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My Perspective

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Is There a Financial Engineer in the House?

By Andrew Kalotay, Ph.D.

When I turned on National Public Radio recently, I was pleasantly surprised to hear my good friend Emanuel Derman being interviewed about his book *My Life as a Quant*. (Readers of *Financial Engineering News* are no doubt familiar with both the author and the book.) The interview was moving along apace as Emanuel described with his customary eloquence the virtues of financial engineering. But suddenly the reporter tossed him a question that seemed to catch him off-guard: "What about the average investor? Is there a way for us to penetrate these complex calculations and use financial engineering?" Emanuel responded that financial engineering was only for institutional players, investment banks and hedge funds and did not really have a role for the average investor. (This is loosely paraphrased; listen to the interview at http://marketplace.publicradio.org/shows/2005/05/25/AM200505252.html.) The answer appeared to disappoint the reporter and the interview ended there.

On the face of it, one can scarcely quibble with Emanuel's answer. Most of us would be hard-pressed to come up with even a single instance of financial engineering applied to Joe Public's financial decisions. As Emanuel indicated, it is strictly an institutional discipline. Yet, as we shall see, the basic financial engineering tools are applicable to some of the most important problems that confront individual consumers. Did you know that millions of us routinely trade embedded options without realizing it? But let's not get ahead of our story.

Assuming that the man in the street could use the help of an FE, the dilemma is that the stakes are too small to hire one on an individual basis. But if, somehow, simple-to-use calculators with financial engineering tools under the hood were made available to the general public, the benefits on a national scale could be staggering.

Let's begin with a common problem facing older investors, for example. How much can a retiree spend annually to maximize his quality of life without exhausting his assets in his lifetime? A couple of years ago, I heard Phil Cooley of Trinity College discuss this problem. The answer obviously depends on the age and health of the individual. According to Phil, in the case of a 65-year-old in

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reasonably good health, financial advisors typically recommend spending 4.5 percent annually, or $22,500 per year for a person with assets of $500,000.

Underlying this recommendation is the ultra-conservative assumption that the assets should consist entirely of risk-free interest-bearing investments. But what if the return could be increased by diversification of the portfolio to include some risk commensurate with the expected longevity of the retiree? According to Phil's study – supported by extensive historical back testing – with proper diversification, the same retiree could comfortably spend as much as seven percent of his assets, or $35,000 per year in the example.

Think of the ramifications of this finding. Not only could it significantly improve the quality of life of millions of individual retirees, but in terms of its impact on the national economy, if the annual disposable income of 10 million households increased by $10,000, the aggregate would be $100 billion!

Perhaps this plain-vanilla portfolio optimization problem lacks the pizzazz of the typical financial engineering milieu, such as option valuation using volatility skew. In that case, let's look at residential mortgages, which provide all the challenges that a financial engineer could ever ask for.

The Most Important Financial Decision of Your Life

Roughly two-thirds of the people in the U.S. live the proverbial American dream, i.e., they own their homes. If you are one of them, you will likely agree that buying a home was one of the most important financial decisions you have ever made. And unless you were sitting on a large pile of cash at the time, you probably took out a mortgage to finance the purchase.

Having somehow chosen from among the plethora of home loan products, you were then faced with the ongoing question of when to refinance. As we will see, selecting and "managing" mortgages are among the most complex financial problems homebuyers ever face. Yet this complexity is lost on the average consumer and little help in making informed decisions can be had from the professionals he or she may work with. How many mortgage brokers, for instance, realize that refinancing a mortgage entails the swapping of embedded options?

Does it Pay to Pay Points?

Let us begin with the problem of selecting the right mortgage. Several factors affect the decision, prime among them, the anticipated length of stay in the house. For someone whose borrowing horizon is only 10 years, the rate of a 30-year mortgage will be unacceptably high.

To keep things simple, let's assume you intend to stay in your home for long enough that a 30-year mortgage makes sense. Lenders will offer you a flat rate with no points, or a range of lower rates corresponding to the magnitude of the upfront points you are willing to pay.

Table 1 below shows typical alternatives along with their APRs (annual percentage rate or internal rate of return) – a required disclosure by lenders for all consumer loans, including mortgages. Which package would you choose? Most mortgage brokers would recommend the mortgage with the lowest APR, in this case the 5 1/4 percent mortgage with 2 1/2 points paid upfront.

Table 1. Selected 30-Year Mortgages

Mortgage	*Points (%)*	*Annual rate (%)*	*APR (%)*
A	0	6.000	6.047
B	0.75	5.500	5.614
C	2.50	5.250	**5.524**

The problem with basing the decision on the APR is that it disregards the borrower's refinancing option (basically a call option, in fixed income terminology) – a standard feature of most U.S. residential mortgages. Even though the nominal term of a mortgage is 30 years, if rates decline the actual term will be much shorter. In that event the mortgage with no points could possibly be the best choice since there may not be enough time to the next refinancing to recover the cost of the upfront points in the alternative offerings.

Given the uncertainty of future interest rates, a financial engineer will recognize that we need to incorporate into the decision the value of the refinancing option that the borrower receives in addition to the cash. Those familiar with fixed income recognize that in order to quantify the value of a call/refinancing option, we need to describe in stochastic terms the evolution of the borrower's optionless yield curve. Unfortunately, an optionless mortgage yield curve cannot be directly observed.

Fortunately, there is a standard solution of dealing with the lack of a borrower-specific yield curve. Bond professionals know this as the "OAS" (Option Adjusted Spread) approach. After all, structurally, a mortgage is simply a callable amortizing bond. The standard inputs required to determine the OAS of a bond are a stochastic interest rate model of the Treasury curve or the swap curve. The volatility can be inferred from the matrix of at-the-money European swaption volatilities; the stickler may also apply a skew adjustment.

This sounds extremely complicated, but swaption traders do this all day. With these inputs, we can determine the OAS of a mortgage so that its value will be fair to the borrower. Among mortgages of similar risk (as measured by effective duration), the borrower should prefer the one with the lowest OAS, i.e., the one with the lowest effective borrowing cost.

Of course for the average consumer, readers of this publication excepted, OAS is far too technical a concept to be meaningful in decision-making. But we can repackage the result using familiar terminology. We can determine the value of the refinancing option using the OAS, and then compute an APR based on the combination of the cash received and the option value. The results are displayed in Table 2 below. On an option-adjusted basis, the right

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Table 2. Option-Adjusted Comparison Mortgages
(16% volatility, OAS 76.6 bps)

Mortgage	Nominal Rate (Points) (%)	Traditional APR(%)	OAS (bps)	Option Value (% of par)	Option-Adjusted APR (%)
A	6.00 (0.00)	6.047	76.6	9.113	5.247
B	5.50 (0.75)	5.614	**40.5**	5.829	**5.100**
C	5.25 (2.50)	**5.524**	49.6	4.558	5.113

choice is Mortgage B. Remarkably, on an option-adjusted basis, the costs of the mortgages are quite similar.

A further consideration is the effect of taxes. Obviously, taxes play a major role in the decisions of corporations. Consumers should be no less savvy. In the case of mortgages, interest payments and upfront points are tax-deductible, but the miscellaneous closing costs are not. Under the framework described above, we can easily compute the taxable equivalent option-adjusted APR.

An Efficient Frontier of Mortgage Portfolios?

Our focus so far has been on quantifying the cost of mortgages. But there is also a risk-dimension, and it depends on the perspective of the borrower. How would you quantify the risk of a mortgage? A reasonable choice is its effective duration: the longer the duration, the lower the risk. Accordingly, fixed rate long-term mortgages are the least risky, ARMs with annual reset are the most risky, and the various so-called hybrids are somewhere between.

A fascinating trend in the mortgage scene is portfolio-based borrowing. A borrower can obtain, under a single contract, a $200,000 fixed rate mortgage and a $100,000 ARM with an annual reset, and a $50,000 10-year interest-only loan. Here is a challenge for a budding financial engineer: determine the option-adjusted efficient frontier of mortgage portfolios, possibly on an after-tax basis!

The Refinancing Decision

When rates decline, a homeowner can replace his fixed-rate mortgage with a new one at a lower rate. The only deterrent to refinancing is closing costs; common sense tells us that the greater this cost the longer we should wait before "pulling the trigger."

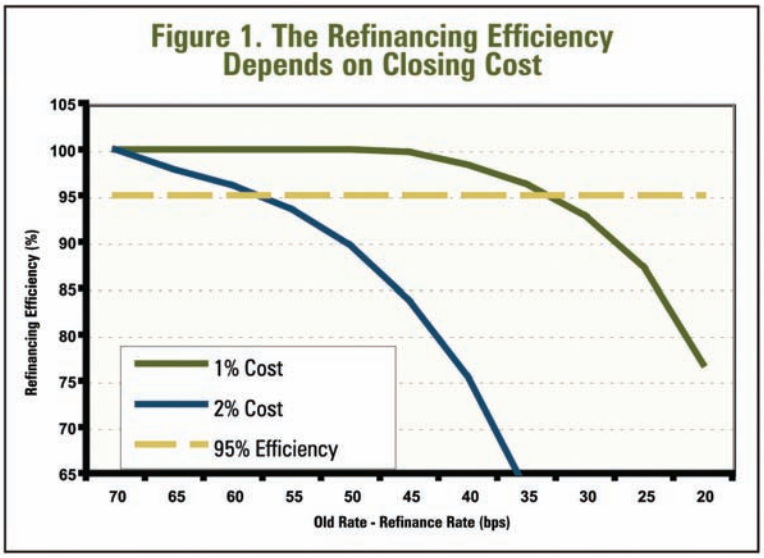
We can employ the artillery of mortgage valuation tools discussed above to determine when to refinance. The decision should be based on the cashflow savings (expressed in PV terms), the forfeited option value of the outstanding mortgage, and the option embedded in the new mortgage. The savings and option values should be adjusted for prevailing and potential transaction costs. These quantities can be combined to define the so-called refinancing efficiency

$$\text{Efficiency} = \text{Cashflow Savings}/\text{Change in Option Value}$$

A rational borrower will refinance whenever efficiency reaches 100 percent (its maximum attainable value). One who is risk-averse may decide to do so slightly below 100 percent. Figure 1 below shows how the refinancing rate affects the efficiency assuming two different levels of refinancing costs. The outstanding mortgage has a rate of six percent. Evidently, at one percent transaction cost the 100 percent efficiency is reached at roughly 50 bps savings, while at two percent refinancing costs, the new loan rate must be about 70 bps.

Applying the discipline of financial engineering to help consumers make financial decisions with sophistication and accuracy is a challenging task. Calculators at http://analytics.kalotay.com/mortgage selector and http://analytics.kalotay.com/refival show how this can be done.

Figure 1. The Refinancing Efficiency Depends on Closing Cost



Conclusion

Financial engineering is at present strictly the province of financial institutions. Investment banks and hedge funds, for example, employ large numbers of professionals in this discipline to assist with transactions whose size is in the millions of dollars.

Yet the tools of financial engineering are also applicable to seemingly mundane problems that confront retail customers. Even though the size of an individual transaction may be modest, on an aggregate level the stakes can be very high and ultimately have significantly positive effects on the economy.

The challenges of selecting and managing mortgages, discussed in this article, should be a convincing case in point. The required analytical tools include a combination of option valuation, option adjusted spreads and possibly after-tax cash flow analysis. As the prototype calculators referred to above will show, these components can be combined in a user-friendly package and widely disseminated on the Web to tens of millions of potential users. Let every pursuer of the American dream have a financial engineer in the house. ■