10 The Poverty of Cost Models, the Wealth of Real Options[1]

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Abstract - The attempts to estimate forward looking costs worldwide are based on cost models whose foundation is traditionally applied discounted cash flow analysis - exactly the method that the real options methodology has shown can give terribly wrong results. However, these cost models are ideal vehicles to adapt to the real options methodology. This paper develops a stylized cost model to quantify several deficits associated with the cost models in use today. Even without the application of real options methodology, the stylized results show a significant difference between the revenue requirements model and a traditional discounted present value model. With the application of real options techniques, the differences become much greater.

The implications are significant. Policymakers who attempt to use proxy cost models to emulate the market behavior of firms in competition without considering real options are acting unwisely. Policies that deal with costs cannot be effective without a fundamental understanding of the implications of real options theory.

1. OVERVIEW OF COST MODELS

This paper reviews and critiques the proxy cost models that have recently been developed for the telecommunications industry. While these cost models go into great detail on the engineering aspects of the telephone network, they lack a fundamental understanding of economics and finance by failing to apply the appropriate traditional techniques of engineering economics. Some do not use discounted cash flow (DCF) techniques to evaluate capital investments.[2] Instead, they simply use a revenue requirement method, based on arbitrary cost allocations. These cost models have ignored DCF's major contribution to asset valuation.[3]

More recently, valuation analysis has been enhanced with "real options theory," which accounts for the investment uncertainties, subject to probability distribution, that are fundamental in the DCF analyses. Applying the real options methodology to DCF analysis can produce a significant change in the valuation – by as much as a factor of two or more.[4] However, all of the cost models ignore the real options effect. The results of the stylized model presented in this paper indicate the underestimation is on the order of 40 to 60 percent.

Given this enormous disparity and major methodological problem, it would be irresponsible to use these cost models for determining access/interconnection prices, unbundled network elements (UNEs), or universal service obligations.[5]

2. SCOPE OF CRITIQUE

While there are several generic problems with the existing telecommunications cost models, this paper cannot hope to go into detail or even enumerate all of them. It attempts to show, however, that the models can be modified to correct the more egregious faults and offers suggestions on how to include the real options effects. The reader should be warned that while the framework of the current models may be salvageable, this does not mean that a simple "adder" can be appended to the results to determine "the number." The corrections introduced by real options considerations are nonlinear. The nonlinearity precludes "additive solutions," but requires the explicit incorporation of a different approach into the models.

The cost models are based on engineering relationships using traditional telecommunications plant design with the best available technology. The network is laid out to meet the quantity demanded, and is designed in extensive detail.[6] It is granular in terms of equipment and geography. For example, version 5.0a of the HAI model has nearly 200 input parameters and would include, *inter alia*, the hardness of the ground for laying transmission facilities (HAI Consulting, Inc., 1998b).

This class of models is generally known as engineering process models.[7] They design the network "on paper," and estimate the physical investment required to serve demand as well as other factors needed to develop the costs associated with the level of investment. This paper is only concerned with the step after the estimation of the physical investment required to serve the demand: the economics/financial methodology of the cost calculation.

Stripped to their simplest form, the engineering process models begin with an estimate of the demand to be served and then design the system to serve this demand based on standard engineering practices and relationships using the latest technology available. This determines the investment required in physical units. The results are then used as a basis for virtually all other calculations:

- The physical units are multiplied by the unit cost of the investments to obtain the total investment cost.

- The expenses are determined as a proportion of investment costs; thus, the level of investment is critical for the determination of the expense elements of costs.
- The annualization of the investment is based on the depreciation schedule and the cost of capital.
- The revenue requirement is the value of the annualized investment, expenses and overheads.
- Dividing the revenue requirements by the quantity defines a "price" (see Figure 1).

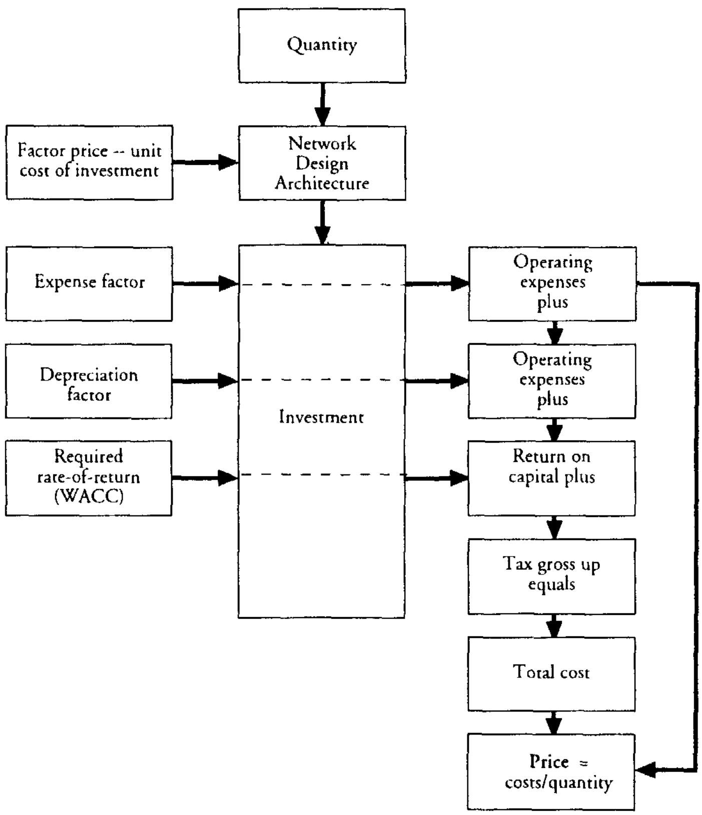

Figure 1. Engineering Process Model
Rate-Base, Rate-of-Return Cost Model Calculation

3. STYLIZED COST MODEL

3.1 A One-Period Model

Virtually all of the models describe in extensive detail how their model networks were designed and built, but the financial and economics descriptions are limited to a few paragraphs (HAI, 1998; NERA, 1999). As a result, the models' economics/financial structure is ambiguous. Explicit interpretations of the calculations are presented below along with discussions of the problems with this approach. A distinction is made between traditional DCF analysis and the revenue requirements (RR) method; various forms of the latter are used in the current cost models. The difference between an RR model and the traditional approach is over 10 percent. This paper shows where real options can be useful in enhancing the accuracy of cost estimates and increasing the exchange access price by up to 60 percent.

Initially, for expository purposes, assume only one period, no depreciation, no taxes and no operating expenses. Then, in their simplest form, RR models compute the price/cost in the following manner. First the required output is determined, followed by the equipment needed to provide this output based on telecommunications engineering principles. That is, with these quantities, the network is sized based on standard engineering design relationships – the size of the central office required for the number of loops to serve this demand, etc. Next, the price of the equipment is determined. The prices of the input times the quantities required determines the total investment. A cost of capital factor is used to compute the revenue requirement, which is then divided by the output to determine the price. To illustrate these points, assume only one type of capital is needed and is used up in this period.

$$Q = F(K) = \updownarrow K \tag{1}$$

If Q is the output, K is the capital required, and w is the price of the capital equipment. Using the subscript $_0$ to indicate the value of the variables and assuming that $\updownarrow = 1$, then:

$$Q_0 = K_0 \text{ and} \tag{2}$$
$$P = w_0 K_0 / Q_0 \tag{3}$$

This is the revenue requirement model in its most basic form. Obviously, this is too simple. However, it illustrates several points about the models that are examined below: 1) the price is driven by the estimate of capital requirement, 2) demand is assumed to be invariant, no mater what the price, and 3) investments and revenue are assumed to occur instantaneously. All these deviations from reality are maintained in all the models under discussion.

3.2 Quantity Determination

As indicated, the quantities necessary to meet demand are first determined via telecommunications engineering relationships. However, no consideration is made for price effects on the quantity demanded. But not having this demand parameter implies a perfectly inelastic demand. That is, no matter what the price, there will be no change in quantity demanded. This, of course, belies all the demand studies made in the telecommunications industry since the late 1960s (Taylor, 1980).

In this module no accounting is made for the decline in either market share due to market competition or, conversely, the increase in demand due to market growth for the services. The local exchange carrier's (LEC) demand, as opposed to the industry demand, will certainly diminish as competition enters the market. This is ignored in the engineering process models.

Moreover, the models do not allow for demand growth (or shrinkage) over time, but are designed to meet the maximum demand. This implies that investments are not added incrementally, but at once. A related assumption of these models, which ignores reality, is that the investment and the revenues derived therefrom occur instantly.

These problems can be summarized as follows:

- The demand is assumed to be perfectly inelastic
- Output is constant
- There is no decrement in market share.

3.3 Multi-Period Models

Expanding the model to multiple periods is the next complication. This introduces several issues. How is the capital treated over the time periods? When does the capital become productive? How does it deteriorate? Must it be augmented? Must it all be in place initially? Does it have any salvage value at the end of its life? How should the time-value of money be handled? And when are revenues received? The method of treating these issues will determine how well the models reflect the realities of the marketplace. The following sections contrast the traditional method of project evaluation with the RR method.

3.4 Traditional Valuation

Traditional project evaluation treats the time periods explicitly using what is known as discounted cash flow (DCF) techniques. The cash flow over time generated by a project or service is estimated; and then the cash flow is "discounted" or reduced over time by the factor $1/(1+r)^t$, where t is the period in which the cash flow occurred.[8] The discount factor, r, represents the opportunity cost of capital for the firm, or what the firm could earn in the marketplace in its next-best alternative.[9]

If the sum of these discounted cash flows, known as the present value (including the initial and any intermediate investments), is greater than zero, the project is "profitable." In a properly constructed cost model, this present value would be set to zero; that is, the discounted revenues just cover the discounted costs and the "revenue requirements" are met. If there are no taxes (yes, an heroic assumption in today's world, but it is dropped later), then accounting depreciation is of no concern. Indeed, economic depreciation is of no concern except in the last period, when the economic depreciation represents the salvage or market value of the investment – what the investment will sell for in the marketplace (or what will be the cost to remove it). The investors are only interested in earning their money back on the investment after accounting for the time value of money (the fact that the cash earned tomorrow is not as valuable as the same amount of cash earned today) plus a return on the investment.

The cash flow is composed of the revenue earned and the cash outlays during the period. While it may seem trivial to note that the revenue is composed of the price of the service times the quantity, this appears to have escaped the cost modelers' notice. The price is endogenous. But what the modelers are attempting to determine is the price. It is axiomatic for economists to consider that price and quantities interact. The downward sloping demand curve is in every economist's tool kit. One cannot determine the quantities without the prices and vice versa. However, this is what the cost modelers have done. Quantities are estimated without regard to prices, and then prices are determined as an output of the model.[10]

3.4.1 Taxes and Depreciation

Before considering how depreciation is handled in the DCF models, it is worthwhile noting how it is handled in the revenue requirement (RR) models. In the RR models, it is added as an expense and reduces the magnitude of the capital upon which the rate of return is calculated.

$$P = [w_0(K_0 - \Sigma D_t) + D + \alpha (K_0 - \Sigma D_t)]/Q_0 \quad (4)$$

Thus, the choice of depreciation can make a significant difference in the price. In the revenue requirement models, the modelers offer it as a parameter to be used to adjust the pricing.[11] This is incorrect. The only factor that should be used is the one the government requires for tax purposes. Any other will not reflect the reality of the tax system and will be inappropriate.

Taxes. In the traditional DCF models, the depreciation required by the tax code is used. It is included because it enters as an accounting expense, which reduces the tax liability. Otherwise, it is an accounting artifact. Taxes are thus calculated based on the depreciation actually used (and required by the tax code).

Depreciation. In the cost models, depreciation schedules are used to determine the number of years over which to annualize the investment. The discount factor used to annualize the investment is the weighted-average cost of capital.

The depreciation schedule is also used to determine the life of equipment. This is needed to annualize the equipment life in the discounting formula. For example, in the HAI model, the depreciation schedule comes from the Joint Board's determination of what the life of the asset should be for regulatory accounting purposes.[12] It is most definitely not the economic life, which can only be determined with knowledge of the output prices. Moreover, it is commonly known in the industry that this schedule is biased toward long-lived depreciation rates, since a very long-lived asset has the effect of keeping exchange rates low.[13]

The DCF model can be rewritten with these changes:

$$DCF = \Sigma\{[(P_tQ_t - CFO_t) - tx_t (P_tQ_t - Exp_t - D_t)]/(1+r)^t\}, \quad (5)$$
$$\text{summed over } t = 0, T$$

Where P_tQ_t is price times the quantity sold (revenue) or cash inflow, CFO represents the cash outflow (that is, any capital outlays along with expenses (Exp_t) or non-capital cash outlays), and tx is the tax rate on net income. The tax burden is represented by the second term in the summation. It is the operating income before taxes. Note that taxes are reduced, *inter alia*, by the accounting depreciation, but this is not a cash outlay and only represents an allocation of an earlier capital outlay.

The more familiar form of the cash flow model is the earnings after taxes plus depreciation, which is equivalent to the above expression (assuming no intermediate capital investments).

$$DCF = \Sigma[(1 - tx_t)(P_tQt - Exp_t - D_t) + D_t]/(1+r)^t \tag{6}$$

In other words, the firm's only concern with the accounting depreciation is its impact on its tax liability and hence, its cash flow. When the project terminates, depreciation (both accounting and economic) becomes a concern. The difference between the salvage value (or the market value) of the asset, and the asset's book value gives rise to a positive or negative (accounting) capital gain.[14] This capital gain or loss is subject to a tax liability or credit. This book value is determined by the accumulated accounting depreciation less the initial cost of the asset.

The difference between the original market price of the assets and its current market value represents the accumulated *economic* depreciation. This suggests that the only depreciation that should be considered for any of the cost models is the depreciation required for tax purposes and an estimation of the salvage value less the book value at the termination of the project. In the United States and most other countries, these schedules are quite precise and codified in the tax law.

While depreciation is important, it is not treated appropriately by modelers. The manner of handling depreciation in these models is suggested when the model treats it as an input or a variable, which can be changed under different scenarios.[15] The arguments as to the use of accounting or economic depreciation are misdirected. In these discussions, the modelers are considering the rate-base, rate-of-return models, where they wish to capture the "using up of capital" in that period. Here, the economic depreciation would be the correct solution, but only if this calculation were made year-by-year. Moreover, the market value of the asset is determined primarily by the price of the output the assets support, which was noted is endogenous. Even then, the tax liability would have to be considered, which is based on the accounting depreciation.[16] What the modelers are attempting to do is the impossible. They are trying to find the output price for a service in a particular year, but then assume that this will be adequate for the remaining life of the service. This makes an additional, inappropriate, assumption: In addition to the previous problems, the following are added:

- Certainty is assumed
- Accounting depreciation is treated as a real cost
- An incorrect discount rate is employed

- Tax treatment is inappropriate
- No growth in demand is assumed

3.4.2 Other Issues

At the risk of being pedantic, the above points can be demonstrated by developing a stylized example of traditional project evaluation, which can be contrasted with the current cost models. It will consist of an eleven period (from 0 to 10) model, which will include, ultimately, all the features an *ab ovo* project should consider.[17] To evaluate the project, the investment and other costs are judged against the income. But, as noted earlier, income is determined by the demand relationship and is endogenous. Assuming this problem away for the moment by assuming a perfectly inelastic demand for the service, the cost side can be examined. Second, just as Rome was not built in a day, the telecommunications network cannot be built instantaneously, although the cost models not only assume this is the case but also that the associated revenue is obtained instantaneously. Thus, this paper's model has the investment occurring in the zero period (that is, in the first year of operation) and the revenue and associated expenses occurring in the later periods. This has at least two impacts that the cost modelers ignore: the delay before income accrues – a return on the investment is required during this gap. It also demonstrates the lack of dynamics in the cost models.

Turning to the traditional evaluation method once more, it can be seen that demand does not remain constant over the periods. This implies that the initial investment can be augmented over time and that both revenue and, perhaps, expenses will increase during this time period. At least two of the cost models handled this dynamic by assuming that the service is provided for the maximum demand anticipated. Thus, until demand grows to this level, capacity is underutilized, even if, as is likely the case, the capacity could have been added incrementally. Neither demand, investment, nor expenses grow. This gives an obvious bias to the results.

This is the first instance where real options methodology can be applied. Demand and its growth are uncertain. If the initial demand does not manifest itself, the firm has the option not to invest and expend additional operating funds; indeed, it has the option to contract its investment. This active management flexibility is not captured by the traditional models, but can be incorporated with real options methods. While analysts may disagree on the characterization of the probability density function, the methodology does make the assumptions explicit and, not as the author was informed recently by a regulator, that they would account for these considerations based on "judgment."

The traditional method evaluates the project in a crude dynamic – estimates of the prices, quantities, expenses, investments and other costs are forecasted for input into the cash flow analysis. Interest rates, economic conditions and other market factors are considered in a sophisticated analysis. Risk or uncertainties are handled in a variety of ways: capital asset pricing methods (CAPM), sensitivity, decision tree, and/or simulation analyses. Real options methodology creates a sophisticated dynamics that none of the models has captured, as is demonstrated below.

Investment Costs. The cost of the investment is determined by multiplying the input price (the unit cost) of the investments by the quantity of the physical investments. The investment input prices are at the "list" price, which could be subject to quantity discounts, but this is not considered.

Expenses. Expenses are determined as a factor of the specific investments. Where available, these factors are based on historical relationships and vary by the specific investment.

Once again, the expense factor shows a lack of economic considerations. The expense factors enter the model as a proportion of the particular investment. And while they may be based on historical relationships, they do not comport with the realities of today's marketplace. There is no ability to tradeoff the expense factors with the magnitude of the investment. The expense factors contain a large amount of labor in their components. Every beginning economist is confronted with the necessity of learning about the tradeoff between labor and capital. As the price of labor goes up, capital is substituted for labor and vice versa. Within the context of these models, this is not possible.

Table 1 summaries these faults in the cost models. But even if the modelers corrected these deficiencies, one glaring defect remains. The new investment theory, known as real options, has not been considered.

Total Cost. The annualized investment, expenses and overhead costs are added together to determine the total cost. This is then divided by the quantity, which started the process, to determine a price.

Additional Problems. Before turning to real options considerations, other points should be noted regarding this modeling.

The prevailing models are static models – what the real options, in part, correct – and are known in economist jargon as light bulb or "one-hoss shay" models (that is, the investment functions as if it were new and needs no maintenance until it

Table 1: Engineering Process Model Modules and Problems

Module	Problem
Quantity	Constant output
Engineering design and relationships	No technological substitution No economies of scope No factor price consideration
Investments determined	One-time investment Static factor costs/prices Light bulb model No economies of scale/scope Static discount/interest rate Constant capacity factor No differentiated risk profile No real options consideration
Expenses	Annualized (constant) as proportion of investments No labor/capital substitution
Depreciation from schedule	Not economic, but accounting Not tax, but regulatory Schedule from Joint Board Certainty of life Non-economic calculation
Rate-base, rate-of-return revenue requirement	No dynamics One price No change in input or output prices Static discount rate
Revenue requirement/quantity **determines price!**	No price (demand) effects Revenue requirement level No competitive impacts No market share loss

suddenly "blows out" or dies). Everything is calculated at the beginning of the period and built instantaneously. There is no allowance for growth in demand or changing factor prices over time. Finally, differential risk profiles, irreversibility and the sunkenness of various investments are ignored. This is critical when considering real options, as shown in the next section.

3.5 Real Options: A Brief Sketch[18]

Real options is based on the fact that one can evaluate real (i.e., physical) assets with the same tools as financial options. Since the Black Scholes method of pricing options was developed over a quarter of a century ago, the methodology has been refined and extended. The essence of the method ensures that the option is evaluated in a risk-neutral way.

3.5.1 What are Real Options?

As outlined above, the traditional approach to project evaluation and investments uses 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. 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 another lesson for the policymakers – if they wish to emulate the competitive process, they cannot rely on applications of traditional 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.[19] Using the firm's 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 that of the local loop element. Calculating the cost/price of these elements using the same discount rate would be incorrect.

However, none of the traditional approaches to dealing with uncertainty such as decision-tree analysis, simulations, and sensitivity analysis has the capacity to deal with uncertainty as meaningfully as real options.

The second insight of the theory is the recognition that a 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. It is not necessary to determine a risk-adjusted discount rate. Uncertainty is not eliminated, but 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 (1973) methods of option valuation.[20, 21]

3.5.2 Concepts and Applications

Real options is a means of capturing the flexibility of management to address uncertainties as they are revealed. Present value methods fail to account for this flexibility. While much of the debate in telecommunications focuses on the irreversibility of investments, the flexibility that management has goes beyond deferring sunk costs, and includes: abandon, shut down and restart, expand, contract, and switch use.

The key valuation concept is 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 rate to replicate the return of the option in a risk-neutral world.

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 framework for the application of real options to investment opportunities is concerned with discrete (binomial) events or with continuous distributions.

The intuition of real options, by accounting for this asymmetry in outcomes, is simple, but profound – management's decisions skew the distribution of possible outcomes toward the upside. Real options methodologies can take the best features of DCF and DTA without their failings.

Real options can be applied to a variety of cases including competitive interactions. However, 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, as shown below. 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. 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 dis-

> count rate must, in effect, be imputed *endogenously* within a forward-looking dynamic programming process.
>
> 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 (Trigeorgis 1996, p. 200).

Assume that a project requires an investment of $104 and has a value of $100 in the first period.[22] It has a return in the second period of either $180 or $60, with an equally likely probability of occurrence. The comparable security is $20 initially and $36 or $12 in the next period. This implies that the cost of capital is 20 percent. If one calculated the DCF of the expected value of the project, the DCF is $ - 4 < 0. Thus, it would not be undertaken. But with management flexibility, the firm could wait one period to see what the state of nature would be. Evaluating this using real options tools, one would solve for the value of the twin security such that it would be risk-neutral (that is, the purchase of the security and borrowing of an amount at the risk-free interest rate that replicated the return). In the example, this implies purchasing 2.82 shares and borrowing $31.33. Solving this for the initial conditions, the value is $25.07. Thus, the option valuation is $29.07 = (($25.07 – ($ - 4)).

This is different from the value calculated with the opportunity cost of capital, which overestimates the value of using the-risk free rate, which underestimates the value. In other words, alternative discount rates cannot correct the deficiencies that real options reveals.[23]

While the example used here is the deferral of the investment, the methodology applies to other areas of management discretion: expand, contract, abandon, and start up or shut down.[24]

While there is a debate about the extent of irreversibility in the local loop, a contraction of the market is also possible with the introduction of competition in the exchange market.

Changes in valuations due to competitive interaction can be dealt with – both exogenous entry and endogenous reactions. Although real options theory is increasingly used in industry,[25] it has not been applied in the telecommunications industry.[26] But, as will be argued below, telecommunications is ripe for this methodology.

3.5.3 Model Discussion

To crudely estimate some of the deficiencies described above, the author built a stylized model based on the traditional cash flow (CF) approach to project evaluation. The major parameters from the HAI model were used. In addition, the price of the revenue requirements (RR) models was forced to $20 a month as a reference point. Twenty dollars is approximately the current national average of the price of exchange access estimated by the hybrid FCC model. The RR model underestimates the CF model by approximately 10 percent. But the main purpose of this construction was to apply the real options methodology to this cash flow. Depending on the volatility factor assumed, the underestimation from the RR model can be as much as 60 percent.

Before discussing these results in detail, the model, including its strengths and weakness, is described. The purpose is not to estimate "the price," but to show the poverty of the RR models in determining "the price" of access and to indicate how inaccurate the estimations are with the correction of only a few of their deficiencies.

The model follows the RR models by assuming that the level of investment, which in turn is determined by the demand, drives the model. However, it was assumed here that the demand grows over time. Arbitrarily, it was also assumed that the demand is 100 units in the initial period. The base case is one percent (1%) per year over the ten-year life of the project. Second, it was assumed that it takes a year to build to the incremental demand. The demand is multiplied by the investment factor and the input price (the cost per unit of investment). This determines the required investment and cost in each period. For simplicity, a straight-line depreciation over ten years was then assumed. It would be preferable to use actual tax depreciation, as noted above, but to compare with the RR this simplifying assumption was made. Had tax depreciation been used, the schedule would have had more depreciation in the early periods, thus providing a larger tax shield in the earlier periods, reducing taxes in these periods and improving the cash flow (lessening the outflow).

Next the expense factor, interest, debt to equity ratio, and tax assumptions of the HAI model were employed. These provide sufficient information to develop the cash flow. First, the costs for tax purposes were calculated (expenses plus interest charges plus depreciation) and then the taxes. (Because only costs are dealt with here, this represents a tax credit to the firm.) To develop the cash flow, investment for the period was added to the expenses, interest and tax charges. (Note, as previously indicated, depreciation is only used for the tax calculation.)

The traditional DCF analysis then applies the discount rate to the cash flow. The proper method to handle this is to use the risk free-interest rate to discount the investments and a risk-adjusted rate to the balance.[27] In the traditional approach, the risk-adjusted rate to use is one that is appropriate to the risk of the project. Thus, a project such as operator services would have a different discount rate from exchange loops. More sophisticated analysis uses the capital asset pricing model (CAPM) to determine the proper discount rate. The CAPM determines the risk-adjusted rate based on the systematic risk associated with the project. The cost models ignore this refinement and simply use the weighted average cost of capital (WACC) for the discount rate.[28] For comparative purposes, this analysis used the WACC rate as a discount rate for the balance of the cash flow.

Using these parameters, the RR model was then set up. Even with these modest corrections to the RR approach, the difference is over 10 percent.

In order to develop the real options methodology, the RR model was solved for a price of $20 by varying the input price of the required investment. With this price of the inputs, the traditional model was solved for the price that would generate sufficient discounted revenues to cover the cost using the traditional method.

The above procedure corrects for the deficiencies of the RR models by ensuring accurate discounting of the investment stream, the appropriate handling of depreciation in calculating taxes, and the growth of demand.

What it does not correct for is the appropriate depreciation rate, the inflexibility of the expense function, the correct risk-adjusted discount rate, price/demand effects, and other problems listed in Table 1. Moreover, the subject of this volume, real options, was not corrected for. Many uncertainties exist in the telecommunications industry, which suggest that real options methodology is appropriate. The most obvious of these impacts is the speed and magnitude of competitive entry in the exchange market, and the uncertainty of judicial and regulatory actions. This refinement is discussed next.

The method selected here to incorporate real options was to use the Black Scholes algorithm to calculate the option value of the service. It was assumed that the risk-free discount present value of the investment is the strike price of the option, and the risk-adjusted discounted stream of non-investment cash flows is the stock price. The risk-free interest rate, the eleven periods of the cash flows, and various volatility rates in the algorithm were employed. This shows that the price may be underestimated by as much as 60 percent.

Because not all of the criticisms of the cost models were incorporated in these calculations, a precise estimate of the misspecification was not possible. However, the objective was not to determine the size of the underestimate, but to show that ignoring real options can make a significant difference in the estimation of costs, which has been done.

4. SUMMARY AND CONCLUSIONS

Attempts to estimate forward-looking costs in both the United States and abroad 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. 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 nonlinear, that is, the modelers cannot simply add an "'additive'" factor to the results of their models to "correct" for the real options impact.

This paper has shown that the cost models have fundamental methodological flaws, even when considering a traditional approach to valuation. Moreover, the models neglect the latest application of valuation theory – real options – and it has been demonstrated that this can make a significant difference in costs. This is consistent with others' results (Dixit and Pyndick, 1994; Hausman, 1998).

Policymakers are ill advised to use these cost models to determine universal service funding, unbundled network elements, or interconnection charges. The magnitude of the error can result in hundreds of millions, if not billions, of dollars of misallocated resources. Incorrect price signals will retard investment, research and development. The mis-estimations can equally cost consumers hundreds of millions, if not billions, in lost welfare. It would be highly irresponsible for policymakers to make decisions without considering the real options impacts. Policies dealing with costs cannot be effective unless they are made with a fundamental understanding of the real options theory's implications.

NOTES

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2 Also referred to as (net) (discounted) present value techniques. These terms are used interchangeably here.

[3] For example, see National Economic Research Associates. 1999. *Estimating the Long Run Incremental Cost of PSTN Access.* Appendix C, pp. 80 ff.

[4] Dixit, Avinash K. and Robert S. Pindyck. 1994. *Investment under Uncertainty*, Princeton, NJ: Princeton University Press, p. 153.

[5] These models serve a variety of purposes: the calculation of universal service obligations, access charges, reciprocal compensation, or UNE prices. These are referred to as "prices" in the remainder of this paper.

[6] While these cost models go into great detail on the engineering aspects 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.)

[7] Unless otherwise specified, this paper's references to cost models are the HAI (1997); INDETEC International, Inc., et al. (1999), FCC (1999) (see http://www.fcc.gov/ccb/apd/hcpm/), and National Economic Research Associates (1999).

[8] Engineering economics texts best illustrate this approach. See, for example, deGamo et al. (1993) or Steiner (1996). These texts delve into the mechanics of DCF analysis and cost estimation methods, but have little, if any, discussion of the capital budgeting or financial considerations of project evaluation, or the determination of the proper discount rate.

[9] The more sophisticated analyses use the risk-adjusted rate of return, which is based on the capital asset pricing method (CAPM), one of the methods used to account for uncertainly in the marketplace. This, however, is not the same as the weighted average cost of capital (WACC) that the cost modelers use in their calculations. Indeed, the real options methodology suggests that the discount rate used in DCF calculations changes each period. See Trigeorgis (1996, pp. 38-52) and the references cited therein. For a brief general exposition of capital budgeting, see Trigeorgis (1996, Chapter 2, pp. 23-68); for an in-depth approach see Hull (1997).

[10] The modelers may argue that the demand is perfectly inelastic, or nearly so. If this is the case, then the universal service obligation cannot be met, no matter what the price of exchange access. No price will be low enough to bring on additional subscribers!

[11] See for example, NERA model, op. cit., HAI model (1999a) and Pelcovits (1999).

[12] The Joint Board is a legacy of regulation. If is composed of the FCC and state regulatory staff. It was designed to determine depreciation for ratemaking purposes, not tax purposes.

[13] See Salinger (1998) for an excellent analysis of the inappropriateness of depreciation handling within the engineering process models. He shows, *inter alia*, that economic depreciation cannot be determined from the engineering process models, since economic depreciation is dependent on the price of the outputs.

[14] In the case of removal costs, the capital gain is unequivocally negative. In other cases, the sign of the gain is indeterminate. The better the accounting depreciation matches the economic depreciation, the smaller will be the gain or loss.

[15] This is clearly the case in the NERA model, op. cit., and appears to be the case in HAI Model Release 5.0a (1998a), which uses the regulatory review process to determine depreciation inputs, not the tax code. Also see Pelcovits (1999) in this volume. See HAI Consulting, Inc. *Inputs Portfolio*, January 27, 1998, page 118 at http://www.hainc.com/hminputs.pdf. The URL for the HAI model descriptions can be found at http://www.hainc.com/ documentation.html.

[16] Salinger (1998) correctly critiques the method by which depreciation is handled in the cost models. Many of his points concern the attempt to capture the depreciation effects in the rate-of return type models.

[17] By convention the period labeled 1 is the end of the first period and the beginning of the second. For expository purposes, this period is assumed to be one year.

[18] This section is adapted from the author's forthcoming review of Lenos Trigeorgis. 1996. *Real Options: Management Flexibility and Strategy in Resource Allocation.*

[19] 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 (1996), pp. 58 - 68.

[20] See Hull (1997) for a complete description of options methods.

[21] 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.)

[22] This example is from Trigeorgis (1996). Also see Copeland et al. (1991).

[23] See Trigeorgis (1996) or Copeland et al. (1991) for the details of this type of calculation.

[24] Many of the commentators in this volume (e.g., Alleman, Noam) leave the impression that the irreversibility of investment is the only driver of the real options methodology. This is the impression left if one only looked at the economic literature and ignored the financial literature on the topic. For example, see footnote 3 in Clarke, this volume, which has no financial citations. Also, the commentators note that real options is only considered in a monopoly environment, but this is not true; for example, see Trigeorgis (1999) and the reference cited therein.

[25] See *The Economist* (1999) for the current state of play of real options in other industries.

[26] Hausman's (1997, 1998) application of options (not real options) theory to value unbundled network elements and Small's (1998) application to network pricing is as close as the industry has come to the author's knowledge.

[27] Many analysts discount the total cash flow by some risk-adjusted discount rate. This is inappropriate because uncommitted investment funds need not make the same return as the balance of the cash flow See Luehrman (1998a) and Alleman (1999).

[28] The WACC is the average of the equity return and the cost of debt weighted by the proportion of each.

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