MODELLING REGULATORY DISTORTIONS WITH REAL OPTIONS

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ABSTRACT

The introduction of uncertainty can make a significant difference in the valuation of a project. This manifests itself, *inter alia*, in the regulatory constraints that can affect the valuations of the firm's investment which, in turn has an adverse impact on consumers' welfare. In particular, the inability to exercise any or all of the delay, abandon, start/stop, and time-to-build options has an economic and social cost. With this view in mind, we specify and estimate a model where regulatory constraints impact on the firm's cash flow and on investment valuation with real options methods.

This paper uses real options analysis to address issues of regulation that have not been previously quantified. We show that regulatory constraints on cash flow have an impact on investment valuations in the telecommunications industry. Specifically, a model is developed to estimate the cost of regulation for broadband services. We show that the cash flow constraints and the inability to delay and abandon has a significant cost. Because some costs are not recognized in a static view of the world, this failure to recognize the operation and implications of non-flexibility by regulators (which can be modeled by real options methods) will lead to a reduction in company valuations which in turn will lead to a reduction in economics welfare.

INTRODUCTION

As the readers of this Journal are aware (Park 1999), (Park 2000), (Nembhard 2000), (Herath 1999), and (Herath 1999), the real option pricing approach utilizes financial option principles to value real assets under uncertainty. In this paper, we evaluate regulatory actions *ex post* in order to determine the impact of regulatory constraints. The genesis of this research began when one of the authors evaluated telecommunications cost models whose foundation was based on the applications of traditional discounted cash flow analysis – exactly the method that real options methodology has shown can give terribly wrong results (Alleman 2002b). If regulation does not account for management's flexibility nor does it account for the constraints regulation imposes on the regulated firm by restraining management's flexibility (nor does static discounted cash flow analysis). What we propose is yet another use of real options methodology. In particular, we show that the cash flow constraints; inability to delay has a significant cost.

We address issues of regulation that have not been previously quantified. Regulation leads to constraints on prices or on profits. Regulation also surfaces in the context of the obligation to serve. Under the current practice in most countries, whenever a customer demands service, the incumbent carriers are obligated to provide the service. It is part of the common carrier obligation. Under the obligation to serve requirement, if the customer proves unprofitable, the carrier still must nevertheless serve this customer. This is in contrast to discretionary services offered by the telephone company providers, such as digital subscriber line (DSL), where reports of consumers' complaints about the unavailability or the slow rollout of the service are heard. Are the carriers using a delay option strategy? (Of course, other explanations are possible.) Consider two cases. The first deals with broadband service. The second deals with payphone service. If the telephone company chooses to limit the availability of broadband service, we have an example of a delay option. If the telephone company wants to cease providing payphone service, we have an example of the abandonment option. If the company faces a common carrier obligation to provide broadband services and to maintain payphones, the requirement to provide broadband services eliminates the company's option to delay. Similarly, the inability to exit the payphone business eliminates the firm's ability to exercise its abandonment option. In the delay case, concerns with the "digital divide" have prompted proposed legislation in the United States to mandate the increased deployment of broadband services by the telephone companies. If passed, this action would limit the companies' ability to delay. In the second case, with the rapid increase in mobile telephone usage, payphone service has experienced a serious decline in its revenues. When the phone companies attempt to exit the service, the regulators forbid it[1].

In the dynamic world, demand, technology, factor prices and many other parameters of interest to a company are subject to uncertainty. The principal uncertainty is the demand for goods, which, in turn, impacts cash flow, investment valuations, profits, and economic depreciation among other economic variables. We solve the investment valuation with deferral and abandonment options with a simple binomial model in an uncertain world of demand to show the cost of the regulatory constraint. (The binomial model is one of the techniques used to determine option prices.) This model provides an intuitive understanding of the result that regulation has a cost. Regulation can restrict the flexibility of the firm through the imposition of price constraints and by imposing costs associated with either delay, abandonment, or shutdown/restart options. In addit ion, the cost models used for public policy decision makers do not account for the time-to-build options available to the firm. If these regulatory impacts are left unaccounted, there are significant costs to the firm and to society. (One of the clearest examples of the telecommunications regulators failures to apply dynamic analysis is in the use of cost models and a type of long run incremental cost methodology to determine prices and obligations-to-serve subsidies. (Alleman 1999))

The literature is divided into three areas: first, regulation's impact on investment – either rate-of-return or incentive regulation – usually in a static context though occasionally with dynamic models of investment behavior; second, generic real options analysis; and third, real options applied to telecommunications. The first two areas have been adequately reviewed elsewhere. For a review of telecommunications regulation prior to the late-eightys, see Kahn (1988); a review of the current state-of-the-art in telecommunications is found in Laffont and Tirole (1999). The static and dynamic aspects of investment under various forms of regulation and optimal (Ramsey) pricing may be found in Biglaiser and Riordan (Biglaiser 2000). Most of this literature assumes static models of which the Averch-Johnson is the most well know (Averch 1962). These models show rate-of-return regulation does not provide the incentive for the firm to minimize costs or capital investments. If the firm's growth is handled at all, it is through exponential models with time as the explanatory variable. Economic depreciation is treated exogenously. The dynamic models are deterministic, complete information growth models.

The literature on real-options research from the financial perspective is reviewed and integrated in Trigeorgis (1996), and from the economists' perspective covered extensively in Dixit and Pindyck (1994) or, for a briefer account, in their 1995 article (Dixit 1995). Dixit and Pindyck and other economists usually only look at the delay option. The finance literature is fuller in its coverage of the various aspects of all of the options available to a firm, for example Hull (2000) has an extensive coverage of options, as does Luenberger (1998). See Smith and Nau (1995) for the relationship between decision trees and real options

A limited literature exists in the applications of real options to telecommunications. Hausman has applied the real options methodology to examine the sunk cost of assets and the delay option in the context of unbundled network elements (UNEs) (Hausman 1999) (Hausman forthcoming). Ergas and Small (2000) have applied the real options methodology to examine the sunk cost of assets and the regulator's impact on the distribution of returns (Ergas 2000). They establish linkages between regulation, the value of the delay option and economic depreciation. Small (1998) studied investment under uncertain future demand and costs with the real options method.

REAL OPTIONS

WHAT ARE REAL OPTIONS?

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. With real options analysis, the idea is similar. The manager identifies options within a project and their exercise prices. If the future is good, the option is exercised; if the outlook is uncertain or bad, the option is not exercised. If the option is not exercised the only loss is the price of the option.

The real options analysis provides a means of capturing the flexibility of management to address uncertainties as they are resolved. Traditional capital budgeting fails to account for management's flexibility and, moreover, it fails to integrate strategic planning. The flexibility that management has includes options to defer, abandon, shutdown/restart, expand, contract, and switch use (see TABLE 1). This methodology forces the firm to assess its simple view of valuation to one that more closely matches the manner in which the firm operates. The use of real options lets the firm modify its actions after the state-of-nature has revealed itself. For example, if demand fails to meet expectations, the firm may chose to delay investment rather than proceed along their original business case. The deferral option is the one that is generally illustrated and is treated as analogous to a call option. But real options analysis can be applied to evaluation of other management alternatives, for example shutdown and restart, time-to-build, or extend the life of a project or enterprise.

TABLE 1: Description of Options

Option	Description
Defer	To wait to determine if a "good" state-of-nature obtains
Abandon	To obtain salvage value or opportunity cost of the asset
Shutdown & restart	To wait for a "good" state-of-nature and re-enter
Time-to-build	To delay or default on project – a compound option
Contract	To reduce operations if state-of-nature is worse than expected
Switch	To use alternative technologies depending on input prices
Expand	To expand if state-of-nature is better than expected
Growth	To take advantage of future, interrelated opportunities

Real options methodologies can take the best features of DCF and decision tree analysis without their failings. As we will show, the real options method can make a significant difference in the valuation; however, a simple linear addition to the valuation of a traditional discounted cash flow analysis cannot correct for the real options impact. Real options expands the notion of manager's flexibility and strategic interaction in skewing the results of the traditional DCF analysis which, as with financial options, allows for gains on the upside, and minimizes the downside potential; thus changing the valuation.

ANALYSIS

ASSUMPTIONS AND MODEL

To explain the application of real options to model regulatory distortions, the following stylized assumptions are made.

Cash flows shifts each period based on a probability – the cash flow is high (a good result) with probability of q or low (a bad result) with probability of $(1-q)$. The model is for two periods and the intertemporal cross-elasticities of demand are assumed to be zero. These simplifying assumptions are enough to capture the effects of time and uncertainty; it leads to an easy understanding of the methodology; and serves as a foundation of the more complex analysis. We explore only one facet of this simple, but not unrealistic assumption, that cash flows are uncertain. We will explore the role of management's flexibility in dealing with two uncertainties when management is constrained in its behavior by regulation: first by the obligations to serve and then with a regulatory constrain on prices. We contrast this with management's unconstrained actions. (This analysis is applicable only when the firm has freedom from other regulatory constraints, such as quality of service constraints. While this will not change the nature of the results, it may well change the magnitude of the options.)

Under the traditional engineering economics methodology, the value of the investment would be evaluated with an expected value of the discounted present value of the profit function. This requires, *inter alia*, the determination of the "correct" discount rate. To account for uncertainty the rate is adjusted for risk, generally using the capital asset pricing model (CAPM). In the regulatory context, this would be equivalent to the determination of the rate-of-return for the firm. In the rate base, rate-of-return regulation context, a "historical" year is chosen and the rate-of-return determined. Prospective costs and revenues are assumed to be estimated with the past and the historical year, representing the mean of that past. Before competition entered the telecommunications industry, discounted present value techniques were a useful analytical technique. The industry had stable, predictable revenues and cost, and hence, cash flow; but more recently, the industry has become volatile (Noam 2002) and (Alleman 2002a).

Our analysis differs from this present value approach in that it treats the investment and cash flow prospectively as a model in which an investment has two possible outcomes: a good result or a bad result. A simple binomial real option model can analyze the investment[2]. Viewed in this fashion, the question is: what is the investment worth with and without management flexibility? In addition to the cash flow constraint, we explore condition to delay in detail. We note other conditions in which regulation can have impact on valuations: abandonment, shutdown/restart and time-to-build options.

REGULATORY DISTORTION

The economist is concerned with the social welfare. The nominal purpose of regulation is to optimize social welfare and ensure that monopoly rents are eliminated from the firm's prices. This requires knowledge of economics cost and benefits. Generally benefits are measures by the consumers' surplus; economics cost are estimated by the firm's historical accounting costs. Both can be difficult to measure, but what we argue here is that not recognizing some costs, i.e., not knowing what to measure, means that the social welfare is distorted. The interaction of the regulation with valuation bears on welfare in several dimensions. First, unrecognized costs on the part of the regulator community means that the prices set by it will not be correct. Second, if the financial community recognizes that the regulatory is not accounting for all the costs of the enterprise, then it will be more expensive to raise debt and equity capital, which, in turn, will increase the cost in a vicious cycle, raising the cost to the consumers.

A major cost that has not been adequately identified or quantified is the obligation to serve. Under the current practice in most countries, whenever a customer demands service, the incumbent carriers are obligated to provide the service. It is part of the common carrier obligation. Most recently, the United States Congress has had legislation before it that would mandate that the telephone companies provide mandatory broadband service. This would not allow the firms to assess the market, determine the best time to enter and where best to enter. They would be on a specific time and geographic schedule. The firms have lost the option to delay. (We will examine broadband in greater detail below.) Moreover, if the customer proves unprofitable, the carrier still must retain this customer. Thus, they also lose their right or option to abandon the service. (The argument that the expansion of the network provides an external benefit – an externality – beyond the value of an additional subscriber may be an offset to this cost, but the externality argument is not compelling in the United States or any area that has significant penetration of telephone service, see Crandall and Waverman (1999).) Payphone service is another area that has not been quantified. As indicated earlier, telephone companies are unable to exit the payphone business. With the rapid increase in mobile telephones, the payphone service has seen a serious decline in its cash flow, but regulators would not let companies stop providing service, especially in markets where the regulator felt the population would not be well served without the payphones. Not surprisingly these were, generally, in low-income urban areas, which also turn out to be the areas of high maintenance cost for payphones. By not allowing the telephone companies to leave, the regulators denied the companies the abandonment option.

In these situations (broadband and payphones), the incumbent carriers are precluded from exercising the option to delay in the first case, and the option to abandon in the second case. A related option is the ability to shutdown and restart operations. This, too, is precluded under the regulatory franchise. Finally, the time-to-build option, which includes the ability to default in the middle of a project, would not be available in the current regulatory context. The lack of options has not been considered in the various cost models that have been utilized by the regulatory community for a variety of policy purposes. Clearly, the lack of these options imposes a cost to the firm and to society[3]. We use the deployment of DSL to illustrate the delay option, and then the learning option. We indicate how both may be quantified and suggest the parameters which are relevant for these options. We then discuss the shutdown/restart option and time-to-build option.

Telephone companies can have alternative strategies to those we enumerate herein including lobbying to change obligations, which the telephone companies have had limited success, legal challenges to the regulations – the recent Supreme Court decisions attest to this strategy, and ignoring their obligations until legally forced to so. The large fines incurred by the Bell companies demonstrate the success, at a cost of this tactic. While we recognize the value of these strategies, it is not our purpose to evaluate each of them in this paper, nor do we have the room to do so[4].

A simple example that shows how the traditional approach concludes that a project is a no-go money-loser, but real-options methodology suggests it's worth the risk. Assume a telephone company is planning to offer DSL in five of its exchanges, at an average cost of $675 a line (following Alleman 2002c). The average revenue for the service is expected to generate is $240, 320, and $400, respectively, in the three years of its life.

But instead of investing all at once to meet the demand, the manager attempts to have a better estimate the potential subscribers by first installing the service in only one central office. The question of whether to delay or expand an investment is precisely the kind of choice that's not handled well in traditional analysis. Each year, there are two possible outcomes: an increase or a decrease in value, assumed to be both equally likely.

Assume the firm has a discount rate of 20% as the expected return on all investments; any project that cannot deliver at that return cannot be approved. The total cash flow on the new service is more than its initial cost – $960 versus $675 investment. But considering the 20% discount rate, the discounted cash flow is negative. The new service does not look desirable. It is dropped.

TABLE 2: Discounted Cash Flow: DSL Service per Line

	Year			
	0	1	2	3
cash flow per line	– $675	$240	$320	$400
discount factor	1.000	.833	.694	.579
discounted cash flow	– $675	$200	$222	$231
discount rate: 20%				
DCF =	– $21			

But there's another way to look at this investment. The manager is not really adding the new service for its own three-year return, but as a trial to see if a complete rollout of the new service is in order. Here is where real-options analysis offers greater insight. Providing a single exchange with DSL today allows the firms to have the option to provide the other four central offices 12 months from now, if the returns continue to look promising in the environment that will exist.

How can this option be valued? Black and Scholes examined a method nearly 30 years ago for pricing financial options, and it's been much refined since then. See, for example (Nembhard 2000), for various methods and techniques to solve thes e real options problems.

While the technique is not perfect, it also can be applied to physical or real assets. To understand the intuition of the method, consider the stock-option comparison. Three things influence the price of stock options: the spread between the current and the exercise price, the length of time for which the option is good, and the volatility of the stock in question. The current price of the asset is known, and the exercise price at which the stock can be purchased sometime in the future is set. The greater the difference between the two, the lower the options price because only a great change in the market will make the stock's value climb above the exercise price and pay off for the owner. And big shifts are less likely than small ones. The date at which the option expires also is a factor. The longer the option lasts, the greater the chance that the stock will overshoot the exercise price, and that the owner will make a profit. So, the price is higher. Finally, the volatility of the stock price over time influences the option price. The greater the volatility, the higher the price of the option, because it's more likely the price will move above the exercise price and the owner will be in the money. Black and Scholes consider these factors to solve the problem of pricing the option. We use their formula to address the DSL example. The price of the "stock" in the DSL example is the discounted value of the cash flow one year later at the risk free rate, under the assumption of perfect correlation between future cash flows. The value of each central office is the discounted value of its future cash flow: $864. The exercise price of this option is the cost of providing DSL, $675 per line. The option expires in one year. Assume that the volatility is measured by the standard deviation. If one assumes this is 40%, and the risk-free interest rate is 5%, we have the necessary information to price this alternative. Using the Black-Scholes method, the value of the alternative is $261. Thus, the project looks worth doing. Note that the value of this option is driven by the volatility; the more certain the cash flow, the less valuable the real options method will be because the uncertainty creates the value.

This example shows one other important attribute of real options as opposed to the traditional discounted cash-flow analysis. In discounted cash-flow analysis, increased risk is handled by increasing the discount rate; the more risk, the higher the return the company has to earn as a reward for investing. This has the effect of decreasing the value of the cash flow in later periods. Thus, uncertainty reduces the value. But in a real-options approach, the value would be increased, because managers have the flexibility to delay or expand the project – as shown in FIGURE 1, the greater the uncertainty, the greater the value.

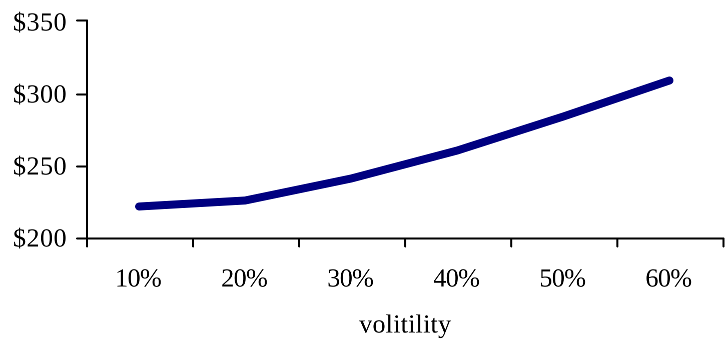


FIGURE 1: Option Price as a Function of Volatility

DELAY DISTORTION, OBLIGATION TO SERVE

Consider the following two-period model in which an investment will have two possible outcomes: a "good" result, V^+, or a "bad" result, V^-, with the probability of q and $(1 - q)$, respectively.

Under traditional practices, this would be evaluated by the expected value of the discounted cash flow of the two outcomes. More recent investment analysis suggests it can be valued with the options pricing methods using Black-Scholes-Merton; Cox, Ross and Rubinstein or other techniques[5]. Many methods exist for solving this problem. The intuition is that delay has a value, since it allows the firm to have the state-of-nature revealed. Below we provide a numerical example to show the impact using the twin security approach.

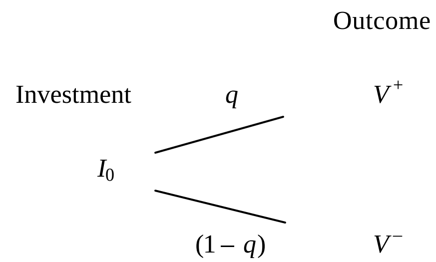


FIGURE 2: Two period binomial outcomes

Consider the following possible equally likely outcomes shown in FIGURE 2. If the good state occurs, it receives a net return of $100 (before discounting) whether it defers or not. If the firm can defer the investment and the bad state occurs, it does not have to invest. However, if it could not defer, its loss is $20. Clearly, deferral has a value.

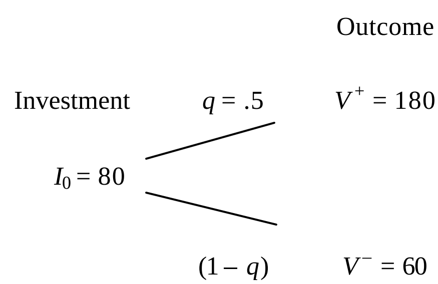


FIGURE 3: Two period binomial outcomes

If the discounted cash flow (DCF) was calculated in the traditional manner, assuming a risk adjusted interest rate of 20 percent, it would have a value of

$$\$ 20 \ (\text{DCF} = -I_0 + [(qV^+ + (1-q)V^-)/(1 + r_f)]).$$

TABLE 3: OUTCOMES WITH AND WITHOUT PRE-COMMITMENT

	Investment	Committed	Net	Deferred
V^+ "good state"	80	180	100	Max (96, 0) = 96
V^- "bad state"	80	60	–20	Max (–20, 0) = 0

As noted above, several methods are available to value this option. Using the twin security approach, we find a security that has the same pattern of outcome – that is it has the same characteristics as the investment. We then find the replicating portfolio that matches the outcome of the project of interest. The value of this portfolio is the value of the flexibility. The value of this flexibility to defer is equal to the difference between the traditional present value of the project and the value of this flexibility.

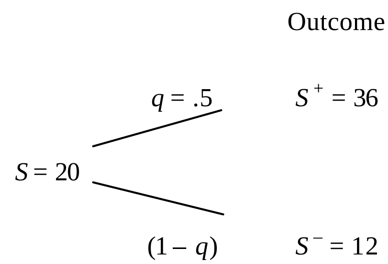


FIGURE 4: Twin security outcomes

Assuming a risk free rate of interest of five percent (5%), we find the twin portfolio which exactly replicates the outcome of deferring the project by solving the simultaneous equations system

$$mS^{+} - (1 + r_f)B = \$96, \text{ and,}$$
$$mS^{-} - (1 + r_f)B = \$\ 0.00.$$

Let B represent borrowing at the risk free rate and m represent the number of shares of the twin security, respectively. Given the parameter $S^{+} = \$36$, $S^{-} = \$12$, and $r_f = 5\%$, we can solve for B and m. These are, $B = \$31.33$ and $m = 2.82$ shares. The value of the option to delay is then $mS - B = \$34.29$. The options value to delay the project is the value of the twin portfolio less the traditional DCF, in this case \$34.29 – \$ 20 = \$14.29. Thus, the option to delay is very valuable. It improves the value of the service by over 71%.

The relevance in the regulatory context is that the regulated firm does not have the delay option available to it – it must supply the basic services as required by its franchise[6]. What is the cost of this inflexibility? It is the value of the option to delay!

DELAY DISTORTION, OBLIGATION TO SERVE WITH REGULATED CASH FLOW

The above analysis only captures the obligation to serve. Additional constraints are generally imposed by regulation. For example, there is often a constraint on earnings or on prices imposed using rate-of-return constraints on capital. Price caps represent a more flexible mode of regulation. In the first case, rate-of-return, a revenue ceiling is imposed on the firm based on operating costs and the rate-of-return on the un-depreciated investment. Because of the distortions noted previously, the regulators have turned to the second form of control, price caps (also called incentive regulation). Here the firm is allowed to change price by no more than a general price index[7]. We model this by constraining the "good" cash flow. The intuition is that the regulator sets the rate-of-return based on the total earnings (cash flow) of the investment based on the risk-adjusted cost of capital.

Using the above example, but capping the cash flow of the good outcome to be equal to the discounted cash flow equal to zero, we can emulate this process. The difference between the constrained and unconstrained cash flows for the delay option is 71 percent.

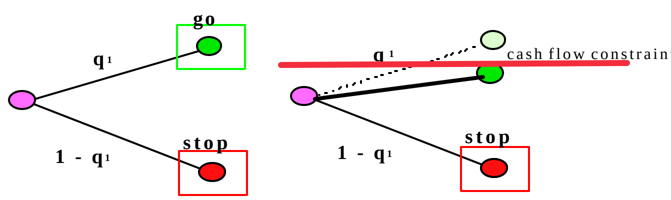


FIGURE 5: Unconstrained and Constrained Cash Flow

While we have not estimated the value of these options for telephone companies, we believe it can be significant. In general, the value of the flexibility will increase as the uncertainty about the future increases. The value of flexibility also increases when management has the ability to quickly respond to new information and circumstances (Ahnani 2000). For example, for telephone companies considering the faster deployment of DSL, one of the relevant parameters would be the scope of the existing infrastructure. Given the projected demand, how many customers are situated along an existing trunk route? To put another way, does meeting expected demand require the installation of new trucks (in addition to the loops)? Answers to these questions are critical to the valuation of the options facing the company.

DELAY OPTION ALTERNATIVES

Four possibilities exist with the delay option in the regulatory context:

- The unconstrained case – no constraints on cash flow and the ability to delay

- The constraint on cash flow, but the ability to delay
- The no constraint on cash flow, but inability to delay. And,
- The total constraint case – a constraint on cash flows and inability to delay

In this hypothetical case, the results are dramatic. Comparing the differences when the firm is unable to delay the service with the case in which the firm can delay can improve the result by 71 percent in the unconstrained case. When a constraint on cash flows is imposed, the delay option has a value of $28.57 or 26 percent of the "good" revenue in the constrained case when both scenarios allow delay. When the firm is constrained to earn its DCF at the risk adjusted rate – here the equivalent of setting the "good" cash flow such that the DCF is exactly equal to zero at the risk adjusted cost of capital – the only excess value is the delay option.

While this shows that cash flow constraints and the delay option have value, the results are only illustrative of the effect and must be applied to actual data.

TABLE 4: COMPARISON OF SCENARIOS

Scenario	Percentage :	Difference
Constrained *v*. unconstrained cash flow	Increase in *CF*	36.4%
No Delay versus Delay option	Increase in expanded *PV*	71.4%

That is, the cash flow constraint lowers the value of the service of the good cash flow by over 36 percent even when the delay option is available. (The detailed results are available from the authors.)

BROADBAND[8]

THE GROWTH TRENDS

The growth of broadband over the last few years has been phenomenal, as seen in FIGURE 6. Noteworthy is the head start of cable modem providers over DSL providers. Indeed, cable modem providers preceded DSL's deployment by several years. To what can we attribute to cable's head start? Better insight? Better managers? Luck? Or, as the ILECs contend, was it due to asymmetrical regulation? We first explore the possible telephone companies' strategies with respect to DSL[9].

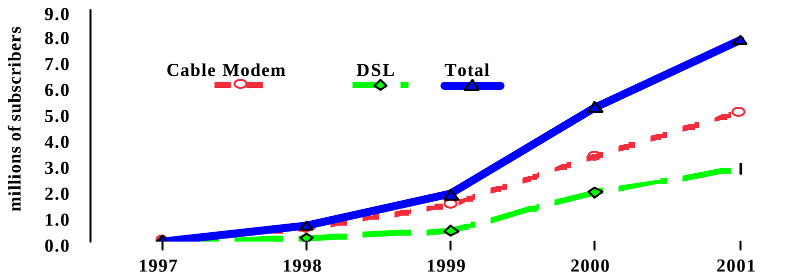


FIGURE 6: Cable Modem and DSL penetration

DSL VERSUS CABLE MODEMS

Data services have been available for decades – including the carriers' bulk offerings such as T1. The large corporate users have been purchasing these larger facilities offerings for some time[10]. Services that were directed to smaller businesses, most notably ISDN, were not as successful[11]. With this early capability and experience with data services for both large and smaller firms, why did the telephone companies get a later start on deploying DSL as compared with cable modem service? Several explanations can be conjectured:

- Concern they would cannibalize their data offering
- Concern they would have to share "their network" with the competitive local exchange carriers (CLECs),
- Poor management and lack of vision of the demand for the service, particularly the residential market for the service,
- Service was not fully developed, and
- Exercising "delay options" i.e., wait until the uncertainties are reduced.

We believe it was a combination of these concerns. Certainly, sharing was a concern, but sharing was compatible with the delay option. If one had no investments, one did not have to share those investments. Lack of competition would reinforce the value of the delay of DSL investments. The ILEC would not lose any first mover advantage, and not give up market share to a competitor. We conjecture that the ILECs had a strategy of delay – thus they evaluated the revenues and costs of delaying the deployment of DSL.

Delay had several advantages to the telcos. It did not cannibalize its other digital offerings. It had a high degree of uncertainty *vis-à-vis* the regulatory situation. Would the FCC require sharing of the DSL portion of the network, as it did with the traditional voice network? The ILECs were arguing that it should not share "new investment" with the CLECs (Tauke 2001). The CLECs did not have enough financial muscle to rollout an extensive facilities-based approach, although what DSL rollout the CLECs had could reduce the uncertainties of demand for the service without offering a significant competitive threat. Furthermore, delay gave the ILECs time to implement a regulatory/legislative strategy that might ensure that new investment in DSL would not be included in any sort of sharing arrangement. Thus, the structure was in place to exercise the delay option; that is to say, if the threat of sharing abated, the demand for the service was shown to be robust, and the regulatory strategy was in place, it could exercise its delay option. The exercise price was the cost of investment in DSL modems, DSLAMs in the central offices, training of technicians, etc. This is an "exercise" price to obtain an additional revenue source from the existing physical plant[12]. However, to initiate DSL service the incumbent has a fixed, irreversible (sunk) cost. This implies the delay option may be valuable.

The downside of this strategy is the loss of revenue from the new service while waiting, but this would be offset by not cannibalizing their other digital offerings. However, what was, apparently, unanticipated was the entry of another technology into the market place[13]. Nor, was the success of the Internet for the residential and small business customer accurately anticipated. This forced the ILECs to exercise their option or lose the market to the cable industry.

Fortunately for the ILECs, by the time the cable modem threat was recognized the CLECs were financially exhausted – bankrupt or nearly so, and did not pose a threat of intra-modal competition that they had earlier.

This hypothesis is consistent with the pattern of deployment seen in FIGURE 6. The ILECs' deployment of DSL occurred later than that of the cable industry. Only when the ILECs realized that there was sufficient demand available to support the service, and that the cable industry could capture much of it, did they mobilize to offer DSL service. Otherwise they would lose not only this new and emerging market, but also some of their other digital services to the cable modem market. Hence, the companies not only exercised the option, they expedited the rollout. The comparative rate of deployment is shown in FIGURE 6. ILECs, while still behind in penetration of the market – cable modems have approximately twice as many subscribers – are catching up quickly.

DELAY HYPOTHESIS

In order to test the delay hypothesis, we have examined data from two telephone companies – a Tier I company and a smaller Tier II company. Both companies are incumbent local exchange companies (ILECs). The Tier I company is large and closely regulated. The Tier I company faces competition from a cable company. The other company, a Tier II company, is not closely regulated; moreover, it does not face cable modem competition. Since the Tier II company does not face either severe regulatory constraints nor competitive threats regarding its deployment of DSL, we use the Tier II company as our base case. We have accurate cost and revenue data from this company. For the Tier I company, we have accurate monthly data on the residential lines, second lines, and DSL connection for nearly three years. Moreover, for the last month in the series, we know which of the Tier I exchanges faced cable modem competition. Approximately half of the exchanges did. We used public sources for prices of the Tier I services. For costs, we used Tier II numbers.

We selected the Tier II company as our base company since it had neither cable competition nor did it face strict regulatory oversight. The base case was constructed for the purpose of assessing the performance of the Tier I company. This is not to say that the Tier II company will not reexamine its delay options. They recognize that technological, demand and financial changes in this market are inevitable. However, management indicated it did consider the delay option in its current valuation analysis. The company did, however, embark on a year trial with a limited number of customers before adopting system wide deployment. The "[d]elay was due to a refinement in the technical solution. It was not delayed because of market demand." (ATC II 2002)

First, examining the Tier I company, we can see that two of our conjectures are upheld by the data. When normalizing the DSL rollout based on the percentage of lines in the exchange, it is clear from FIGURE 8 that if the company had cable modem competition, it initiated the DSL rollout sooner and with a faster rate.

To model this decision, we specified a logit model to analyze the growth in DSL penetration. We estimated two logit models. Time was used as a trend variable and the availability of cable as a dummy variable in the first model. The interaction of cable with trend was included to test for changes in the slope (growth rates) between cable and non-cable areas. In the second model, time squared was added as an explanatory trend variable. This term was included to reflect the fact that, after a certain point, growth is unlikely to be continually increasing.

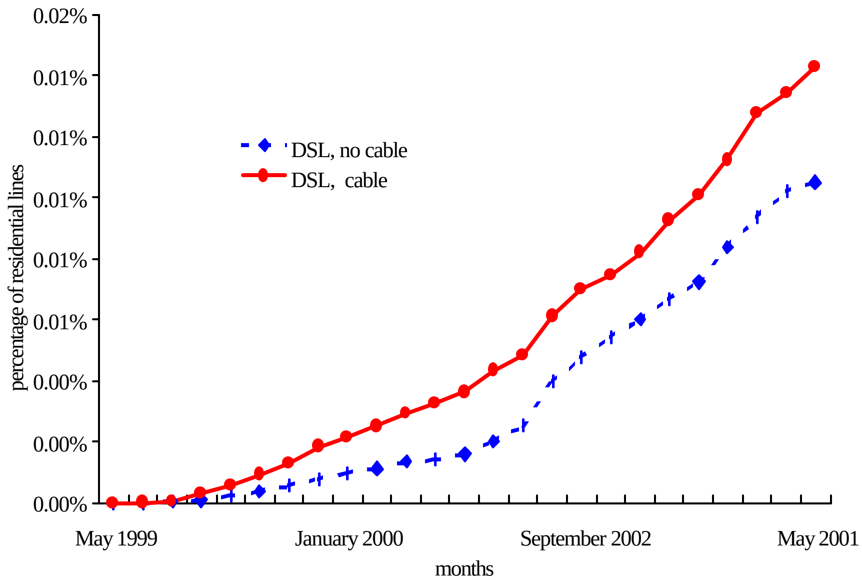


FIGURE 7**: DSL penetration with and without cable modem availability.**

DSL MODELS:

TABLE 5A: **DSL MODEL 1. MODEL SUMMARY**

R	.918
R Square	.842
Adjusted *R* Square	.831
Std. Error of the Estimate	.2901
Predictors: (Constant), *TCABLE*, *TREND*, *CABLE*	

TABLE 5B: **DSL MODEL 1. ANOVA (B)**

	Sum of Squares	*Df*	Mean Square	*F*	Sig.
Regression	19.346	3	6.449	76.640	.000
Residual	3.618	43	8.414E–02		
Total	22.964	46			
Predictors: (Constant), *TCABLE*, *TREND*, *CABLE*					
Dependent Variable: *dsl_logit*					

TABLE 5C: DSL MODEL 1. COEFFICIENTS (A)

	Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	*t*	Sig.
(Constant)	–4.468	.175		–25.545	.000
TREND	9.537E–02	.009	2.153	10.459	.000
CABLE	–2.397	.439	–1.714	–5.465	.000
TCABLE	–3.141E–03	.013	–.107	–.251	.803

Dependent Variable: *dsl_logit*

The model states that the penetration (probability) of DSL is a function of time (over time, everything else equal, DSL penetration rate will increase). Moreover, this penetration rate will be lower for those areas where there is cable modem service – note the negative signs for the indicator variable *CABLE* and for the interaction term – *TCABLE* (See figure 7). The slope of the DSL function is lower in the cable areas (*TCABLE* is negative). There is also an intercept shift (*CABLE* < 0) – suggesting that DSL service areas without cable modem competition are and will likely remain behind DSL service areas with cable modem competition. The interaction term, *TCABLE*, is statistically insignificant.

TABLE 6A: DSL MODEL 2. MODEL SUMMARY

R	.969 (a)
R Square	.940
Adjusted *R* Square	.934
Std. Error of the Estimate	.1813

a Predictors: (Constant), *TCABLE*, *TREND*, *CABLE*, *TREND* 2

TABLE 6B: DSL MODEL 2. ANOVA (B)

	Sum of Squares	*Df*	Mean Square	*F*	Sig.
Regression	21.584	4	5.396	164.206	.000 (a)
Residual	1.380	42	3.286E–02		
Total	22.964	46			

a Predictors: (Constant), *TCABLE*, *TREND*, *CABLE*, *TREND* 2

b Dependent Variable: *dsl_logit*

TABLE 6C: DSL MODEL 2. COEFFICIENTS (A)

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	*t*	Sig.
(Constant)	–5.956	.211		–28.251	.000
CABLE	–12.143	1.212	–8.684	–10.016	.000
TREND	.287	.024	6.471	12.009	.000
*TREND*2	–5.313E–03	.001	–7.933	–8.253	.000
TCABLE	–.300	.038	–10.190	–7.988	.803
Dependent Variable: *dsl_logit*					

This model differs only by the addition of a nonlinear trend term (trend squared). The variables in the second model are all statistically significant.

This specification supports the notion that at some point, the increase in DSL (trend) slows (the negative coefficient for *TREND*2). As with Model I, *CABLE* and *TCABLE* enter with negative signs. In this model, both terms are statistically significant suggesting that growth rates of DSL in areas also served by cable companies are lower. The intercept shift (*CABLE* < 0) – suggesting that DSL service areas without cable modem competition is and will likely remain behind DSL service areas with cable modem competition, as in Model 1.

The overall fit and statistical significance of both models and especially Model 2, is not eworthy.

DSL BASE CASE

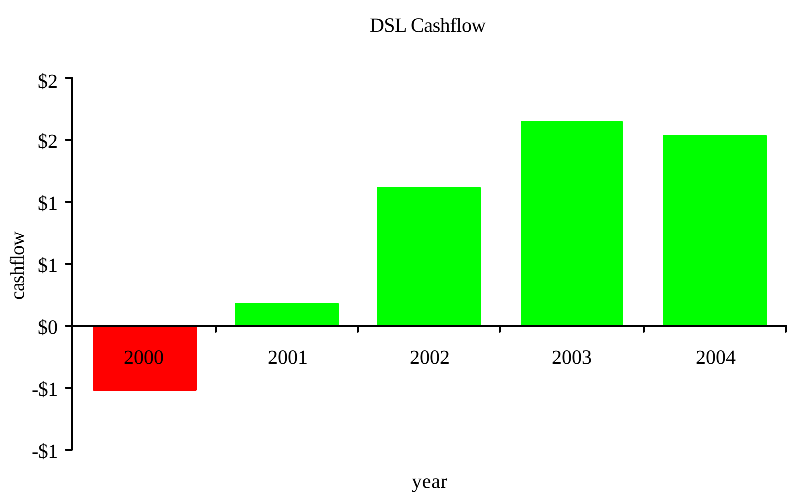
Based on the Tier II company's data, the investment per line for DSL could be as high as $1,600. Using reasonable assumptions, namely, that the monthly rental is $40, the firms requires a return of 20 percent and the service lasts for four years, the traditional net present value of this new service is negative, as seen in the TABLE 6 below.

TABLE 6. DSL Present Value (estimated per line)

Description	Value
Monthly rental charge	$45
Initial investment	$1600
Discount rate	20%
Asset life (months)	48
Net discounted present value	($138)

Sensitivity analysis shows that it can vary form positive to negative. This does not account for the aforementioned uncertainties, particularly the problem of network sharing and regulatory constraints.

FIGURE 8 shows the pattern of rollout of the DSL base case (ATC II 2002)[14]. ATC II is chosen as the base case because it does not have cable service competition, nor does it have extensive data services to cannibalize. As a Tier II carrier, it is not pervasively regulated. The traditional discount ed present value analysis of the DSL rollout is significant. The company's internal rate of return is nearly thirty percent, using conservative estimates. If this magnitude of return would accrue to the Tier I ILEC without the concern of cannibalization and regulation, it is hard to imagine that they would not make the required investment. The comparison of the Tier II internal rate of return to that of the Tier I company provides a metric or benchmark by which to calibrate the social cost of regulation. But before addressing this issue, we also note that this DSL investment can be viewed as an option to learn. The future revenue streams occur with some uncertainty. This can be modelled as a learning option[15]. An initial investment "tests the waters" as to the robustness of the demand. If it proves strong, then exercise the option and continue to invest.



Source: ATC II 2002

FIGURE 8: DSL Cash Flow

While the Tier II carrier shows a strong case for DSL deployment, the case for DSL deployment is weak for the Tier I company. Our analysis suggests that for the first three years, the discounted cash flow is negative. A positive net discounted present value occurs only in the fourth year. Seen from this perspective, it is not clear whether DSL service, as currently configured, will be viable. Under a traditional DCF analysis, this project would not be undertaken. However, if we treat the service as a series of options, then the value of the project is more encouraging. Investing now allows the firm to "learn" if the environment is viable. One strategy for the firm is to re-evaluate its option to continue to invest in the project each year. Under the assumption used in our model, the sunk cost of investment for the next year takes place at the beginning of the year. Hence, this yearly investment can be thought of as the exercise price on an option on the stream of earning resulting from this investment. These options values increase the value significantly. That is, at the end of the first year, the firm can determine whether to invest the money to expand the service to more customers. And, if conditions remain favorable, the firm can continue its investment in the second year and so forth.

Notice that we value these options as a sequence. Investing in the first year allows the opportunity to invest in the second year. We value these rights as call options using the Black-Scholes formula for each year. The results are show in TABLE 9. As expected, the service viewed through the options perspective is more valuable, since it takes account of the fact that management could kill the project if the economic environment does not turn out as expected.

It is interesting to note that the normalized (based on the number of connections at the end of the year in question) difference between valuations with the presence of cable and no cable competition are lower in the cable case. This suggests, once again, that the presence of cable has an impact on the demand for DSL. It has dampened the demand, and hence the return to the service is reduced.

TABLE 9: DSL EXPANDED PRESENT VALUE
(PRESENT VALUE PLUS OPTION VALUE)

Description (normalized to connects	No Cable	Cable
Present Value (first year)	– $ 280	– $ 270
Present Value plus one year option	– $ 255	– $ 185
Present Value plus two year options	$ 114	$ 135
Present Value plus three year options	$ 267	$ 193

SUMMARY

We have shown that the introduction of uncertainty can make a significant difference in the valuation of a project. This manifests itself, *inter alia*, in the manner in which regulatory constraints can affect the value of the investment. In particular, the inability to exercise the delay, abandon, start/stop, and time-to-build options has an economic and social cost. Moreover, we show that regulatory constraints in cash flow have an impact on investment valuations.

Regulators and policymakers cannot afford to ignore the implications and methods developed by real options analysis. Effective policy dealing with costs cannot be made without a fundamental understanding of the implications of real options theory.

The real options approach is a powerful tool to be used to address the effect of uncertainty on regulatory policy. Real options methodology offers the possibility to integrate major analytical methods into a coherent framework that more closely approximates the dynamics of the firm's behavior without heroic assumptions regarding the dynamics of the environment.

FUTURE RESEARCH

We plan to expand our analysis to multi-period and continuous models of the regulatory distortion. We will also attempt to empirically estimate the magnitude of the delay and other options.

Another area we feel would be fruitful to explore is the issue of economic depreciation with these models. Clearly, (economic) depreciation is determined, *inter alia*, by the price the asset commands in the market (Hotelling 1925) and (Salinger 1998)). In contrast to others, we allow uncertain demand to set the optimal capacity path. Rather than assuming a user cost-of-capital, we can assume economic depreciation is determined endogenously by the demand function.

In addition, we plan to model dynamic Ramsey pricing under uncertainty. The approach will utilize the option principles to value real assets and allow for the recovery of options cost as well as classical investment and operating costs.

ENDNOTES

[1] This is true in the United States and Japan. The authors have not investigated it in other countries.

[2] The simplicity of the model should not mis-lead the reader. The two period model can be expanded into an n-period model. Cox, Ross, and Rubinstein (1979) show how to solve these models and how, in the limit, the results converge to the Black-Scholes option pricing result.

[3] This is not to imply that these public policies be abandon, but in order to weigh the policy alternatives, their costs must be understood.

[4] As an anonymous referee pointed out, the telephone companies can have alternative strategies to those we enumerate herein including lobbying to change obligations, which the telephone companies have had limited success, legal challenges to the regulations – the recent Supreme Court decisions attest to this strategy, and ignoring their obligations until legally forced to so. The large fines incurred by the Bell companies demonstrate the success, at a cost of this tactic. While we recognize the value of these strategies, it is not our purpose to evaluate each of them in this paper, nor do we have the room to do so.

[5] Dixit and Pindyck (1994) develop an example using traditional methods but account for the ability to delay the decision.

[6] The exception of discretionary services such as DSL has already been noted.

[7] Usually a productivity factor is included in the calculation, which limits the increase in the price increase. See Laffont and Tirole (2000) for a discussion of incentive regulation in the telecommunications industry. See Kahn (1998) for a history of regulation under traditional rate-base, rate-of-return regulation.

[8] This case is based on actual telephone companies. However, for confidentiality we have changed identifying information (data with authors). Hereafter referred to Anonymous Telephone Company I (ATC I) or II (ATC II) for the Tier I and Tier II company, respectively.

[9] We use the term 'telephone company', 'telecom', and 'Incumbent Local Exchange Carrier' (ILEC) interchangeably. The term Competitive Local Exchange Carrier (CLEC) refers to a competitor to the ILECs. The Digital Local Exchange Carrier (DLEC) refers to a (CLEC) which provides digital service to its customers as opposed to the tradition telephone service.

[10] These bulk services allowed the larger users to avoid the cross-subsidies associated with the small business services and residential long distance users support of exchange access (Universal Service).

[11] ISDN was a strategy that the world's telecoms had their hopes on, but it never succeeded. One reason for the lack of success of ISDN was the high price (relative to DSL), but, unlike DSL, the total phone system had to be replaced with a digital system.

[12] One estimate of the investment cost per subscriber (the strike price) is between $500 and over a $1,000 (ATC II 2002).

[13] Perhaps, even other competitors, e.g. Covad, Northpoint, and Rhythms, in the digital local exchange carriers (DLEC) market. We do not have the data to address this area.
[14] ATC II (2002) data
[15] See Alleman (2002b).

ACKNOWLEDGEMENTS

The author would like to thank Larry Darby, Alain deFontenay, Gary Madden, Eli Noam, Michael Noll, Scott Savage, and Chris Schlegel for useful comments and discussion of the ideas developed in this paper. An anonymous referee provided valuable comments, as well. Of course, the usual disclaimer applies.

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