J
H
R

An Empirical Analysis of Residential Mortgage Refinancing Decision-Making

Swati Virmani and Austin Murphy***

Abstract

This research empirically investigates the relative optimality of several different methods of making refinancing decisions on residential mortgages. The results indicate that a simple rule of refinancing whenever the mortgage rate has dropped 1% was approximately as effective as application of an option pricing model in minimizing the cost of financing over the 1980–2007 interval.

The refinancing decision for residential mortgages is a very important subject of investigation, especially because of the multi-trillion dollar size of the market. However, with the exception of Chen and Ling (1989), who incorporated into the modeling analysis the effect of interest rate volatility on the value of homeowners' prepayment rights, researchers' typical approach to the task does not employ option valuation models (Fortin, Michelson, Stanley, and Weaver, 2007). Most academic investigations of normative mortgage refinancing decision-making tend to focus on simple Net Present Value (NPV) analysis of fixed contractual cash flows (Hoover, 2003), which ignores the option value of the prepayment rights of those assets.

Some simple rules of thumb have also been suggested, such as refinancing whenever mortgage rates have dropped 2% (Noyan and Eugene, 1993) or 1% (Bennett, Keane and Mosser, 1999) from an existing mortgage coupon. The 2% rule was prevalent in the 1980s (Moving.com, 2008) when interest rates were much higher.[1]

Option valuation models have long been utilized successfully to value callable debts and analyze prepayment decisions thereon (e.g., Kalotay, 1979; and Murphy, 1988), and they are also widely used by investors to value prepayable residential mortgages (Murphy, 2000a). However, their use by homeowners in making refinancing decisions may not be widespread, and, partially as a result, financial modelers make assumptions about suboptimal refinancings when valuing pools of residential mortgages, such as assuming that the majority of homeowners wait longer to prepay on their mortgages than would appear to be optimal given ex ante information (Murphy, 1991).[2]

Chen and Ling (1989) have shown the theoretical advantages of using such a framework in comparison to simple NVP models that implicitly assume non-stochastic interest rates to make residential mortgage refinancing decisions. While Chen and Ling's research clearly indicated that application of an option valuation model to the refinancing decision is superior to that of simple NPV analysis,[3] they did not compare option pricing theoretically or empirically to the simple heuristics widely used in practice. Nevertheless,

S
N

under various assumptions regarding the refinancing costs (4%), the holding period of a mortgage (1–12 years), and the expected drift (−2% to 2%) and volatility of interest rates (5%–15%), the authors did find that mortgage refinancings are optimal when market rates are apparently 1%–4% below the homeowner's existing coupon. When just the midpoint for expected drift (0%) and volatility (10%) of interest rates was assumed, the optimal trigger point ranged between about 175 and 250 basis points, with the latter figure applicable to an expectation that the mortgage would be held for 12 years if it was not refinanced.

The purpose of this article is to empirically evaluate the usefulness of an option pricing model in making prepayment decisions on residential mortgages by comparing its performance to application of simple rules of thumb. Although the usefulness of option theories of mortgage values have long been recognized (Kau and Keenan, 1995), prior research reported in the literature has neglected empirical analysis of their optimality in making prepayment decisions.

The findings of this study indicate that the performance of an option pricing model would have been insignificantly different from that of a simple 1% heuristic over the 1980–2007 interval. However, the option pricing model did perform significantly better than the 2% heuristic that has been used longer by homeowners evaluating refinancing decisions.

Empirical Testing Procedure and Data

An examination of the effectiveness of different refinancing decision tools is initially conducted by simulating the total financing cost to a homeowner from applying each of several criteria. A hold-out sample is used to evaluate the persistence of relative performance.

The option pricing model of refinancing to be used employs a forward iterating technique to determine the optimal refinancing point using option pricing valuation of future prepayment opportunities given the stochasticity of interest rates (Murphy, 1988). The value of a mortgage is computed by subtracting out the present value of prepayment options in future years from the present value of future promised cash flows if it is not called. Refinancing is considered if the present value of an existing mortgage exceeds the principal value by the cost of refinancing. However, for optimal refinancing to take place, that present value must also exceed the present value of a new mortgage at market rates by the cost of refinancing.

For purposes of computing mortgage model values, the yield curve and the implied expected drift in future interest rates are estimated with data obtained from the Federal Reserve website by using the interpolative method explained by Murphy (1991), which is based on standard textbook methods for estimating forward rates from the spot yield curve (Murphy, 2000b). The volatility for Treasury bond futures options estimated at the Chicago Board of Trade's website (www.cbot.com) is input into the model for purposes of incorporating the market estimates of interest rate volatility (Murphy, 1991). The credit rating for the mortgages is assumed to be A2 based on data provided by Murphy (2000b), who tabulated a historical relationship between credit ratings, credit losses, and credit spreads above Treasury yields that compensate for the default and systematic risks of debt investments and that therefore are utilized to determine the required promised yield on debts.

The expected values of the portion of future mortgage prepayments that are uncorrelated with changes in future interest rates and that are therefore modeled as non-stochastic are estimated utilizing Murphy's (1991) model. That framework itself is based on findings by Heuson (1988), who indicated autonomous prepayments caused by such factors as homeowners moving can be estimated with a specific formula. By so incorporating such repayments that are exogenous to refinancing decisions but are not totally independent of the interest rate environment, there is no need to impose an arbitrary or artificial assumption on the expected mortgage holding period.

This overall modeling procedure, when adjusted for slow prepayers, has been found empirically to result in values that are significantly more related to the market prices of mortgage-backed securities than other methods (Murphy, 2000a). The typical alternative mortgage modeling framework assumes prepayments are strictly a function of the relationship between a contractual mortgage rate and future interest rates that are simulated using a particular specified process (Chen and Yang, 1995). The latter option pricing models, which are based on backward iterations, are also less theoretically valid, besides being computational inefficient (Murphy, 1992).

The fees associated with the refinancing of conventional mortgages are generally substantially less than the 4% cost of refinancing FHA mortgages, and so refinancing costs are assumed to be 1.2% as in the previous applications of the Murphy model in pricing residential mortgages. These fees represent costs exclusive of points that represent a trade-off between the coupon rate and the principal discount, which is independent of the decision criteria for refinancing incorporated into the Murphy model.

The total mortgage costs over time associated with the strategy of employing the option pricing model to make prepayment decisions is compared with heuristic rules specified as refinancing whenever mortgage rates drop by a pre-specified amount. Both the 1% and a 2% algorithm will be examined.

For the empirical test, data on mortgage rates for the first Friday of each month are gathered from the Federal Reserve website over the period 1980 through 2007. This sample, which supplies 336 observations, assumes that the homeowner begins with a 12.85% mortgage rate on January 4, 1980.

As shown in Exhibit 1, the market rates average 9.29% over the sample interval, ranging between 5.26% and 18.37% and ending with a rate of 5.96% in December 2007. There was thus a steep downward trend in mortgage rates over the sample interval (of 6.89%), and the change in mortgage rates was positively autocorrelated, with an autocorrelation coefficient of .29. An indication that the decline in interest rates was not fully expected by market participants is provided by the Exhibit 1 data, indicating a yield curve that sloped upward on average (by over 1%), although the yield curve began with apparent expectations of declining interest rates of 1.50%.

Initially the period 1980–1999 will be employed to determine an optimal heuristic rule of thumb to apply with respect to the exact drop in mortgage rates that will optimally trigger a refinancing. Of the three alternative decision-making criteria for refinancing that

Exhibit 1. Summary Statistics for Empirical Sample Tested for Optimality of Refinancing Rules (1980–2007)

	Mean	High	Low	Beginning	Ending
Mortgage Rates[a]	9.29%	18.37%	5.26%	12.85%	5.96%
10-Year Treasury Yield	7.52%	15.68%	3.36%	10.52%	3.97%
LT-ST Treasury Yields[b]	1.12%	3.32%	−3.12%	−1.50%	0.80%

Notes:
[a] Average 30-year fixed-rate conventional mortgage coupon rate reported in an FHLMC survey of rates on mortgages contracted by lenders.
[b] Difference between the yield to maturity on 10-year Treasury notes and the 1-year Treasury obligations that provide an illustration of the slope of the yield curve and hence of the drift in the interest rate process that is assumed: 9.29% over the sample interval, ranging between 5.26% and 18.37% and ending with a rate of 5.96% in December 2007. The change in mortgage rates are positively autocorrelated, with an autocorrelation coefficient of .29.

were being suggested in 1999, the rule that yields the lowest cost of mortgage financing for the period 1980–1999 (inclusive of 1.2% refinancing costs) will then be evaluated for superiority with out-of-sample data covering the interval 2000–2007.

Empirical Results

The results of the initial empirical examination are shown in Exhibit 2. The findings indicate that the optimal rule to have followed from 1980 to 1999 was to refinance whenever mortgage rates had fallen by at least 1% from the homeowner's existing mortgage. In particular, the total cost of mortgage financing with the 2.0% and 1.0% heuristics were 10.64% and 9.72%, respectively, versus 10.05% for the option pricing model.[4]

Exhibit 2. Evaluation of the Effect of Different Refinancing Criteria Over Separate Intervals (1980–1999; 2000–2007)

	Total Mortgage Cost[a]	# of Refinancings	Average Gross Rate Reduction From Each Refinancing
1980–1999			
Option Pricing	10.05%	7	0.86%
1.0% Rule	9.72%	5	1.18%
2.0% Rule	10.64%	3	2.08%
2000–2007			
Option Pricing	6.99%	5	0.50%
1.0% Rule	6.81%	2	1.07%
2.0% Rule	6.97%	1	2.00%

Note:
[a] Using average coupon rate reported in Fed data on contracted mortgages for the first Friday of each month and assuming a fixed 1.2% refinancing fee.

S
N

The results of applying the 1% rule in the out-of-sample period of 2000–2007 indicated persistence in the success of this strategy.[5] In particular, that heuristic was again superior to both the 2% rule and the option pricing model criterion, although the difference between the total costs of using each model was less than 20 basis points.

Since refinancing costs may have been higher early in the sample, additional tests were conducted using refinancing costs of 4% over the 1980–2007 interval. The 4% costs may have also been relevant across the entire sample for mortgages on homes with lower values (given the fixed costs of many mortgage origination fees).[6] As shown in Exhibit 3, the 1% rule remained superior, with average total mortgage costs of 9.37%, 9.78%, and 9.61% for the 1%, 2%, and option pricing criteria, respectively.[7] Exhibit 3 also indicates the superiority of the 1% rule over the entire 1980–2007 interval when assuming the original 1.2% refinancing cost, with total costs of 8.77% compared to 9.48% for the 2% heuristic and 9.00% for the option pricing analysis.[8]

However, a different starting period can affect the performance of any refinancing procedure/rule. For instance, when the starting time period was specified as the first Friday in June 1980, application of the option pricing model led to a cost through December 2007 that was lower for the option pricing model (at 8.97%) compared to the 1% algorithm (that cost 9.01% over that time interval).

In order to enable evaluation of the effect of different starting periods, the relative total cost of home financing associated with each of the different refinancing rules is examined with a series of various beginning dates. In particular, by assuming the initial mortgage is taken out on the first Friday of the last month of each quarter starting with March 1980, the cost through 2007 using each procedure is compared. That comparison continues for each quarter through 1987, resulting in a total of 32 quarterly observations for each decision-making criterion.

The results of these tests are shown in Exhibit 4. The 1% rule remained superior to the 2% heuristic, but it was insignificantly different from the option pricing analysis. In exactly half of the 32 different starting quarters, the 1% rule resulted in lower mortgage costs, but the option pricing analysis was superior in the other half. The difference in performance was less than 0.02%, which was statistically insignificant from zero in

Exhibit 3. Evaluation of the Effect of Different Refinancing Criteria With Different Refinancing Costs (1980–2007)

	Total Mortgage Cost[a]	
1980–2007	1.2% Refinancing Cost	4% Refinancing Cost
Option Pricing	9.00%	9.61%
1.0% Rule	8.77%	9.37%
2.0% Rule	9.48%	9.78%

Note:
[a] Using average coupon rate reported in Fed data on contracted mortgages for the first Friday of each month and a fixed refinancing fee.

S
N

Exhibit 4. Evaluation of Refinancing Criteria Using Different Quarterly Starting Points[a] (1980–1987 until 2007)

	Average	Compare to 1% Rule		Compare to 2% Rule	
	Mortgage Cost[b]	Student *t*	Mann-Whitn. U	Student *t*	Mann-Whitn. U
Option Pricing	8.39%	0.11	532	−3.61*	711*
1.0% Rule	8.37%	—	—	−3.72*	722*
2.0% Rule	8.97%	3.72*	722*	—	—

Notes:
* Significantly different at the .01 level.
[a] Assuming an initial mortgage origination on the first Friday of the third month of the quarter.
[b] Using average coupon rate reported in Fed data on contracted mortgages and a fixed 1.2% refinancing fee.

Student *t*-tests. On the other hand, Mann-Whitney nonparametric U tests and Student *t*-tests indicated that both the 1% rule and the option pricing method significantly outperformed the 2% rule at the .01 level.

The Effect of Data Biases and Sample-Dependent Characteristics

One cause for the recently successful performance of the simple 1% heuristic may be related to a bias in the Federal Reserve's mortgage rate data, which are based on surveys of lenders on contractual coupon rates reported to the Federal Home Loan Mortgage Corporation (FHLMC) that may have average refinancing fees and discount points that vary across time. The bias may exist because the reported contracted coupon rates themselves are affected by the relative number of homeowners who choose to accept higher coupon rates in return for higher cash received as a percentage of principal owed (i.e., for lower origination discount or points and fees). If refinancing mortgagors, who dominate the market in periods of heavy refinancings, prefer less (and perhaps no) points and fees (as may be optimal since they may be more likely to refinance again), the average reported contracted coupon rate during periods of falling interest rates may overstate the true cost relative to an unavailable series of offered mortgage rates actually existing in the market at a fixed amount of fees and points. As a result, when interest rates have fallen recently, the mortgage rate in the reported contractual data may underestimate the actual mortgage coupon rate offered in the market for a given amount of points and fees. This factor leads to the 1% heuristic, indicating a refinancing when the actual offered coupon rate with fixed refinancing fees and points offered in the market has actually fallen significantly more than 1%.

To attempt to partially adjust for the average effect of this bias of unknown magnitude, an analysis of the total cost of applying a heuristic of refinancing when there is a 1.1% drop in reported rates was conducted over the initial testing interval (1980–1999). The results (not shown) indicated that the performance of the heuristic declined materially, with costs rising 36 basis points to 10.08%. Thus, making only a slight adjustment to attempt to mimic a realistic application of the 1% heuristic to the actual coupon rates offered in the market with fixed fees and points over that time interval results in the heuristic having higher costs than the option pricing model (whose costs were 10.05%, as reported in Exhibit 2, and whose refinancing decisions are not affected by the bias).[9]

Moreover, given that mortgage rates were declining through most of the sample, it is not clear whether the 1% heuristic would be as successful as the option pricing model in an another environment, even with biased data. For instance, the same tests in the future may reveal the option pricing model to be superior, since that environment may likely be characterized by choppy or rising interest rates, given how far interest rates have already fallen. Perhaps, most importantly, however, the failure of forward market yields to predict even the direction of future interest rates (as indicated by the past large fall in interest rates having been preceded by forward forecasts of rising rates on average) may not be repeated in the future. With less biased information incorporated into the option pricing model that estimates the drift using such rates, or at least with such information not biased in the same direction, the 1% heuristic might turn out to be far inferior in performance.

In addition, the effect of autocorrelation in mortgage rates could have affected the results. If such autocorrelation is intrinsic to the true distribution of those rates, it might be possible to develop new algorithms or models for refinancing. However, the significant autocorrelation over the 1980–2007 horizon could have been spurious to the sample. Further testing would be required to determine whether adjustments to the prepayment decision should be made for some special distribution of mortgage interest rates that market participants might normally be expected to arbitrage away.

Conclusion

This research shows empirically that application of a simple 1% heuristic would have been at least as effective as an option pricing model in reducing overall costs of residential mortgage financing over the 1980–2007 period. However, the typical procedure advocated in practice through most of the sample was a rule to refinance whenever mortgage rates had dropped 2%, and this algorithm was found to be inferior to both the option pricing method and the 1% rule, which has been proposed more recently.

Although the option pricing model was found to be no better than a 1% heuristic over the 28-year interval investigated, the effectiveness of that simple decision-making rule may have depended on the particular interest rate environment that has persisted over the past few decades. Moreover, there may have been biases in the empirical data based on average coupon rates reported on mortgage contracts. It is left to future research to determine whether the option pricing model performs significantly better in reducing mortgage financing costs in other environments with other data. Such research could also test the usefulness of alternative mortgage pricing models, such as that proposed by Brunson, Kau, and Keenan (2002), who integrate loan defaults with the prepayment decision by including housing prices in the analysis.

Regardless, this study is important for showing that, for those homeowners and advisors to homeowners without option valuation software, the 1% rule seems to be superior to the 2% heuristic, which was long advocated by practitioners. Even for those utilizing option pricing software in their refinancing decisions, the 1% algorithm, or similar heuristics developed from data as exists in Exhibit 2, may be useful as a simple screening tool to indicate the approximate drop in mortgage rates that should prompt an analysis of whether refinancing should occur.[10]

Endnotes

[1] Making mortgage refinancing decisions using a rather subjective payback method is widely suggested today, requiring some subjective evaluation of the number of years it takes for the interest savings from replacing the old mortgage with a new one to offset the points and fees associated with refinancing, as explained at the website Moving.com (2008). This procedure is rather arbitrary and, for a given cost of refinancing, is implicitly incorporated into a heuristic based on the drop in the mortgage rate.

[2] Because empirical data indicate mortgage refinancings tend to prepay most rapidly after an initial drop in interest rates, with prepayments dropping thereafter (Hakim, 1997), modelers have long divided mortgagors into several categories that include those who prepay quickly upon the occurrence of a sufficient drop in interest rates, those who refinance only with a delay, and those who do not ever prepay (Davidson, Herskovitz, and Van Drunen, 1988).

[3] As shown by Chen and Ling (1989), the NPV criteria indicates refinancing is optimal whenever rates fall by various amounts below 0.5%, and the rapid refinancing results in a far higher cost of mortgage financing over time. For instance, a mortgagor with a 7% mortgage would find it optimal using the NPV criteria to refinance when market rates had fallen only 0.375%, and existing market practices would even enable the homeowner to refinance with no costs or fees by taking on a new mortgage with only a 0.125% reduction in the coupon. If rates fell another 0.375%, a further 0.125% would be saved, for a total of 0.125% + 0.125% = 0.25% despite a 0.375% + 0.375% = 0.75% interest rate decline. In contrast, option pricing models might indicate refinancing only after the full 0.75% decline in rates, and so there would be only one refinancing in this scenario, resulting in a 0.5% reduction in the coupon net of 0.25% amortized refinancing costs (that many lenders allow mortgagors to pay in the form of a higher coupon rate than otherwise).

[4] While Fortin, Michelson, Stanley, and Weaver (2007) have suggested that the tax deductibility of interest should also be considered when evaluating mortgage refinancing decisions, assumptions of various tax rates (such as 33%) were found (not shown) to have no impact on the relative optimality of the various decision rules, and so the results are reported without consideration of any tax effects.

[5] Additional tests were also run that evaluated the effectiveness of other heuristics with much lower reductions in interest rates needed to trigger a refinancing, as would be consistent with application of a simple NPV model. The empirical results using these decision criteria in this sample demonstrated empirically (not shown) that employment of such rapid refinancing thresholds were substantially less effective than the option pricing model, as well as with both the 1% and 2% heuristics.

[6] Since many homeowners with lower housing values take out FHA mortgages, an analysis was conducted using FHA mortgage rates and their 4% cost of refinancing over the interval 1980–1999 for which data are available. The results (not shown) indicated the same relative ranking of the different criteria, with the 1%, 2%, and option pricing rules resulting in costs of 10.21%, 10.59%, and 10.51%, respectively.

[7] A reduction in refinancing costs over time would be expected to make the 2% heuristic less applicable than before, thereby providing part of the motivation for the later development of the 1% heuristic. The results reported for 4% refinancing costs, indicating

a lower difference in costs between the 1% and 2% heuristic, seems to be consistent with this hypothesis.

[8] The performance of the option pricing model was actually slightly improved when refinancing was assumed to occur anytime the present value of the old prepayable mortgage exceeded the present value of a mortgage at current market rates by more than the refinancing costs (instead of also requiring the old prepayable mortgage to exceed the principal value by the refinancing costs). However, the reduction in costs was only 6 basis points to 8.94% (with 5 additional refinancings for a total of 14 over the 1980–2007 interval).

[9] In addition, it should also be mentioned that, because the average reported coupon rate used for the empirical examination may have been relatively higher than the actual rate at which homeowners could truly refinance with the assumed fixed refinancing costs, the results reported here for the option pricing model (which uses actual market interest rates to make prepayment decisions) may overestimate the total costs using that evaluation procedure. Moreover, since individual borrowers, who are more aggressive in evaluating refinancing decisions, are more likely to have access to even lower mortgage rates than the reported averages, there may be yet another bias in the reported results that makes the 1% heuristic seem relatively better than it is in actual practice.

[10] The reduction in the interest rate drop necessary to prompt a refinancing to about 0.5% for the 2000–2007 interval implies that a 0.5% heuristic might be optimal in the future as a screening device.

References

Bennett, P., F. Keane, and P. Mosser. Mortgage Refinancing and the Concentration of Mortgage Coupons. *Current Issues in Economics and Finance*, Federal Reserve Bank of New York, 1999, 5.

Brunson, A., J. Kau, and D. Keenan. A Fixed-Rate Mortgage Valuation Model in Three State Variables. *Journal of Fixed Income*, 2002, 11, 17–27.

Chen A. and D. Ling. Optimal Mortgage Refinancing with Stochastic Interest Rates. *Journal of the American Real Estate and Urban Economics Association*, 1989, 17, 278–99.

Chen R. and T. Yang. The Relevance of Interest Rate Processes in Pricing Mortgage-Backed Securities. *Journal of Housing Research*, 1996, 6, 315–32.

Davidson, A., M. Herskovitz, and L. Van Drunen. The Refinancing Threshold Refinancing Model: An Economic Approach to Valuing MBS. *Journal of Real Estate Finance & Economics*, 1988, 1, 117–30.

Fortin, R., S. Michelson, S.D. Stanley, and W. Weaver. Mortgage Refinancing: The Interaction of Break Even Period, Taxes, NPV and IRR. *Financial Services Review*, 2007, 16, 197–209.

Hakim, S. Autonomous and Financial Mortgage Prepayment. *Journal of Real Estate Research,* 1997, 13:1, 1–16.

Heuson, A. Mortgage Termination and Pool Characteristics: Some Additional Evidence. *Journal of Financial Research*, 1988, 11, 143–52.

Hoover, G. The Mortgage Refinancing Decision: An Equation Based Model. *Financial Services Review*, 2003, 12, 319–37.

Kalotay, A. Optimal Bond Calling and Refunding. *Interfaces,* 1979, 9, 36–49.

Kau, J. and D. Keenan An Overview of the Option-Theoretic Pricing of Mortgages. *Journal of Housing Research*, 1995, 6, 217–44.

Moving.com. Refinancing: Making the Right Choices. 2008. www.homefair.com/articles/finance/refinancing-choices.asp?cc=1.

Murphy, A. A Discounted Cash-Flow Model of Fixed-Income Securities Subject to Multiple Calls. *Southern Economic Journal*, 1988, 55, 21–36.

——. An Empirical Test of an Option Pricing Model of Mortgage-Backed Securities Pricing. *Journal of Economics and Business*, 1991, 43, 37–48.

——. Research Solutions to the Financial Problems of Depository Institutions. Quorum: Westport, 1992.

——. A Comparative Analysis of the Price-Process Model of Mortgage Valuation. *Review of Financial Economics*, 2000a, 9, 65–82.

——. A. Murphy. *Scientific Investment Analysis*. Quorum: Westport, 2000b.

Noyan, A. and P. Eugene. Revisiting the Economics of Mortgage Refinancing. *Journal of Retail Banking*, 1993, 15, 45–8.

The very useful comments of the reviewer at the Journal of Housing Research are gratefully acknowledged.

Swati Virmani, University of Manchester, Manchester M13 9PL or swati.virmani@postgrad.manchester.ac.uk.

Austin Murphy, Oakland University, Rochester, MI 48309-4493 or amurphy09@comcast.net.