Access Regulation and the Timing of Infrastructure Investment*

by

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This paper examines infrastructure investment incentives under a system of "regulation by negotiation." Abstracting away from the competitive implications of alternative access regimes, we demonstrate that an appropriately specified access pricing rule can induce private firms to choose to invest in infrastructure at a socially optimal time. This is true even in environments where the access seeker can feasibly duplicate the facility. The optimal regulatory regime allocates investments to the access provider and seeker based on their relative use-values of the facility. It is superior to an unregulated environment because it commits firms ex ante to an access charge that allows for some investment cost recovery. As such, it influences the investment timing choice in an optimal matter. In addition, we demonstrate that when the time that access is sought is flexible both replacement and historical cost asset valuation methodologies can lead to optimal investment incentives. However, when access seeker timing is restricted, historical cost can give rise to distorted incentives. *Journal of Economic Literature* Classification Numbers: C78 (Bargaining Theory), L40 (Antitrust Policy), and L50 (Regulation).

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The new Part IIIA of the Australian *Trade Practices Act* establishes a regime of access to essential facilities. The regime applies to the infrastructure created by public utilities such as electricity grids or gas pipeline networks. It also applies to privately-provided infrastructure such as railway lines, roads and ports that mining companies have built to get their minerals into ships.

This paper examines the effect of access regulation on incentives to invest in infrastructure of the type that may be subject to an access claim. In particular, we examine "regulation by negotiation" whereby regulation occurs only in the event of an access dispute. To this end, we view investment as being undertaken by an infrastructure provider (*P*) and access being sought by an access seeker (*S*). The regulator, if called upon to make an access determination, will choose an access regime that maximises social welfare.

S can negotiate access with *P*. But if *P* and *S* cannot reach agreement *S* can compel *P* to provide access through a two-stage process. Under, Part IIIA of the *Trade Practices Act*, *S* must first secure a declaration from the relevant minister who makes a decision after obtaining advice from the National Competition Council (NCC). Section 44H(4) sets out the criteria to be used by the Minister (and the NCC) in deciding on applications for declaration.

> s44H(4): The designated Minister cannot declare a service unless he or she is satisfied of all of the following matters:
> (a) that access (or increased access) to the service would promote competition in at least one market (whether or not in Australia), other than the market for the service;
> (b) that it would be uneconomical for anyone to develop another facility to provide the service;
>
> (c) that the facility is of national significance, having regard to:
> (i) the size of the facility; or
> (ii) the importance of the facility to constitutional trade or commerce; or
> (iii) the importance of the facility to the national economy;
> (d) that access to the service can be provided without undue risk to human health or safety;
> (e) that access to the service is not already the subject of an effective access regime;
> (f) that access (or increased access) to the service would not be contrary to the public interest.

Once *S* has succeeded in obtaining a declaration, it must then try and negotiate terms of access with *P*. If agreement on terms cannot be reached, the dispute goes to the Australian Competition and Consumer Commission (ACCC) for arbitration. (Decisions by the NCC and the ACCC may be appealed to the Australian Competition Tribunal). The criteria to be used in pricing arbitrations are set out in s44X.

> s44X (1) The Commission must take the following matters into account in making a determination:
>
> (a) the legitimate business interests of the provider, and the provider's investment in the facility;
> (b) the public interest, including the public interest in having competition in markets (whether or not in Australia);
> (c) the interests of all persons who have rights to use the service;
> (d) the direct costs of providing access to the service;
> (e) the value to the provider of extensions whose cost is borne by someone else;
> (f) the operational and technical requirements necessary for the safe and reliable operation of the facility;
> (g) the economically efficient operation of the facility.
>
> (2) The Commission may take into account any other matters that it thinks are relevant.

It is likely that the ACCC and the Tribunal will give a heavy weight to economic efficiency in pricing arbitrations under Part IIIA.

Much of the infrastructure that is subject to access claims under Part IIIA has a long life and excess capacity. So the social opportunity cost of requiring access is very low. But this does not mean that the access charge should be set close to zero. The variable part of a two-part tariff may be set low but the lump-sum part should be such as to provide an incentive to invest in infrastructure (Freebairn and Trace, 1992).

We wish to focus explicitly on the influence that this process of access regulation has on incentives to invest in socially valuable infrastructure. To this end we will examine a particular type of infrastructure -- *non-rival facilities*. These are facilities that having been made are not subject to congestion, either on the cost-side (marginal use costs are zero) or on the value-side (i.e., the value of use to one party is independent of the intensity of use by another). While no cost-side congestion is consistent with the definition of a natural monopoly, the assumption on value-side congestion is substantive. In particular, it rules out situations in which *P* and *S* are engaged in imperfect competition downstream. However, it is satisfied if *P* and *S* produce for different markets (e.g., mines for two different minerals) or produce for a perfectly competitive world market (e.g., most primary commodities). As we will demonstrate, this non-rival base case illustrates the influence of access regulation on investment incentives, abstracting away from complicating strategic elements. We will, however, comment upon how our findings might extend to the rival case at the end of the paper.

Our model involves two stages: an investment timing decision followed by negotiations between the investor and an access seeker over the price of the latter's access. A key assumption is that *P* and *S* cannot sign an access agreement *ex ante* that commits to a price once the investment has taken place. That is, the investment decision and values derived by each firm are not *ex ante* contractible. We assume, however, that the values of infrastructure use to the seeker and provider are ex post contractible. The key feature of this assumption is that no contract can be signed that is contingent on the timing of the investment, or indeed, the time that access is sought. This could be simply because there are many potential seekers and the identity of the one that eventually seeks access is unknown. This is an assumption of *ex ante anonymity* (see Pitchford and Snyder, 1996). Nonetheless, when investment has taken place, there is nothing preventing the time of investment being part of the access price. However, this happens *ex post* and no formula can be committed to *ex ante*.

Any number of examples may be given of the problem we have in mind. Consider the extensive deposits of iron ore in Western Australia's Pilbara Region. Most of these deposits were discovered in the early 1960s. The deposits, of course, vary in quality. The ore bodies are well away from the coast; and, when they were discovered, there were no service facilities -- such as ports, railways, towns, electricity or water. These had to be provided by the companies who moved first. In general, they did not enter into *ex ante* contracts with the owners of other leases. This was possibly because those other leaseholders were not known (i.e., not all the ore had been discovered when the initial infrastructure was created). Alternatively, it could be because there was so much uncertainty and potential disagreement surrounding the future exploitation and value of leases that the transactions costs of *ex ante* contracting could not be justified.

In this environment, we demonstrate that, in the absence of regulation, investment timing is delayed relative to the social optimum. While the negotiated access charge is efficient in a static sense – it is a two-part tariff with the usage charge set equal to marginal cost – the fixed charge involves the sharing of rents from the seeker's activity. As such, as it cannot appropriate the full social returns from its investment, the provider prefers to wait for the reduced investment costs afforded by technological progress. Regulation alters the outside options of both parties in negotiations. In a non-cooperative bargaining game akin to Rubinstein (1982), the regulatory option commits both parties to agree to the regulatory access price. While regulated pricing involves the same usage charge as the no regulation outcome, the basis of the fixed charge is fundamentally different. The regulatory access regime can build in timing variables through asset valuation techniques and hence, if this regulatory access price is known *ex ante*, we demonstrate that it can allow commitment to a socially optimal pricing regime. The optimal access regime turns out to be the Lindahl equilibrium for our model. Moreover, we contrast the use of replacement and historical cost valuation methods and demonstrate that when access seeker timing is flexible, the methods yield equivalent outcomes.

The previous literature on access regulation does not consider dynamic issues such as the determinants of infrastructure. That literature has been mainly concerned with the allocative efficiency implications of access regulation in an imperfectly competitive setting (Armstrong, Cowan and Vickers, 1994; King and Maddock, 1996). However, the industrial organisation literature on technology policy and incentives to undertake research and development has considered dynamic issues similar to those we explore. For instance, a patent is a mechanism that regulates an industry in order to enhance innovation incentives. We, therefore, draw on portions of that literature below.

The next section introduces the formal set-up for our model. This is based on the framework of Katz and Shapiro (1987) and allows for a simple specification of the investment timing decision and alternative asset valuation methods. In section II, we analyse the model based on an assumption that the seeker is "small." We then turn in Section III to consider implications when both firms are "large" and characterise their "race" to become a provider. A final section concludes and provides directions for future research.

I. The Basic Framework

There are two firms in the economy that might have a use for the infrastructure. We assume that capital markets are perfect so that each might conceivably become a provider if the returns to so doing are positive. We concentrate our analysis on the timing of infrastructure investment by the first firm to invest. While it might be possible for the second firm to duplicate the facility, this will not occur in equilibrium. Hence, we will always refer to the first investor as the provider, P, and the other firm as the seeker, S.

Investment Costs

Following Katz and Shapiro (1987), we assume that time periods have length Δ and explore continuous time solutions as Δ approaches 0. In each time period, each firm 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 rate $\delta = e^{-r\Delta}$ and $F(T)$ is the present value, viewed from time 0 of investment expenses.

We also assume that the costs of infrastructure investment decline due to technical progress, i.e., $d(F(T)e^{rT})/dT < 0$ and $d^2(F(T)e^{rT})/dT^2 > 0$. Let F be the limit of current investment costs as T approaches infinity and F_0 be the cost of investment at time 0. On occasion we shall consider a particular functional form $F(T) = F_0 e^{-\lambda T}$, so that investment costs decline exponentially. We would need to assume that $\lambda > r$, so as to consistent with our earlier assumptions. In addition, we shall assume that the asset does not deteriorate over time or with usage. This simplifying assumption allows us to avoid the issue of re-investment and maintenance incentives. Finally, as our focus is on fixed access charges in multi-part pricing, we assume that use of the infrastructure involves a zero marginal cost.[1]

To fix ideas on these costs concepts, suppose that the cost of building the infrastructure today (at T = 0) is \$100, the annual interest rate, r, = 5% and the rate of technological progress, λ, = 10%. Table One below shows the infrastructure costs in both present value and current cost of a plant constructed at zero, five and ten years.

Table One: Illustrative Costs of an Infrastructure Project

Time of Construction	0	5	10
Present Value at Time 0	\$100	\$60.65	\$36.79
Current Cost	\$100	\$77.88	\$60.65

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[1] This is a simplifying assumption only and could be generalised, so long as the natural monopoly characteristics of the infrastructure were preserved. Thus, all results from regulatory theory concerning the relationship between usage charges and short-run marginal costs (e.g., Armstrong et.al., 1994) could be applied in conjunction with our conclusions below regarding fixed charges.

Motives for Investment

The discounted value of the benefits from use of the infrastructure by firm i is denoted by v_i. As discussed in the introduction, v_i is known to each firm ex ante but only becomes verifiable to the regulator after investment has actually taken place. Moreover, the values for each firm are independent of one another. Therefore, social value is maximised if both firms are given access to the infrastructure.

While technological progress raises the value of waiting, each individual firm has two distinct motives to build infrastructure sooner rather than later. The first reflects their *willingness to pay* for the infrastructure. This is the benefit they receive from building the infrastructure themselves in the absence of any strategic concern. For firm i, if investment takes place at time T_i and they expect to receive an access price of p_i at time T_j, the present value of their payoff is:

$$W_i(T_i) = \int_{T_i}^{\infty} r v_i e^{-rt} dt + \int_{T_j}^{\infty} r p_i e^{-rt} dt - F(T_i) = v_i e^{-rT_i} + p_i e^{-rT_j} - F(T_i).$$

Let $\hat{T}_i$ be the value of T_i that maximises this function, taking into account the fact that T_j might be contingent in T_i. Indeed, if $T_j = T_i$, as we will show it does, then we refer to $v_i + p_i$ as i's willingness to pay for the infrastructure.[2]

The second motive to build infrastructure earlier is a strategic one. Each firm might be concerned that the other firm might *pre-empt* them by investing first. The benefit to investing first at time T_i is given by $W_i(T_i)$ above. However, if firm j invests first, firm i must pay j a price for access. We demonstrate that this is always preferred by i to duplicating the facility. Moreover, once the infrastructure is built, there is no benefit to i

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[2] Katz and Shapiro (1987) refer to this as i's stand-alone incentive. While this might be natural in their context of research and development, here we prefer to use an alternative terminology that reflects the idea that the investment is being used by both parties. Below stand-alone will be defined to be the case where a firm invests in infrastructure for their own use only.

from delaying its access demand. Hence, if it expects an access price of p_j, firm i's payoff in the event that it does not invest first is:

$$L(T_i) = \left(v_i - p_j\right)e^{-rT_i}$$

where T_i is now the time that access is sought. If both firms choose to invest at the same time, then we assume that the investor is determined by a coin toss so that firm i earns $\frac{1}{2}\left(W_i(T) - L_i(T)\right)$. Following Katz and Shapiro (1987), we say that "firm i is willing to preempt at T" if $W_i(T) \geq L_i(T)$. Moreover, our assumptions on $F(.)$ guarantee that the current pre-emption value, $\left(W_i(T) - L_i(T)\right)e^{rT}$, is increasing in T; that is, if it is worth pre-empting at some time, it is worth pre-empting at any time after that. With this in mind, we can define the earliest pre-emption date for firm i, $\tilde{T}_i$ by $W_i(\tilde{T}_i) = L_i(\tilde{T}_i)$ or, alternatively, $p_i + p_j = F(\tilde{T}_i)e^{r\tilde{T}_i}$. We refer to $p_i + p_j$ as firm i's pre-emption motive for investment. Note that the motive for pre-emption comes from the difference between being paid an access charge and having to pay an access charge. However, this implies that the pre-emption incentives are identical for both firms, i.e., $\tilde{T}_i = \tilde{T}_j$.

Given this formal set-up, we can define a firm's stand-alone investment timing. This is the timing it undertakes if it were the only firm to derive use from a facility. In this case, a firm i chooses T_i to maximise $v_i e^{-rT_i} - F(T_i)$ which satisfies the first order condition, $v_i = -F'(T_i^{SA})e^{rT_i^{SA}} / r$. We denote by π_i^{SA} the maximised present value of i's stand-alone payoff. This concept will prove useful in characterising a seeker's by-pass options below.

We can contrast the stand-alone timing with the socially optimal investment timing. Timing choices allow infrastructure to be used by firms but also to potentially supply new goods to consumers or reduce final goods prices. For the purpose of this paper, we ignore this impact on consumer surplus and treat social value as simply the sum of each firm's use-values.[3] The social planner, therefore, chooses T to maximise $(v_i + v_j)e^{-rT} - F(T)$ which satisfies the first order condition, $v_i + v_j = -F'(T^{SO})e^{rT^{SO}} / r$. Note that socially optimal timing is earlier than stand-alone timing choices.

Before turning to analyse how the willingness to pay and pre-emption incentives interact to determine equilibrium investment timing, it is important to look at how these incentives are themselves derived. Therefore, we look first at the outcome of negotiations over access in the no regulation and regulation cases.

II. Negotiations Over Access

Suppose that investment has taken place at time T_P and access is being sought at time $T_S \geq T_P$. In this section, we will analyse the outcome of bargaining that takes place at time T_S and contrast the no regulation and regulation cases respectively. In the latter case, the regulatory option is only realised in the event of a breakdown in access negotiations. We will also look at the S's timing decision in light of different negotiation outcomes.

No Regulation Case

When P invests it has the option of refusing access to S. However, given the non-rival characteristics of the investment, this will not be in its own interest. P and S will, therefore, begin negotiations at T_S over the access charge p.[4] This negotiation takes a non-cooperative form similar to Rubinstein (1982). That is, negotiations can potentially take time, however, in contrast to Rubinstein where the offeror alternates each period, we

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[3] This condition is not too restrictive when considering firms selling to a perfectly competitive market. To relax the condition would complicate our analysis of the regulatory solutions below and invariably require some subsidy to investment to achieve the social optimum.

[4] As mentioned earlier, this charge represents the fixed charge in a multi-part tariff. Given our assumption of zero marginal costs, efficient Rubinstein bargaining would not lead to any usage access charges. For a discussion of this issue see King and Maddock (1996).

symmetrise the bargaining game and assume that nature chooses the offeror in each period at random. That offeror makes a take-it-or-leave-it offer to the offeree who either accepts the offer (in which case the game ends) or rejects it (in which case agreement is delayed and the process is repeated in the next period). The extensive form game is depicted in Figure One.

Note that *S* can only opt out of the bargaining process when responding to an offer by *P* (see Figure One). This assumption is made in order to eliminate supergame effects (i.e., brinkmanship) and simplify the bargaining equilibrium. Allowing a less restrictive process would not alter the qualitative conclusions reached below.[5] With this assumption, we can prove the following result.

Proposition 1. *The above bargaining game in continuous time has a unique subgame perfect equilibrium in which the initial offeror (whether S or P) makes an offer at* T_S *of* $p^N = \min\left[\frac{1}{2}v_S, v_S - \pi_S^{SA}e^{rT_S}\right]$ *that is accepted immediately.*

The proposition is an application of the continuous time results in Sutton (1986). The access charge is either one half of *S*'s value or an amount that allows *S* to just earn the current value of its stand-alone payoff, $\pi_S^{SA}e^{rT_S}$ -- that being *S*'s outside option when there is no regulatory option. We refer to these as the *unconstrained* and *constrained* access charges respectively. Clearly, if *S* is so "small" that it would never invest on its own, the access charge will be unconstrained by the duplication option.

Note that for either the unconstrained or constrained access charge, *S* chooses to set $T_S = T_P$. That is, it seeks access as soon as the investment is built. This is because the equilibrium access charge is either independent or decreasing in the time that access is sought, so *S* would rather earn value sooner rather than later.

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[5] King and Maddock (1997) analyse this type of brinkmanship in an access negotiations context. See Osborne and Rubinstein (1990) for a discussion of the restrictiveness of our assumption.

Regulation Case

Suppose that regulation is an option. That means that, if negotiations break down, either S or P can ensure that the regulatory option is exercised. S can do this by simply asking the regulator to determine the appropriate access charge. Once again, we assume that it can only do this following a rejection of P's offer. P can potentially obtain a regulatory outcome by simply refusing to continue negotiations. For the same reasons as above, we assume that it can only exercise this outside option following a rejection of S's offer. This modified game is depicted in Figure 2. By refusing to negotiate, P forces S to pursue the regulatory solution, at least when it is "small." When it is "large," it is possible that S might choose to exercise its by-pass option in preference to a regulatory solution.[6]

The regulator can commit ex ante to an access charge $\bar{p}^R$. This charge could, in turn, depend on T_P and T_S in a well-defined way, although the timing choices are themselves ex ante non-contractible. As p^N is unique, it is straightforward to see that either $\bar{p}^R > p^N$ or $\bar{p}^R \leq p^N$. Therefore, the regulatory option will be binding for either S or P and hence, will be exercised. Given this, we can prove the following.

Proposition 2. *The bargaining game with the regulatory option of $\bar{p}^R$ in continuous time has a unique subgame perfect equilibrium in which the initial offeror makes an offer at T_S of $p^R = \min\left[\bar{p}^R, v_S - \pi_S^{SA} e^{rT_S}\right]$ that is accepted immediately.*

Once again, this proposition is a corollary of the continuous time results in Sutton (1986). Note that regulation here merely serves to change the outside options and is not, in fact, exercised. As we have not specified how or whether the regulated access price depends on T_S, we cannot at this stage analyse seeker timing.

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[6] We show below, however, that the optimal regulatory solution chooses an access regime that avoids this possibility.

The regulatory option, if anticipated, provides an ex ante commitment to $\overline{p}^R$ rather than the outcome of Proposition 1. As $\overline{p}^R$ can potentially depend on variables that are non-contractible ex ante, it can play a role in influencing investment incentives.

III. Investment Incentives: "Small" Seeker Case

In order to build intuition, we start by analysing timing choices when one firm is "small," in the sense that it will never find it profitable to be the provider. The case when both firms are "large" will be dealt with in the next section. For this firm, S, $v_S + \frac{1}{2}v_P < F$ and hence, $\pi_S^{SA} < 0$, so that, under no regulation, it will never build the infrastructure. This implies that $L_S(T) > W_S(T)$ so the firm has no pre-emption incentive. The fact that S cannot pre-empt P leaves the timing choice completely determined by P's willingness to pay incentive.

No Regulation Case

As noted earlier, when $p^N = \frac{1}{2}v_S$, S chooses to seek access as soon as the infrastructure is built, i.e., $T_S^N = T_P^N$. Anticipating this, P adjusts its timing accordingly. Therefore, P chooses T_P to maximise:

$$\pi_P^N = \left(v_P + \tfrac{1}{2}v_S\right)e^{-rT_P} - F(T_P).$$

The profit maximising choice of T_P satisfies: $v_P + \frac{1}{2}v_S = -F'(\hat{T}_P^N)e^{r\hat{T}_P^N} / r$. Notice that $\hat{T}_P^N \leq T_P^{SA}$.

Regulation Case

The no regulation choice of investment timing is delayed relative to the socially optimal timing because P does not appropriate the full social returns from its decision. At first glance, it would appear that setting $\overline{p}^R = v_S$ would implement the social optimum. This effectively involves merging both firms. While not a particular concern for this setting this does have consequences for richer settings with many firms or downstream competition. Therefore, in this paper, we examine solutions based on cost sharing rather than a reallocation of benefits.

Suppose that the regulated access price is of the class $\overline{p}^R = \alpha B(.)$, where $B(.)$ is the valuation of the asset at the time access is sought, while $\alpha \in [0,1]$ is *S*'s contribution to that value. There are two natural methodologies for assessing the value of the infrastructure: replacement cost and historical cost. Under *replacement cost*, the infrastructure receives a valuation equal to the cost of replacing it at time T_S with an equivalent asset. This would amount to setting $B(.) = F(T_S)e^{rT_S}$. In this case, valuation is affected by the time access is sought but not (directly) by the investment timing itself. In contrast, *historical cost* is a valuation based on the cost of constructing the actual facility, i.e., at the technology of time T_P. Under this methodology, $B(.) = F(T_P)e^{rT_P}$, the original investment cost. So while historical cost is not affected by the time access is sought, it is influenced by the timing of investment itself. An example of asset valuation outcomes for both methodologies is depicted in Table 2 where the infrastructure is built at year 0 but the access dispute arises in year 5. We will consider the impact of each of these asset valuation methodologies in turn.

Table 2: Example of Asset Valuation (F_0 = \$100, λ = 0.1, r = 0.05)

	Replacement Cost	Historical Cost
Present Value from year 0	\$60.65	\$77.88
Current Cost at year 5	\$77.88	\$100

Beginning with replacement cost, we need to understand how this affects *S*'s incentives as to the time it seeks access. Observe that by delaying T_S away from T_P *S* reduces the access price it has to pay. However, this behaviour would not be socially optimal and so the regulator would need to choose α to prevent this from happening. S chooses T_S to maximise $\pi_S^R = v_S e^{-rT_S} - \alpha F(T_S)$. However, to determine whether there is any delay we need to examine the incentives of P under this regime. To consider this, suppose that the regulator is successful in choosing α so that $\hat{T}_S^R = T_P$. Anticipating this, P chooses T_P to maximise: $\pi_P^R = v_P e^{-rT_P} - (1-\alpha)F(T_P)$. The regulatory problem is then to choose α such that $\hat{T}_P^R = T^{SO}$.

It turns out that in this framework, the regulator's problem is equivalent to finding the Lindahl equilibrium in this setting.[7] The choice of investment timing is in fact a choice regarding the level of a public good. A Lindahl equilibrium occurs when for a given cost sharing arrangement, both firms prefer the same level of the public good; in this case, investment timing. It has been demonstrated elsewhere that such an equilibrium is Pareto optimal (see Cornes and Sandler, 1996, pp.201-203). Here, for a given α, the preferred timing for P and S are given by the following first order conditions:

$$\frac{v_P}{1-\alpha} = -F'(T)e^{rT} / r \text{ and } \frac{v_S}{\alpha} = -F'(T)e^{rT} / r$$

These are in agreement if and only if,

$$\frac{v_P}{1-\alpha} = \frac{v_S}{\alpha} \Rightarrow \alpha = \frac{v_S}{v_P + v_S}.$$

Therefore, each firm pays a proportion of the assessed costs equal to its share of total value. As these use-values are observable to the regulator ex post they can be used as part of the regulated access price. Moreover, it is easy to confirm that $\hat{T}_P^R = T^{SO}$ and that $\hat{T}_S^R = \hat{T}_P^R$ so that the socially optimal timing is in fact implemented for this cost sharing regime.

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[7] We thank Simon Grant for suggesting this equivalence.

Looking now at an access regime based on historical cost, we can see that a similar outcome is possible. When $\bar{p}^R = \alpha F(T_P)e^{rT_P}$, S's timing choice does not influence the access price. Therefore, S will choose to seek access as soon as possible and hence, $\hat{T}_S^R = T_P$. As there is no distance between the time of the investment and the time that access is sought, there is in fact no difference between the realised historical and replacement values for the asset. P's payoff is the same as the replacement cost case. So the optimal access regime will involve $\alpha = v_S / (v_P + v_S)$ regardless of the asset valuation method.[8]

Regulation serves to implement the socially optimal investment incentives by committing P to a regulated access regime before it makes an investment. Such commitment was not possible in the no regulation case because of the ex ante anonymity of the seeker. So long as there is no uncertainty regarding the form of the regime, it ensures that P internalises the full value of the innovation to S when making its timing decision.

IV. Timing Choices When Both Firms are Large

We now turn to consider what happens when both firms can potentially become infrastructure providers, even in the no regulation case (i.e., $v_i + \frac{1}{2}v_j > F$ for $i \neq j$). This means that both pre-emption and willingness to pay motivations will play a role. We will demonstrate that regulation based on cost sharing implements the socially optimal timing both by ensuring that the initial investor internalises the value to the other firm and also, because regulation removes any pre-emption incentives for investment. Once again, we consider the no regulation and regulation cases in turn.

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[8] In a later section, we introduce some inflexibility as to the time access is sought so as to consider differences between the two asset valuation methodologies.

No Regulation Case

For ease of exposition we subscript each firm by $i = 1, 2$ and assume that $v_1 > v_2$. This implies that the stand-alone timing for 1 is greater than that for 2 and hence, that $T_1^{SA} < T_2^{SA}$. In addition, recall that the pre-emption incentives for each firm are identical, i.e., $\tilde{T}_1 = \tilde{T}_2$.

What about the willingness to pay incentives? In Proposition 1, we determined the outcomes of negotiations between a seeker and provider. Table 3 lists the payoffs that each firm *i* receives if it is the provider while *j* is the seeker. Notice that in each unconstrained case, the seeker will always choose to seek access as soon as possible while in the constrained case it is indifferent. Hence, we will suppose here that it seeks access earlier rather than later.[9] The willingness-to-pay timings for four possible cases are depicted in Table 4. Notice that when one outcome is constrained, the provider's willingness to pay timing choice is socially optimal. This is because the provider in that instance appropriates the other firm's entire value and pays them a lump-sum to compensate them for their stand-alone payoff. Moreover, it is entirely possible that the "smaller" firm has a greater willingness to pay incentive (when the outcome is constrained in that instance). However, whether these socially optimal timings are actually implemented in equilibrium depends on whether pre-emption is a concern.

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[9] By seeking access earlier the seeker improves the provider's payoff. Hence, the provider will always pay the seeker an arbitrarily small amount to break its indifference in its favour. For ease of notation we have omitted such small payments here.

Table 3: Payoffs when i is the Provider, j is the Seeker

	Unconstrained	Constrained
$\pi_i^N(T_i, T_j)$	$v_i e^{-rT_i} - F(T_i) + \frac{1}{2} v_j e^{-rT_j}$	$v_i e^{-rT_i} - F(T_i) + v_j e^{-rT_j} - \pi_j^{SA}$
$\pi_j^N(T_i, T_j)$	$\frac{1}{2} v_j e^{-rT_j}$	π_j^{SA}

Table 4: Willingness-to-Pay Timing Choices

		Firm 2 Provider: Unconstrained	Firm 2 Provider: Constrained
Firm 1 Provider	Unconstrained	$\hat{T}_1^N < \hat{T}_2^N$	$\hat{T}_1^N > \hat{T}_2^N = T^{SO}$
	Constrained	$\hat{T}_1^N = T^{SO} < \hat{T}_2^N$	$\hat{T}_1^N = \hat{T}_2^N = T^{SO}$

The following proposition characterises the equilibrium outcomes for the no regulation case.

Proposition 3. *Suppose that $\hat{T}_i^N \le \hat{T}_j^N$, then (i) if $\tilde{T}_i \le \hat{T}_j^N$ there exists a unique equilibrium outcome with investment taking place at the earlier of $\hat{T}_i^N$ and $\tilde{T}_i$; (ii) if $\tilde{T}_i \le \hat{T}_j^N$ and $W_i(\hat{T}_i^N) \le L_i(\hat{T}_j^N)$ there exists another equilibrium with investment taking place by firm j at $\hat{T}_j^N$.*

This proposition is a special case of Theorem 1 of Katz and Shapiro (1987, p.410). Pre-emption incentives determine the equilibrium if the timing choice that equates the winning and losing payoffs for each firm is earlier than either firm's willingness to pay timing choice. When either firm faces a constrained outcome in negotiations this means that the equilibrium timing choice occurs at an earlier date than would be socially optimal.

Regulation Case

Unlike the "small" seeker case, the regulatory option does not necessarily commit the firms to the regulated access price as $\overline{p}^R$ might exceed π_i^{SA}. Whether this occurs or not depends on the choice of $\overline{p}^R$. Proposition 4 below demonstrates that the optimal regulated price respects the by-pass possibility and ensures that it is not a credible outside option in negotiations.

Proposition 4. *When regulation is an option, an optimal regulatory access price involves* $\bar{p}^R = \alpha B(.)$ *where* $\alpha = v_S / (v_P + v_S)$ *and* $B(.)$ *is governed by either the replacement or historical cost methodology. Under this regime, the unique subgame perfect equilibrium involves investment taking place at its socially optimal level,* T^{SO}*.*

The proof of the proposition is in the appendix. Note that while regulation serves a similar role as in the "small" seeker case, here it also serves to remove pre-emption incentives. Because each firm's share of costs is fixed no matter when investment takes place, each is indifferent between being the provider and being the seeker at any time T (i.e., $W_i(T) = L_i(T)$ for all i and T). Therefore, in the "large" seeker case, regulation is useful in eliminating incentives for firms to invest in technologically inferior facilities even when it might be commercially feasible for either firm to duplicate the facility.

V. Fixed Seeker Timing

When access seeker timing is flexible, the optimal regulatory regime is constructed so as to encourage the seeker to seek access as soon as possible. This means that the historical and replacement cost methodologies will be equivalent in equilibrium. In this section, we consider a special case where S is "small" (in that, $v_S + \frac{1}{2} v_P < F$) and, moreover, S can only choose to seek access after an exogenous time $\bar{T}_S$, where $\bar{T}_S > T_P^{SA}$. In this case, P anticipates that access will not be sought immediately and this drives a wedge between the replacement and historical cost methodologies from its point of view.

To consider this, observe that in the no regulation case, P invests at T_P^{SA}, as given the exogenous seeker timing, it anticipates that it will to earn an access charge only sometime after this date. Note that, in this context, this is also the socially optimal timing, as that decision is independent of v_S, being part of a simple additive term.

Under the replacement cost methodology, $\overline{p}^R = \alpha F(T_S)e^{rT_S}$. However, this means that S's profit maximising choice will always be $\overline{T}_S$, as it would otherwise prefer to seek access at an earlier date if its timing choice were completely flexible. Anticipating this, P chooses its timing to maximise: $v_P e^{-rT_P} - F(T_P) + \alpha F(\overline{T}_S)e^{r(\overline{T}_S - T_P)}$. This is equal to T_P^{SA}, so the regulatory outcome introduces no distortion.

The effect is quite different under historical costs, where $\overline{p}^R = \alpha F(T_P)e^{rT_P}$. As the access charge is independent of seeker timing, S will seek access as soon as it can, i.e., at $\overline{T}_S$. However, P's choice of timing now influences the access charge it expects to receive. Under our assumptions, current infrastructure costs are decreasing in T_P. As such, by speeding up investment, P can increase the access charge it ultimately receives. Therefore, $\hat{T}_P^R < T_P^{SA}$. For any α, the use of the historical cost methodology encourages P to invest in an inferior technology relative to the social optimum. Indeed, in this situation, free access (i.e., $\alpha = 0$) would be socially superior.[10]

VI. Conclusions and Future Directions

This paper has modelled the dynamic implications of access regulation in an environment where infrastructure is privately provided and has natural monopoly characteristics. We conclude that access regulation provides incentives for socially optimal timing decisions that cannot be achieved in the absence of such regulation. It does this by fixing the outside options of access providers and seekers in a model based on the

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[10] Observe that for functional form we can consider the case where $r > \lambda$ so that current investment costs rise rather than fall overtime. In this case, under no regulation investment takes place at time 0 and this is socially optimal. However, under the historical cost methodology, P may choose to delay investment so as to increase the access charge it earns. No such distortion occurs under the replacement cost methodology.

"regulation by negotiation" philosophy that is at the heart of Australian competition policy.[11]

Our results demonstrate that, even in an environment where firms do not compete in downstream markets, appropriate regulatory guidelines can have in important role in shaping the expectations of potential investors. As such, it strengthens traditional economic reasoning regarding the role of regulation in aligning private and social incentives. In particular, it reinforces the notion that regulatory pricing formulae should be clearly set out by regulators (such as the ACCC) so as to have the intended impact on investment decisions.

Our basic principle is that regulatory access charges that compensate providers for a proportion of infrastructure value provide the optimal incentives for timely investment and use. By allowing investment costs themselves to form part of the basis of fixed access charges, a signal is sent to investors regarding the value of their investment. In particular, if others derive more value from access to the infrastructure, providers can expect to recover a greater proportion of their investment expenses when access is sought. The model demonstrates that issues of asset valuation can also play an important role in incentives to provide and seek access. When the only constraint on the time access is sought is the time infrastructure is built, in equilibrium, both historical and replacement cost methodologies do not have a practical difference. Access is sought as soon as possible. However, when the timing of a seeker is determined by other criteria, a historical cost methodology – being independent of subsequent technological progress – can lead to distortions in the initial investment decision.

The obvious issue that we have not dealt with is what occurs when there is rivalry among firms. This is a complex issue that has been at the heart of static pricing issues in access regulation (see King, 1997). In particular, when a provider is vertically integrated and in competition with downstream firms, they have limited incentives to grant access in

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[11] For an informal review of these pricing principles see Gans and Williams (1998).

the first place. The *Trade Practices Act* guarantees other downstream firms access with the intended effect of promoting competition downstream. However, as studied by King and Maddock (1997), while access is guaranteed by the Act, this does not necessarily mean that competitive outcomes will be preserved downstream. A provider and a seeker have an incentive to by-pass direct regulation in favour of a negotiated outcome that preserves monopoly rents in the industry.

The above analysis highlights issues of investment incentive that also arise the rival case. That is, any effective regulation, to the extent that it improves the prospects for competitive outcomes, necessarily reduces overall rents that can be appropriated by a private investor – distributing them either to consumers or other firms. Thus, regulators face a dilemma: in order to assure socially efficient usage of natural monopoly infrastructure – i.e., competitive downstream pricing – they must necessarily reduce overall rents that can be appropriated by investors. Hence, regulators trade-off competition with timely investment in much the same way as patent policy necessarily encourages inefficient use of an invention in the hope of raising the returns to private research and development.

Nonetheless, this paper suggests that when there is more than a single potential provider of the infrastructure, pre-emption concerns also influence investment timing. Hence, competition among them to actually provide the infrastructure may speed up investment decisions. This suggests that, even when downstream competition is anticipated, providers might be persuaded to invest at the socially optimal time (taking into account consumers as well as producer surplus) with a judicious choice of access pricing formula. This direction has been pursued in Gans (1998). In that paper, it is demonstrated that a regulator can utilise the “racing” features of infrastructure investment decisions to encourage even rival firms to compete to become the provider. In a direct regulation environment, where firms have no negotiation option, the regulated price can determine the “prize” in this competition and potentially allow both the timely provision and efficient use of privately funded infrastructure. That work amends the fully distributed cost allocation rule proposed in this paper suggesting that its efficiency properties extend beyond the simple environment modelled here.

Appendix

Proof of Proposition 4

The text of the paper demonstrates that the pre-emption incentives of the two firms are not binding under the regulatory regime while the same argument for the "small" seeker case carries over as to why the replacement and historical cost methodologies yield equivalent outcomes. It only remains to show that the stand-alone payoff of the seeker is lower than the seeker's payoff when it exercises the regulatory option. In the latter case, the seeker (if it is firm *i*) receives $v_i e^{-rT^{SO}} - \frac{v_i}{v_j + v_i} F(T^{SO})$. Note that if it exercised the regulatory option at time T_i^{SA}, it would be better off than if it duplicated the facility. Moreover, T^{SO} maximises *i*'s payoff under this reduced cost structure. Therefore, it must earn a greater payoff by exercising the regulatory option than by duplicating the facility.

Figure One

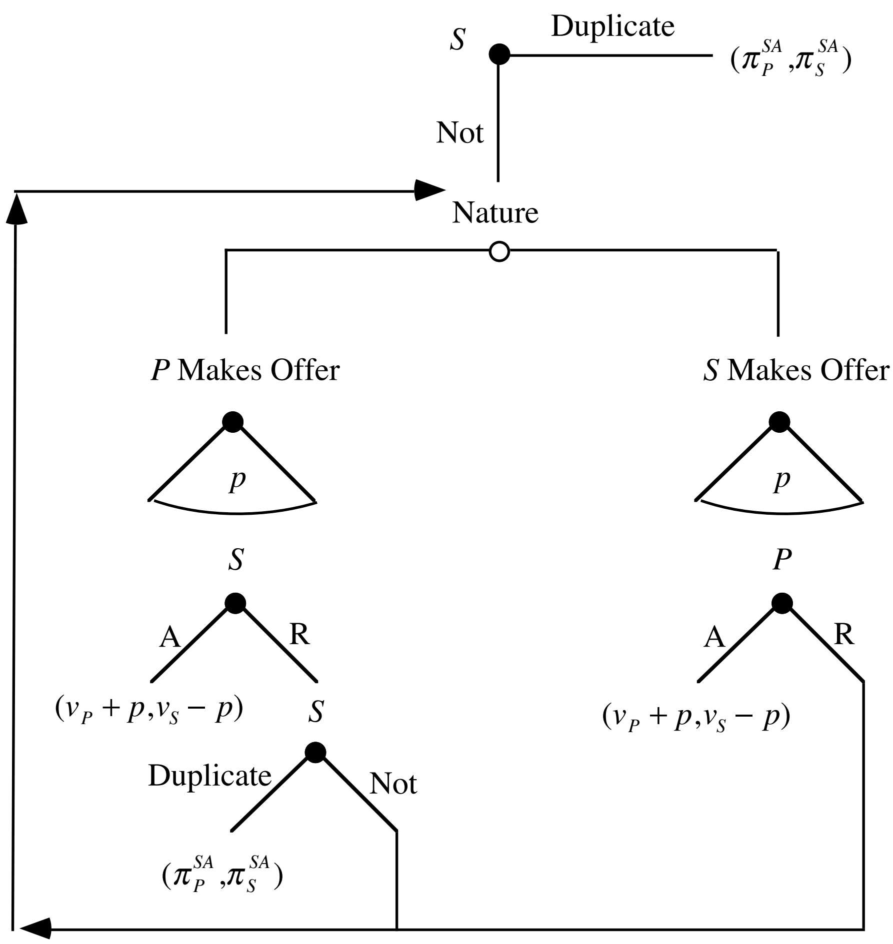
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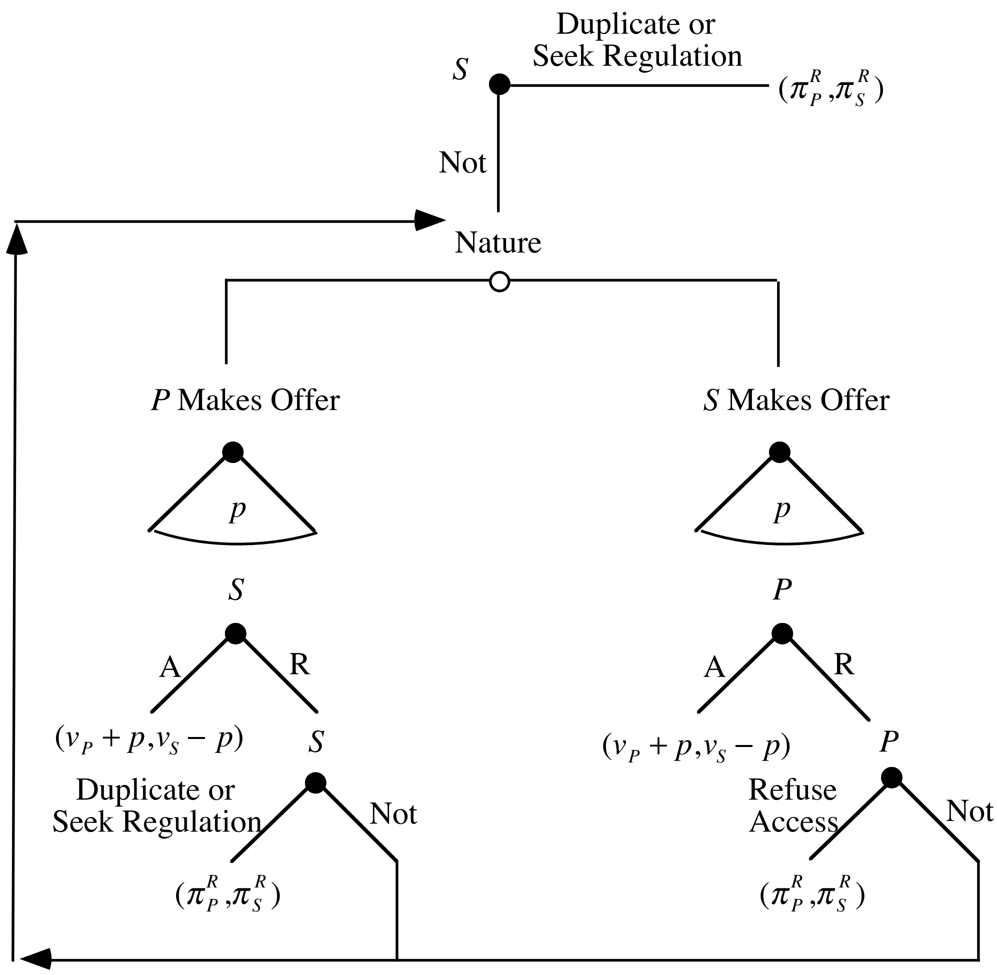
Figure Two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