Book Review

Lenos Trigeorgis, *Real Options: Management Flexibility and Strategy in Resource Allocation,* MIT Press, Cambridge, Mass., 1996.

A book nearly three years old and now in its third edition would seem an odd choice to review in this journal, particularly since it does not appear to be relevant to the telecommunications industry. It is exactly for this reason that we are reviewing *Real Options* by Lenos Trigeorgis first published in 1996 -- it would not be generally recognized as applicable to the telecommunications industry. However, real options theory and methods have profound implications for the telecommunications industry and, indeed, for the development of economic theory.

With this review we hope to convey how real options theory can be useful for the telecommunications industry in a wide variety of applications including capital budgeting, strategic planning, and the current cost modelling efforts being undertaken by the industry.

Business is beginning to recognize the value of real options analysis as demonstrated by recent articles in the *Harvard Business Review* (Dixit and Pindyck, 1995; Luehrman, 1998a,b). Moreover, the non-telephone utility industry and many other industries facing decisions on R&D spending, project/asset evaluation, mergers, acquisitions and other investments have utilized real options valuation for years.

We first explain what real options are, give a flavor of the methodology, review the book itself, and then indicate what we can gain from the book.

WHAT ARE REAL OPTIONS?

The traditional approach to project evaluation and investments uses discounted present value (DPV) or discounted cash flow (DCF) methods. These methods explicitly assume the project will meet the expected cash flow with no intervention by management in the process. All the uncertainty is handled in the (risk-adjusted) discount rate. It is static. At most, the expected value of the cash flow is incorporated into the analysis. Management's flexibility to make decisions as states of nature are revealed is assumed away by this methodology. However, management discretion has value, which is not incorporated into the DPV. The real options methodology goes beyond this naïve view of valuation and more closely matches the manner in which firms operate. It allows for the flexibility the firm has to abandon, contract, expand or otherwise modify its actions after nature has revealed itself. This is the first lesson for the policymakers – if they wish to emulate the competitive process, they cannot rely on application of naïve DCF methods in cost models.

Decision-tree analysis (DTA) moves the analysis one step forward by allowing that decisions can be made after information has been received. But, as in the case of DCF, the appropriate risk-adjusted discount rate is virtually indeterminate.[1] Using the firm's

[1] While it is possible to determine the risk-adjusted discount rate, it involves certainty equivalent or risk neutral probabilities, which are not easy to calculate. Moreover, real options methodology remedies this problem. See Trigeorgis, pp. 58 - 68.

opportunity cost of capital is inappropriate if the project does not correlate with the company's cost of capital -- another lesson for the telecommunications industry. Unbundled network elements have different levels of risk. For example, the operator services element's risk/return is much different from the local loop element. To calculate the cost/price of these elements using the same discount rate would be incorrect.

The second insight of the theory is recognition that well-developed financial/portfolio theory applies to asset/project evaluation. This allows for the integration of capital budgeting issues with physical, i.e., 'real', assets on the one hand; and the incorporation of decision-tree analysis on the other. A portfolio of securities is created which is (perfectly) correlated with the investment. The portfolio's price and return are known. Rather than considering the expected value of outcomes, it incorporates the probability density function within the analysis. Determination of a risk-adjusted discount rate is not necessary. While uncertainty is not eliminated, it is accounted for in the density function and the twin portfolio. The construction of an equivalent portfolio to the asset in question can be evaluated with the techniques that have been developed for financial options, for example the Black-Scholes methods of option valuation (Black and Scholes, 1973. See Hull, 1997 for a complete description of options methods).[2]

REAL OPTIONS

Trigeorgis' book is a compilation and integration of the literature on real options research -- he is a major contributor to this literature -- into a coherent whole that allows the reader to begin to understand the significance of the theory and its practical applications. While the theory is complex in its mathematics (I am sure the early users of DPV analysis had the same thoughts, of course; financial calculators, let alone computers were not available to them!), the effort to master the book is worth it.

The book has twelve chapters. The first gives an overview of real options as a means of capturing the flexibility of management to address uncertainties as they are revealed. He notes the failure of capital budgeting to account for this flexibility and, moreover, its failure to integrate with strategic planning. The flexibility that management has includes: Defer, abandon, shutdown and restart, expand, contract, and switch use. This chapter reviews the historical development of the theory.

For those familiar with capital budgeting Chapter 2 can be skipped. The chapter reviews the capital asset pricing model (CAPM) and its limitations, as well as many of the traditional approaches to dealing with uncertainty such as simulations, decision-tree analysis and sensitivity analysis.

The next chapter is a review of options theory. The key valuation concept, i.e., that an option can be priced based on the construction of a portfolio of a specific number of shares of an underlying asset, and that one can borrow against the shares at a riskless

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[2] A financial option is the right to buy (a call) or sell (a put) a stock, but not the obligation, at a given price within a certain period of time. If the option is not exercised, the only loss is the price of the option, but the upside potential is large. The asymmetry of the option – the protection from the downside risk with the possibility of a large upside gain – is what gives the option value. (A European option can only be exercised on a specific date, while an American option can be exercised any time before the expiration date).

rate to replicate the return of the option in a risk neutral world, is presented and developed here.

While both these chapters can be skipped for those familiar with capital budgeting (Chapter 2) and options theory (Chapter 3), they are a useful review to those who have been away from the material for awhile. In addition to serving as a review, they allow the reader to become familiar with the notion used throughout the rest of the text.

Chapter 4 develops the framework for what follows. It begins by exploring the analogy between financial options and real options, and refers to the analogy's limitations. Trigeorgis notes how the options theory is able to overcome the deficiencies of the traditional present value technique through an understanding of the interactions, interdependencies, and competitive interactions among projects. The application of real options to this taxonomy is addressed in later chapters.

Chapters 5 and 6 begin the meat of the analysis. They develop the framework for the application of real options to investment opportunities. Chapter 5 is concerned with discrete (binomial) events whereas Chapter 6 is concerned with continuous distributions.

Chapter 5 ties the theory to decision-tree analysis, but more importantly, it shows the failure of DTA. Contingent claims analysis can correct the DTA by providing the proper risk-neutral probabilities to the analysis. The intuition is simple, but profound -- management's decisions skew the distribution of possible outcomes toward the upside. Trigeorgis then shows how real options methodologies can take the best features of DCF and DTA without their failings. The use of real options as applied to a variety of cases is discussed in the earlier chapters. In addition, this chapter introduces cases of competitive interactions and interdependent projects. A simple linear addition to the valuation of a traditional discounted cash flow analysis cannot correct for the real options impact. This method can make a significant difference in the valuation. It expands the notion of manager's flexibility and strategic interaction in skewing the results of the traditional DPV analysis which, as with financial options, allows for gains on the upside, and minimizes the downside potential; thus increasing the valuation. Strategic considerations are magnified or made explicit by the analysis. Viewed in light of traditional economic theory, *Real Options* suggests that the traditional theory needs re-evaluation.

> No ad hoc, exogenously provided, single risk-adjusted discount rate properly captures the interdependencies between current and future decisions in the presence of managerial flexibility, since risk changes endogenously in time, with the underlying uncertain variable, and with managerial response. Since the value of a flexible project and the optimal operating (exercise) schedule must generally be determined concurrently, the discount rate must, in effect, be imputed *endogenously* within a forward-looking dynamic programming process.
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> An option-based (expanded-NPV) analysis bypasses the discount-rate problem by relying on the notion of a comparable security to properly price risk while still being able to capture the dynamic interdependencies between cash flows and future optional decisions (p.200).

A review of continuous values real options literature is the foundation for Chapter 6. The deficiency in this literature prepares the transition to the next chapter, which deals

with the complex interactions of the business world. In this and other chapters, Trigeorgis does not simply summarize the material, but clearly lays out the tools needed to continue the work.

Chapters 8 and 9 deal with the implications of real options for strategic planning, one of the major uses of the theory. Chapter 8 focuses on the integration of strategic planning, capital budgeting, and control. It sets the framework, which is further developed, in the next chapter.

Competitive interaction valuations are dealt with in Chapter 9 – both exogenous entry and endogenous reactions. Trigeorgis shows how real options theory can be applied in a game-theoretic context and the difference it can make to a firm's strategy.

Chapter 10 reviews numeric methods to solve real options problems, which have no closed-form analytical solutions – of which there are many. Generally speaking the American-type options create the difficulties, since early exercise of the options is possible.

Applications are addressed in Chapter 11. Although real options theory is increasingly used in industry, it has not been applied in the telecommunications industry.[3] But, as will be argued below, telecommunications is ripe for this methodology.

Chapter 12 summarizes the major results and points the direction for future research.

RELEVANCE TO TELECOMMUNICATIONS

The book and related literature are relevant to telecommunications in several areas: Strategic evaluation, estimation and cost modelling.

Strategic Evaluation

The relevance to strategic planning is obvious. The bulk of 'strategic' planning in the telecommunications industry has revolved around budget projections and scenario analysis based on discounted cash flow analysis. Concerns such as price elasticity, uncertainty and other economic considerations came late to the industry.[4] Indeed, in the era of monopoly control and rate-of-return regulation, strategic planning or the lack of it was not critical. The whole game was in the regulatory strategy. Times have now, obviously, changed and so must the analysis in order for telecommunications companies -- emerging, new and old -- to become or remain viable. The real options approach will aid in this endeavor.

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[3] Hausman's application of options (not real options) theory to value unbundled network elements is as close as the industry has come to my knowledge (1998. See also Hausman, 1997).

[4] To cite two example in the telephone industry: Taylor indicated that the telephone industry did not concern itself with price elasticity effects until it was confronted in the regulatory arena (Taylor, 1980.). While I was with GTE (I left in 1990), its method of 'strategic' planning consisted of growing annual budgets by a given percentage from the previous year's budget.

Estimation

Many behavior assumptions are embedded in econometric structures that are necessary for the interpretation of the estimates, but real options changes the nature of these with the resulting consequence for the veracity of the estimations. Little, if any, work that I am familiar with has addressed this issue, although the consequences have been reported (Dixit and Pindyck, 1994; Slade, 1998). For example, real options theory changes the nature of the shut-down point in the theory of the firm. It may no longer be optimal for the firm to close when revenues go below variable costs because, in the dynamic world, it may be optimal to keep the option open to serve the market when demand is more robust. Closing down might preclude this option. Allowing for the incorporation of the dynamics of real options into traditional economic theory, in addition to the obvious integration of finance into the models, could dramatically change the outcomes of traditional theory.

Cost Modelling

Attempts to estimate forward-looking costs in the United States and around the world are based on cost models whose foundation is traditionally applied discounted cash flow analysis -- exactly the method that real options methodology has shown can give terribly wrong results.[5] These cost models are ideal vehicles to adapt to the real options methodology. All the data are in a form to which real options considerations can be applied without a measured change in their structure. However, it should be cautioned that the results are non-linear, that is, the modellers cannot simply add an 'additive' to the results of their models to 'correct' for the real options impact.

As Trigeorgis' book and others have shown, valuation analysis has been enhanced with real options theory that accounts for the investment uncertainties, subject to probability distribution, which are fundamental in the DCF analysis. Applying the real options methodology to DCF analysis can make a significant change in the valuation -- as much as a factor of two.[6] All current cost models ignore this enhancement.

These models serve a variety of purposes: the calculation of universal service obligations, access charges or unbundled network elements (UNE) prices. Given the major methodological problems, it would be irresponsible to use these cost models for determining access/interconnection prices and unbundled network elements, as well as universal service obligations.

CONCLUSION

Real Options is a major contribution -- it consolidates and integrates the results of the disparate literature on the topic. While academics in the field of finance are generally conversant with this literature, those who are involved in engineering economics,

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[5] While these cost models go into great detail on the engineering aspect of the telephone network, many lack a fundamental understanding of economics and finance, i.e., they fail to apply the appropriate, traditional techniques of engineering economics. Some do not use present discounted value or discounted cash flow (DCF) techniques to evaluate the capital investments. They simply use a revenue requirement method, based on arbitrary cost allocations. Many of the cost models have ignored DCF's major contribution to asset valuation (e.g., NERA 1999, pp.80ff.)

[6] Dixit and Pindyck (1994, p.153) achieve this result with numerical analysis of a reasonable set of parameters that compares traditional DCF with the real options approach.

industrial organization or related disciplines may not be aware of this theory. It should be high on their reading list. Managers cannot afford to ignore the implications and methods developed by real options analysis.

For policymakers who attempt to model the market behavior of firms in competition, it should be required reading. Effective policy dealing with costs cannot be made without a fundamental understanding of this theory's implications.

Real options offers the possibility to integrate major analytical methods into a coherent framework which more closely approximates the dynamics of the firm's behavior without heroic assumptions regarding the dynamics of the environment.

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