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Access Pricing Under Imperfect Competition[1]

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Abstract: The study investigates optimal access charges when the downstream markets are imperfectly competitive. Optimal access charges have been examined in the literature mainly under the condition where only the incumbent has market power. However, network industries tend to exhibit an oligopolistic market structure. Therefore, the optimal access charge under imperfect competition is an important consideration when regulators determine access charges. This essay investigates some general principles for setting optimal access charges when downstream markets are imperfectly competitive. One of the primary objectives of this essay is to show the importance of the break-even constraint when first-best access charges are not feasible. Specifically, we show that when the first-best access charges are not feasible, the imposition of the break-even constraint on only the upstream profit of the incumbent is superior to the case where break-even constraint applies to overall incumbent profit, where the latter is the most commonly used constraint in the access pricing literature. Bypass and its implications for optimal access charges and welfare are also explored.

Key words: Optimal Access Charges, Non-negativity Constraint, Regulation

JEL Classification: L13, L51, L97

Introduction

Industries such as telecommunications, electricity, natural gas, railroads, water, and the postal service all have both naturally monopolistic and potentially competitive segments. Hence, these industries can be viewed as having a vertical integrated structure. In the telecommunications industry, local loops can be regarded as the naturally monopolistic segment, whereas long distance and the value-added services can be regarded as potentially competitive. In the electric power industry, transmission and distribution are naturally monopolistic segments, while electricity generation is potentially a competitive segment. Similarly, in the natural gas industry, pipelines are the naturally monopolistic segment whereas extraction can be classified as a potentially competitive segment. In the railroad industry, tracks and stations are in the naturally monopolistic segment while passenger and freight services are potentially in the competitive segment. All of these industries are similar in the sense that they contain both potentially competitive segments and natural monopolistic segments.

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Naturally monopolistic segments of these industries are often referred to as bottleneck segments. Therefore, effective potential competition requires the non-discriminatory access to bottleneck segments. Without question, unbundling and/or access pricing is the main policy instrument for introducing competition in these industries. In other words, access pricing is a critical policy for deregulation of industries where a vertically integrated dominant firm controls the supply of a bottleneck input.

Access pricing is not a new issue in regulatory economics. Its roots derive from the essential facilities doctrine that dates back to a U.S. Supreme Court decision for railroads in the early 20th century. In 1912, the Supreme Court forced the Terminal Railroad Association to allow its competitors to use its terminal facilities.[3,4] As Sherman (2008, p. 266) observed following the Supreme Court decision, when a firm has monopolistic power over a facility that is required by other firms in order to compete, it has been argued that other suppliers should have access to the facility on non-discriminatory terms and conditions.[5]

Access pricing became the main policy instrument for regulators after vertically integrated monopolies were deregulated. Increased criticism of regulation in the 1970s and 1980s led to network unbundling with the goal of increased competition. For example, in Britain before privatizing the national railway in 1994, the railways were sold to approximately seventy companies, and the most important company, Railtrack, owned and maintained the infrastructure.[6] In the United States, the most recent example of unbundling as an industrial policy is the 1996 Telecommunications Act.[7] Section 251 (d) (2) of the 1996 Telecommunications Act directs the Federal Communications Commission (FCC) to determine the specific network elements that incumbent local exchange carriers (ILECs) must provide to their competitors on an unbundled basis at "cost-based" rates.[8] Nevertheless, the ILECs and the competitive local exchange carriers' (CLECs) are at odds with respect to the pricing of unbundled network elements (UNEs) at cost-based rates. The ILECs contend that economic efficiency requires that prices for UNEs be based on the actual, forward-looking costs. Conversely, the CLECs contends that economic efficiency demands that prices for UNEs be based on the forward-looking costs of an ideally efficient ILEC as this standard is consistent with the competitive market structure that the 1996 Telecommunications Act envisioned.[9]

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[3] See United States v. Terminal Railroad Ass'n, 224 U.S. 383 (1912) and 236 U.S. 194 (1915).

[4] The Terminal Railroad Association was an organization of railroads that owned a railroad bridge and other facilities in St. Louis, Missouri.

[5] See Lipsky and Sidak (1999) and Robinson and Weisman (2008) for detailed review of the essential facilities doctrine.

[6] For more detailed discussion, see Gómez-Ibáñez J. A. (2003, p. 247, 264-297).

[7] The 1996 Telecommunication Act Section 251 (d) (2): In determining what network elements should be made available for purposes of subsection (c) (3), the Commission shall consider, at a minimum, whether

(A) access to such network elements as are proprietary in nature is necessary; and
(B) the failure to provide access to such network elements would impair the ability of the telecommunications carrier seeking access to provide the services that it seeks to offer.

[8] See Kahn,Tardiff and Weisman (1999) for a comprehensive discussion of the economics underlying the 1996 Telecommunications Act.

[9] See Weisman (2002) and Weisman (2000).

Both approaches can be criticized on various grounds. First, ILECs may have incentives to misreport their actual costs. Whether the inefficiencies of ILECs should be reflected in UNE prices is another point of criticism. Moreover, the ILEC might not have proper incentives to achieve efficiency if UNE prices are based on actual costs. On the other hand, the definition for the ideally efficient ILEC is unclear, and the proper standard to determine what constitutes "an ideally efficient" ILEC is a difficult question to answer. Moreover as Weisman (2000, p. 196) observed "If regulators had sufficient information to implement the efficient–firm cost standard, competition would be wholly unnecessary."

Therefore, the complex issue of optimal access charges lies at the core of deregulation efforts in network industries. In other words, a sound access pricing policy is crucial for the efficient development of competition in industries with bottleneck inputs. Moreover, Laffont and Tirole (2001, p. 98-99) observed that an optimal access charge policy must serve numerous purposes. It must generate efficient use of networks, encourage incumbents to invest, promote cost minimization, and create an efficient amount of entry into infrastructure, and do all this at a reasonable regulatory cost.

Realizing all of these objectives simultaneously with a single policy instrument is complex. As Laffont and Tirole (2001, p. 99) point out, the access price is critical in order to give incumbents the correct signals for their choices of investment in infrastructure and induce potential competitors to enter into socially desirable segments.

Optimal access pricing has become one of the central topics in modern regulatory economics. In the access pricing literature, there is a distinction between one-way access pricing and two-way access pricing. In one-way access, pricing only competitors require vital inputs from the monopolistic incumbent. In the case of two-way access pricing, all firms in the market need to purchase critical inputs from each other. In this study we focus on one-way access pricing.[10]

The purpose of this study is to examine optimal access charges under an oligopolistic market structure. Although formerly regulated industries post-deregulation exhibit properties that are closer to an oligopolistic market structure, most of the optimal access pricing literature focuses on contestable/perfect competition models. In this respect, we study key characteristics of optimal access charges in a simple Cournot competition model where only one input is necessary for the downstream production. This is a simple framework and many complicated real-word issues such as asymmetric information, investment decisions, and dynamics are suppressed. Nonetheless, this analysis provides a useful starting point for the analysis and future research.

As Vickers (1995) observed, Cournot competition results in market outputs with positive markups. Hence, a vertically integrated firm has a markup over the marginal cost of the input while a competitor will have a markup over the price of the critical (essential) input. These are downstream markups. On the other hand, if the access price exceeds marginal cost, then there would be a second markup from the upstream market. Hence, determining the optimal access charge requires regulators to address these two markups within the Cournot framework.

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[10] See Chapter 5 in Laffont and Tirole (2001), Armstong (2002, p. 350-379), and Chapters 5 and 6 in Dewenter and Haucap (2007) for studies that examine two-way access pricing.

Optimal access charges are closely related to the concepts of the first-best and the second-best efficiency. When the non-negativity profit constraint of the vertically integrated incumbent is not taken into account, optimal access prices are the first-best access prices. However, first-best access pricing may result in negative profit for the vertically integrated incumbent threatening its financial viability. This is the case when the incumbent's break-even constraint is binding at the social optimum. Therefore, the effects of the profit constraint must be explicitly taken into account. Taking into account the profit constraint of the incumbent gives rise to the concept of second-best access pricing.

The non-negativity profit constraint of the incumbent is extensively used in the access pricing literature. The general approach is to examine a non-negativity constraint that applies to the overall profit of the incumbent. However, this potentially distorts competition in the downstream market since applying a non-negativity profit constraint to the overall profit of the incumbent guarantees normal profit for the incumbent in both the regulated upstream market and the competitive downstream market. This might tend to create a bias that favors the incumbent's downstream production. Guaranteeing a normal profit for the incumbent provider leads to a distortion in the retail market by suppressing at least some of the advantages expected of competition. Moreover, it might be the case that the incumbent's inefficiencies are passed on to the retail market. In the competitive/contestable market framework with retail price regulation, guaranteeing non-negative overall profit may not create a serious distortion compared with the first-best output. However, in an oligopolistic market structure the non-negativity assumption leads to a potentially large deviation from first-best output levels.

One solution for the given problem would be to impose a non-negativity constraint to the incumbent's upstream profit only while deregulating the downstream segment of the industry. One of the objectives of this paper is to compare the welfare effects of these two policies. To that end, we evaluate the welfare properties within the Cournot model and show that imposing the non-negativity constraint on only upstream profits provides higher total welfare than imposing the non-negativity constraint on overall profits.

Our simple framework is also used to examine the effect of bypass. Bypass arises when the competitor – rather than using the incumbent's network – uses an alternative source for the bottleneck input. We show that under certain conditions bypass can be welfare-enhancing.

The organization of the remainder of this essay is as follows. Section 2 provides a literature review. Although there is a voluminous literature on the topic, the focus here is primarily on studies that explore optimal access charges. Section 3 discusses the main elements of the model. The first–best and second–best access prices in an oligopolistic market structure are derived in Section 4. This section also includes the welfare comparisons of two possible policies regarding the non-negativity constraint of the vertically integrated provider. In Section 5, the possibility of bypass and its effects on optimal access charges are examined. Section 6 contains the conclusion.

Literature Review

Since network unbundling has developed into a key policy instrument for introducing competition into previously regulated industries, the topic has attracted significant interest from researchers. As a result, a voluminous access pricing literature has emerged. However, since our objective is to investigate general principles for optimal access charges under an oligopolistic market structure, we limit the discussion to studies that focus on properties of optimal access charges.

Perhaps one of the most important results in the optimal access charge literature is known as the Baumol-Willig efficient component pricing rule (ECPR). Willig (1979) and Baumol (1983) advocate the ECPR.[11] Their analyses depend on contestable markets which can be treated as part of a perfect competition framework. The optimal access price of a bottleneck input based on the ECPR should be equal to the direct incremental cost of access plus the opportunity cost borne by the integrated access provider in supplying access. The opportunity cost is the decrease in the incumbent's profit caused by the provision of the bottleneck input to a rival. Therefore, the access charge can be higher than the direct incremental cost by a substantial margin. The ILECs generally favor such an access pricing policy. However, the fact that previously regulated industries are far from being competitive is a serious point of criticism. Moreover, the inclusion of the opportunity cost term in this form of access pricing means that less-efficient incumbents will receive higher prices for their input, ceteris paribus.

Spencer and Brander (1983) focus on departures from marginal cost pricing induced by imperfect competition in industries that require publicly-produced inputs. As they assumed the public enterprise has a vertically-integrated structure, their analysis is conducted with and without the non-negative profit constraint imposed on the public enterprise. They show that in order to induce the socially desirable output under imperfect competition, the first best access charge requires an input price set below the marginal cost of the input. However, when the profit constraint is introduced, the second-best input price exceeds the marginal cost of the input.

Vickers (1995) examines a vertically integrated industry structure with naturally monopolistic and competitive segments. He examines whether the upstream monopolist should be allowed to operate in the deregulated competitive sector. Vickers employs a Cournot model in an asymmetric-information environment, and compares total welfare under linear and unit-elastic demand functions in the cases of vertical integration and vertical separation. Vickers' analysis reveals that the access charge should be higher or lower than marginal cost depends on whether the number of firms in the downstream competition is sensitive to the level of the access charge. In particular, his analysis suggests that when the number of firms is sensitive to the level of the access price, the optimal access charge should be above the marginal cost, and vertical integration yields higher welfare in this case. Conversely, if the number of firms in the downstream market is insensitive to the access charge, the optimal access price should be set below marginal cost, and vertical separation produces higher welfare results in this case.

Laffont and Tirole (1994) investigate optimal access prices in a competitive fringe model using a principal-agent framework. In their analysis, the key assumption is that the regulator can make up any possible earnings deficiency for the incumbent using public funds. The authors show that the first-best access pricing should be marginal cost pricing. However, when marginal cost pricing results in an earnings shortfall for the

[11] See also Chapter 7 in Baumol and Sidak (1994).

incumbent provider, competitors should contribute to the fixed cost of the network. The authors state that the contribution takes the form of an access charge exceeding the marginal cost of the input.

Armstrong, Doyle and Vickers (1996) use a competitive fringe model to show that the ECPR can be a useful benchmark for determining optimal access charges. They analyze the precise meaning of ‘opportunity cost’ under differing demand and supply conditions. Throughout their analysis, they assume that the price for the downstream product is a choice variable for the regulator while competitors take this price as given. In the benchmark case, they show that the optimal access charge should be equal to the marginal cost of the bottleneck input when the incumbent’s break-even constraint is not binding at the social optimum. Conversely, if the break-even constraint is binding at the social optimum, the optimal access price should exceed marginal cost. Moreover, their results reveal that the latter benchmark case with price regulation implies an optimal charge fully consistent with the ECPR.

Armstrong and Vickers (1998) extend the analysis of Armstrong et al. (1996) to the case where there is a retail price deregulation. The authors analyze a model for a homogeneous product and price-taking rivals. They find that the optimal access charge can be above, below or equal to the marginal cost of the bottleneck input. In particular, when the demand and rival supply for the downstream product is linear, the authors show that the optimal access price should be set equal to marginal cost as long as the break-even constraint is not binding. However, based on the demand and the competitors’ supply functions, the optimal access charge can be above or below marginal cost.

Armstrong (2002) provides one of the most comprehensive studies to date in the access pricing literature. By making use of unit demand, competitive fringe, perfect retail competition, and partial deregulation models, Armstrong examines topics such as the foreclosure problem, fixed retail prices, unregulated prices and bypass. In this study, he sheds light on topics such as access charges, dynamic issues and two-way access pricing in the telecommunications industry.

Model

The incumbent is a vertically integrated producer in this model, and a monopolist in the production of the essential input. The essential input is assumed to be the sole input necessary for the production of the downstream product. The incumbent’s downstream affiliate and (n-1) competitors produce and market the retail product. The upstream and downstream production technologies are assumed to exhibit constant returns to scale. The incumbent’s marginal cost is c. The incumbent sells the essential input to its rivals at unit price w. The price of the essential input is determined by the regulator. The incumbent’s and a representative competitor’s downstream production are denoted by q_1^I and q_i, respectively. For simplicity, we assume that a linear inverse demand function is given by $P\left(q_1^I + \sum_{i=2}^{n} q_i\right)$, where $P'(\cdot) < 0$ and $P''(\cdot) = 0$.

The incumbent and the (n-1) competitors are assumed to engage in Cournot competition in the downstream market. The profit functions of the incumbent and the representative competitor are given, respectively, by:

$$\Pi_1^I = (w-c)\sum_{i\neq 1}^{n} q_i + \left(P(Q)-c\right)q_1^I \text{, and} \tag{1}$$

$$\Pi_i = \left(P(Q)-w\right)q_i \text{,} \tag{2}$$

where Π^I and Π_i are profits of the incumbent and the representative competitor. The first term in (1) is the upstream profit that the incumbent realizes from selling the essential input to the competitors. The second term is the incumbent's profit from its downstream operations. The essential input cost is assumed to be identical for the incumbent's upstream and downstream affiliates.[12]

The regulator has full information regarding the demand, cost structure and the nature of competition. The following two-stage game is considered based on these assumptions. In the first stage, the regulator's objective is to establish an optimal access charge. In the second stage, the incumbent and the (n-1) competitors take the input price as given and engage in quantity competition in the downstream market. Finally, consumers make their purchase decisions after observing the market price.

Main Findings

Assuming an interior solution, the first order necessary conditions of the incumbent and the representative competitor for the profit maximization are the equality of marginal revenue and marginal cost: $P'q_1^I + P = c$ and $P'q_i + P = w$. Totally differentiating the first-order conditions and allowing for an infinitesimal change in the price of essential input yields:

$$P'dq_1^I + P'(\cdot).\left(dq_1^I + \sum\nolimits_{i=2}^{n} dq_i\right) = 0 \quad \text{and} \quad P'dq_i + P'(\cdot).\left(dq_1^I + \sum\nolimits_{i=2}^{n} dq_i\right) = dw \quad .$$

Solving the previous n equation system yields:

$$dq_1^I = -\frac{n-1}{(n+1)P'}dw \text{, and} \tag{3}$$

$$dq_i = \frac{2}{(n+1)P'}dw \,. \tag{4}$$

The measure of total welfare employed here is the unweighted sum of consumer surplus and total industry profits, or, $W = CS + \Pi_1^I + \sum_{i=2}^{n}\Pi_i$, where consumer surplus (CS) is given by $U\left(q_1^I + \sum_{i=2}^{n} q_i\right) - P(\cdot)\left(q_1^I + \sum_{i=2}^{n} q_i\right)$.

[12] The regulators impose parity requirements on vertically integrated producers in order to prevent sabotage. See Sappington and Weisman (2005, p. 156) footnote 3.

Proposition 1 specifies the general principles regarding the optimal access charge under the stated assumptions.

Proposition 1: *At the welfare optimizing essential input price, (i) the downstream product price equals the marginal cost of the essential input in the downstream market, and (ii) the optimal access charge is lower than the marginal cost of access under specified assumptions.*

Proposition 1 (i) states that the welfare-optimizing access price in our simple Cournot framework enables market price to equal marginal cost for the critical input. In a sense this is the first-best access charge. Therefore, allocative efficiency can be attained at the optimal access charge.

Two observations are instructive regarding the first-best optimal access charge. First, when price equals marginal cost, the incumbent's downstream production is zero according to the necessary first-order condition for the incumbent.[13] This result is consistent with Vickers (1995).[14] Second, based on the first-order condition of the competitor, its downstream production is positive if and only if the optimal access charge is lower than the marginal cost of access. This result is identical to Spencer and Brander (1983). They showed that in the case of first-best pricing of a publicly produced input with imperfect downstream competition, the input price should be lower than marginal cost of the input and downstream product price equals marginal cost.15 Based on these observations and Proposition 1, it follows that the regulator uses the upstream markup to achieve the first-best output level in the retail market. In other words, by charging less than the marginal cost for the bottleneck input, the regulator is subsidizing access to harmonize the downstream product price with the marginal cost of production. The key point here is that the regulator compensates for downstream market power by reducing the critical input price below marginal cost to increase output in the retail market.

Henceforth, for analytical convenience and clarity in comparisons of various regulatory policies, the market inverse demand function for the downstream product is assumed to have the general form:

Assumption 1: $P(Q) = \alpha - \beta Q = \alpha - \beta\left(q_1^I + q_2 + \cdots + q_n\right)$,

where $\alpha > 0$ and $\beta > 0$.

[13] One logical question concerns why the incumbent firm's downstream production is zero at the first-best access charge. In other words, is the incumbent able to reduce its losses in the upstream market by producing positive output in the downstream market? To answer this question, note that the first-best access charge results in market price equal marginal cost (*c*) in the equilibrium. Therefore, if the incumbent firm produces some positive quantity for the downstream market at the optimal access charge, the market price for the downstream product should be lower. Hence, producing positive output actually increases the incumbent's losses in this case.

[14] Vickers shows that in the case of linear demand, when the vertically integrated producer is allowed into the downstream market, welfare is lower than the case where it is not allowed into the downstream market. Hence, Vickers' result can be interpreted as the incumbent's downstream production is zero at the optimal access price.

[15] See Spencer and Brander (1983) Proposition 1.

To solve the sub-game perfect Nash equilibrium of the two stage game, backward induction is employed. In this respect, we first solve for the equilibrium values in the second stage. The incumbent's and a representative competitor's profits under assumption 1 are:

$$\Pi_1^I = (w-c)\sum_{i\neq 1}^{n} q_i + \left(\alpha - \beta q_1^I - \beta \sum_{i\neq 1}^{n} q_i - c \right) q_1^I , \tag{5}$$

and

$$\Pi_i = \left(\alpha - \beta q_i - \beta \sum_{j=1,\, j\neq i}^{n} q_j - w \right) q_i . \tag{6}$$

Lemma 1 summarizes industry profit and consumer surplus for the specified model.

Lemma 1: *When Assumption 1 holds and the downstream market is characterized by Cournot competition, the equilibrium incumbent's profit, representative competitors' profit and consumer surplus are given, respectively, by:*

$$\Pi_1^I = (w-c)(n-1)\frac{\alpha + c - 2w}{\beta(n+1)} + \frac{\left(\alpha - nc + (n-1)w\right)^2}{\beta(n+1)^2}; \tag{7}$$

$$\sum_{i=2}^{n} \Pi_i = \frac{(n-1)\left(\alpha + c - 2w\right)^2}{\beta(n+1)^2}; \text{ and} \tag{8}$$

$$CS = \frac{\left(n\alpha - c - (n-1)w\right)^2}{2\beta(n+1)^2}. \tag{9}$$

Total welfare (W) is assumed to be the unweighted summation of (7), (8) and (9). The optimal access charge (w^*) for the essential input can be found by maximizing total welfare (W) with respect to the access price (w). Hence, the optimal access charge is given by $w^* = (nc-\alpha)/(n-1)$.[16] Note that w^* is the access charge that allows the market price for the downstream product to equal the marginal cost of the input. This is the first-best access pricing policy and $w^* = (nc-\alpha)/(n-1)$ is lower than marginal cost of the input. Hence at the first-best access price the incumbent makes negative profit from the upstream market. In addition, as previously stated, the optimal access charge

[16] Notice that the first-best access charge, $w^* = \frac{nc-\alpha}{n-1}$, increases with the number of firms (n). Moreover, $\lim_{n\to\infty^+} w^* = \frac{nc-\alpha}{n-1} = c$ implies that as the number of firms approaches to infinity, the first-best access charge approaches the marginal cost of the input. This result is not surprising since as n approaches to infinity, the firms become price takers and the results of the model become consistent with the perfect competition models. In other words, as n grows large, the regulator needs be concerned less with downstream market power, and hence w approaches to c.

leads the incumbent's downstream affiliate to not produce any output in the downstream market. Therefore, the vertically integrated producer makes negative profit at the essential input price w^* since the incumbent's break-even constraint will bind at the social optimum. In the case where no lump-sum transfers are available to cover the incumbent's losses, this access charge is not feasible.

Since the first-best access pricing policy is inconsistent with the financial viability of the incumbent provider, the regulator may opt to determine the optimal access charge under the break-even constraint. There are two possibilities regarding the break-even constraint from the regulator's perspective. The first policy option is that the break-even constraint for the incumbent applies to the incumbent's overall profits. The second policy option entails applying the break-even constraint to the incumbent's upstream activities only. Vickers (1995, p. 14) summarizes these two possibilities in the following statement in which he contemplates extensions of his analysis:

"It has been assumed that the participation constraint for M (vertically integrated incumbent) applies to its profits overall, including profits from the downstream competitive activity… Indeed, it is more in the spirit of deregulation to allow the firm independently to take it chances along with other competitors in deregulated activities, and not to prejudge the outcome of competition there... This suggests that a more realistic formulation might be to require that M at least break even in its upstream regulated activities."

However, Vickers does not actually conduct the formal analysis that he contemplates. Throughout the vast optimal access pricing literature that focuses on the non-negativity constraint of the incumbent's overall profit, to our knowledge there is no study that concentrates on a non-negativity constraint applied exclusively to the incumbent's upstream profit. One reason for this is that the models used in the previous studies include perfect downstream competition with price regulation. In these models, there is no business-stealing-effect unless there is product differentiation. When downstream competition is imperfect, implying that each firm in the downstream market has some degree of market power, a one-for-one displacement of outputs from the incumbent to the competitors typically does not hold in equilibrium. Therefore, the regulator solves the following problem:

$$\begin{aligned} &\max \quad CS + \sum_{i \neq 1}^{n} \Pi_i + (\Pi_{1u}^I + \Pi_{1d}^I) \\ &s.t. \quad \Pi_{1u}^I + \theta \Pi_{1d}^I \geq 0 \end{aligned} \tag{10}$$

where $\theta \in [0,1]$, $\lambda > 0$ is the Lagrange multiplier and Π_{1u}^I and Π_{1d}^I denote upstream and downstream profits of the vertically-integrated incumbent, respectively. The boundary points on this closed interval characterize two possible break-even constraints under examination. When $\theta = 0$, the break-even constraint applies to only incumbent's upstream market. Conversely, when $\theta = 1$, the break-even constraint is implemented for the total (upstream and downstream) profits of the incumbent.

Finding the optimal access charge for the incumbent's profit constraint requires solving the regulator's constrained maximization problem in (10). The second-order conditions are assumed to hold, hence, the focus is on an interior solution here. The optimal access price can be found by setting the derivative of the Lagrange function equal to zero and solving it for the access charge (w).[17] The optimal access charge is given by:

$$w^* = \frac{\left(2\theta\left(1+\lambda\right)+\lambda(n+1)-3\right)\alpha-\left(2\theta n\left(1+\lambda\right)-3\lambda(n+1)-3n\right)c}{(n-1)\left(3-2\theta(1+\lambda)\right)+4\lambda(n+1)} \tag{11}$$

The optimal access charge in (11) is the second-best access charge. Notice that the optimal access charge exceeds the marginal cost of access.[18] This implies that the second-best optimal access price allows the incumbent's downstream production to be positive.

Lemma 2 summarizes industry profit and consumer surplus in the model at the optimal access charge when the incumbent's profit constraint is binding at the social optimum.

Lemma 2: *When Assumption 1 holds and the incumbent's profit constraint is binding at the optimal access charge, the equilibrium value of the incumbent's profit, the competitors' profit and the consumer surplus are given by:*

$$\begin{aligned}\Pi_1^I &= \frac{n-1}{\beta}\frac{\left(2\theta(1+\lambda)+\lambda(n+1)-3\right)\left(3+2\lambda-2\theta(1+\lambda)\right)}{\left[(n-1)\left(3-2\theta(1+\lambda)\right)+4\lambda(n+1)\right]^2}(\alpha-c)^2 \\ &+\frac{1}{\beta}\left[\frac{\lambda(n+3)(\alpha-c)}{(n-1)\left(3-2\theta(1+\lambda)\right)+4\lambda(n+1)}\right]^2;\end{aligned} \tag{12}$$

$$\sum_{i=2}^{n}\Pi_i = \frac{n-1}{\beta}\left[\frac{\left(3+2\lambda-2\theta(1+\lambda)\right)(\alpha-c)}{(n-1)\left(3-2\theta(1+\lambda)\right)+4\lambda(n+1)}\right]^2 \text{; and} \tag{13}$$

$$CS = \frac{1}{2\beta}\left[\frac{\left[(n-1)\left(3-2\theta(1+\lambda)\right)+\lambda(3n+1)\right](\alpha-c)}{(n-1)\left(3-2\theta(1+\lambda)\right)+4\lambda(n+1)}\right]^2. \tag{14}$$

Equations (12) – (14) define total social welfare under the optimal access charge. Specifically, when $\theta=1$, equations (12) – (14) denote total welfare under the second-best optimal access charge when the break even constraint applies to the incumbent's

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[17] The focus here is an interior solution where the non-negativity profit constraint is binding at social optimum. Therefore, we only discuss the results of Kuhn-Tucker conditions where $\lambda>0$. In the case where $\lambda=0$, we have unconstrained optimization whose results have already been discussed above.

[18] The mark-up in producing the bottleneck input at the optimal access price for the incumbent is given by $w^* - c = \frac{2\theta(1+\lambda)+\lambda(n+1)-3}{\left((n-1)\left(3-2\theta(1+\lambda)\right)+4\lambda(n+1)\right)(\alpha-c)}$, where the denominator is unambiguously positive. Hence, the optimal access charge exceeds marginal cost if $2\theta(1+\lambda)+\lambda(n+1)-3>0$. Since θ is a positive exogenous value determined by the regulator, there always exists a positive value of λ for different θ's that satisfy this inequality.

overall profit. Conversely, when $\theta = 0$, equations (12) – (14) define total social welfare under the second-best optimal access price when the break-even constraint for the incumbent applies to its upstream profit only. Proposition 2 provides a comparison of the two possibilities regarding the break-even constraint for the incumbent.

Proposition 2: *Assume that Assumption 1 holds and the downstream market is characterized by Cournot competition,*

(i) The incumbent's profit is higher when the break-even constraint for the incumbent applies to its overall profits $(\theta = 1)$,

(ii) The consumer surplus, the competitors' profit and total welfare are higher when the break-even constraint for the incumbent applies to its upstream profit only $(\theta = 0)$.

The findings of Proposition 2 are intuitive regarding the incumbent's break-even constraint. When the break-even constraint is introduced, the optimal access charge results in a welfare reduction relative to the first-best optimal access charge. In addition, the higher price-marginal cost markup for downstream output, the greater the welfare loss, ceteris paribus. Applying the break-even constraint to the incumbent's overall profit including its profits from downstream activities leads to a higher markup over the marginal cost compared to the case when the break-even constraint for the incumbent applies to the upstream profit only. In other words, applying the break-even constraint to the incumbent's overall profit leads to a higher deviation from the first-best optimal access charge than applying it to the incumbent's upstream profit only. Therefore, applying the break-even constraint to the incumbent's upstream profit only yields both a lower access charge and a market price closer to marginal cost, ceteris paribus.

Notice that the incumbent's downstream production is positively related to the access price. The same observation is also true for the incumbent's overall profit due to the fact that the second-best access price exceeds marginal cost of the bottleneck input. On the other hand, a competitor's downstream production and profit are inversely related to the access price. Thus, as compared to the case where the non-negative profit constraint is restricted to upstream profit, the incumbent's downstream output and profit increases when the non-negativity constraint applies to overall profit. For competitors, the converse is true. In addition, the competitors' production falls by more than the increase in incumbent's production. Therefore, higher access charges lead to a decrease in the market equilibrium quantity. Hence, consumer surplus will be lower in the case where the break-even constraint applies to the incumbent's overall profit rather than its upstream profit only. This implies that social welfare is lower due to the fact that the overall decrease in the entrants' profit and consumer surplus outweigh the increase in the incumbent's profit.

Hence, when the downstream market structure is oligopolistic rather than competitive, regulators must exercise caution in applying the break-even constraint on the operations of the incumbent provider. To wit, applying a break-even constraint to overall profits rather than limiting it to upstream profits tends to result in higher market distortions and hence larger reductions in social welfare.

Bypass

It is common in the access pricing literature to consider the effect of the entrants' ability to substitute away from the incumbent's network. This concept is generally referred to as bypass. Armstrong, Doyle and Vickers (1996) state two reasons why the fringe is able to bypass the incumbent's access service: (i) the fringe may supply the access service itself or purchase it from a third party; and (ii) the technology used by the fringe is a variable-coefficient technology and for high access charges the fringe may use proportionately less of the bottleneck input. The competitive fringe model of Armstrong, Doyle and Vickers reveals that the possibility of bypass reduces the optimal access charge compared to the non-bypass scenario by reducing the displacement ratio. Additionally, Armstrong (2002, pp. 323-324) suggests that when competitors have bypass opportunities, both the market price for the final product and the access charge are priced above marginal cost.

We assume that m of n-1 firms make their own input, and hence n-1-m firms buy the bottleneck input from the incumbent. Note that the number of firms that make the input is exogenous. Furthermore, for simplicity, we assume that the marginal cost of producing the input is also c for the competitors who bypass the incumbent (i.e., make their own input). One possible explanation for having the same marginal cost with the incumbent would be the marginal cost is the result of cost minimizing production technology of the bottleneck input. Therefore, the profit function for the incumbent, one of m firms and one of n-m-1 firms are given as follows.

$$\Pi_1^I = (w-c)\sum_{n-m-1} q_i + \left(\alpha - \beta q_1^I - \beta \sum_{i\neq 1}^{n} q_i - c\right) q_1^I , \tag{15}$$

$$\Pi_i^m = \left(\alpha - \beta q_i - \beta \sum_{j=1,\, j\neq i}^{n} q_j - c\right) q_i \text{, and} \tag{16}$$

$$\Pi_i^B = \left(\alpha - \beta q_i - \beta \sum_{j=1,\, j\neq i}^{n} q_j - w\right) q_i \,. \tag{17}$$

Lemma 3 summarizes the components of total social welfare in the case of bypass. In this respect, we obtain total industry profit and consumer surplus at the equilibrium when m of n-1 competitors can bypass the incumbent's network.

Lemma 3: *When Assumption 1 holds and the downstream market is characterized by Cournot competition, the equilibrium incumbent's profit, the competitors' profit and consumer surplus are given, respectively, by:*

$$\Pi_1^I = (w-c)(n-m-1)\frac{\alpha+(m+1)c-(m+2)w}{\beta(n+1)} + \frac{1}{\beta}\frac{\left[\alpha-(n-m)c+(n-m-1)w\right]^2}{(n+1)^2}; \tag{18}$$

$$\sum_m \Pi_i^M = \frac{m}{\beta}\frac{\left[\alpha-(n-m)c+(n-m-1)w\right]^2}{(n+1)^2}; \tag{19}$$

$$\sum_{n-m-1} \Pi_i^B = \frac{n-m-1}{\beta}\frac{\left[\alpha+(m+1)c-(m+2)w\right]^2}{(n+1)^2};\ \text{and} \tag{20}$$

$$CS = \frac{1}{2\beta}\frac{\left[n\alpha-(m+1)c-(n-m-1)w\right]^2}{(n+1)^2}. \tag{21}$$

Summation of expressions (18) – (21) yields total social welfare. It is straightforward to show that the optimal access charge when the incumbent's budget constraint is not binding at the social optimum. The first best optimal access charge is $w^* = ((n-m)c-\alpha)/(n-m-1)$ in the bypass case. First, notice that when the number of firms that make the input (m) is zero, w^* is equal to the first-best access charge when bypass is not feasible.[19] Second, w^* decreases with the number of firms that can bypass.

Therefore, this optimal access charge would be the first-best optimal access price in this case, and once more the first best optimal access charge equates the market price to the marginal cost of the input, or c. However, the first-best optimal access charge leads to the same qualitative results as in the non-bypass case. In other words, at the first-best optimal access charge, the downstream production of the incumbent–and the competitors that make the key input–is zero, since the optimal access charge is lower than the marginal cost of the access. Hence, the incumbent's financial viability is threatened in the bypass case as well.

The regulator's objective is therefore to determine the optimal access charge under the non-negativity profit constraint for the incumbent's profit. We previously showed that applying the non-negativity constraint to the incumbent's upstream profit only yields higher welfare in the non-bypass case. Therefore, we assume that the regulator's objective is to determine the optimal access charge when the non-negativity profit constraint applies only to the incumbent's upstream profit. In this case, the regulator's problem is given by:

[19] See page 11.

$$\begin{aligned} &\max \quad CS + \sum_{i \neq 1}^{n} \Pi_i + (\Pi_{1u}^I + \Pi_{1d}^I) \\ &s.t. \quad \Pi_{1u}^I \geq 0 \end{aligned} \tag{22}$$

where $\lambda > 0$ and Π_{1u}^I and Π_{1d}^I denote upstream and downstream profits of the vertically-integrated incumbent, respectively.

The optimal access charge can be found by setting the derivative of the Lagrange function equal to zero and solving it for the access charge (w). Therefore the optimal access charge is given by

$$w^* = \frac{(\lambda(n+1)-1)+((n-m)+\lambda(n+1)(3+2m))c}{(m-n-1)+2\lambda(n+1)(m+2)}. \tag{23}$$

The expression in (23) characterizes the second-best access charge. Notice that the second-best access price exceeds the marginal cost of the input.[20] Hence, the incumbent and the competitors that provide their own input realize positive downstream production at the second-best access price.

Lemma 4 summarizes equilibrium industry profit and consumer surplus in the model at the optimal access charge when the incumbent's profit constraint is binding at the social optimum.

Lemma 4: *When Assumption 1 holds and the incumbent's profit constraint is binding at the optimal access charge, the equilibrium values of the incumbent's profit, the competitors' profit and the consumer surplus are given, respectively, by:*

$$\begin{aligned} \Pi_1^I &= \frac{n-m-1}{\beta} \frac{\big(\lambda(n+1)-1\big)\big(\lambda(m+2)+1\big)}{\big[(n-m-1)+2\lambda(n+1)(m+2)\big]^2}(\alpha-c)^2 \\ &+ \frac{1}{\beta}\left[\frac{\lambda(n+m+3)(\alpha-c)}{(n-m-1)+2\lambda(n+1)(m+2)}\right]^2; \end{aligned} \tag{24}$$

$$\sum_M \Pi_i^M = \frac{m}{\beta}\left[\frac{\lambda\big(m+n+3\big)(\alpha-c)}{(n-m-1)+2\lambda(n+1)(m+2)}\right]^2; \tag{25}$$

$$\sum_B \Pi_i^B = \frac{n-m-1}{\beta}\left[\frac{(\lambda\big(m+2\big)+1)(\alpha-c)}{(n-m-1)+2\lambda(n+1)(m+2)}\right]^2 \text{; and} \tag{26}$$

[20] The mark-up for the bottleneck input at the optimal access price for the incumbent is $w^* - c = \frac{(\lambda(n+1)-1)(\alpha-c)}{(n-m-1)+2\lambda(n+1)(m+2)}$, where the denominator is unambiguously positive. Hence, the optimal access charge exceeds marginal cost if $\lambda > \frac{1}{n+1}$.

$$CS = \frac{1}{2\beta}\left[\frac{\left[(n-m-1)+\lambda(3n+m+2mn+1)\right](\alpha-c)}{(n-1)\left(3-2\theta(1+\lambda)\right)+4\lambda(n+1)}\right]^2 . \tag{27}$$

Expressions (24) – (27) define total welfare at the second-best optimal access charge. Proposition 3 provides selected comparative statics for changes in the second-best optimal access charge (w^*) and welfare (W^*) in the presence of bypass opportunities.

Proposition 3: *Suppose that Assumption 1 holds and that downstream competition is characterized by Cournot competition. At the second-best optimal access charge: (i)* $\frac{\partial w^*}{\partial m} < 0$ *and (ii)* $\frac{\partial W^*}{\partial m} > 0$.

First, it is straightforward to show that the second-best optimal access charge is inversely related to bypass opportunities. In other words, as the number of firms that makes their own input increases, the second-best optimal charge approaches the marginal cost of access. This results in higher equilibrium market output. The rationale for this finding is that there are fewer firms requiring the input from the incumbent compared to the non-bypass case. Hence, there are more firms producing the downstream output at a marginal cost c which is lower than the second-best optimal access price. Therefore, the regulator can set a lower access charge compared to the non-bypass case by lowering the mark-ups of all firms. Hence the effect of bypass is no different than the effect of an industry-wide cost reduction under the Cournot equilibrium.

Since the equilibrium market output is higher with bypass, the consumer surplus is also unambiguously higher compared to the non-bypass case. The incumbent’s profit is unambiguously lower in the bypass case. This can be shown by taking the derivative of the expression given in equation (24) with respect to the number of firms that make the input (m). Unlike the consumer surplus and the incumbent’s profit, the manner in which bypass affects the competitors’ profit is ambiguous since it depends on the initial value of m. However, total welfare unambiguously increases with bypass. This is due to the effect of the lower markups discussed above.

Conclusion

Although deregulation typically results in market structures that are closer to oligopoly, the access pricing literature has focused primarily on contestable/perfect competition models. This essay addresses that issue with a simple Cournot competition model with perfect information. This simple model yields some useful results concerning optimal access pricing in imperfectly competitive markets. A vertically-integrated industry is assumed to be deregulated and the formerly regulated firm is the only provider of the bottleneck input in the upstream market and one of n competing firms in the downstream or retail market in which all firms possess some market power.

When n firms engage in Cournot competition, the first best access charge equates the market price of the downstream product to its marginal cost. However, the first-best optimal access charge is not feasible without governmental transfers since it threatens the financial viability of the vertically-integrated firm. On the other hand, the second-best optimal access charge exceeds the marginal cost of access. The regulator is assumed to have two policy options for determining the second-best optimal access charge: (1) The regulator could apply the non-negativity constraint to the incumbent's provider overall profit; or (2) The regulator could impose the constraint only on the upstream profit of the incumbent provider. Our results suggest that the latter yields higher social welfare. The policy implication of this result is that regulators should be cautious in determining the access prices in imperfect markets when they are required to satisfy a profit constraint for the vertically integrated firm. Specifically, imposing the non-negativity profit constraint on the overall profit of the incumbent may introduce distortions in the downstream product market and reduce economic welfare. We also examine the effect of outsourcing by allowing some of the firms to bypass the vertically-integrated firm's network. With efficient bypass, our model reveals that optimal access charges decrease and welfare increases, *ceteris paribus*.

The model developed in this paper uses a very simple framework and therefore suppresses some complicated real-world issues. For example, throughout the analysis the total number of competitors and the number of competitors that bypass the incumbent firm's network are assumed to be exogenous. Additionally, we assume the regulator has perfect information regarding the cost and demand structures. We also disavow the possibility that the vertically-integrated producer engages in sabotage or is subject to moral hazard problems. Given that the assumptions of our model are somewhat restrictive, developing more general models with less restrictive assumptions would prove fruitful in terms of future research.

Appendix- Proofs for Propositions

Proof of Proposition 1: Total welfare is the unweighted sum of consumer surplus and total industry profits, $W = CS + \Pi_1^I + \sum_{i=2}^{n} \Pi_i$, where consumer surplus is given by $U\left(q_1^I + \sum_{i=2}^{n} q_i\right) - P(\cdot)\left(q_1^I + \sum_{i=2}^{n} q_i\right)$. Totally differentiating total welfare yields

$$dW = dCS + \sum_{i=2}^{n} d\Pi_i + d\Pi_1^I \tag{A1}$$

$$dCS = -P'(\cdot)\left(dq_1^I + (n-1)dq_i\right)\left(q_1^I + (n-1)q_i\right) \tag{A2}$$

$$\sum_{i=2}^{n} d\Pi_i = (n-1)\Big(P'(\cdot)\left(dq_1^I + (n-1)dq_i\right)q_i - (n-1)q_i dw + (P-w)dq_i\Big) \tag{A3}$$

$$d\Pi_1^I = (n-1)\left(q_i dw + (w-c)dq_i\right) + P'(\cdot)\left(dq_1^I + (n-1)dq_i\right)q_1^I + (P-c)dq_1^I \tag{A4}$$

Substituting (A2), (A3) and (A4) into (A1) by making use of (3) and (4) yields

$$dW = (P-c)\left(dq_1^I + (n-1)dq_i\right) = (P-c)\frac{(n-1)}{(n+1)P'}dw \tag{A5}$$

and therefore

$$\frac{dW}{dw} = (P-c)\frac{(n-1)}{(n+1)P'} = 0\,. \tag{A6}$$

Equation (A6) characterizes the welfare optimizing access price in our simple Cournot model, one that equates the market price with the marginal cost of access. This completes the proof part (a). To prove part (b), note that the first-order conditions for the profit maximization condition of a representative competitor is $P'q_i + P = w$. The first-order condition with $P = c$ implies that $q_i > 0$ if and only if $w < c$. This completes the proof of part (b).

Proof of Proposition 2: In order to prove part (i), take the derivative of the incumbent's profit in (12) with respect to θ:

$$\frac{\partial \Pi_1^I}{\partial \theta} = \frac{2\lambda(1+\lambda)(n-1)(n+3)^2(\alpha-c)^2\left(3-2\theta(1+\lambda)+2\lambda\right)}{\beta\left[(n-1)\left(3-2\theta(1+\lambda)\right)+4\lambda(n+1)\right]^3} > 0\cdot \tag{A7}$$

Hence, the incumbent's profit increases with θ. This implies that incumbent's profit is higher when the break-even constraint for the incumbent applies to its overall profits. This completes part (i).

Similarly, to show that part (ii) holds we take the derivative of the competitors' total profit, given in equation (13), and of consumer surplus given in equation (14), with respect to θ. Therefore:

$$\frac{\partial\left(\sum_{i=2}^{n}\Pi_i\right)}{\partial \theta} = -\frac{8\lambda(1+\lambda)(n-1)(n+3)(\alpha-c)^2\left(3-2\theta(1+\lambda)+2\lambda\right)}{\beta\left[(n-1)\left(3-2\theta(1+\lambda)\right)+4\lambda(n+1)\right]^3} < 0\cdot \tag{A8}$$

Hence, the competitors' total profit decreases with θ, so the competitors' total profit is higher when the break-even constraint for the incumbent applies only to its upstream profits.

$$\frac{\partial CS}{\partial \theta} = -\frac{2\lambda(1+\lambda)(n-1)(n+3)(\alpha-c)^2\left[(n-1)\left(3-2\theta(1+\lambda)\right)+\lambda(3n+1)\right]}{\beta\left[(n-1)\left(3-2\theta(1+\lambda)\right)+4\lambda(n+1)\right]^3} < 0\cdot \tag{A9}$$

Similarly, consumer surplus is lower when the break-even constraint for the incumbent applies to its overall profits since the consumer surplus is decreasing in θ.

Summing (12) – (14) yields economic welfare. Taking the derivative of economic welfare with respect to θ yields

$$\frac{\partial W}{\partial \theta}=-\frac{2\lambda^2(1+\lambda)(n-1)(n+3)^2(\alpha-c)^2}{\beta\left[(n-1)\left(3-2\theta(1+\lambda)\right)+4\lambda(n+1)\right]^3}<0. \tag{A10}$$

Hence, total welfare is decreasing in θ. This implies that total welfare is higher when the break-even constraint for the incumbent applies only to its upstream profit. This completes part (ii).

Proof of Proposition 3: Taking the derivative of (23) with respect to *m* yields:

$$\frac{\partial w}{\partial m}=-\frac{(\lambda(n+1)-1)(2\lambda(n+1)-1)}{(n-m-1)+2\lambda(n+1)(m+2)}(\alpha-c)<0. \tag{A11}$$

Therefore, the second-best optimal access charge is decreasing in *m*

Summation of (24) – (27) gives the total welfare at the second-best optimal access charge. Taking the derivative of total welfare with respect to *m* yields:

$$\frac{dW}{dm}=\frac{2}{\beta}\frac{\lambda^2(n+1)(\lambda+n\lambda-1)(m+n+3)}{\left((n-m-1)+2\lambda(n+1)(m+2)\right)^3}(\alpha-c)^2>0 \tag{A12}$$

Hence, total welfare increases with bypass, *ceteris paribus*.

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