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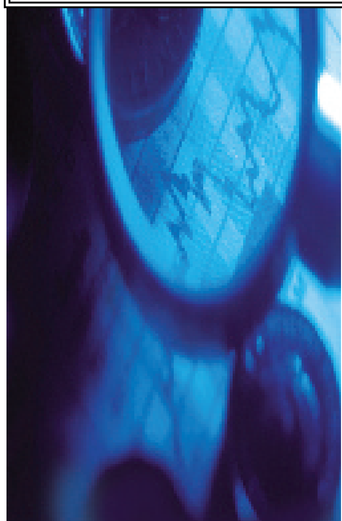
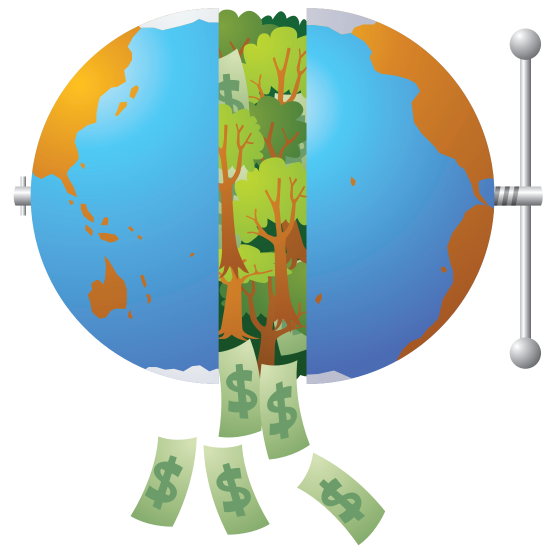


Topics in Fixed Income

Andrew Kalotay

When It's Time to Get off the Tree



In the early 1970's Phil Babcock, the treasurer of New Jersey Bell, took a lot of ribbing from his counterparts at the other Bell companies. On his books, sticking out like a sore thumb, was the highest-coupon callable bond issue in the Bell System – the $100 million 9.35's of 2010. These bonds were brought to market in June 1970, just as interest rates had hit a post-war high (Figure 1). Phil took the ribbing in good humor. After all, everyone knew that they could easily have been in his shoes.

The 9.35's first became callable in 1975. By the summer of 1976 rates had declined enough that these bonds could be profitably called and refunded, notwithstanding the 108.01 call price. Senior management of New Jersey Bell convened to decide how to proceed, and at Phil's invitation I sat in as a technical advisor from AT&T.

The meeting at New Jersey Bell's downtown Newark headquarters was memorable. It began with a lively discussion of the logistics of bond calling. Various parties opined about details of obtaining regulatory approval, issuing the refunding bonds, notifying investors, contacting the press and so on. But eventually the executives had to confront the only question that really mattered: call or wait?

The stakes were high, and so were the risks. If rates continued to decline after the call, you'd look foolish for not having waited. On the other hand, if you waited and rates popped up, you'd look irresponsible for not having taken the bird in hand.

The savings from calling were more than 100 basis points of annual interest – the threshold for acting, according to a venerable rule of thumb – but less than 125 basis points, which would have been the optimal level to call (more about this later). Noting the indecision around the table, I offered what I thought was a reasonable compromise: "Why not call half the issue?"

A stunned silence followed. Apparently no one had even remotely considered this alternative. Finally the VP of the State Regulatory group broke the silence and declared emphatically, "It can't be done."

"But the indenture specifically allows for a partial call," I protested.

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"This is not about the indenture," he responded with a look of exaggerated patience, as if explaining things to a child. "I can tell the regulators why we want to call, and they will approve our decision. I can also tell them why we don't want to call, and they will approve. But if I tell them we want to call half the issue, they would look at me and say, 'You folks at New Jersey Bell sure don't know what you're doing, do you?'"

This was my introduction to being a quant in the real world. And it serves to bring us to the broad theme of this article: how options are exercised in practice.

My biggest challenge was to persuade senior managers to trust our analytical model.

Figure 1. Rates on New Long-Term Aaa Public Utility Bonds 1969-1977

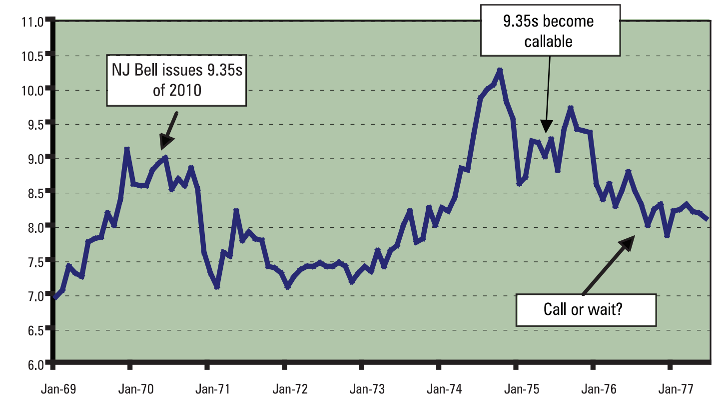
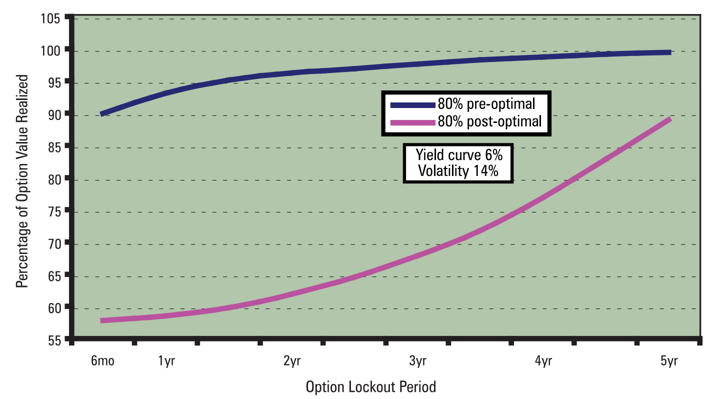


Figure 2. Suboptimal Option Exercise on 6.50% 10-yr Callable Bond



Optimal Option Exercise

It so happened that I had spent the previous year working on the problem of how to call bonds optimally. A review of the literature revealed virtually nothing relevant. This was not particularly surprising against the backdrop of the broadly upward trend of rates since World War II. Black-Scholes was in its infancy, and in any case it was applicable only to non-dividend-paying stocks. Under that model, call options should be exercised only at expiration.

The legendary Ed Thorpe, with whom I had the good fortune to discuss this in 1975, confirmed that there was nothing helpful in literature. "It sounds like a great problem," he said. Buoyed by this encouragement, Bill Boyce, a mathematician at Bell Labs, and I decided to tackle the problem.

The gist of our approach was to assume that interest rates follow a lognormal random walk, represent this process as a binomial tree, and recursively determine the optimum stopping points. To make things more realistic we also included transaction costs and corporate income taxes (see "Optimum Bond Calling and Refunding," *Interfaces*, November 1979).

Our analysis indicated that the optimal time to call a long-term Bell bond is when rates have declined roughly 125 bps below the coupon. This was a bit more aggressive than, but still fairly

close to, the prevailing "100 bps rule," whose origins are lost in the fog of decades-old tradition. My biggest challenge was to persuade senior managers to trust our analytical model. These were people who for the most part were blissfully unencumbered by financial theory, preferring instead to rely on rules of thumb and "common sense." Establishing that the "100 bps rule" was reasonably close to being optimal went a long way towards making our approach acceptable (see "The Sure Thing," *OR/MS Today*, April 1993).

Pre-Optimal and Post-Optimal Policies

This brings me to the main focus of this article: suboptimal option exercise. Textbooks tend to treat option exercise in a somewhat cavalier way. For example, members of the efficient market school simply recommend that the option be exercised when the market price of the underlying asset equals the strike. But what if the asset is illiquid (most bonds trade by appointment) or simply does not trade (such as a residential mortgage)?

Of course, in the case of a European-style option the decision is simple, because it can be exercised only once. American- or Bermudan-style options are a more complicated matter. For these, the textbook approach is to build a tree of the prices of the underlying asset, and exercising the option at nodes where it is worth more dead than alive. By following this optimal policy, the value of the option is maximized.

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But what if one is not comfortable with this tree-based approach? Let's face it – most corporate and municipal treasurers are not. Some may want to take the money and run, while others hold out for a home run. By deviating from the "optimal" policy they leave some money on the table. The question is how much?

As an aside, the recent housing finance literature is replete with references to the enormous amount of money wasted by homeowners through not refinancing optimally. But in order to quantify the amount, first one needs to specify what is optimal. Curiously, there is not a single paper in housing finance that provides a workable definition of optimal refinancing.

Under the optimal policy the option should be exercised when the value of waiting is less than the exercise value. What would be a constructive definition of a suboptimal policy? The reader may want to give this some thought before proceeding.

Observe, first, that there are two distinct ways of deviating from optimal: exercising early (i.e., extracting less than the full value of the option) and exercising late (more precisely, waiting when the full value of the option could have been realized). We will refer to the former as a "pre-optimal" or "leaper" behavior and to the latter as a "post-optimal" or "laggard" behavior. One could perhaps characterize a pre-optimal policy as risk-averse and a post-optimal one as risk-preferring.

For the sake of simplicity, assume that the option can be exercised only annually. Denote by E today's exercise value, and by W the value of waiting. Finally, let f be a fraction between 0 and 1. Table 1 provides a rigorous definition of f-pre-optimal and f-post-optimal policies.

Table 1. Suboptimal Option Exercise

Policy	Exercise Rule
f-pre-optimal	whenever $E > f \bullet W$
f-post-optimal	whenever $f \bullet E > W$
E=exercise value, W=value of waiting, $0 < f < 1$	

According to a pre-optimal policy, the option is exercised whenever the exercise value is a sufficiently high fraction (f) of the value of waiting. In a post-optimal policy, the option is exercised only if the resulting value is sufficiently higher than the value of waiting. In other words, the option is not exercised unless it is expected to decay at a sufficiently high rate.

Of course, there are other reasonable ways of describing suboptimal policies. For example, one can use a volatility different from the "correct" one – a lower one for pre-optimal, and a higher one for post-optimal.

Suboptimal May Not Be Bad

Let's consider some examples using the definitions in Table 1. In Figure 2, we show how suboptimal policies affect realized option value for 6.50 percent 10-year callable bonds. A flat yield curve of six percent and a volatility of 14 percent are assumed. Observe that leapers are much less wasteful than laggards. For example, given a short time to exercise (lockout), an 80 percent leaper captures a defensible 90 percent of option value, while an 80 percent laggard realizes less than 60 percent of the same.

A second effect is that as lockout lengthens, the results of suboptimal behavior are substantially closer to those of optimal behavior. For example, if the lockout is five years, 80 percent leapers capture almost 100 percent and 80 percent laggards capture roughly 80 percent of option value. I encourage you to try to explain these results.

... managers can minimize the potential damage from suboptimal exercise by structuring call options with longer lockout periods or by restricting themselves to European-style options.

In Conclusion

We have shown that a reasonable pre-optimal policy may not result in much waste, particularly if there is a fairly long lockout. On the other hand, a post-optimal policy is likely to leave a lot of option value on the table. The effects of suboptimal behavior can be mitigated by extending the lockout or by acquiring European-style options, whose optimal exercise is automatic.

Since the capital markets provide various ways to monetize the option synthetically, financial managers should not exercise it unless they extract at least 90 percent of its theoretical value (see "How to Succeed in Derivatives Without Really Buying," *Journal of Applied Corporate Finance*, Fall 1993). In addition, managers can minimize the potential damage from suboptimal exercise by structuring call options with longer lockout periods or by restricting themselves to European-style options.

Recent financial engineering graduates, no doubt schooled by seasoned academics, have a tendency to be highly critical of decisions that deviate from what they consider to be mathematically optimal. But, as we have demonstrated, descending from the tree can be an enlightening experience. ■

About the Author

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