Regulation and the Option to Delay

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Deposited By:

Fernando T. Camacho
University of Queensland

Flavio Menezes
School of Economics
University of Queensland

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Fernando T. Camacho and Flavio M. Menezes
School of Economics, The University of Queensland

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1. Introduction

The role of price regulation has experienced a significant shift in many countries. After its inception in the 1990s following corporatisation and privatisation of government owned enterprises, price regulation was often used as an instrument to provide incentives for regulated network businesses to reduce costs in an environment where capacity constraints were lax in many industries. However, sustained economic growth over the past decade as well as substantial technological change in industries such as telecommunications, have shifted the focus of price regulation towards providing the correct investment incentives.

The relationship between price regulation and investment incentives is highlighted, for example, in the current debate on the deployment of fiber-optic infrastructure and the so-called Next Generation Networks (NGNs). We anticipate that this relationship will be increasingly important in a low carbon world where substantial amounts of renewable and gas-fired micro generation will be introduced into the electricity system. The achievement of such change will necessitate significant new investment to adapt and expand existing electricity networks, mainly because renewable energy involves site-specific power plants.[1]

Although it is not the responsibility of regulators to provide firms with incentives to make particular investments (for example in NGNs), they must ensure that the incentives for efficient investment are not distorted. This requires a regulatory framework that correctly accounts for the risks faced by firms when investing in a network facility. These risks are related to two underlying characteristics: (demand) uncertainty and irreversibility.

Future cash flows in almost all network industries depend significantly on uncertain events such as the evolution of technology, fashion, general economic conditions and natural events and on competition from newly developed close substitutes. Arguably most, if not all, firms in a competitive economy face such uncertainty. However, it is the combination of demand uncertainty and large irreversible investments that characterises network industries. If the investments were reversible in the case of insufficient cash flows ("bad news") to cover the capital costs, an investor would be able to recover its losses through the resale of its assets and at the same time, in the absence of uncertainty the irreversibility concept would be irrelevant.

Investments in network industries are also irreversible in one of the two following forms. First, for some types of investment, recovery through resale is simply not possible. For example, in telecommunications it is not economically viable to remove and resell copper or fiber-optic cable that has been placed underground. Second, even if certain equipment can be uninstalled and resold, it is likely to be industry-specific and its value dependent on the economic conditions of the industry. Even if a firm wanted to resell an asset, it is unlikely that other firms would be willing to buy the equipment, at least at a price that recovered the investment made.[2]

The combination of uncertainty, irreversibility and investment timing flexibility provides the building blocks of option to delay theory. Although the notion of an option to delay in investment decisions under uncertainty has been extensively studied in competitive markets[3], its implications on regulated prices and investment incentives are less well understood. Indeed, this has been a subject of much debate recently.[4]

This paper examines a simple two-period model of an investment decision in a network industry characterized by demand uncertainty, economies of scale and sunk costs. In the absence of regulation we identify the minimum price that an unregulated monopolist demands to bear the demand uncertainty and invest early, that is, the price that incorporates the value of the option to delay. In a regulated environment, we show that in the absence of downstream competition and when the regulator cannot commit to ex-post demand contingent prices, a regulated price that incorporates the option to delay is the minimum price that ensures early investment. Furthermore, when the regulator has a preference for early investment, the option to delay price generates higher welfare than other forms of price regulation. We also show that when the vertically integrated network provider is required to provide access to downstream competitors, and the potential entrant is less efficient than the incumbent, an access price that incorporates the option to delay generates the same investment level output as and higher overall welfare than an unregulated industry that is not required to provide access. By contrast, under the same market conditions an ECPR-based access price generates the same overall welfare than an unregulated industry. Moreover, when the potential entrant is more efficient than the incumbent*,* an Option to Delay Pricing Rule generates the same investment level output as and (weakly) higher overall welfare than the Efficient Component Pricing Rule (ECPR). In addition, the option-to-delay-based access price is (weakly) lower than the ECPR-based access price.

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[1] A site-specific power plant is an electric generating facility that can be only built in one specific location due to natural conditions. For example, a hydro power plant or wind farm.
[2] See, for example, Pindyck (2004).
[3] See, for example, Dixit and Pindyck (1994) and Trigeorgis (1996).
[4] For instance, in New Zealand, the Commerce Commission stated in a discussion paper that "the obligation to provide interconnection services removes the option for access providers to delay investment in their fixed PSTNs. If this option has a value, the costs of foregoing the option are a cost that should be reflected in interconnection prices" (Commerce Commission 2002). In its latest cost of capital consultation, the Telco regulator in the UK proposed that "Ofcom should begin to develop a framework by which regulatory policy might reflect the value of these options (real options)" and "a key area identified by Ofcom as being one in which the value of wait and see options might be significant was that of next generation access networks" (Ofcom 2005).

Earlier papers that addressed the role of the option to delay in regulated industries include those by Hausman (1999) and Hausman and Myers (2002). These authors argue that regulated prices in telecommunications and railroad industries should reflect the importance of sunk costs and the irreversibility of investments. In particular, Hausman (1999) examines a situation where the incumbent is required by regulation to yield a free option to the entrant, where an option is the right but not the obligation to purchase the use of the unbundled elements of the incumbent's network.

Pindyck (2004, 2005) addresses the impact on investment incentives of the network sharing arrangements mandated by the Telecommunications Act of 1996, with a focus on the implications of irreversible investment.[5] The author argues that because the entrant does not bear the sunk costs, this leads to an asymmetric allocation of risk and return that is not properly accounted for in the pricing of the network services. Pindyck argues that such asymmetric allocation of risk and return creates a significant investment disincentive.

In particular, Pindyck (2004) considers two distinct frameworks to analyse the link between the option to delay and regulated prices. The first framework consists of a single firm assessing a network investment that will generate cash flows in perpetuity. The firm can invest in the first period or wait until the second period to decide whether to invest in the network. The cash flow in the first period is known, but the cash flow in the second period can either increase or decrease. This uncertainty is resolved in the second period and from there onwards the same cash flow (high or low) will eventuate each year. The required investment amount is unchanged from the first to the second period – that is, the real cost of investment decreases over time. Thus, the combination of uncertain cash flows and a declining investment requirement in real terms creates an incentive for the firm to delay. The cost of waiting is the first period cash flow, which is foregone when the firm delays its investment. This framework is used to explain the basic concept of option value. Additionally, in order to illustrate the problem of ex post access regulation, Pindyck uses a numerical example of irrational behavior by a firm; that is, it is optimal to wait but the firm invests early nonetheless. At the time of the investment there was no regulation and the unregulated firm should not have invested. In contrast to Pindyck's (2004) example, we develop a model where the firm does have the option to delay and if faced with appropriate incentives, it (weakly) prefers to invest early.

Pindyck (2004) also examines a hypothetical example where an incumbent installs a telecommunications switch that can be utilized by an entrant. As in the previous example, it is optimal for the incumbent to wait until uncertainty is resolved but the firm invests anyway. In this

[5] Pindyck (2005) develops a methodology to adjust the pricing formulas used to set lease rates to account for the transfer of option value from incumbents to entrants. The author estimates the average size of the adjustment for land-based local voice telecommunications in the U.S.

example, the author argues that the investment is mandatory and the firm has a duty to serve. Pindyck shows that when there is entry, the entrant's expected gain is precisely the incumbent's expected loss. In order to correct access prices to account for the option to delay value, Pindyck suggests that the entrant's expected cash flow should be set equal to zero - that is, the incumbent would be indifferent between providing access to entrants and providing the retail service itself (an ECPR-type methodology). Again in contrast to Pindyck's example, when entry is possible in our model, the entrant's expected gain in equilibrium is equal to zero and the incumbent's expected loss equals the expected increase in consumer surplus. In this environment, a regulated access price that incorporates an option to delay (which is (weakly) lower than the ECPR), is sufficient to provide the correct investment incentives and generates higher welfare.

This paper is organized as follows: Section 2 develops the investment decision model in an unregulated industry. In Section 3 we proceed to calculate the option to delay value. Unlike other papers in this area, we identify the minimum price that the firm demands to compensate uncertainty and irreversibility. Section 4 investigates the effect of retail price regulation in the incentives to invest. More specifically, we consider a monopolist firm that faces no downstream entry and is subject to a price cap on the downstream retail (final good) market. Here we distinguish between different regulatory approaches for setting up the price cap and their welfare consequences. In Section 5 we examine the effects of the regulation of access prices on the firm's investment decision as well as compare the outputs of the ECPR and an Option to delay type rule. Section 6 concludes the paper.

2. The Investment Decision Model

This Section develops a simple two-period model framework to investigate the role of the option to delay on investment decisions in network industries. Our framework encompasses four common characteristics of network industries: timing flexibility when making the investment decision, demand uncertainty, investment irreversibility and natural monopoly.

We consider a firm's decision whether to build a network in order to provide a new service. It is worth mentioning that here we are considering a case where a player is deciding whether to invest in a new network facility; this is not a marginal investment decision such as a quality enhancing investment or an expansion of an existent network.

In this two-period model the firm can either build the network at $t=0$ or at $t=1$. Moreover, if the firm does not invest at $t=0$, it has the right but not the obligation to invest at $t=1$. Although the network is built instantaneously, production only takes place at $t=1$ regardless of the construction date.

The investment outlay to build the network at $t=0$ is equal to I, whereas the outlay to build it at $t=1$ is equal to $(1+k)I$, where k is the project's cost of capital. However, as we know, production only takes place at $t=1$. Thus, when the firm invests at $t=0$, there is a negative cash flow (investment) at $t=0$ and a positive cash flow (sales revenue) at $t=1$. Given the investment's opportunity cost, the expenditures at $t=0$ and $t=1$ are equivalent, that is, the investment expenditure is financially neutral over time. In addition, the investment is sunk and there are no maintenance or operational costs to run the network.

The inverse demand function is characterized by a choke price equal to $\bar{P}$. At any price below or equal to $\bar{P}$, the demand for the new service is a fixed (but uncertain) quantity. The demand at a price above $\bar{P}$ is always equal to zero. As said before, demand is only realised at period $t=1$; at $t=1$ the demand will be either equal to uQ (where $u>1$) or equal to dQ (where $0<d<1$) with probabilities θ and $(1-\theta)$, respectively. As such, the gross value of future cash inflows will fluctuate in line with the random fluctuations in demand. Demand uncertainty creates an incentive for the firm to delay its investment decision until $t=1$. Moreover, as the investment expenditure is financially neutral over time, by building the network at $t=0$ the firm bears all demand uncertainty, that is, our model isolates the demand uncertainty.

In what follows, we assume that society has a preference for investment to take place at $t=0$ and this preference is measured by a constant $\Gamma \geq 0$. This assumption can be justified on the basis that early adoption of technology can have spill over effects on other sections in the economy. As discussed in Section 4, we can dispense with this assumption by considering that the firm will not invest in a zero net present value project.

The network is used to provide services to final consumers. The technology is such that the production of the final good requires one unit of the network service and one unit of a generic input with unit price c. Therefore, the firm's cost function to provide the downstream service at $t=1$ is given by:

$$C(q)=(1+k)I+cq \qquad (1)$$

Where $q=uQ$ or $q=dQ$.

Thus, although the provision of network services constitutes a natural monopoly, entry might be possible in the production of the final good by allowing access to the network services. This possibility is analysed in Section 5 below.

In the next section we analyse the investment decision of an unregulated monopolist who does not anticipate that its prices will be regulated. The firm checks the choke price consumers would pay for its new service and also expected demand and then decides whether to invest in the network facility to provide the service. We show that there are three possible cases: (i) the firm will never invest; (ii) the firm does not bear the demand uncertainty and invests at $t=1$ only if demand turns out to be high; and (iii) the firm is indifferent between investing at $t=0$ or at $t=1$; In this case we assume that the firm bears the demand uncertainty and invests at $t=0$. This paper will be concerned with case (iii) and will determine in sections 4 and 5 the minimum regulated price that will not affect the firm's decision to invest at $t=0$.

3. Pricing the Option to Delay

In this Section we compute the value of the Option to Delay (OD). That is, in this simple investment model we determine the minimum amount that the unregulated monopolist is willing to receive in order to invest at $t=0$ and forego the flexibility that it has in terms of the timing of its investment.

First, we will calculate this investment decision as a standard NPV. Note that if the firm invests at $t=0$ then at $t=1$ the project is expected to generate a net value equal to

$$NV = \theta\left[\left(\bar{P}-c\right)uQ-(1+k)I\right]+(1-\theta)\left[\left(\bar{P}-c\right)dQ-(1+k)I\right].$$

We assume that the investment outlay is discounted at the opportunity cost of capital k, resulting in a net present value (NPV) of $\left(\bar{P}-c\right)Q-I$ (Figure 1). That is, we consider investment projects with a profile such that for any u and d, the relationship between θ and $k>0$ satisfies the following identity $\theta u+(1-\theta)d=1+k$.

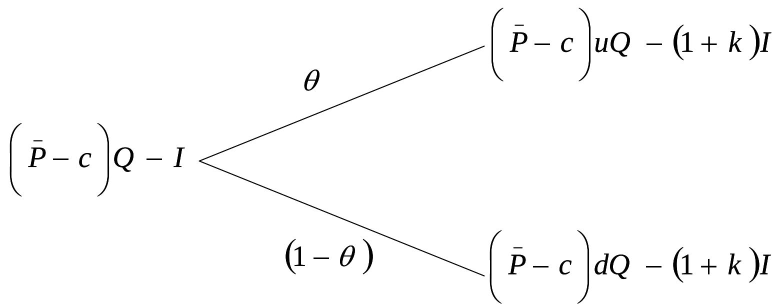

Figure 1

The same NPV can be calculated using a risk-neutral valuation. Such methodology will be used to estimate the risk-neutral probabilities which are fundamental to determine the value of this investment decision as an option to defer. In a risk-neutral world, all assets would earn the risk-free return r, and so expected cash flows (weighted by the risk-neutral probabilities, p and $(1-p)$) could be appropriately discounted at the risk-free rate. Note that in this case the investment outlay to build the network at $t=1$ is equal to $(1+r)I$.

Denoting by $R^{+}=\dfrac{\left(\bar{P}-c\right)uQ-(1+r)I}{\left(\bar{P}-c\right)Q-I}-1$ the return under the high demand, and by $R^{-}=\dfrac{\left(\bar{P}-c\right)dQ-(1+r)I}{\left(\bar{P}-c\right)Q-I}-1$ the return if the demand is low, the risk-neutral probability p can be obtained from the condition that the expected return on the investment in a risk-neutral world must equal the risk-free rate, that is,

$$pR^{+}+(1-p)R^{-}=r.$$

Solving for p yields

$$p=\frac{(1+r)-d}{u-d} \qquad (2)$$

Thus, the NPV of this investment decision is equal to

$$NPV = \frac{\theta\left[\left(\bar{P}-c\right)uQ-(1+k)I\right]+(1-\theta)\left[\left(\bar{P}-c\right)dQ-(1+k)I\right]}{(1+k)} =$$

$$= \frac{p\left[\left(\bar{P}-c\right)uQ-(1+r)I\right]+(1-p)\left[\left(\bar{P}-c\right)dQ-(1+r)I\right]}{(1+r)}$$

As said before, the risk-neutral methodology will also be used to calculate this investment decision as a call option as illustrated in Figure 2 below.

$$
\begin{array}{lll}
 & \nearrow & OD^{+} = Max\left(\left(\bar{P}-c\right)uQ - I(1+r), 0\right) \\
OD & & \\
 & \searrow & OD^{-} = Max\left(\left(\bar{P}-c\right)dQ - I(1+r), 0\right)
\end{array}
$$

Figure 2

The rationale of using the risk-neutral methodology refers to the fact that since the cash flows' risk profile of the deferral option is different from the standard NPV these cash flows cannot be discounted using the same cost of capital k as in the NPV case. Thus, instead of calculating the correct risk-adjusted discount rate applied to the expected cash flows from the project given deferral we simply calculate the risk-neutral probabilities and then discount the cash flows using the risk free rate. So, the expected return on the option must also equal the risk-free rate in a risk-neutral world, that is,

$$OD = \frac{pOD^{+} + (1-p)OD^{-}}{1+r}$$

or

$$OD = \frac{pMax\left[\left(\bar{P}-c\right)uQ-(1+r)I, 0\right]+(1-p)\,Max\left[\left(\bar{P}-c\right)dQ-(1+r)I, 0\right]}{1+r}. \qquad (3)$$

Figure 3 below depicts both the market value at $t=0$ of the Option to Delay (OD) and the Net Present Value (NPV).[6] It is worth noting that when the payoff of investing at $t=1$ in the low demand scenario is non-negative, the NPV and OD values coincide and, as a result, the firm will be indifferent between investing at $t=0$ or at $t=1$. We assume that when indifferent, the firm invests at $t=0$.

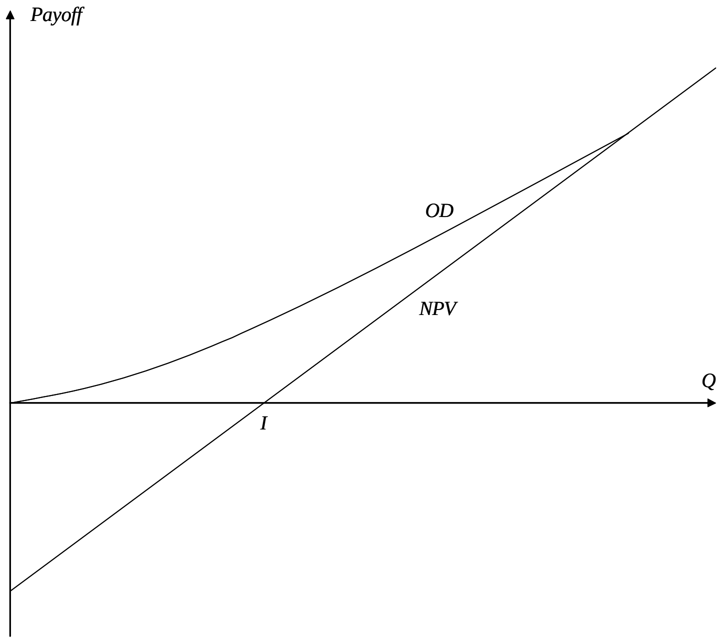

Figure 3

Equation (3) implies that:

Investment Decision	**Condition at $t=1$**
The firm never invests if	$\bar{P} < \frac{(1+r)I}{uQ} + c$
The firm invests at $t=1$ if	Demand $= uQ$ and $\frac{(1+r)I}{uQ} + c \leq \bar{P} < \frac{(1+r)I}{dQ} + c$
The firm is indifferent between investing at $t=0$ or at $t=1$ (and we will assume that the firm invests at $t=0$) if	$\bar{P} \geq \frac{(1+r)I}{dQ} + c$

Table 1

[6] Clearly, OD is the net present value of investing at $t=1$ (note that the firm only invests if the payoff is

Once more, this is an investment decision of an unregulated monopolist who does not anticipate that its prices will be regulated. The firm checks the choke price consumers would pay for its new service and also the expected demand and then decides whether to invest in the network facility to provide the service. The focus of this paper is on the case where an unregulated monopolist invests at $t = 0$, that is, the firm bears the demand uncertainty when it decides to invest. Thus, we have just established the following result:

Proposition 1: *Under demand uncertainty, the minimum final good price at $t = 1$ that the firm requires to invest at $t = 0$ is equal to P_{OD}, named the Option to Delay Price, where* $P_{OD} = \dfrac{(1+r)I}{dQ} + c$.

The first term of P_{OD}, $\dfrac{(1+r)I}{dQ}$, remunerates the network investment. The second term of P_{OD}, c, is the necessary amount to cover the marginal cost of transforming the network service into a final consumption good. Note that at a price equal to P_{OD} the firm's profit is 0 when demand is equal to dQ and equal to $(1+r)I\left[\dfrac{u}{d} - 1\right]$ when demand is equal to uQ.

It is worth mentioning that P_{OD} only depends on "bad news". This is the foundation of Bernanke's (1983) Bad News Principle. In the presence of investment irreversibility, uncertainty acts asymmetrically since only the unfavourable scenario affects the investment decision.

For the remainder of this paper we focus on market environments where the market price is such that an unregulated firm not subject to downstream competition would necessarily choose to invest at $t = 0$ (given its indifference); that is, we consider situations where given the expected demand Q we have $\bar{P} = \dfrac{(1+r)I}{dQ} + c + M$, $M \geq 0$.

Finally, if the firm invests at $t = 0$ the total welfare at the same period is given by:

$$W_M = \left(\bar{\bar{P}} - \bar{P}\right)Q + \alpha\left(\left(\bar{P} - c\right)Q - I\right) + \Gamma = \alpha\left(\left(\bar{\bar{P}} - c\right)Q - I\right) + \Gamma \qquad (4)$$

positive). and NPV is the net present value of investing at $t = 0$.

where $0 \le \alpha \le 1$ denotes the weight assigned to firm's profits and $\Gamma \ge 0$ represents a non-negative constant associated with the regulator's preferences for investment to take place at $t = 0$.

The next section clarifies the role of regulation. As seen in this section, the case of interest is one where an unregulated monopolist, who does not anticipate the introduction of regulation, verifies the choke price as well as the expected demand and then decides to invest at $t = 0$. Indeed, this is the case where the firm bears the demand uncertainty when it decides to invest. In the presence of regulation the same dynamic exists, that is, the regulator reveals the price setting and the firm decides whether to invest in the network facility. Then, the role of regulation is to determine the minimum regulated price at which this investment decision remains the same. We stress that the firm is not required to invest. In particular, the firm will only decide whether or not to invest after the regulator determines the format that regulation will take.

4. Retail Regulation

This section investigates the effect of retail price regulation on the incentives to invest. More specifically, we consider a monopolist firm that faces no downstream entry and is subject to a price cap on the downstream retail (final good) market. Here we distinguish between different regulatory approaches for setting up the price cap and their welfare consequences.

4.1 Ex Ante versus Ex Post Regulation

The regulator is fully informed about the nature of demand uncertainty and the cost function. The first type of regulatory contract involves setting an *ex ante* non-contingent demand price contract equal to P_{OD}, the Option to Delay Price, that the firm will be allowed to charge at $t = 1$. In this case, it is known that under this regulated price the firm invests at $t = 0$. Moreover, this regulation creates the following overall expected welfare function at $t = 0$:

$$W_{OD} = \left(\bar{P} - P_{OD}\right)Q + \alpha\left(\left(P_{OD} - c\right)Q - I\right) + \Gamma \qquad (5)$$

It can be seen that the difference between (5) and (4) is equal to $(1-\alpha)\left(\bar{P} - P_{OD}\right)Q \ge 0$. Thus, we have established the following result:

Proposition 2: *Suppose* $\alpha < 1$. The *ex ante demand non-contingent option to delay price contract yields (weakly) higher overall welfare (with strict inequality for* $M > 0$*) and generates the same investment level output at* $t = 0$ *than an unregulated industry.*

Note that as discussed before, under this *ex ante* regulatory contract, the firm's profit is 0 when demand is equal to dQ and $(1+r)I\left[\frac{u}{d}-1\right]$ when demand equals uQ.

Now, assume for the moment that the regulator can also fully observe, at $t = 0$, the resolution of demand uncertainty at $t = 1$ and commit to offer ex-post demand contingent prices. Under our commitment assumption, it follows that a regulator can extract all profits by offering an *ex post* demand contingent price contract specifying the following prices that the firm can charge at $t = 1$: (i) $P_{EP}^{u} = \frac{(1+r)I}{uQ} + c$ if demand is high; and (ii) $P_{EP}^{d} = \frac{(1+r)I}{dQ} + c$ if demand is low. This contract yields the following expected welfare function at $t = 0$ assuming that the firm invests at $t = 0$ (as it is indifferent):

$$W_{EP} = \frac{p\left(\bar{P} - P_{EP}^{u}\right)uQ + (1-p)\left(\bar{P} - P_{EP}^{d}\right)dQ}{(1+r)} + \Gamma \qquad (6)$$

It is clear that the difference between (6) and (5) is equal to $(1-\alpha)\left(\frac{u}{d}-1\right)Ip \geq 0$. Thus, we have established the following result:

Proposition 3: *Suppose* $\alpha < 1$. The *ex post demand-contingent price regulation contract yields higher overall welfare and generates the same investment level output at* $t = 0$ *than an unregulated industry.*

4.2 Regulatory Expropriation

An important reason why the firm might not invest at $t = 0$ under the *ex post* contingent demand price contract refers to the regulatory expropriation problem, which can be illustrated as follows. Suppose that the firm believes that there is a small probability that, *ex post*, the regulator will set a price that is lower than $P_{EP}^{d} = \frac{(1+r)I}{dQ} + c$ when demand turns out to be low. This can happen, for example, as a result of political pressure on the regulator not to allow the high prices necessary for full capital maintenance when demand is low. It might also happen if the regulator, even at $t = 1$, cannot observe the realised demand at period $t = 1$ and has to make an assessment of the validity of the firm's claimed realised demand.

In particular, we assume for simplicity that there is a probability λ that the regulator will set a price equal to $P_{EP}^{d} = \frac{(1+r)I}{Q} + c$ when demand is low whereas the price remains equal to $P_{EP}^{u} = \frac{(1+r)I}{uQ} + c$ when demand is high. It is simple to show (see Tables 2 and 3 below) that in this scenario the firm never invests at period $t = 0$. As we have seen in the previous section, P_{OD} is the minimum ex-ante (non-demand contingent) price at which the firm will invest at $t = 0$.

Investment at $t = 0$

Demand	**Price at** $t = 1$	**Firm's Profit at** $t = 1$
dQ	$P_{EP}^{d} = \left[\frac{(1+r)I}{Q} + c\right]$ or $\frac{(1+r)I}{dQ} + c$	$(1+r)(d-1)I < 0$ or 0
uQ	$P_{EP}^{u} = \frac{(1+r)I}{uQ} + c$	0

Table 2

Investment at $t = 1$

Demand	**Price at** $t = 1$	**Firm's Profit at** $t = 1$
dQ	$P_{EP}^{d} = \frac{(1+r)I}{dQ} + c$	0
uQ	$P_{EP}^{u} = \frac{(1+r)I}{uQ} + c$	0

Table 3

That is, we have established the following result.

Proposition 4: *When the regulator cannot commit to appropriate (demand contingent) ex-post prices, the ex ante demand non-contingent option to delay price* P_{OD} *is the minimum price that will not distort the unregulated monopolist's decision to invest at* $t = 0$

This proposition establishes the minimum price that will not distort investment at $t = 0$. However, this price includes a premium (the value of the option to delay) that is essentially a transfer from Consumer Surplus to Producer Surplus (profits). If $\alpha = 1$ (so that firm and consumers have the same social weights) then clearly P_{OD} is socially efficient. However, if $\alpha < 1$, then one could ask whether it is not best for society to simply forego the investment at $t = 0$, and let the investment to take place at $t = 1$.

Note that it is not guaranteed that at prices P_{EP}^{d} and P_{EP}^{u} investment will take place at $t = 1$. The reason is that this investment yields zero profits for the firm. Although one can argue that in a fully competitive economy this firm would undertake such investment, real economies often present investment opportunities that will yield economic profits at least temporarily. If this is the case, then this network service will not be provided under ex-post prices P_{EP}^{d} and P_{EP}^{u} and society will forego the benefits associated with the provision, measured by the difference between the choke price and the costs of provision.

Here, instead, we make the conservative assumption that the firm invests at $t = 1$ under ex-post prices P_{EP}^{d} and P_{EP}^{u} . This investment yields the following expected welfare function at $t = 0$:

$$W_{EP} = \frac{p\left(\bar{P} - P_{EP}^{u}\right)uQ + (1-p)\left(\bar{P} - P_{EP}^{d}\right)dQ}{(1+r)} \tag{7}$$

By taking the difference between (7) and (4), we can show that if $\Gamma > (1-\alpha)\left[MQ + \left(\frac{u}{d} - 1\right)Ip\right]$, the welfare at $t = 0$ that results from an investment at $t = 1$ in the regulated case is lower than the welfare in the unregulated case when the firm invests at $t = 0$.

We have just established the following result:

Proposition 5: *If $\alpha < 1$, then for sufficiently large gamma (as a function of alpha), society prefers the ex ante demand non-contingent option to delay price and investment at $t = 0$, than other forms of price regulation that lead to investment at $t = 1$.*

Importantly, the point we want to make is more general and does not depend on the particulars of this example. The crucial issue is the regulator's inability to commit at $t = 0$ to offer appropriate ex-post demand contingent prices. For example, investment will also not take place at $t=0$ if the regulator is able to offer at $t=1$ an average of the demand contingent prices. This follows as we have shown that the minimum price at $t=1$ that will make the firm indifferent between investing at $t=0$ or at $t=1$ is P_{OD}, the option to delay price.

Finally, perhaps one could be tempted to argue that the price set by the regulator does not need to incorporate an option to delay to secure investment at $t=0$. Instead, the regulator might make early investment a part of licence requirements. However, this argument can be readily dismissed. While it is true that a firm that faces no alternative investment opportunities would indeed not require a price that reflects the option to delay, this seems to be a rather special case. On the contrary, one expects that the firm will have at its disposal a portfolio of projects in which some provide returns that include the option to delay value. As a result, this firm would choose not to operate in this regulated industry and would not comply with the licensing requirements.

5. Access Regulation

In this Section we examine the effects of the regulation of access prices on the firm's investment decision. Our starting point is an unregulated, vertically integrated firm who does not have to provide access to its network. The technology is the same as described in Section 2 and the incumbent firm faces an inverse demand such that $\bar{P}=\frac{(1+r)I}{dQ}+c+M$. We have shown above that the unregulated firm, which does not face competition downstream, is indifferent between investing at $t=0$ or at $t=1$ and is assumed to invest at $t=0$.

In such a setting where consumers pay a maximum total price $\bar{P}$ for the new service, the incumbent firm can serve the entire demand at $\bar{P}$ and as the product is homogeneous, the incumbent has no incentive to allow access to its network by downstream competitors.

Suppose now that the regulator wants to promote competition in the downstream (retail) market and, therefore, requires the incumbent to provide access to its network. We assume that there are (infinitely many) potential entrants with the same technology as the incumbent and retail unit costs equal to c_E. Firms compete á la Bertrand; thus we assume that at identical prices consumers will prefer to buy from the incumbent.

In the following section we examine the implications of access price regulation in terms of welfare and the incentives for investing at $t=0$. In particular, we consider two distinct price methodologies: The Efficient Component Pricing Rule (ECPR) and the Option to Delay Pricing Rule (ODPR).

5.1. The Efficient Component Pricing Rule - ECPR

The ECPR is a regulatory pricing rule that links retail and wholesale prices. It reflects the incumbent's true opportunity cost of selling one unit of access to an entrant and so comprises the resource costs of providing access as well as the revenue loss from selling one less unit in the retail market. At the ECPR, the incumbent is indifferent between providing access to entrants or providing the retail service itself.[7]

Thus, we can define the access price following the ECPR as:

$$A_{ECPR} = \frac{(1+r)I}{dQ} + M \,.$$

At this access price the incumbent firm would be indifferent between providing access to the entrant and receiving A_{ECPR} or providing the retail service itself and receiving $\bar{P} = \frac{(1+r)I}{dQ} + c + M$. Moreover, at this price any entrant with retail marginal cost $c_E < c$ can enter the market, provide the retail service and fulfil the entire demand at a price $P_{ECPR}^{E} = \frac{(1+r)I}{dQ} + M + c_E$.

As the ECPR would not distort the incumbent's decision to invest at $t=0$, this regulation creates the following overall expected welfare at $t=0$ when $c_E < c$:

$$W_{ECPR} = \left(\bar{P} - P_{ECPR}^{E}\right)Q + \alpha\left[\left(A_{ECPR}Q - I + \left(P_{ECPR}^{E} - \left(A_{ECPR} + c_E\right)\right)Q\right)\right] + \Gamma \qquad (8)$$

As the difference between (8) and (4) is equal to $(c - c_E)Q > 0$, we have established the following result:

[7] See, for example, Willig (1979) and Baumol (1983).

Proposition 6: When $c_E < c$ *the ECPR increases the overall welfare and generates the same investment level output at* $t = 0$ *as an unregulated industry that is not required to provide access.*

It is worth mentioning that when the potential entrant is less efficient than the incumbent an ECPR-based access price is ineffective, that is, it generates the same investment level output as and same overall welfare than an unregulated industry that is not required to provide access.

5.2 The Option to Delay Pricing Rule - ODPR

Under this methodology, the access price is set at $A_{ODPR} = \frac{(1+r)I}{dQ}$.

As seen above, this is the minimum price that the firm demands *ex ante* to remunerate its network investment and be indifferent between investing at $t = 0$ or at $t = 1$. Also note that in order to avoid exclusionary conduct, this methodology must be applied in combination with an imputation test which assures that the incumbent firm will charge retail consumers a price greater than or equal to $\frac{(1+r)I}{dQ} + c$, the cost of providing the service. Table 4 below shows the three possible outcomes under Bertrand competition between the incumbent and (infinitely many) potential entrants:

Entrant's Marginal Cost	**Retail Price at** $t = 1$	**Retail Service Provided By**
$c + M \leq c_E$	$\bar{P} = \frac{(1+r)I}{dQ} + c + M$	Incumbent
$c \leq c_E < c + M$	$P^E_{ODPR} = \frac{(1+r)I}{dQ} + c_E < \frac{(1+r)I}{dQ} + c + M$	Incumbent
$c_E < c$	$P^E_{ODPR} = \frac{(1+r)I}{dQ} + c_E$	Entrant

Table 4

When the potential entrant is less efficient than the incumbent and $c \leq c_E < c + M$, the treat of entry leads the incumbent to reduce its price to $P^E_{ODPR} = \frac{(1+r)I}{dQ} + c_E$. This is a clear advantage when compared to the ECPR where potential entry only impacts prices when the entrant is more efficient than the incumbent. In this case the ODPR creates the following overall expected welfare function at $t = 0$:

$$W_{ODPR} = \left(\bar{P} - P_{ODPR}^{E} \right) Q + \alpha \left[\left(P_{ODPR}^{E} - c \right) Q - I \right] + \Gamma \qquad (9)$$

Note that when access pricing is determined by the ECPR, entry only occurs when $c_E < c$. Thus, when $c \leq c_E < c + M$**,** we must compare the ODPR with the unregulated monopoly case. The difference between (9) and (4) is equal to $(1-\alpha)(M + c - c_E)Q \geq 0$.

Proposition 7: *When the potential entrant is less efficient than the incumbent (i.e., $c \leq c_E < c + M$) and $\alpha < 1$, the Option to Delay Pricing Rule generates the same investment level output at $t = 0$ and higher overall welfare than an unregulated industry that is not required to provide access.*

When the potential entrant is more efficient then the incumbent (i.e., $c_E < c$), ODPR yields the following overall expected welfare function at $t = 0$:

$$W_{ODPR} = \left(\bar{P} - P_{ODPR}^{E} \right) Q + \alpha \left[\left(A_{ODPR} Q - I + \left(P_{ODPR}^{E} - \left(A_{ODPR} + c_E \right) \right) Q \right) \right] + \Gamma. \qquad (10)$$

The difference between (10) and (8) is equal to $(1-\alpha)MQ \geq 0$. Therefore, we have established the following result:

Proposition 8: *when the potential entrant is more efficient than the incumbent (i.e., $c_E < c$) and $\alpha < 1$, the Option to Delay Pricing Rule generates the same investment level output at $t = 0$ and (weakly) higher overall welfare than the Efficient Component Pricing Rule. In addition, the ODPR-based access price is (weakly) lower than the ECPR-based access price, with strict inequalities for $M > 0$.*

This differs from Pindyck (2004) who shows that when there is entry the entrant's expected gain is identical to the incumbent's expected loss. Pindyck suggests, as discussed in Section 1, that in order to account for the option to delay value the access price should be set according to an ECPR-based methodology; the price at which the incumbent would be indifferent between providing access to entrants or providing the retail service itself. At this price, the entrant's expected cash flow would be set equal to zero. In contrast, when entry is possible in our model, the entrant's expected gain in equilibrium is equal to zero - this follows from the assumption of a perfectly elastic supply of entrants - and the incumbent's expected loss equals the expected increase in consumer surplus. In this environment, the ODPR-based access price, which is weakly lower than the ECPR with strict inequality for $M > 0$, is sufficient to provide the correct investment incentives and generates higher welfare. It is also important to note that, in contrast with the ECPR methodology, under an ODPR-based access price the potential entrant constrains the monopoly power of the vertically integrated firm even when $c \leq c_E < c + M$. In this case, the incumbent is required to charge a lower retail price to block entry by an inefficient entrant.

To sum up, in contrast to Pindyck (2004) which advocates in favour of an ECPR-based access price to account for the option to delay value, we show that the ODPR-based access price, which is weakly lower than the ECPR, is sufficient to provide the correct investment incentives and generates higher welfare. Importantly, the ODPR-based access price is superior to the ECPR-based access price in that it is the lowest price that provides the correct investment incentives.

6. Conclusion

This paper examines a simple two-period model of an investment decision in a network industry characterized by demand uncertainty, economies of scale and sunk costs. In the absence of regulation we identify the minimum price that an unregulated monopolist demands to bear the demand uncertainty and invest early, that is, the price that incorporates the option to delay value. In a regulated environment, we show that in the absence of downstream competition and when the regulator cannot commit to demand contingent price caps, a regulated price that incorporates the option to delay is the minimum price that ensures early investment. We also show that this price might generate higher welfare than other forms of price regulation.

When the vertically integrated network provider is required to provide access to downstream competitors, we show that when the potential entrant is less efficient than the incumbent, an access price that incorporates the option to delay generates the same investment level output as and higher overall welfare than an unregulated industry that is not required to provide access. This follows from the need for the incumbent to reduce retail prices to block entry under ODPR. By contrast, under the same market conditions an ECPR-based access price is ineffective in reducing retail prices and as a consequence generates the same overall welfare than an unregulated industry. Moreover, when the potential entrant is more efficient than the incumbent, an Option to Delay Pricing Rule generates the same investment level output as and (weakly) higher overall welfare than the Efficient Component Pricing Rule (ECPR). In addition, the option-to-delay-based access price is (weakly) lower than the ECPR-based access price.

Indeed, when entry is possible in our model, the entrant's expected gain in equilibrium is equal to zero - this follows from the assumption of a perfectly elastic supply of entrants - and the incumbent's expected loss equals the expected increase in consumer surplus. In this environment, the ODPR-based access price, (which is (weakly) lower than the ECPR), is sufficient to provide the correct investment incentives and generates higher welfare. These results further clarify the analysis undertaken by Pindyck (2004) by identifying conditions under which an ODPR-based pricing rule is appropriate.

Finally, we should note that when entry is possible in our model, there is entry in both states of nature: high and low demand. Indeed, one important characteristic of our model is that it isolates the impact of demand uncertainty on firm's investment decision. As a result, the net present value is always lower than or equal to the option to delay value and the firm invests at $t=0$ when both rules yield the same outcome. Thus, the incumbent's profit in the low demand scenario is always non-negative and if the entrant is more efficient than the incumbent, there will be entry even when low demand eventuates.

By contrast, in Pindyck (2004), the incumbent's profit in the low demand scenario could be negative when the firm invests at $t=0$. In this case, the net present value is higher than the option to delay value (the payoff is higher than the investment plus the option value) and the firm follows the former rule. In such models, one could be tempted to argue that there will be no entry at $t=1$ when the incumbent's profit in the low demand scenario is negative. Since there would be no need for access regulation under a low demand scenario, the firm's investment decision is not distorted and there is no need for a regulated access price to incorporate an option to delay when demand is high. However, this argument can be discounted. Although the low demand scenario might be unprofitable for the incumbent firm, there is no guarantee that it will be unprofitable for all entrants. In particular, if there is a small probability that a more efficient entrant might profitably enter the market under low demand, then the access price should incorporate the option to delay in all demand states. The firm will not invest at $t=0$ when facing the probability of entry by a more efficient firm unless the regulated price incorporates an option to delay. To the extent that society prefers earlier investment, an option to delay access price seems inevitable under these circumstances.

References

Baumol, W. J. (1983). "Some subtle issues in railroad regulation", *Journal of Transport Economics* 10: 341-55

Bernanke, B. S. (1983). “Irreversibility, Uncertainty, and Cyclical Investment”, *Quarterly Journal of Economics* 98, 85-103

Commerce Commission (2002) Application of a TSLRIC Pricing Methodology – Discussion paper, December. Available at: www.comcom.govt.nz/IndustryRegulation/Telecommunications/InterconnectionDeterminations/TotalServiceLongRunningIncrementalCost/ContentFiles/Documents/TSLRIC%20discussion%20paper%202%20July%2020020.pdf

Dixit, A., and R. Pindyck, (1994), *Investment under Uncertainty*, Princeton University Press: Princeton.

Hausman, J. and S. Myers (2002) “Regulating the US Railroads: The Effects of Sunk Costs and Asymmetric Risk”, *Journal of Regulatory Economics* 22:3 287-310.

Hausman, J. (1999). “The Effect of Sunk Costs in Telecommunications“, in Alleman, J and Noam, E, (eds.) *The New Investment Theory of Real Options and its Implications for the Costs Models in Telecommunications*, Kluwer Academic Publishers.

Ofcom (2005). Ofcom’s approach to risk in the assessment of the cost of capital.

Pindyck, R. S. (2004). “Mandatory Unbundling and Irreversible Investment in Telecom Networks”, *NBER Working Paper No. 10287*.

Pindyck, R. S. (2005). “Pricing Capital under Mandatory Unbundling and Facilities Sharing”, *NBER Working Paper No. 11225.*

Trigeorgis, L. (1996), *Real Options - Managerial Flexibility and Strategy in Resource Allocation*, MIT Press.

Willig, R. (1979). “The Theory of Network Access Pricing”, in Harry M. Trebing (ed.) *Issues in Public Utility Regulation*, Michigan Sate University Public Utility Papers.