

**Real Options and the Regulation of Brazilian Fixed-Line Telephone Operators:
The Markup on the Cost of Capital^{*}**

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Abstract

This study argues in favor of the *real option* methodology to calculate the access price for Brazilian fixed-line phone operators. The new cost-oriented regulatory framework for interconnection of telecommunication networks, established in 2005, poses questions regarding the adequate remuneration of investments. By investing in a fixed-line telephone network while giving access to new entrants, the incumbent is actually providing an option to access its infrastructure. Since options aren't costless, to properly compensate the investment, an effort to estimate the option premium is justified. We suggest a pragmatic approach where the real options rationality appears as a markup over the sector's cost of capital. Failing to consider the real option granted by incumbents discourages investment in infrastructure in the sector and hinders the intertemporal maximization of social welfare.

Key words: Real options, access price, Brazilian fixed-line telephone service, interconnection tariffs.

JEL: L51, L96, G13

1. Introduction

The regulatory framework for the telecommunications sector in Brazil is undergoing important changes. On the heels of Decree 4733, issued in 2003, and the end of the original concession contracts for landline operators in 2005¹, numerous directives and other measures have been established aiming to create competition, especially in the traditionally concentrated local fixed telephone market.

One of the main objectives of regulatory policies to stimulate competition is to ensure results in regulated sectors as near as possible to those that would prevail in a competitive market. In other words, policies to spur competition seek moderate tariffs and efficient results from the technical, allocative or dynamic standpoint. But much more attention has been paid to keeping tariffs low than to the question of efficiency, particularly regarding dynamic efficiency, that is, the pattern of investments in infrastructure and innovation. In a sector like telecommunications, which is subject to such dynamic technological transformations, this imbalance is a serious error.

The mechanisms put forward to ensure competition are many and have been the subject of intense academic and practical debate in recent decades. Specifically regarding the local fixed telephone sector in Brazil, new rules have been proposed for setting public and interconnection tariffs, such as disaggregating networks and providing portability of telephone numbers.

In this article we start from the premise of the new cost-oriented regulatory framework for interconnection of telephone networks brought by Anatel Resolution 396, issued in 2005. This policy poses serious questions regarding the adequate remuneration of investments. By investing in a fixed-line telephone network while giving access to new entrants, the incumbent is actually providing an *option* to access its infrastructure.

This work follows the recent literature on sectorial regulation and consists of establishing – based on real options theory, a well-known methodology in the field of finance – a markup over the sector's cost of capital as a pragmatic way to consider the *option* to access the network granted by incumbents to new players. This

¹ The telecommunications sector was privatized in 1998, with the Brazilian government auctioning off its controlling interests in long distance and local service providers, along with concessions to the new regional fixed and mobile operators. A regulator, the National Telecommunications Agency (Anatel), was also created.

discussion has strong practical bearing and is much in evidence in the various public consultations of several regulatory agencies, such as England's Office of Communications (Ofcom), America's Federal Communications Commission (FCC) and the Australian Competition and Consumer Commission (ACCC).

The study innovates in the sense of incorporating the impact of technological paradigm shifts on the economic results of fixed telephone operators.

Failing to consider the markup means the incumbent will be remunerated below its opportunity cost, which will inevitably discourage investments in infrastructure in the sector and consequently reduce both the dynamic efficiency of the policy adopted to stimulate competition and the social welfare generated by these services.

The article is divided into four sections, followed by a conclusion with future recommendations. Section 2 presents a review of the literature to situate the reader within the academic debate and discusses the legal and regulatory framework to contextualize the work's importance to the practical debate still ongoing. Section 3 supplies important insights on the role of new technologies and how they can affect the fixed telephone business. Section 4 presents the real option model and discusses the robustness of the results in relation to the sensitivity to parameter changes. The last section presents our conclusions and a public policy suggestion.

2. Literature Review

In recent decades the theory of regulation has been concerned with determining the optimal rule for prices in sectors with natural monopoly characteristics².

The question becomes even more complex in network industries, to the extent that reforms advance in the direction of regulation by incentives, deregulation and other measures to stimulate competition. Vogelsang (2002) offers an interesting analysis of the performance of regulation with incentives in the past 20 years. According to the author, in the case of network industries, the opening of access to the incumbent's network and its correct pricing can play a fundamental role in the efficiency of the regulatory apparatus and the maximization of social welfare³.

² Viscusi et al. (1996) offer an ample and detailed discussion of the theme.

³ The literature on access prices is more recent, among which we can mention Laffont and Tirole (1993, 1994), Armstrong, Doyle and Vickers (1996) and Vogelsang (2003). Haucap and Dewenter (2006) offer a more complete and integrated view of the literature. Specifically

In parallel to the discussion of access prices and competition, another debate has arisen regarding access prices and investment, particularly in fixed local telephone services, a sector that in many countries is facing a new wave of cost-based regulation. The basic question lies in the correct incentives for investments offered to regulated firms, that is, "*are regulators, even if based on a forward-looking approach, supplying the correct incentives for investment and dynamic efficiency?*"

Works such as Sidak and Spulber (1997), Valletti and Estache (1998), Gans and Williams (1999), Jorde, Sidak and Teece (2000), Gans (2001), Mandy and Sharkey (2003), Kotakorpi (2004) and Hori and Mizuno (2006) address the various aspects of the theme. Based on a variety of arguments, they reach a *positive* conclusion about the need to establish a markup on the forward-looking costs to stimulate investment⁴. The hypothesis adopted in this work converges to the same conclusion except by following another line of research. We rely on the *real options* methodology to establish the markup on the incumbent's long-term forward-looking costs. This markup serves to remunerate the access provided to a new entrant, allowing correct decisions to invest in network infrastructure in a scenario of large and irreversible sunk costs and high uncertainty about future demand.

The theory of options originated with the seminal works of Black and Scholes (1973) and Merton (1973), and was subsequently applied to real investments in pioneering studies such as Tourinho (1979), Myers (1984), Mason and Merton (1985), Brennan and Schwartz (1985), McDonald and Siegel (1986), Majd and Pindyck (1987), Kester (1988) and Paddock, Siegel and Smith (1988), among others⁵. Basically, the value (premium) of an option is the worth of the right to buy or sell a share (a call or put option, respectively), by a pre-established price (the strike price) until a certain date (the expiration time). Real options methodology consists of using the established tool of financial options to quantify the value of investments that encompass a series of flexibilities (options). This technique helps to reach decisions in certain projects in which the traditional cash flow method is not efficient.

regarding the telecommunications sector, the discussion of access pricing is well summarized in Laffont and Tirole (2000) and Armstrong (2002).

⁴ The most detailed discussion of this subject can be found in Bragança (2005).

⁵ Dixit and Pindyck (1994) and Trigeorgis (1996) are the classic references on the theme.

The question of real options has been directly related to regulation of tariffs and return on capital in regulated sectors since the works of Salinger (1998), Small and Ergas (1999), Alleman and Noam (1999) and Hausman (1999). These authors pointed out that investments will be discouraged when failing to consider the value of the options in determining tariffs or prices based on costs. More recent studies, such as Holms (2000), Hausman and Myers (2002), Clark and Easaw (2003), Dobbs (2004), Pindyck (2004, 2005) and Evans and Guthrie (2006), have sought to refine the models by adding different elements to the stochastic processes that underpin them. This study is based on those of Pindyck (2004, 2005), which introduced the pragmatic concept of the markup on the weighted average cost of capital (WACC) of operators to cope with the option rationality. We additionally simulate the possibility of new technological paradigms, which cause negative jumps in market demand.

3. Technological Aspects of the Sector

The forms of interconnection we know today, regulated or not, are based on traffic between networks, associated with the provision of some type of service. The adoption of new technologies defines the infrastructures used as well as the range of services enabled. New technologies also can result in new business models and change the rules on competition and investment, even in the apparently consolidated fixed-line telephone business.

Therefore, an understanding of the possible technological developments is essential to model the option premium, especially the component related to technological shocks.

3.1. Technology Trends

The evolution forecast in the area of telecommunication technology can be classified into three trends: i) growth of data traffic, ii) development of network architectures; and iii) offer of new services resulting from new technologies. These involve new forms of interconnection as well as changes in the rules on which the regulated forms of interconnection are currently based.

3.1.1 Growth of Data Traffic

Data traffic has been growing briskly, while purely voice traffic has been declining. The accelerated growth of data traffic is being driven by the spread of Internet access

and of private corporate data networks. Another tendency is the substitution of voice by data traffic, with the adoption of Voice over Internet Protocol (VoIP). Expectations are that new services will become available for both voice and data traffic, promoting their convergence.

The evolution of data traffic depends on a series of factors, such as the technology available, the penetration of access networks and the development of new services based on data traffic. Among these, the development of IP telephony, next generation networks (NGNs) and wireless broadband access will be the leading determinants of the expansion of data traffic.

3.1.2 Evolution of Network Architectures

The forms of interconnection and the respective regulatory frameworks are based on interfaces between network architectures according to the type of traffic (fixed-mobile, for example). Nevertheless, both the traffic and architecture characteristics are expected to change substantially in the foreseeable future, making current regulatory models ineffective.

Many of the technologies that will play important roles in this evolution of networks already exist, although they do not yet represent a significant portion of telecommunications traffic. The most relevant developments in network architectures identified regarding interconnection are NGNs, Wi-Fi, 3G and Wimax. There is a reasonable consensus that these new technologies will play leading roles in the local fixed telephone market. A closer examination of these technologies can supply important indicators of the magnitude of the parameters incorporated in the model.

3.1.3 New Services

The evolution of networks and the increase in data traffic permit offering a greater variety of telecommunications services. The trend is one of convergence of data and voice traffic in the direction of multimedia services.

3.2 Technological Shocks

The technologies considered most relevant in determining where fixed telephony is headed are NGNs, VoIP, Wi-Fi / Wimax networks and 3G networks. As an example, below we look briefly at the prognosis for Wi-Fi / Wimax networks, which are one of the main threats to the local fixed telephone business model in the medium term.

3.2.1. Wi-Fi / Wimax

The Wi-Fi technology is based on wireless networks for high-speed data transmission⁶. Wi-Fi permits wireless access to a data network from a fixed connection point. Because it provides high-speed data access, Wi-Fi can enable a greater supply of data services, aimed at a specific market segment, characterized by the need for mobility.

A more powerful version of Wi-Fi, Wimax has been gaining importance. There are two types of Wimax: fixed and mobile. Fixed Wimax⁷ provides users with Internet access from a notebook anywhere, for example, within a radius of 50 kilometers of an antenna or radio base station (RBS). In contrast, mobile Wimax⁸ permits Internet access even while moving, at speed up to 100 Km/h, by switching signals between antennas.

The medium-term impacts of Wimax technology on the revenue flows of fixed local telephone companies may well be significant. According to a study by Frost & Sullivan (2006) evaluating the impacts of implementing Wimax in Brazil, the adoption of this technology can reduce traditional local traffic measured in pulses (minutes starting in 2007)⁹ by at least 10% to 15% a year¹⁰.

⁶ Obeying the 802.11 standard from the Institute of Electric and Electronics Engineers (IEEE).

⁷ IEEE 802.16d standard.

⁸ IEEE 802.16e standard.

⁹ One "pulse" is charged as soon as the call is answered, and another one, dubbed random, is charged sometime in the next four minutes of the call. The others are charged at the rate of four every four minutes after the random pulse. In this way, a user who talks for one minute will be charged for at least one pulse, and will have a 25% chance of being charged for another (1 min/4min = 0.25). In reduced-rate periods (normally from midnight to 6:00 a.m.), only one pulse is charged, regardless of the calling time. The new billing method measured in minutes is purely based on time. The tariff unit will be a tenth of a minute (six seconds), with a minimum billing time of 30 seconds. In reduced-rate periods, as before, the charge will be per call answered, regardless of duration.

¹⁰ The integral adoption of Wimax (3.5 and 10.5 Ghz) technologies started to be defined by Anatel for an auction originally scheduled to take place in the second half of 2006. But lawsuits and errors in the bid invitation, indicated by the Federal Accounts Tribunal, forced its

4. Real Option Model

By investing in a fixed line telephone network, a landline operator deals with several features, such as the magnitude of sunk costs, uncertainty of demand, unpredictable technological shocks, flexibility of delay and competitive erosion. Such characteristics have intrinsic links to the option pricing literature, where the rational investor demands a premium above the sunk cost to commit in any investment. Roughly speaking, the more the uncertainty, the higher the premium requested.

Regarding the Brazilian fixed telephone system, according to the current regulation the incumbent must provide unfettered access to its infrastructure to new entrants. Therefore, by incurring in the investment, the landline operator is actually providing an *option* to access its network.

Having in mind the economic reasoning that options are not costless and interconnection price are defined by the regulator and not by incumbents, the regulator should attempt to consider the option as an *effective cost* incurred by the fixed operators when establishing the proper tariffs, i.e., the access price.

However, despite the theoretical debate on estimating the interconnection price, the new regulatory orientation points to a tariff policy based on long-run incremental costs (LRIC). LRIC consist mainly (particularly in the local fixed segment) of the sunk costs and the corresponding return on capital employed or invested.

We argue that the economic reasoning of option pricing is not being addressed, and an effort to estimate the option premium is required in order to adequately remunerate the operator, providing economic incentives to supply both the magnitude and trajectory of local network infrastructure investments that would occur in a competitive environment. In short, the regulator should enforce dynamic efficiency without harming the objectives of encouraging competition.

cancellation. The new auction is now scheduled for the second half of 2007. The entry price for this technology is still very high by Brazilian standards (around US\$ 500.00 per access line), which can slow this rate of decline of traditional local traffic measured in pulses. Additionally, the inclusion of incumbent fixed providers in the auction for Wimax frequency spectrum by court order (albeit still subject to appeals) might simply mean the substitution of local pulses by switching and transport of packets via the incumbents' local and Wi-Fi networks, meaning maintenance or even gain of revenues.

A markup on the cost of capital (i.e. the weighted average cost of capital – WACC) of the Brazilian telephone sector is a pragmatic approach to cope with the economic rationality of option pricing.

Let P^* be the interconnection price corrected by the access option f granted by the incumbent in undertaking the investment, and P be the usual LRIC without considering any options adjustments. The appropriated tariff P^* that compensates the operator can be represented by the following equation, which considers the access option f as an *additional sunk cost* incurred by the operator:

$$P^* = P + f \quad (2)$$

We adopt a similar criterion as Pindyck (2004, 2005), where the usual interconnection price P refers to the investment cost k reimbursed for its capital cost through a WACC (ρ) based annuity payment, over lifetime T of the facility.

$$P = \left(\frac{\rho \cdot (1 + \rho)^T}{(1 + \rho)^T - 1} \right) k \quad (3)$$

Since the WACC is closely related to the risks and characteristics of the sector under analysis, namely fixed local telephony, we assume that the WACC estimated by the regulator in the tariff revision process is valid for establishing the interconnection tariff based on the LRIC.

By using Eq. (2) and Eq. (3), the corrected tariff P^* can be written as a function of the adjusted cost of capital WACC (ρ^*). This corrected WACC (ρ^*) is a pragmatic way to cope with the rationality of real options, and can be viewed as a markup over the cost of capital of the sector.

$$P^* = \left(\frac{\rho^* \cdot (1 + \rho^*)^T}{(1 + \rho^*)^T - 1} \right) k = \left(\frac{\rho \cdot (1 + \rho)^T}{(1 + \rho)^T - 1} \right) (k + f) \quad (4)$$

Therefore, the problem resumes in determining f , the option premium for access. Access is granted at the time the investment is incurred. Therefore the option must be estimated at the moment of its optimal exercise. The option premium calculation is shown in the next section.

4.1 The Investment Opportunity

Consider an operator with significant market power, which holds an investment opportunity f (option) to invest in a fixed-line phone network. The sunk cost k of the investment equals the strike price of the option. Each line produces annual cash flows during a lifetime of T years. The present value V of these cash streams corresponds to the current value of the project, the underlying asset of the option.

We assume that V follows the Merton jump-diffusion type model¹¹, where α is the expected return of the project over an infinitesimal time dt , λ is the frequency of the jump process, ϕ is the percentage magnitude of the jump, dz is the Wiener process¹² and dq is the Poisson increment, with $dq \cdot dz = 0$.

$$\frac{dV}{V} = (\alpha - \lambda\phi)dt + \sigma dz + dq \quad (5)$$

Eq.(5) states that most of the time the value of the project evolves continuously according to a Brownian diffusion process (second term of Eq.(5)), while allowing for the probability of unpredictable and discrete variations, i.e. jumps (last term of Eq.(5)). When a jump occurs, the project increases ($\phi > 0$) or decreases ($\phi < 0$) its value by ϕ percent.

The reasoning of the jump-diffusion model is to capture some well-known stylized facts of the telecommunications sector, especially of the fixed-line phone system, such as technological shocks with negative impact on the value of the project that could even alter the economic feasibility of the whole investment.

We assume that the jump term is idiosyncratic, representing only unsystematic risks, that is, sector-specific risks, which can be eliminated through a diversification strategy. Options theory permits rewriting Eq.(5) in the risk-neutral measure of Eq.(6), replacing the expected rate of return α by the difference between the risk-free rate r and the opportunity cost δ of the option (equivalent to a convenience or dividend yield):

$$\frac{dV}{V} = (r - \delta - \lambda\phi)dt + \sigma dz + dq \quad (6)$$

¹¹ Merton (1976).

¹² A Wiener process, also known as Brownian motion, has three classic properties. It is a Markovian process, with independent increments, where changes in the process in a finite interval follow a normal distribution with variance that increases linearly with time.

The opportunity cost of an option consists by the cost of holding the option instead of the project itself. This cost represents losses by competitive erosion, costs for keeping the option “alive”, or even the cash flows generated by the project not received by the option holder. By using the same argument presented by Dixit and Pindyck (1994), the opportunity cost can be written as the difference between the project’s cost of capital ρ and the project’s expected growth rate α , so that $\delta = \rho - \alpha > 0$.

The investment opportunity $f(V)$ corresponds to a perpetual call option that can be exercised at any moment by paying the strike price k . The dynamic of the option is given by the following partial differential equation:

$$\frac{1}{2}\sigma^2V^2f_{VV}(V) + (r - \delta - \lambda\phi)Vf_V(V) - (r + \lambda)f(V) + \lambda f[(1 + \phi)V] = 0 \quad (7)$$

subject to the standard boundary conditions:

$$f(0) = 0 \quad (8)$$

$$f(V^*) = V^* - k \quad (9)$$

$$f_V(V^*) = 1 \quad (10)$$

Eq.(8) is usual in the continuous Brownian process, Eq.(9) represents the value-matching condition where the option is exercised by paying the strike price, and Eq.(10) is the smooth-pasting condition.

By inspection, the solution of Eq.(7) is given by:

$$f(V) = AV^\beta \quad (11)$$

where β is the positive root of the following nonlinear equation:

$$\frac{1}{2}\sigma^2\beta(\beta-1) + (r - \delta - \lambda\phi)\beta - (r + \lambda) + \lambda(1 + \phi)^\beta = 0 \quad (12)$$

The optimal exercise moment V^* is given by:

$$V^* = \frac{\beta}{\beta-1}k \quad (13)$$

and the constant A is determined as follows:

$$A = \frac{V^* - k}{(V^*)^\beta} \quad (14)$$

4.2 Parameter Estimates

In this section we estimate the parameters for the proposed model using data from the Brazilian fixed-line phone operators.

Table 1 presents the economic feasibility analysis of an average line in service (ALS) with a lifetime of 10 years, showing a typical free cash flow forecast. The main accounting rubrics are revenue net of taxes and other charges of the fixed network (*net rev*); the operating cost of the ALS (*opex*), usually expressed as a percentage of net revenue; the investment sunk cost, or capital expenditure (*capex*); and the accounting depreciation (*depr*), since the latter includes the corporate tax benefit rate (τ).

The components of net revenue include: i) subscription fee; ii) local fixed-fixed calls (the number of local pulses billed divided by the average number of lines in service times the average rate per pulse); and iii) local fixed-mobile calls (the number of VC-1 minutes elapsed from the fixed-line entering the mobile system divided by the average number of terminals in service times the average VC-1 rate per minute).

The subscription fee was obtained from the weighted average of the subscriptions in the residential, non-residential and trunk classes. Through data from Anatel's Tariff Adjustment System (Anatel (2006)), we ascertained that 55% of lines belong to the residential class, 35% are non-residential and 10% are trunk lines. Therefore, weighting the average tariff rate approved by Anatel in 2005 by the percentage for each class in each concession area, we reach an average tariff net of taxes and other charges of around BRL\$ 35.00 per month.

For local fixed-fixed revenue, the average number of pulses billed in Brazil in 2005 was 114 minutes a month per average line in service (ALS), according to the SRT data from Anatel (2006). The average rate approved by the agency for a local pulse, weighted by the number of lines in each concession area, was estimated for 2005 at BRL\$ 0.11/pulse (Anatel, 2004, 2005b, 2005c, 2005d and 2006).

Finally, regarding local fixed-mobile traffic (VC-1), we started with aggregated national data on the number of fixed-mobile minutes in the same geographic region billed by the local landline incumbents, which represents the average number of minutes of local calls between fixed and mobile phones. According to SRT data from Anatel (2006), the VC-1 traffic observed in 2005 was 419 minutes. The VC-1 tariff was the overall average of all those approved by Anatel, which led to a value of BRL\$ 0.47/minute, also according to SRT data.

Regarding the projection of the net revenue streams over the lifetime of an ALS, we assumed a rate of decay of 2% p.a., a figure obtained from the hypothesis adopted by Anatel (2007) and based on the concessionaires' financial statements.

For *opex*, the direct proportion of the net revenue is taken from the sum of the list of accounts specified in Anatel Resolution 396, issued in 2005¹³. We used a figure for *opex* similar to that employed by Anatel, which corresponds to 53% of the net revenue of the ALS.

The *capex*, which corresponds to the strike price of the option (*k*), was also taken from Anatel Resolution 396¹⁴. We obtained a value of BRL\$ 1374 per ALS as the required investment on average to establish a local fixed-line network.

Considering a corporate tax rate (τ) for Brazil at 34% (KMPG (2006)), a 10-year linear depreciation for *capex* and a cost of capital WACC (ρ) for the telecommunication sector estimated as 14% p.a. in real terms (Bragança, Rocha and Camacho (2006)), the present value (*V*) of the cash flows of the project is estimated at BRL\$ 1381, for a internal rate of return (IRR) of 14.13% p.a.

Table 1 – Cash Flow Projection

Year	0	1	2	3	4	5	6	7	8	9	10
+ Net Revenue		752	737	722	708	694	680	667	653	640	628
Subscription fee		412	403	395	387	380	372	365	357	350	343
<i>BRL\$ 35 / month</i>											
Local F-F		147	145	142	139	136	133	131	128	126	123

Traffic (114 monthly pulses /ALS)

¹³ This resolution specifies the breakdown of the accounting system that must be used by fixed concessionaires, by separation and allocation of accounting rubrics. The first data adjusted to this resolution are in the database of Anatel's Office of Public Services for 2005. The main innovational of this resolution is to disaggregate the expenses and revenues of landline concessionaires according to service rendered, giving more precision than previously provided in the traditional balance sheets and other financials published by the operators according to the rules of the Brazilian Securities Commission (CVM). Thus, there is greater accuracy, for example, in obtaining the costs tied to local service of an average line in service.

¹⁴ The disaggregated network elements were calculated through the accounting statements and specific investments in the essential elements to offer local services. We decided to use an overall average because of the idiosyncrasies of each fixed concessionaire in relation to the region of the country.

Average tariff of BRL\$ 0.11/pulse

Local F-M	193	189	185	182	178	175	171	168	164	161
VC-1/ALS traffic (419 min/year)										
Average tariff of BRL\$ 0.47/min										
- Opex (53% of Net Revenue)	-399	-391	-383	-375	-368	-360	-353	-346	-339	-333
= EBITDA	353	346	340	333	326	320	313	307	301	295
-Depreciation	-137	-137	-137	-137	-137	-137	-137	-137	-137	-137
-Income Taxes/Contributions @ 34%	-73	-71	-69	-66	-64	-62	-60	-58	-56	-54
+Depreciation	137	137	137	137	137	137	137	137	137	137
= FCF	280	275	271	266	262	258	253	249	245	241
Present Value V @ 14% p.a.	1381									
IRR	14.13%									
Capex (k)	1374									

Source: Annual balance sheets of the Brazilian fixed-line operators (2000 to 2005).

The analysis of Table 1 permits establishing the current values of the option, which are the underlying asset (V_0), BRL\$ 1381/ALS, and the strike price (k), R\$ 1374/ALS. To estimate the volatility parameter (σ) described by Eq.(5) for the project's return, we followed Brandão and Dyer (2005a, b). We estimated the volatility parameter to be 2.7% p.a.¹⁵ as shown in the Appendix.

We assumed a 10% p.a. for the risk-free rate (r) in real terms¹⁶, -2% p.a. for the growth rate (α)¹⁷ and 16% p.a. for the opportunity cost of capital (δ)¹⁸.

For the technological shocks we based our assumption on the analysis conducted by Anatel (2007b), by which a technological shock (ϕ) with an effect of -20% on the project's value will occur once every five years, meaning a jump-frequency (λ) of 20% p.a.

¹⁵ The low volatility is due to the subscription fee, considered a deterministic variable, and equal to 55% of the total net revenue.

¹⁶ The risk-free rate in real terms was estimated by using the rates on 10-year DI x IPCA swaps on the Mercantile and Futures Exchange (BM&F) as of October 2006. DI is the Brazilian interbank deposit rate and IPCA is the Brazilian consumer price index.

¹⁷ This figure was employed by Anatel (2006) in estimating the revenue per average line in service.

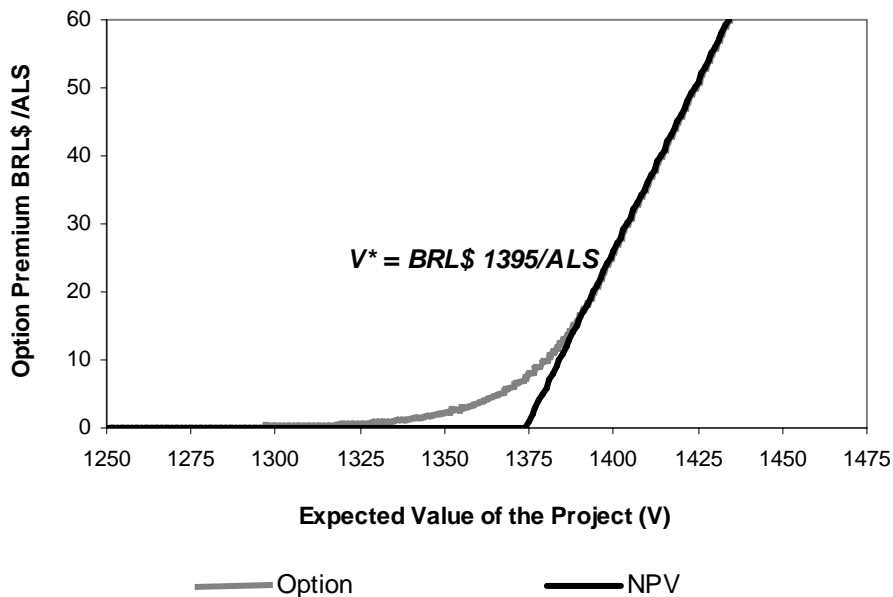
¹⁸ The opportunity cost of capital, as explained, is given by the difference between the expected rate of return and the capital gains, $\delta = \rho - \alpha$. For more details see Dixit and Pindyck (1994).

Given all the parameters called for in Eq.(5), the option premium and the markup on the cost of capital can be estimated using Eqs. (7-10) and Eq.(4).

4.3 Results

Figure 1 presents the option value for the investment in an ALS. The option converges smoothly to the NPV rules as the project's expected value increases. Option is triggered immediately at the threshold V^* , i.e. the optimal timing for exercising the option. Thus, the classic investment rule is not satisfied, since a rational investor will demand an additional premium over the sunk cost of R\$ 1374 (k) in order to commit to the investment. This premium grows as the uncertainties involved in the project increase.

Figure 1 – Option Value and Optimal Exercise



Having established the option premium f at the optimal timing¹⁹, we used Eq. (4) to estimate the adjusted cost of capital (ρ^*) that copes with the real option reasoning. We estimated an adjusted WACC at 14.4% p.a., which represents a markup of 0.4% in the cost of capital of the sector.

¹⁹ At the time of exercise, the option equals the NPV, that is, $V^* - k$.

We should point out that this additional 0.4% applies on an estimated remuneration base of more than BRL\$ 25 billion²⁰ according to the preliminary calculations of Anatel for 2004 (the most recent figure available at this writing).

Also, our estimates show that the 0.4% markup on WACC is quite sensitive to both volatility of project's return and technological shocks. Figures 2, 3 and 4 depict the sensitivity analysis in relation to these critical parameters.

²⁰ US\$ 14 billion converted by the exchange rate of October 2007, BRL\$ 1.78 / USD.

Figure 2 – Markup on WACC x Volatility

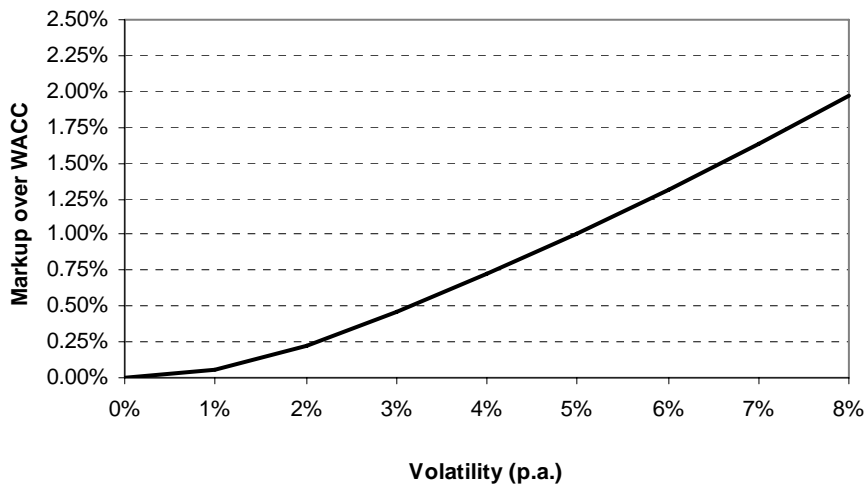
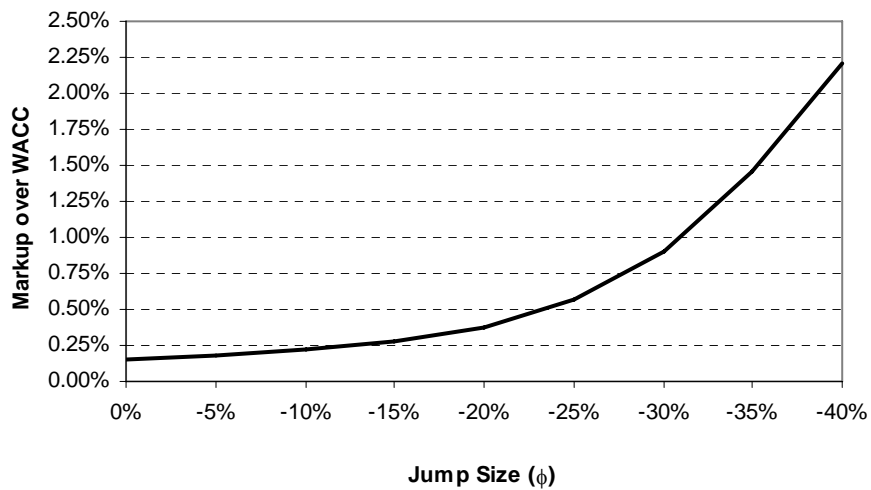


Figure 3 – Markup on WACC x Jump Arrivals



Figure 4 - Markup on WACC x Jump Size



As it can be seen in these graphs, under reasonable scenarios of volatility and technological shocks, the markup on the traditional cost of capital can reach significant levels of over 1% with the reasoning of real options pricing.

5. Conclusions and Future Recommendations

Policies to stimulate competition in the fixed telephone sector rest on the basic pillars of interconnection and disaggregation of networks. The new cost orientation policy implemented in Brazil in 2005 with the goal of establishing interconnection tariffs and pricing of unbundled network elements makes the return on capital a key factor.

By investing in a fixed-line telephone network while giving access to new entrants, the incumbent is actually providing an *option* to access its infrastructure, which should be considered as an effective *cost* by the regulator in determining the interconnection tariff of the network.

The literature on access price and real options shows that simply establishing prices equal to the long-run incremental cost (LRIC) in a climate of uncertainties and sunk costs creates an imbalance in the incumbent's risk / return ratio that can cause serious damage to the trajectory of investments in network infrastructure and innovation.

Based on some stylized factors of the sector, such as technological shocks, this study proposed a pragmatic effort to incorporate the real options rationale as a markup on the cost of capital (WACC) of the sector.

We based our estimation on public financial and operating data from the financial statements of the telephone companies, several resolutions issued by the regulator (Anatel) and inferences regarding the demand for fixed-fixed and fixed-mobile local calls.

The result points to a markup of roughly 0.4%, recalling that this will be applied on a remuneration base greater than BRL\$ 25 billion (roughly US\$ 14 billion in October 2007).

In light of these findings, we believe it is important for Brazilian policymakers to consider real options in implementing the LRIC, and consequently, the cost-oriented competition policies in the sector. Failing to consider this rationality means the incumbent will be remunerated below its opportunity cost, which will inevitably discourage investments in infrastructure in the sector and consequently reduce both

the dynamic efficiency of the policy adopted to stimulate competition and the social welfare generated by these services.

Appendix: Estimating the Project Volatility

To estimate the volatility parameter (σ) of the expected project's return described in Eq. (5), we followed Brandão and Dyer (2005a, b), who modified the Copeland and Antikarov (2003) approach²¹, and propose estimations based on conditional expectations. Stochastic inputs of the project are simulated just one period ahead and the *expected* present value of the project (VP_1) is estimated *conditional* to the simulation up to this period.

The volatility of the project's return (σ) is given by the standard deviation of the distribution z , defined by Eq.(A1), where VP_0 equals the *expected* present value of the project in period zero:

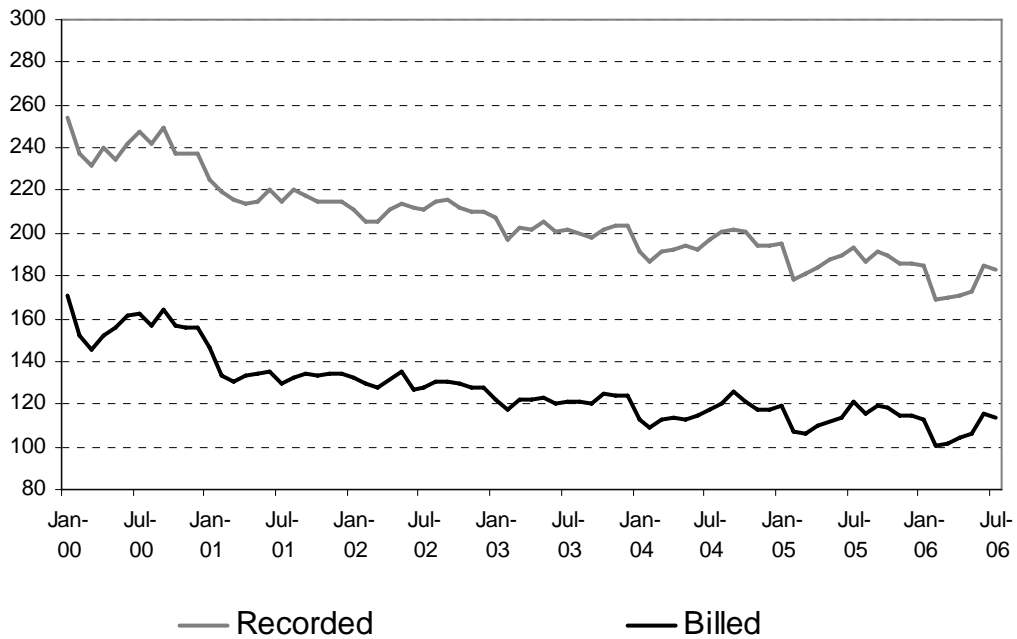
$$\tilde{z} = \ln\left(\frac{\tilde{VP}_1}{VP_0}\right) \quad (A1)$$

The stochastic inputs used to estimate the project's value in a telephone line (ALS) rely on the demand side for the service: i) pulses billed (x) per average line in service (ALS); and ii) VC-1 traffic (y) per ALS. The subscription fee, which represents a large proportion (55%) of the ALS revenue, was considered deterministic.

Figure A1 depicts the demand for local fixed telephone service with the monthly evolution of the pulses recorded and billed in the period from January 2000 through July 2006, according to SRT data from Anatel (2006) (the difference between the two series corresponds to the subscription free).

²¹ We also recommend the debate available at Smith (2005).

Figure A1: Pulses per Average Line in Service



Source: Annual financial statements of fixed operators from 2000 to 2006.

We assumed that both pulses billed (x) per ALS and the VC-1 traffic (y) per ALS follow the stochastic differential equations below, with dz_1 and dz_2 not correlated.

$$\frac{dx}{x} = \alpha_x dt + \sigma_x dz_1 \quad (A2)$$

$$\frac{dy}{y} = \alpha_y dt + \sigma_y dz_2 \quad (A3)$$

We estimated the volatility σ_x at 2.87% per month, or 10% p.a.²² and due to the lack of data for VC-1 traffic, we adopted the conservative hypothesis of $\sigma_y = \sigma_x$, i.e., the volatility of fixed-mobile (VC-1) traffic is the same as for fixed-fixed traffic. Regarding the growth rates α_x and α_y , we employed the same figure of Anatel (2006) of -2% p.a.

After estimating the stochastic inputs, we run simulations for the project's value. Following Eq.(A1) we estimate the volatility (σ) for the project's return at 2.7% p.a.

²² Considering that the variance grows with time.

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