	−0.122	0.43	13.3
*RELOCK*1	−0.294	**	−7.3	−0.027	0.64	−1.0
*RELOCK*2	−0.336	*	−8.4	0.128	0.19	4.5
*RELOCK*3	−0.215	0.13	−5.2	0.445	0.01	14.9
15-*YEAR*	−0.166	*	−4.0	0.032	0.51	1.2
ARM	−0.341	**	−8.6	−0.263	*	−9.8
NORTHEAST	−0.119	0.08	−2.8	−0.076	0.38	−2.8
MIDWEST	0.399	**	8.2	0.369	**	12.6
WEST	−0.380	**	−9.6	−0.225	**	−8.4
RATE				0.030	0.59	1.1
N	20097			10089		
%Close	74.43			65.39		
Base Probability	76.9			63.82		
Corrsq	3.28			4.58		

* indicates *p*-value < 0.01; ** indicates *p*-value < 0.0001

impact for the *SHORTRELOCK* variable. Because the indicator variable indicates a lock period of fourteen or fewer days, fourteen days was used as the number of *LOCKDAYS*, along with the value 1 for *SHORTLOCK* and *SHORTRELOCK*, when computing their impact. While *LOCKDAYS* by itself is a significant variable in explaining closing, the positive sign on the *SHORTLOCK* variable suggests that short locks are where the most impact is observed. The highest negative impact is for *MULTIUNIT* at −12.4%. The first and second relocks are about 7%–8% less likely to close all other things held constant while a third or higher relock has no statistically significant effect. The impact measure also shows that ARMs are 8.6% less likely to close and fifteen-year applications are 4% less likely to close. Women applicants are somewhat less likely to close, and closing probability is increased with number of years of schooling. Closing is less likely as the applicants *QRATIO* increases though this impact is relatively small. The impact of changing interest rates is quite modest given the long-term financial impact. As the price of the reference instrument increases by one standard deviation (i.e., interest rates fall),

Exhibit 3
Logistic Regression Estimates for FHA Mortgages

	Mortgages for Purchase			Mortgages for Refinance		
	Coeff.	p-Value	Impact (%)	Coeff.	p-Value	Impact (%)
Intercept	0.471	0.03		0.758	0.14	
DISCPOINT	−0.014	0.29	−0.6	−0.140	**	−7.1
DELPRICE	−0.057	**	−3.4	−0.099	**	−6.8
VOLATILITY	4.742	0.01	1.4	4.671	0.35	1.6
LOCKDAYS	−0.017	**	−10.0	−0.016	*	−10.7
QRATIO	−1.109	**	−2.8	0.348	0.36	1.0
SCHOOL	0.068	**	5.8	0.020	0.21	2.1
AGE	−0.004	0.03	−1.4	−0.004	0.36	−1.7
MULTIUNIT	−0.568	**	−20.2	−0.601	0.01	−24.0
RENTAL	−0.299	0.20	−10.4	0.406	0.02	14.7
WOMAN	−0.030	0.50	−1.0	0.062	0.61	2.4
SINGLE	0.043	0.26	1.4	−0.062	0.56	−2.4
SHORTLOCK	0.475	*	26.8	−0.234	0.34	9.98
SHORTRELOCK	0.159	0.32	19.9	−0.281	0.38	8.31
RELOCK1	0.172	*	5.5	0.133	0.24	5.0
RELOCK2	0.447	**	13.6	0.071	0.74	2.7
RELOCK3	0.458	0.01	13.9	−0.012	0.97	−0.5
15-YEAR	−0.385	*	−13.5	0.158	0.12	5.9
ARM	0.092	0.01	3.0	0.199	0.10	7.4
NORTHEAST	−0.138	0.09	−4.7	−0.589	**	−23.5
MIDWEST	0.384	**	11.8	−0.262	0.28	−10.3
WEST	−0.327	**	−11.4	−0.503	**	−20.0
RATE				0.181	0.17	6.8
N	16737			2710		
%Close	65.01			62.92		
Base Probability	66.78			61.68		
Corrsq	3.90			5.21		

* indicates p-value < 0.01; ** indicates p-value < 0.0001

the probability of closing declines by only 3.6%. Rosenblatt and Vanderhoff (1992) found a similar result, although their measured impact was somewhat stronger. Discount points, interest-rate volatility, borrower age, and marital status prove to be statistically insignificant (for *alpha*=0.05). Regional differences in the closing rates are noted with *MIDWEST* applications 8.2% more likely to close, *WEST* applications 9.6% less likely, and *NORTHEAST* applications showing no statistical difference from the baseline *SOUTH*. The only statistically significant covariate to have a sign opposing that hypothesized is the fifteen-year indicator.

The second set of results presented in Exhibit 2 is for conventional applications for refinance. Overall the closing rate is almost 10% lower than for purchase applications. One reason may be that the applicants do not realize how costly refinance is until after applying for the loan, and perhaps find the expected savings are lower than envisioned causing greater sensitivity to the financial variables. Also, refinance applicants are currently using the residence under an existing mortgage and thus will have a more elastic

Exhibit 4
Logistic Regression Estimates for VA Mortgages

	Mortgages for Purchase			Mortgages for Refinance		
	Coeff.	p-Value	Impact (%)	Coeff.	p-Value	Impact (%)
Intercept	−0.204	0.58		0.201	0.83	
DISCPOINT	−0.007	0.76	−0.4	0.009	0.86	0.5
DELPRICE	−0.133	**	−9.7	−0.128	*	−9.2
VOLATILITY	6.956	0.04	2.6	12.975	0.16	4.7
LOCKDAYS	−0.015	**	−10.5	−0.017	0.04	−12.2
QRATIO	−0.915	0.07	−2.8	0.203	0.80	0.6
SCHOOL	0.071	**	7.7	0.021	0.49	2.2
AGE	−0.004	0.18	−1.7	−0.007	0.34	−2.9
MULTIUNIT	−0.136	0.66	−5.6	−0.579	0.43	−24.1
RENTAL	n/a	n/a	n/a	−0.062	0.87	−2.5
WOMAN	−0.362	*	−15.1	−0.267	0.35	−11.0
SINGLE	−0.028	0.72	−1.2	0.367	0.11	14.2
SHORTLOCK	1.080	**	47.5	−0.164	0.70	14.7
SHORTRELOCK	0.226	0.33	25.7	−0.001	1.00	20.5
RELOCK1	0.545	**	20.8	0.170	0.39	6.8
RELOCK2	0.382	0.01	14.9	0.258	0.41	10.1
RELOCK3	0.898	*	32.0	−0.022	0.96	−0.9
15-YEAR	0.257	0.23	10.2	0.412	0.01	15.8
ARM	0.066	0.39	2.7	0.511	0.06	19.3
NORTHEAST	0.186	0.12	7.5	−0.143	0.64	−5.8
MIDWEST	0.488	**	18.8	−0.599	0.10	−24.9
WEST	−0.062	0.39	−2.6	−0.447	*	−18.6
RATE				0.345	0.08	13.4
N	5074			899		
%Close	60.47			64.29		
Base Probability	59.07%			59.54%		
Corrsq	6.86			6.00		

* indicates p-value < 0.01; ** indicates p-value < 0.0001

response to changes in the financial environment. Refinance applications are more sensitive to the number of discount points, and changes in the interest rates than are purchase applications though the impact remains minor. Because current tax law requires refinance points to be deducted over the life of the loan, rather than at loan origination, it is sensible for refinance applicants to be more sensitive to points. Interest-rate volatility shows a modest positive impact which is opposite the hypothesized effect. Refinance applications are also more sensitive to lock days, which remains an important covariate of closing. The indicator variables for a short lock are not significant, showing that there is no additional impact of short locks, beyond the effect captured with the LOCKDAYS variable. Applicant characteristics tend to show the same signs, but with higher impacts than those for purchase. Applicant characteristics such as age, gender and marital status are not statistically important. The first two relocks are no different than the original lock, but a third relock is more likely to close. Fifteen-year applications show no difference, but ARMs are less likely to close. The indicator variable unique to refinance

applications, whether the refinance is interest rate or equity motivated, is statistically insignificant. The regional impacts are similar to those for purchase applications.

Exhibit 3 presents the models for FHA applications. For purchase applications, most of the signs and impacts are the same as for conventional. Some differences are that *WOMAN* and *RENTAL* are not statistically significant. The *SHORTLOCK* indicator variable is significant, but the *SHORTRELOCK* variable is not. Another difference is the effect of relocks on closing rates, which is the opposite of that observed with conventional applications. FHA applications are more likely to close on subsequent relocks, perhaps indicating that delays in processing FHA applications may cause some applications to not close during the initial lock. Fifteen-year applications reveal a higher negative impact, and ARMs show the opposite sign, though with a small impact compared to conventional applications.

The FHA refinance applications show results are also similar to that for conventional refinance. *VOLATILITY* retains a positive sign, but it is not statistically significant. The qualifying ratio is also not important, as may be expected on refinance applications. Results also indicate that ARMs are more likely to close, whereas for conventional refinance there was a measurable negative effect. The overall base closing probability for FHA loans is about 10% lower than for conventional for purchase but only about 2% lower for refinance.

Exhibit 4 shows that for VA purchase applications, discount points do not matter, a reasonable result given than the seller often pays the discount points. These loans show a greater sensitivity to interest-rate changes than do conventional and FHA. *LOCKDAYS* shows a strong effect, and as with FHA mortgages, the *SHORTLOCK* indicator variable is significant while the *SHORTRELOCK* indicator is not. Male applicants are more likely to close and schooling has a somewhat stronger positive effect than with the other loan programs. Even more so than for FHA, subsequent relocks have a statistically higher closing probability than the original lock. Fifteen-year and ARM applications are not statistically different than thirty-year FRMs. There appears to be less of a regional impact for applications than for conventional or FHA applications. Many impact figures are higher than those observed for other loan types.

The model for VA refinance shows few statistically significant effects. One reason may be that the sample size is too small to achieve precise measures of the impacts. Fifteen-year applications also show a higher propensity to close whereas the result was not significant for FHA and conventional refinances. An interesting result is that the base closing probability for VA refinances was about the same as for purchase. The overall base closing probability of VA applications is lower than that for conventional and FHA.

Summary

This study has determined several findings of interest for those devising mortgage pipeline hedging strategies. The overall closing rate for a given lock was about 2/3 with about 80%–90% of applications ultimately closing. The average closing rate, over all locks, ranged from 74% for conventional applications for purchase to 60% for VA applications for purchase. In general, FHA and VA applications are less likely to close than conventional applications, and refinance applications are less likely to close than those for purchase.

The variable that most positively effects closing is a short lock period. This result seems reasonable, given that short locks will only make sense when the applicant is nearly ready to close. Some of the short locks may be for relocks where the application process was not quite complete on the previous lock, which delayed closing into a subsequent lock. Applications for multi-unit properties and for rental properties also showed a strong effect, though in the negative direction.

The next most influential covariate is for interest-rate changes. When interest rates rise, the applicant is more likely to close and vice versa. The strength of this effect is moderate (about a 3%–9% change in closing probability as the price of the reference instrument increases by one standard deviation). If applicants ruthlessly pursued their close/fall-out option, a much greater effect would be observed, and a much bigger risk would ensue for the mortgage originator. The remaining covariates tend to have minor effects, or effects that vary by loan program.

Note

[1] The mortgage originator regularly contacts applicants and thus can rapidly determine when the applicant withdraws his or her application.

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