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Access Holidays and the Timing of Infrastructure Investment*

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For risky infrastructure investment, 'regulatory truncation' can diminish investment incentives. We model the truncation problem, showing the link to regulatory commitment, and derive optimal state-contingent access prices. If regulators cannot commit ex ante *to specific* ex post *access prices then a regulatory commitment to a fixed period free of access – an access holiday – can improve investment incentives. We establish conditions under which an access holiday may improve investment timing and show how an optimal holiday depends on the underlying profit flows from the investment. In particular, we show that an optimal holiday may leave investors with positive expected economic profits.*

I Introduction

Access regulation is a key part of Australian competition policy and the introduction of an access regime for essential infrastructure facilities was a major recommendation of the Hilmer Report. Subsequent reforms to the *Trade Practices Act* (1974) and the introduction of various state-based access regimes have resulted in incumbent firms in rail, gas, electricity, ports, airports, payment systems and telecommunications being required to make their infrastructure services available to competitors with the aim of improving upstream or downstream competition.

Recent reviews of the *Telecommunications Competition Regulation* (2001a) and *National Access Regime* (2001b) by the Productivity Commission highlight potential undesirable side-effects from infrastructure access. Inappropriate access regulation can have a 'chilling' effect on infrastructure investment. This occurs if access regulation reduces investors' profits when their investment is successful, but fully exposes those same investors to any losses from unsuccessful investment. This 'regulatory truncation of profits' can alter the return profile of investments, either delaying investment or, in the extreme, dissuading socially desirable investment from going ahead.

There is a clear economic basis for these concerns. Infrastructure investment often involves large sunk costs. In such situations, competition between facilities may be both socially undesirable and commercially unsustainable. Access regulation attempts to substitute for facilities-based competition by requiring a firm that owns a 'bottleneck' infrastructure facility to provide its potential competitors with access to that facility.[1] At the same time, a private firm will only incur the cost of building an infrastructure facility if it expects to receive at least a normal rate of return on average from this investment. Access regulation is triggered when potential

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[1] The economic ideas underlying access regulation are discussed in King and Maddock (1996) and Productivity Commission (2001b, Chapter 3).

entrants wish to compete with an incumbent. In practice, this means that regulation is most likely to occur when an investment is proven to be commercially successful. This reduces the investors' realised profits in those situations, without any compensating reduction in losses when the investment is not successful and access is not sought. Thus, anyone contemplating such investment will anticipate that the high-end of the distribution of possible returns may be truncated by access regulation, reducing their expected returns and hence, their incentives to invest.[2]

The potential for regulatory truncation depends on the access regulation imposed on investors *after* they make their investment. If a regulator could, *ex post*, set access prices that allow an investor an appropriate return to cover all relevant *ex ante* risk, then regulatory truncation need not arise. In practice, however, such pricing is unlikely. Regulators do not know the true *ex ante* project risk and investors will tend to exaggerate their claims of such risk in order to boost the regulated access price. Access seekers will argue that such risks are overstated or non-existent. Most importantly, a regulator, who sets an access price after the relevant investment is sunk, has a strong social incentive to set a low access price. Such an access price will promote efficient use of the facility, competition and social welfare without deterring the investment that has already occurred. Thus, the problem of regulatory truncation is directly related to the ability of a regulator to commit *ex ante* not to set socially desirable access prices *ex post*. If the regulator can make such a commitment then regulatory truncation can be avoided. However, the truncation problem has arisen in practice because regulators have a limited ability to make credible *ex ante* commitments over long-term access prices.

The Productivity Commission (2001b) considered a variety of regulatory responses to the truncation problem. For example, regulators could commit to setting higher access prices that include a 'truncation premium' before any investment takes place.[3] To be effective, such an approach would need to overcome the problem of regulatory commitment so that a regulator could commit to a 'regulatory access contract' in advance. Alternatively, investors could apply for an 'access holiday', that would grant an infrastructure investor a period of time over which they would not be subject to access regulation.[4] During this time, they could charge monopoly prices or deny access to competitors. The logic here is similar to the temporary monopoly granted by a patent; to allow the inventor supra-competitive returns so as to provide an incentive to innovate.[5] For an infrastructure investor, the period free of regulation would both reduce regulatory uncertainty and raise investment returns, increasing the incentives for infrastructure investment.

The problems of regulatory commitment and investment returns have also been important in overseas discussions of regulation (e.g. Sidak & Spulber 1998; Newbury 1999). But neither the Productivity Commission nor overseas commentators have formally modelled the truncation problem and the economic basis for an access holiday. In contrast, this paper formally investigates these issues to determine both when truncation is likely to create a regulatory concern and to evaluate the veracity of alternative solutions that have been suggested for the truncation problem. In Section II, we develop a model of investment timing under uncertainty and analyse the conditions for the truncation problem to arise. Section III shows that the regulator can avoid the truncation problem by committing to appropriate linear access prices *ex ante*. However, the optimal access prices will not involve a simple 'truncation premium' but rather resemble state-contingent Ramsey prices, trading off investment incentives with the social costs of distorted access prices in different states-of-nature. Section IV formally analyses access holidays. We show how an access holiday can alter investment incentives and offset the truncation

[2] A simple numerical example to illustrate this truncation effect is presented in Gans and King (2003).

[3] Gans and Williams (1999) and Gans (2001) propose 'efficient investment pricing' rules for access, which, if committed to *ex ante* by regulators, would result in socially desirable investment timing. These papers focus on the case of contestable investment under certainty and assume that a regulator can commit to any access pricing regime. Our analysis below both extends this work to consider investment under uncertainty and focuses on the truncation problem for a monopoly investor.

[4] This approach to preserving investment incentives was suggested by King and Maddock (1996) under the rubric of a 'null undertaking'. Caillaud and Tirole (2001) also evaluate investment incentives in an access context and explore the impact of access holidays in part of their paper. However, their context is one of asymmetric information between the incumbent, entrant and regulator and they focus on the use of access prices to elicit information from the incumbent. Their approach is one of mechanism design where the regulator does not have the commitment problems emphasised in our paper.

[5] Issues of investment and adoption have been discussed extensively in the innovation literature. Reinganum (1989) provides a survey.

problem. Changing the length of the holiday may either hasten or slow investment, depending on the marginal monopoly profits at the end of the holiday. We investigate the socially optimal access holiday and show how, in general, this will involve leaving some monopoly profits with the investor in expectation. Section V extends the analysis to consider state-contingent access holidays and contestable investments while in Section VI we consider some issues relating to the implementation of access holidays and conclude.

II Infrastructure Investment and the 'Truncation' Problem

We begin by presenting a model of investment timing. There is a well-defined infrastructure facility that can be built by a firm P, the infrastructure provider P can invest in the facility at any time $t \geq 0$. We initially assume that P is the only firm able to build the facility. For example, the facility might require interconnection with or modification of existing infrastructure owned by P. If this firm chooses to build the facility then the services provided by the facility will be subject to a regulated access regime and these services may be purchased by an access seeker, S.

Following Katz and Shapiro (1987) and Gans and Williams (1999), we assume that time periods have length Δ and explore continuous time solutions as Δ approaches 0. In each time period, firm P decides whether to invest or wait. Once investment has taken place, the infrastructure appears immediately. If a firm invests at date T, the current cost of investment is simply $F(T)e^{rT}$, where we assume that the discount factor is $\delta = e^{-r\Delta}$ and $F(T)$ is the present value, viewed from time $t = 0$ of investment expenses.

We assume that the costs of infrastructure investment decline due to technical progress, i.e. $dF(T)e^{rT}/dT < 0$ and $d^2F(T)e^{rT}/dT^2 > 0$.[6] The asset does not deteriorate over time or with usage. This allows us to avoid the issue of re-investment and maintenance incentives.

(i) Uncertainty

There are N states of the world that may arise after the investment has occurred, labelled $n = 1, \ldots, N$. Prior to P investing in the infrastructure, all parties are uncertain about the true state. For example the states can refer to the different levels of realised demand for the retail services produced by the infrastructure assets. *Ex ante* the probability of state n arising is given by $p(n)$. Once the investment has occurred, the true state becomes common knowledge.

(ii) Access Prices

Once the investment has been made, the regulator sets access prices. These are prices that firm S will pay to firm P if S decides to use P's facility. The regulator can set a two-part access price involving a usage charge, a, and a fixed fee, A. In general these prices are able to vary depending on the actual date t, the time that the investment occurred, T, and the realised state of the world n. Thus, the access prices are denoted by $a(t, T, n)$ and $A(t, T, n)$. We assume that both a and A are non-negative for all t, T and n. Further, we restrict the regulator to setting access price functions that are twice continuously differentiable with respect to both t and T. This latter assumption simply ensures analytical tractability.

(iii) Benefits from Investment

If the investment has occurred prior to t and the realised state is n, it generates a social surplus of $v(t, T, a, n)$ in period t of which $\pi_P(t, T, a, n) + A$ and $\pi_S(t, T, a, n) - A$ represent the profits for that period of the provider and seeker, respectively. Under standard models of oligopolistic competition, $\pi_P(.)$ is increasing while $\pi_S(.)$ is decreasing in a for any t, T and n. We assume that P and S produce competing retail products so that $\pi_P + \pi_S$ is increasing in a for any t, T and n. Given competitive interaction, $v(t, T, a, n)$ is concave in a for any t, T and n with maximum social surplus achieved at $a^*(t, T, n)$.

If the access provider could exclude its rival or, equivalently, if the regulator set arbitrarily high access prices, then firm P would earn a monopoly profit of $\pi_P^m(t, T, n)$ leading to social surplus of $v^m(t, T, n) < v(t, T, a^*, n)$.

We assume that all of the profit and surplus functions are twice continuously differentiable and bounded above. Profit functions are bounded below by zero.[7] Define the expected total profits to P (excluding the fixed cost of investment) from investing at time T by $\Pi_P(T, a, A) = \sum_n p(n) \int_T^\infty (\pi_P(t, T, a(t, T, n), n) + A(t, T, n))e^{-rt} dt$. The expected total profits to S are denoted Π_S with expected total social surplus of

[6] These cost assumptions are most relevant for infrastructure services facing technological change, such as telecommunications, transportation and financial services.

[7] Noting that the profit functions do not include the fixed cost of investment, this simply means that either firm can cease production in any period. Total profits for firm P may be negative if it does not make sufficient operating profits to cover its fixed infrastructure cost.

$$V(T,a)-F(T)=\sum_n p(n)\int_T^\infty v(t,T,a(t,T,n),n)e^{-rt}dt-F(T).$$

If firm P is able to act as a monopolist then we denote these present value profits by $\Pi_P^m - F(T)$.

(iv) Investment Timing

Under the socially optimal access regime, the access usage price will be set at a^* for every period after the investment is made. Socially optimal investment timing involves setting $T = T^*$ to maximise $V - F(T)$. By differentiation:

$$\sum_n p(n)\left(v(T^*,T^*,a^*(T^*,T^*,\ n))e^{-rT^*} - \int_{T^*}^\infty \left(\frac{\partial v(t,T^*,a^*)}{\partial T} + \frac{\partial v(t,T^*,a^*)}{\partial a^*}\frac{\partial a^*(t,T^*)}{\partial T}\right)e^{-rt}dt\right) = -F'(T^*) \quad (1)$$

In contrast, a monopoly access provider that is not subject to access will invest at T^m where

$$\sum_n p(n)\left(\pi_P^m(T^m,T^m,n)e^{-rT^*} - \int_{T^m}^\infty \frac{\partial \pi_P^m(t,T^m,n)}{\partial T}e^{-rt}dt\right) = -F'(T^m) \quad (2)$$

while if P believes that it will be subject to the access regime a and A after investment then it will invest at T^P such that

$$\sum_n p(n)\left((\pi_P(T^P,T^P,a(T^P,T^P,n),n) + A(T^P,T^P,n))e^{-rT^P} - \int_{T^P}^\infty \left(\frac{\partial \pi_P(t,T^P,a,n)}{\partial T} + \frac{\partial \pi_P(t,T^P,a,n)}{\partial a}\frac{\partial a(t,T^P,n)}{\partial T} + \frac{\partial A(t,T^P,n)}{\partial T}\right)e^{-rt}dt\right) = -F'(T^P) \quad (3)$$

Comparing these equations, there is no reason in general why the socially optimal time of investment, T^* will coincide with the time of investment chosen by either a monopoly infrastructure provider or a regulated infrastructure provider. Thus, there will generally be a conflict between socially desirable investment timing and privately profitable investment timing. The exception to this is when the regulated firm receives all the social returns from their investment.

Proposition 1. *If for all states n, $\pi_P(t, T, a(t, T, n), n) + A(t, T, n) \equiv v(t, T, a(t, T, n), n)$, then $T^P = T^*$.*

This result follows directly from substitution into equations 1 and 3.

Comparing equations 1 and 3, the access price is able to alter the investment timing of firm P. This was noted by Gans and Williams (1999) and Gans (2001), and exploited in the presence of alternative potential investors to align social and private timing. The 'truncation problem' is closely related to these issues of optimal investment timing.

(v) The Truncation Problem Under Access Regulation

Suppose that after building the facility at time T the infrastructure investor (rationally) believes that the regulator will set access prices functions a and A. Further, suppose that for investment at time T^m, $\Pi_P^m - F(T^m) > 0$ so that firm P will find it profitable to build the facility if there is no access regime. Then, the access regime creates a truncation problem if for all times T, $\Pi_P(T, a, A) - F(T) < 0$. In other words, there is a truncation problem if the firm P does not find it profitable to invest given the *ex post* access functions a and A set by the regulator, even though the firm would invest and build the facility in the absence of access regulation.

There are a number of important points to note relating to the truncation problem.

1 **The truncation problem is simply an extreme example of investment timing distortion under access regulation**. The investment timing chosen by either a regulated or a monopoly infrastructure access provider will not generally coincide with socially optimal investment timing. The truncation problem is an extreme case where the regulated infrastructure provider never finds it desirable to invest.
2 **The truncation problem (and any other distortion to investment timing) is directly related to limits on government directly subsidising new infrastructure facilities**. This follows from Proposition 1. For example, suppose that the government could subsidise a new privately built infrastructure facility through transfers G so that P's operating profits in any period and any state are $\pi_P + A + G$. If the government set G so that $\pi_P + A + G = v$ for all t, T, then firm P's incentives would be perfectly aligned with society's incentives and the firm would invest at the socially optimal time. Other solutions to the truncation problem, such as access holidays, are only required because there are either political or other constraints on the government making such transfers.[8]

[8] Similarly, if the government or the regulator could set non-linear access *and* final product prices that pass all

3 The truncation problem is directly related to an inability by the regulator to commit to access prices prior to an investment being made. If the regulator could commit to set the regulated access prices sufficiently high, so that $\pi_P + A = \pi_P^m$ for all t and T, then the truncation problem would disappear. Firm P would receive the equivalent of monopoly profits in each period and would invest at time T^m. While this is not necessarily the socially optimal timing, it avoids the situation where investment never occurs. Thus, regulatory commitment and the truncation problem are intimately connected and the truncation problem cannot be analysed without considering the issue of regulatory commitment.

4 The truncation problem can be avoided if, after the facility is built, the services provided by the facility are exempt from access for a sufficiently long period of time. This follows directly from the discounting of future payoffs and the assumption that monopoly profits are bounded from above. Thus, take any finite sequence of monopoly profits for firm P of length τ. The present value of these profits must approach π_P^m as τ approaches infinity. But noting that $\pi_P + A \geq 0$ for all T and t, this means that if the facility is exempt from access for a sufficiently long period of time τ, then firm P will find it optimal to invest in the facility at some finite time T.

The fourth observation is the foundation of an 'access holiday'. If a new infrastructure asset is exempt from providing access to any competing firms for a sufficient length of time, then the extreme version of truncation, where investment does not occur, can be avoided. Of course, this observation does not provide information about the specific design of an access holiday. We consider the optimal design below.

The third observation shows that the truncation problem is simply one example of a general set of regulatory problems. If regulators cannot commit to their actions ex ante then they may engage in behaviour that, from the investor's perspective, is opportunistic. There have been a variety of debates relating to regulatory opportunism overseas, for example relating to stranded assets (for example relating to stranded assets and forward looking asset valuation as in Sidak & Spulber 1998).

social surplus to the facility investor then any conflict over investment timing would be avoided. The information required for such first-degree discriminatory pricing, however, is unlikely to be available to either the government or any regulator *ex post*.

Because regulatory commitment lies at the heart of the truncation problem, claims that the problem can be avoided by simply raising the allowed access price (e.g. Productivity Commission 2001b, pp. 297–301) are true but trivial. If the regulator could commit to sufficiently high access prices then there would not be a truncation problem.

(vi) Stationary Projects and Access Prices

The model presented above considers the truncation problem in considerable generality. Most of the results, however, can be shown in a simplified environment involving stationary investments and access prices. In these situations (i) the flow of surplus and profits, π_P, π_S and v, only depend on the time since the investment occurred, $t - T$; (ii) the usage access charge, a, is time invariant; and (iii) any fixed access charges A only depend on the time since the investment occurred, $t - T$.[9]

Given these three assumptions, the present value (at $t = 0$) of P's profits if it invests at time T are given by:

$$\Pi_P(T, a, A) - F(T) = \sum_n p(n)\left(\int_0^\infty (\pi_P(x, a, n) + A(x, a, n))e^{-rx}dx\right)e^{-rT} - F(T) \quad (4)$$

where $x = t - T$. Thus, the investor's profits only depend on the time of investment through the discount factor. Similarly:

$$\Pi_P^m(T) = \sum_n p(n)\left(\int_0^\infty \pi_P^m(x, n)e^{-rx}dx\right)e^{-rT}, \quad (5)$$

$$\Pi_S(T, a, A) = \sum_n p(n)\left(\int_0^\infty (\pi_S(x, a, n) - A(x, a, n))e^{-rx}dx\right)e^{-rT} \quad (6)$$

and $$V(T, a) = \sum_n p(n)\left(\int_0^\infty v(x, a, n)e^{-rx}dx\right)e^{-rT} \quad (7)$$

Proposition 2. *With stationary projects and access prices, the socially optimal time for investment*

[9] These assumptions do not require that real revenues or profits are constant. Rather, real revenues and profits can rise and/or fall depending on the time since investment and the state-of-nature under these assumptions. As such, they cover a wide range of situations where a risky new investment project may follow any of a variety of product life cycles.

is less than the time of investment chosen by a monopoly investor, which in turn is less than the time of investment chosen by an investor subject to access regulation, i.e. $T^* < T^m \leq T^P$.

Proof. Differentiating $V(T, a) - F(T)$, the socially optimal investment timing is given by $rV(T^*, a) = -F'(T^*)$. Similarly, differentiating $\Pi_P^m(T) - F(T)$ and $\Pi_P(T, a, A) - F(T)$, a monopoly that is not subject to access will invest when $r\Pi_P^m(T^m) = -F'(T^m)$ and a firm subject to access will invest at time T^P where $r\Pi_P(T^P, a, A) = -F'(T^P)$. Noting for any $T > 0$, $a > 0$ and $0 \leq A \leq \pi^S$, that $V(T, a) > \Pi_P^m(T) \geq \Pi_P(T, a, A)$, it follows that $T^* < T^m \leq T^P$.

From Proposition 2, firm P will delay investment from a social perspective even if there is no access regime. An effective access regime will simply exacerbate this problem of investment delay.

The investment delay has a simple intuition. Even as a monopoly, firm P does not receive all social benefits from the investment. For example, they do not receive any surplus that accrues to consumers. Thus, the investor does not bear all the social cost of any delay in investment but does gain all the cost savings associated with delay. As such, firm P postpones investment for too long from a social perspective. This effect is exacerbated under an access regime because the investor receives even less of the total social benefit of the investment. The truncation problem is the extreme situation where, given the expected access prices, firm P 'delays' investment for ever.

III The Optimal Regulatory Access Pricing Contract

The truncation problem is intimately connected with both the inability of government to directly subsidise infrastructure investment and the inability of the regulator to commit to access prices *ex ante*. A regulatory access contract that enables the regulator to commit to access prices prior to any investment has been suggested as a way to avoid the problem of regulatory opportunism. From an economic perspective, what should such a regulatory contract look like?

In this section, we consider a regulator who can commit to access prices prior to investment being made but must make the access regime 'self funding' in the sense that the total access payment received by the investor is constrained to be no greater than total industry profits. Thus, the maximum 'lump sum' transfer to the investor in any state is given by the access seeker's profits.

Given our assumption about stationary projects, let $\Omega_P(a, n) = \int_0^\infty \pi_P(x, a, n)e^{-rx}dx$ and $\Omega_S(a, n) = \int_0^\infty \pi_S(x, a, n)e^{-rx}dx$. These refer to the present value at time T of the state-dependent profits of the access provider and access seeker, respectively, ignoring any access transfers A. Thus, Ω_S represents the present value of the maximum lump-sum transfer that can be provided to the access provider in state n. Similarly, let $\Lambda(a, n) = \int_0^\infty v(x, a, n)e^{-rx}dx$. This is the present value at time T of the state-dependent social value from the investment. Finally, let $\tilde{A}(a, n) = \int_0^\infty A(x, a, n)e^{-rx}dx$ so that $\tilde{A}$ is the present value at time T of any future lump sum access payments.

The optimal regulatory contract involves setting access usage prices $a(n)$ and lump sum access fee functions $A(x, a, n)$ for each state of nature and an investment time T to maximise expected social value subject to both firms making non-negative profits and firm P choosing investment timing to maximise profits. Formally, the optimal regulatory access regulatory contract finds T, $a(n)$ and $\tilde{A}(a, n)$ for all n to maximise $\sum_n p(n)\Lambda(a, n)e^{-rT} - F(T)$ subject to:

$$\sum_n p(n)(\Omega_P(a, n) + \tilde{A}(a, n))e^{-rT} - F(T) \geq 0, \qquad (8)$$

$$-r\sum_n p(n)(\Omega_P(a, n) + \tilde{A}(a, n))e^{-rT} - F'(T) = 0 \qquad (9)$$

$$\text{and} \quad \tilde{A}(a, n) \leq \Omega_S(a, n) \quad \text{for all } n. \qquad (10)$$

The first constraint requires that firm P expects to make non-negative profits. The second constraint is simply the timing of the investment by firm P. The third constraint requires that fixed access fees do not exceed the access seeker's operating profits.

The truncation problem requires that the first constraint, reflecting investor profits, must be met with equality. It is because this constraint is violated in the absence of a regulatory access contract that the contract is needed. Similarly, we expect that the third constraint will hold with equality, as we know that the investor will invest 'too late' from a social perspective even if it receives monopoly profits.[10]

Proposition 3. *The optimal set of regulatory access prices require that for all states n and n′,*

[10] This is confirmed by Kuhn-Tucker optimisation.

$$\frac{\dfrac{\partial \Lambda}{\partial a(n)}}{\dfrac{\partial \Omega_P}{\partial a(n)}+\dfrac{\partial \Omega_S}{\partial a(n)}}=\frac{\dfrac{\partial \Lambda}{\partial a(n')}}{\dfrac{\partial \Omega_P}{\partial a(n')}+\dfrac{\partial \Omega_S}{\partial a(n')}}.$$

Proof. Solving the first order conditions for the optimal access prices gives $a(n)$ such that

$$\frac{\dfrac{\partial \Lambda}{\partial a(n)}}{\dfrac{\partial \Omega_P}{\partial a(n)}+\dfrac{\partial \Omega_S}{\partial a(n)}}=-\lambda-r\mu \qquad (11)$$

where λ is the Lagrange multiplier on the investor profit constraint and $\mu=\dfrac{r\sum_n p(n)\Lambda(a,n)e^{-rT}+F'(T)}{r(-F'(T)+F''(T))}$ is the multiplier on the investment timing constraint. But as this holds for all n, the result immediately follows.

Interpreting this result is straightforward. Consider equation 11. The numerator of μ is the social trade off from investment at time T and is positive whenever investment is delayed from a social perspective. Thus, μ represents the cost to society from the delay in private investment. The numerator of the left-hand side of (11) is the reduction in social surplus when the access usage price is increased in state n while the denominator is the associated increase in industry profits in state n. Thus, Proposition 3 says that the optimal access prices equate the ratio of the loss in welfare to the gain in industry profits from a marginal change in the access price in each state.

This result reflects the underlying truncation problem – that the access regime makes the project unprofitable and delays investment from a social perspective. To overcome this problem, the regulator needs to commit to higher access prices. As transfers from S to P have no social consequences, fixed access charges are set equal to the economic profit of the access seekers. But this cannot overcome the investment delay problem completely and the regulator will want to commit to higher access usage prices. It is undesirable, however, to raise access prices equally in each state. Rather the regulator should raise access prices more when this has a high effect on industry profits (and hence the profits of the investor) compared to the diminution of social welfare.

This result is essentially a form of generalised Ramsey pricing.[11] If the regulator can commit to a regulatory contract *ex ante* then it is socially desirable for this contract to have higher access usage prices in states where project profits are high relative to the dead weight loss from increased final product pricing, either because demand for the relevant final product is inelastic or demand is relatively high at any price. The regulator should commit to lower access prices in those situations where demand for the final product is relatively low or relatively elastic.

[11] See Laffont and Tirole (1999) for a discussion of Ramsey pricing in the context of a static model of infrastructure access.

IV Access Holidays

An access holiday involves a fixed-term over which an infrastructure provider would not be subject to access regulation. In this section, we consider the socially optimal design of an access holiday.

(i) Access Pricing

The truncation problem is directly related to the inability of the regulator to commit *ex ante* to specific access prices. As discussed in Section III, if the regulator can commit to access prices in advance, then these prices can be used to overcome the truncation problem. But if the regulator cannot commit to an access regime in advance then an access holiday might be required to ensure that socially desirable investment is privately profitable.

Any discussion of an access holiday must be tied to a set of regulatory access prices that create the truncation problem. In general, regulators in Australia have, *ex post*, attempted to set access prices so that an investor can recover its 'legitimately' incurred costs. Thus, in states, n, where the investment creates operating profits that exceed the investment cost, the regulator sets access prices so that $(\Omega_P(a,\ n)+\tilde{A}(a,\ n))e^{-rT}-F(T)=0$. Such pricing necessarily leads to a truncation problem. In any state where the investment is commercially viable, the regulator sets access prices so that P only gains a 'fair' return on investment. In these states it makes no economic profit. However, if there exist states such that even a monopoly would be unprofitable *ex post*, then such an access regime will deter any investment. The investor faces the downside risk of any investment but does not receive profits when the investment is successful. In this section, we assume that the regulator will impose this form of access pricing *ex post* unless they are prevented by a legislated access holiday.

(ii) Successful and Unsuccessful States of Nature

Denote the length of the holiday by τ. In other words, if firm P invests in a facility at time T it does not have to allow access until time $T+\tau$. After the holiday expires the regulator will set access prices that just recover the 'legitimate' costs of firm P, including any capital costs, if this is possible. The truncation problem and the need for an access holiday relate to the 'success' or 'failure' of a project in individual states n.

A project is successful if, after the access holiday has expired, the regulator can set access prices such that the firm can recover its 'legitimate' per period costs including its capital costs over the remainder of the project life. As firm P's profits are continuous in the access usage fee, this will be possible when ever $\int_\tau^\infty \pi_P^m(x, n)e^{-rx}dx - F(T)e^{r(T-\tau)} \geq 0$. Thus, a project is successful if, after the expiration of the access holiday, the remaining monopoly operating profits over the project life (as measured at time T) are more than sufficient to fund the present value of the flow cost of capital. If the project is unsuccessful then $\int_\tau^\infty \pi_P^m(x, n)e^{-rx}dx - F(T)e^{r(T-\tau)} < 0$ and firm P does not provide access even after the access holiday has expired.

It is convenient to divide states of nature clearly between those where the project is a success and where it is a failure. Thus, we order states so that in states $1, \ldots, M$ the project is 'unsuccessful' and in states $M+1, \ldots, N$ the project is 'successful.'[12]

(iii) Access Holidays and Investment Timing

Before analysing the socially optimal access holiday, it is worth considering how a finite access holiday alters investment incentives. By definition of the truncation problem and our analysis in Section II we know that the truncation problem will be avoided if the access holiday is long enough. Suppose that this is the case. In states where the project is 'successful' and firm P invests at time T, the firm receives monopoly profits for τ periods but also bears the flow capital costs, $rF(T)e^{rT}$ for these periods. The total capital cost borne by the investor is $\int_0^\tau rF(T)e^{rT}e^{-rt}dt = F(T)e^{rT}(1 - e^{-r\tau})$. After the access holiday expires, the firm is only allowed to make zero economic profits. Thus, the present value profit of firm P at the time of investment in states where the investment is successful is given by $\int_0^\tau \pi_P^m(x, n)e^{-rx}dx - F(T)e^{rT}(1 - e^{-r\tau})$.

If the project is not successful the regulator allows firm P to continue as a monopoly after the access holiday has expired and the present value profit of firm P at the time of the investment is given by $\int_0^\infty \pi_P^m(x, n)e^{-rx}dx - F(T)e^{rT}$. Thus, the expected profit at $t = 0$ for firm P from investment at time T is given by:

$$\sum_{n=1}^{M} p(n)\left(e^{-rT}\int_0^\infty \pi_P^m(x, n)e^{-rx}dx - F(T)\right) + \sum_{n=M+1}^{N} p(n)\left(e^{-rT}\int_0^\tau \pi_P^m(x, n)e^{-rx}dx - F(T)(1 - e^{-r\tau})\right) \tag{12}$$

Note that this is equal to:

$$\Pi_P^m(T) - F(T) - \sum_{n=M+1}^{N} p(n)\left(e^{-rT}\int_\tau^\infty \pi_P^m(x, n)e^{-rx}dx - F(T)e^{-r\tau}\right) \tag{13}$$

Maximising profit with respect to T, the optimal time of investment for firm P under an access holiday is T^H where:

$$-r\Pi_P^m(T^H) - F'(T^H) + \sum_{n=M+1}^{N} p(n)\left(re^{-rT^H}\int_\tau^\infty \pi_P^m(x, n)e^{-rx}dx + F'(T^H)e^{-r\tau}\right) = 0 \tag{14}$$

Note that the first part of equation 14 is the same as the optimal monopoly investment decision, and equals zero at $T = T^m$. Thus T^H will be greater or less than T^m as $\sum_{n=M+1}^{N} p(n)\left(re^{-rT^H}\int_\tau^\infty \pi_P^m(x, n)e^{-rx}dx + F'(T^H)e^{-r\tau}\right)$ is greater or less than zero. In other words, if the monopoly profits foregone *after* the access holiday is completed are relatively large, then the access holiday will delay investment relative to the investment timing of an unregulated monopolist. But if the monopoly profits in successful states are relatively high before the access holiday expires, then an access holiday cannot only overcome the truncation problem but can lead to investment earlier than under no regulation. Remembering that, from a social perspective, even monopoly investment is 'too late', the potential for access holidays to lead to

[12] This is equivalent to assuming that marginal changes in the length of the access holiday do not shift projects from being successful to being unsuccessful or vice-versa. This is reasonable if the main causes of success and failure are exogenous market factors such as realised product demand, rather than the access regime itself.

investment at an earlier time than a monopoly is likely to be socially desirable.[13]

For a given access holiday, τ, we can say that project profits are 'front loaded' ('back loaded') if $\sum_{n=M+1}^{N} p(n)\left(re^{-rT^m} \int_{\tau}^{\infty} \pi_P^m(x, n)e^{-rx}dx + F'(T^m)e^{-r\tau} \right)$ is less (greater) than zero. Noting that $F'(T^m) = -r\Pi_P^m(T^m)$, profits are front loaded if the average monopoly profits after the access holiday ends exceeds the average monopoly profit over the whole life of the project. Otherwise, profits are back loaded. The following result follows directly from (14).

Proposition 4. *Consider an access holiday of length τ that is sufficiently long to overcome the truncation problem. If project profits are front loaded with respect to τ then the access holiday will lead to investment earlier than an unregulated monopoly. If project profits are back loaded with respect to τ then the access holiday will lead to investment later than an unregulated monopoly.*

Proposition 4 shows that an access holiday will have the strongest investment timing affects when the project has front loaded profits. But, for new infrastructure projects involving significant uncertainty, profits are most likely to be back loaded. First, in any state, such projects often have a life-cycle with relatively low profits in early years, and then a growth in profits over time as demand for the relevant services grows. Even a monopoly may face low operating profits in the short term compared with the medium term, resulting in back loaded profits. Second, the profits considered for back or front loading only refer to those states where the project is relatively profitable. By definition, these profits will tend to be higher than 'average' monopoly profits, automatically back loading the profits under an access holiday.

To the extent that most risky infrastructure projects have back loaded profits, an access holiday may overcome the truncation problem but is unlikely to avoid socially undesirable investment delays, even compared with an unregulated monopoly.

(iv) Changing the Length of an Access Holiday

Consider an access holiday of length τ that overcomes the truncation problem and has a profit maximising investment date of T^H. This investment date satisfies equation 14 and is a (local) maximum so that the second order condition for firm P's optimal investment problem at time T^H is negative. Will increasing the length of the holiday promote earlier investment or delay investment?

Proposition 5. *The sign of $dT^H/d\tau$ will be the same as the sign of $-re^{-r\tau} \sum_{n=M+1}^{N} p(n)(\pi_P^m(\tau, n)e^{-rT^H} + F'(T^H))$.*

This result directly follows from totally differentiating equation 14. To interpret this result, note that $\pi_P^m(\tau, n)e^{-rT^H}$ is the marginal increase in profits in state n (in date zero dollars) when the access holiday is increased. These represent an increase in the marginal cost of delay when the access holiday is increased. In contrast, $F'(T^H)$ is the marginal gain from delay. Only if the marginal gain from delay is less than the marginal cost will investment be accelerated by an increase in the access holiday.

In practice, this means that so long as the access holiday is sufficiently long to overcome the truncation problem, the effect of a marginal change in the length of the holiday depends critically on how monopoly profits are changing at the end of the holiday. If the holiday ends when per period monopoly profits are relatively low, then reducing the length of the holiday may actually encourage earlier investment.

(v) Optimal Access Holidays

The optimal length of an access holiday will set T and τ to maximise expected social welfare, $\sum_{n=1}^{N} p(n)\Lambda(a, n, \tau)e^{-rT} - F(T)$, subject to firm P making positive profits and firm P's investment timing decision which is given by equation 5 above.

The non-negative profit constraint means that the minimum access holiday is $\underline{\tau}$, the smallest value of τ such that:

$$\Pi_P^m(T^H) - F(T^H) - \sum_{n=M+1}^{N} p(n)\left(e^{-rT^H} \int_{\underline{\tau}}^{\infty} \pi_P^m(x, n)e^{-rx}dx - F(T^H)e^{-r\underline{\tau}} \right) \geq 0; \tag{15}$$

remembering that T^H depends on the length of the access holiday $\underline{\tau}$. In general, however, $\underline{\tau}$ need not represent a social optimum. It will be socially desirable to increase the access holiday (even though this leads to strictly positive expected economic profits for the investor) if the marginal social loss from an extension in period of monopoly is more than outweighed by the benefits of encouraging earlier investment.

To see this, note that the social planner's optimisation problem need not be convex but the globally optimal access holiday τ^* must also be a

[13] The investment incentives noted here are similar to the cost incentives created by the 'incremental surplus subsidy' scheme of Sappington and Sibly (1988). See also Gans and King (2000).

local optimum. Maximising social welfare subject to firm P's investment timing decision leads immediately to Proposition 6.

Proposition 6. *The socially optimal length of an access holiday is either the minimum access holiday that just sets investor profit equal to zero, τ, or τ^* that satisfies:*

$$\sum_{n=1}^{N} p(n)\frac{\partial \Lambda}{\partial \tau} e^{-rT^H} - re^{-r\tau^*}\left(r\sum_{n=1}^{N} p(n)\Lambda(a, n, \tau^*)e^{-rT^H} + F'(T^H) \right)\frac{dT^H}{d\tau^*} = 0 \quad (16)$$

This result is easily interpreted. Notice that the first term in equation 16 represents the social cost of an increased access holiday, and is negative. It reflects the direct cost of a longer period of monopoly service provision. The second term has two key elements. The term $dT^H/d\tau^*$ is self-explanatory. This is the rate at which investment will be delayed due to a marginal increase in the access holiday. The term $r\sum_{n=1}^{N} p(n)\Lambda(a, n, \tau^*)e^{-rT^H} + F'(T^H)$ represents the marginal social benefit of waiting rather than investing at time T^H. At an optimum, both of these terms will be negative, so that lengthening an access holiday will speed up investment *and* this is socially desirable because private investment is undesirably delayed from a social perspective. An optimal access holiday trades off the marginal loss from an increased period of profits with the marginal social gain from earlier investment.

In summary, the optimal access holiday can be no shorter than the minimum necessary to eliminate the truncation problem. But, in general, the minimum holiday need not be socially optimal. Rather, the holiday should be extended so long as this encourages earlier investment and the marginal social benefits of this earlier investment outweigh the marginal social costs. This has an important practical implication. An optimal access holiday is *not* designed *ex ante* just to leave the investor with zero expected profits. Thus, a rule that designs an access holiday just to overcome the truncation problem and leave firm P with positive, but minimal, expected economic profits will generally lead to too short a holiday.

V Extensions

(i) State Contingent Access Holidays

The analysis above assumed that the government could only set a single (project specific) length of time for an access holiday. However, it may be possible to set access holidays where the length of the holiday depends on the realised state of nature n.

Optimal state-contingent holidays follow similar 'Ramsey pricing' principles to the state-contingent access prices. Because firm P invests before the true state of nature is revealed, there are no state specific effects associated with the investment decision. The timing of investment depends on the expected monopoly profits. However, state-contingent holidays can be used to reduce the period-by-period social cost of investment. Holding expected monopoly profits (and hence investment timing) fixed, it is socially desirable to raise the length of the access holiday in states where this leads to only a small loss in social welfare, while it is desirable to reduce the length of the holiday in states where monopoly is relatively costly.

State-contingent access holidays raise important practical problems. While it is relatively easy for a government or regulator to commit to a fixed length access holiday, having state-contingent holidays raises the problem of *ex post* verification of the true state of nature. As a result, state-contingent access holidays, at a minimum, will lead to increased disputation between P, S, and the regulator, and at worst will re-introduce the commitment problems that access holidays are designed to eliminate.[14]

(ii) Contestable Projects

The analysis above assumes that firm P alone can invest in the relevant infrastructure facility. Alternatively, suppose that either firm P or S could build the facility. The first firm to build becomes the access provider and the other firm becomes the access seeker. Gans and Williams (1999) and Gans (2001) note that in such a situation investment may occur either before or after the socially optimal time. Investment occurs too soon from a social perspective if the firms 'race' to become the access provider leading one firm to build the facility with too high fixed costs.

An access holiday provides scope for the government to manipulate this race by altering the length of the access holiday. The access seeker is always made worse off by a longer access holiday, so an increase in the length of the holiday tends to intensify the investment race. Thus, a marginal increase in the length of the access holiday tends to intensify the investment race and result in earlier investment. The reverse holds if the access holiday is shortened.

[14] Gans and King (2003) discuss these issues in more detail.

(iii) Non-Stationary Projects

The analysis above concentrated on the case of stationary projects and stationary access prices. If projects are not stationary, then the analysis becomes more complex.

For example, suppose that the demand for the services from a particular project depends, not only on the time since the investment was made but also on 'calendar' time. If demand is growing over time irrespective of the date of investment, then this will alter the efficacy of an access holiday. The holiday creates an 'option' for the investor over a finite period of monopoly profits and the investor will exercise this option when it is most valuable. This was noted above in the trade off between delayed investment (and delayed profits) with the benefits of lower investment costs over time. When demand is also growing over time there is an additional benefit to waiting as delayed investment means that demand grows and the current-time value of monopoly profits grows. An investor might postpone investment in order to gain greater value from the holiday.

This effect is somewhat orthogonal to our analysis above. While it alters the optimal length of an access holiday, it does not alter the basic lesson, that an access holiday can be used to overcome the severe truncation problem that arises from an inability of the regulator to commit to access prices prior to the investment occurring.

(iv) Facility Size

Our analysis assumed that P could only build a single size of facility. Implicitly, this means that we have ignored capacity constraints. It is well known that an infrastructure provider subject to regulated access might manipulate the size of their facility in order to restrict feasible access and, potentially, to raise the access price. King and Maddock (1996) discuss these investment issues.

At best, an access holiday may reduce the incentives for P to manipulate facility size if this manipulation leads to reduced monopoly profits during the holiday period. Otherwise, access holidays are unlikely to significantly alter this form of manipulation. In Australia, the incentives to artificially constrain facility size are limited by the provisions of the *Trade Practices Act* that allow regulators to require facility expansion if this is required for efficient access.[15]

VI Summary and Conclusion

The analysis in this paper highlights the underlying cause of the 'truncation problem' and how this problem can be overcome by either a regulatory access contract or an access holiday. The truncation problem is closely connected to regulatory commitment. If such commitment is possible then the regulator should set socially optimal state-contingent access prices. If the regulator is unable to commit to such prices then an access holiday provides a desirable alternative. The access holiday can overcome the truncation problem and allow private investment to go ahead where it would otherwise be unprofitable.

When designing the optimal length of an access holiday, a regulator needs to consider the profit profile of the investment. Many risky projects will have back loaded profits in the sense that average monopoly profits tend to rise over time. In such situations, investment will be undesirably delayed even under a relatively generous access holiday. At the same time the ability of a longer access holiday to stimulate earlier investment depends on the size of marginal monopoly profits at the end of the holiday. If these profits are high an increased length of holiday will hasten investment. This means that when a regulator designs an access holiday it will generally be undesirable to choose the minimum length of holiday that just overcomes the truncation problem. Leaving some expected economic profit with the investor will often speed up initial investment in a socially desirable way.

Our model shows that a number of claims made in the Productivity Commission (2001b) are not consistent with formal economic analysis. For example, the Commission favoured a 'truncation premium' to be built into access prices. Our analysis showed that this approach was simplistic and suboptimal. It ignores the commitment issue at the heart of the truncation problem, and even if this problem could be overcome then simply raising the allowed return on the project equally in each state of nature would not lead to appropriate access prices. The Productivity Commission also considered that access holidays might be most appropriate for contestable investments. While the length of an access holiday may be used to manipulate investment timing when

[15] The interaction of a number of other specific aspects of the Australian access laws are worthy of further consideration. For example, in Australia, an access provider can lodge an 'access undertaking' prior to building a facility. Such an undertaking establishes specific access prices for a fixed period and may help to reduce both regulatory opportunism and the need for an access holiday. At the same time, undertakings often have a relatively short life (e.g. 5 years) so that even an access undertaking that generously protects P's profits at best replicates an access holiday. It was for this reason that access holidays were originally referred to as null undertakings in the Australian debate.

that investment is contestable, there is no reason to believe that an access holiday is more desirable in such circumstances. Our analysis shows that access holidays help overcome the truncation problem for non-contestable investments as well.

The model presented in this paper has considerable generality. The analysis of the truncation problem involves few assumptions and allows for a wide variety of access prices and flows of profits. While the analysis of optimal access prices and access holidays was limited to stationary projects, these still involve considerable generality. For example, while access usage charges were constant, fixed access charges could vary over the project life. Similarly, profit flows were only restricted to depend on the time since investment. Other than that, any differentiable streams of revenues and profits can be considered by our analysis. Thus, our model is relevant for most risky infrastructure investments, particularly where consumers learn about the benefits of the final product over time.[16]

Optimal holidays need to be judged on a case-by-case basis. This is likely to be difficult in practice. Rather, clear simple rules need to be established relating to the type of projects that are eligible for access holidays. The length of such holidays will be contentious. In our opinion, for relatively high risk projects involving infrastructure with a 30- to 50-year lifespan, a 10- to 20-year holiday would seem appropriate.

While our analysis highlights the potential benefits of access holidays, it also shows that they are very much a second-best tool to improve investment timing. Clearly further research is needed on both regulatory commitment and on appropriate policy tools that can be used to overcome the problems raised by regulatory opportunism.

[16] Thus the model applies, for example, to the Alice Springs to Darwin railway line, to new cable networks or to gas pipeline extensions to new regions. In each case, the project is likely to face considerable risk in part because there is not an existing consumer base for the final product and demand is likely to grow over time *after* the facility is built.

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