

ON THE IRRELEVANCE OF INPUT PRICES FOR MAKE OR BUY DECISIONS

by

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The Telecommunications Act of 1996 opened the U.S. telecommunications industry to competition.¹ It did so in part by authorizing new suppliers of local telecommunications services to purchase (or lease) key elements of incumbent suppliers' networks rather than build their own networks from scratch. The prices that competitors must pay to access the facilities of incumbent suppliers have been hotly contested. Incumbents typically advocate high prices while competitors recommend low prices.

With the ultimate approval of the U.S. Supreme Court,² the Federal Communications Commission has adopted a pricing methodology that essentially sets prices for key network elements equal to the incumbent supplier's cost of producing these elements.³ This methodology has been promoted in part on the grounds that it ensures efficient make or buy decisions.⁴ In particular, when the price for a network element is set equal to the incumbent's (efficient) cost of producing the element, a competitor will purchase the element from the incumbent whenever the incumbent is the least-cost supplier of the element, and produce the element itself whenever it can do so at lower cost than the incumbent.⁵

This logic seems compelling on its surface. Furthermore, the logic and its implications for the structuring of input prices pertain to many industries, not just the telecommunications industry.⁶ Despite the appeal, practical importance, and widespread applicability of the logic, it

is at best incomplete. Although input prices that reflect the cost of an (efficient) incumbent supplier can ensure efficient make or buy decisions, so can other input prices. In fact, in simple, standard models of retail price competition, any prices for key inputs that ensure the solvency of the incumbent producer will induce the efficient make or buy decision.

The simple logic presented above is incomplete because it fails to account fully for the impact of a new competitor's make or buy decision on subsequent retail price competition. When the incumbent sells an upstream input to the new competitor ("the entrant"), the incumbent faces an opportunity cost of expanding its retail output. The opportunity cost is the profit the incumbent forgoes on the sale of the input to the entrant when the incumbent's expanded retail output reduces the entrant's retail output, and thus its demand for the input. The sum of the incumbent's opportunity cost and physical production cost often turns out to be the sum of the specified input price and the incumbent's downstream cost of production. Consequently, when it engages in retail price competition, the incumbent acts as if its upstream cost of production is equal to the specified input price. Therefore, by choosing to purchase the upstream input from the incumbent, the entrant effectively equalizes the upstream costs of the two rivals. Such equalization improves the entrant's position in the ensuing retail price competition whenever the entrant's upstream production cost exceeds the incumbent's innate upstream production cost. Consequently, regardless of the price of the upstream input, the entrant will choose to buy the upstream input from the incumbent whenever the incumbent can produce the input at lower cost than can the entrant. In contrast, whenever the entrant has an innate upstream cost advantage, it will prefer to maintain this advantage by producing the upstream input itself. Thus, the entrant will undertake the efficient make or buy decision even if the price of the upstream input varies substantially from the cost the incumbent (efficiently) incurs to produce the input.

This observation is developed more fully in the ensuing analysis as follows. Section I describes the formal model under consideration. Section II characterizes equilibrium outcomes in the model and proves that the entrant will make the efficient make or buy decision regardless of the price it must pay to purchase the upstream input from the incumbent.⁷ Section III concludes the analysis with a brief discussion of the extent to which this finding generalizes to other settings and some suggestions for future research. The proofs of all formal results are provided in the Appendix.

I. Elements of the Model.

The downstream interaction between an incumbent supplier and a single competitor (called “the entrant”) is captured by the standard Harold Hotelling (1929) model of price competition with differentiated products. The incumbent is located at point 0 and the entrant is located at point 1 in product space. N consumers are uniformly distributed on the unit interval. A consumer at location $L \in [0, 1]$ incurs transportation (e.g., disutility) cost tL if she purchases the retail product from the incumbent. She incurs transportation cost $t[1 - L]$ if she purchases the product from the entrant.⁸ Each consumer buys at most one unit of the retail product, and secures gross value v from this unit. This value, v , is assumed to be sufficiently large that all N consumers buy one unit of the retail product in equilibrium. Each consumer purchases the product from the firm that offers the smallest sum of retail price and transportation cost.

Each unit of the retail product is produced by combining one unit of an upstream input with one unit of a downstream input. Each firm supplies its own downstream input (which might encompass customer service, for example). The incumbent’s constant unit cost of producing the downstream input is denoted c_d^I . The corresponding unit cost for the entrant is denoted c_d^E .

For simplicity, the upstream input is also assumed to be produced with constant returns to scale. The incumbent's and entrant's unit costs of producing the upstream input are denoted c_u^I and c_u^E , respectively.⁹ Because the incumbent may have a substantial cost advantage in producing the upstream input, industry costs may be minimized if the entrant is able to purchase the upstream input from the incumbent rather than produce the upstream input itself (as envisioned in the Telecommunications Act of 1996, for example).¹⁰ In the present model, w will denote the (wholesale) unit price at which the entrant is authorized to purchase the upstream input from the incumbent. Of primary interest here is the level (or levels) of w that will induce the entrant to undertake the efficient make or buy decision. The entrant undertakes the efficient make or buy decision if it purchases the upstream input from the incumbent whenever the incumbent is the least-cost supplier of the input (so $c_u^I < c_u^E$) and produces the upstream input itself whenever it is the least-cost supplier of the input (so $c_u^E < c_u^I$).¹¹

The timing in the model is as follows. First, the price (w) at which the entrant can purchase the upstream input from the incumbent is established. Second, the entrant decides whether it will buy the upstream input from the incumbent or produce the input itself. Third, the entrant and incumbent choose retail prices simultaneously and independently.¹² Finally, consumers make their purchase decisions. The entrant chooses the make or buy option that maximizes its profit, anticipating the downstream price competition to follow. When the firms choose their retail prices, each firm acts to maximize its profit, taking as given the upstream input price (w), the entrant's make or buy decision, and the retail price charged by its competitor. The upstream input price, the firms' costs and objectives, and consumers' preferences are all common knowledge.

II. Findings.

It is convenient to focus on settings where both the incumbent and entrant serve retail customers in equilibrium. This will be the case when the production costs of the two firms are not too disparate relative to consumers' unit transportation cost (t). Formally, it is assumed throughout the ensuing analysis that $maximum \left\{ \left| c_d^I - c_d^E \right|, \left| c_u^I + c_d^I - (c_u^E + c_d^E) \right| \right\} < 3t$.¹³ Attention is also restricted to upstream input prices that leave the incumbent with non-negative profit in equilibrium when the entrant chooses to buy the upstream input from the incumbent at unit price w .¹⁴

Under these maintained assumptions, equilibrium prices (p), output levels (Q), and profits (Π) are as characterized in Lemmas 1 and 2. Prices, outputs and profits for the incumbent and the entrant are denoted by the superscript I and E , respectively. The subscript M (respectively, B) denotes prices, outputs, and profits following the entrant's decision to make (respectively, buy) the upstream input.

Lemma 1. If the entrant chooses to produce the upstream input itself, equilibrium retail prices, outputs, and profits are (for $i, j = I, E, j \neq i$):

$$(1) \quad p_M^i = t + [2(c_u^i + c_d^i) + c_u^j + c_d^j] / 3 ;$$

$$(2) \quad Q_M^i = N [3t + c_u^j + c_d^j - (c_u^i + c_d^i)] / [6t] ; \text{ and}$$

$$(3) \quad \Pi_M^i = N [3t + c_u^j + c_d^j - (c_u^i + c_d^i)]^2 / [18t] .$$

Lemma 2. If the entrant chooses to buy the upstream input from the incumbent, equilibrium prices, outputs, and profits are (for $i, j = I, E, j \neq i$):

$$(4) \quad p_B^i = t + w + [2c_d^i + c_d^j]/3 = t + [2(w + c_d^i) + w + c_d^j]/3;$$

$$(5) \quad Q_B^i = N[3t + c_d^j - c_d^i]/[6t] = N[3t + w + c_d^j - (w + c_d^i)]/[6t];$$

$$(6) \quad \Pi_B^E = N[3t + c_d^I - c_d^E]^2/[18t] = N[3t + w + c_d^I - (w + c_d^E)]^2/[18t]; \text{ and}$$

$$(7) \quad \Pi_B^I = N[w - c_u^I] + N[3t + c_d^E - c_d^I]^2/[18t]$$

$$= N[w - c_u^I] + N[3t + w + c_d^E - (w + c_d^I)]^2/[18t].$$

A comparison of equations (1) – (3) and equations (4) – (7) reveals a key effect of the entrant’s decision to purchase the input from the incumbent. Notice that, except for the upstream component of the incumbent’s profit in equation (7), equilibrium prices, quantities, and profits are the same when the entrant buys the upstream input from the incumbent as they would be if the entrant produced the upstream input itself and the upstream unit cost of both the incumbent and entrant were w , the established unit price of the upstream input. In essence, following a decision by the entrant to buy the upstream input at price w , the incumbent acts as if its upstream unit cost of production is w when it chooses its profit-maximizing retail price. This behavior arises from the following consideration.

When the incumbent sells the upstream input to its downstream competitor, the incumbent incurs both a physical cost and an opportunity cost of expanding its sales to retail consumers. The physical cost is $c_u^I + c_d^I$ per unit, which is the sum of the incumbent’s upstream and downstream unit production costs. The opportunity cost is $w - c_u^I$ per unit, which is the profit from selling the input to the entrant that the incumbent forgoes when the incumbent’s increased retail output reduces the entrant’s retail supply, and thus its demand for the upstream input.¹⁵ The sum of this physical unit cost of production and opportunity cost of production is

$w + c_d^I$. Thus, when setting its retail price following the entrant's decision to buy the upstream input, the incumbent acts as if its unit cost of producing the upstream input is w .

It remains to determine when the entrant prefers to induce the incumbent to act in this manner by deciding to purchase the upstream input from the incumbent. As Proposition 1 indicates, the entrant prefers to do so whenever the incumbent is the least-cost producer of the upstream input (i.e., whenever $c_u^I < c_u^E$). To see why, notice that if the entrant decides to produce the upstream input itself when $c_u^I < c_u^E$, it will compete downstream against a rival with an upstream cost advantage. It is apparent from equations (2) and (3) that the entrant secures a smaller market share and less profit the more pronounced is the upstream cost advantage of the incumbent, *ceteris paribus*. To reduce the incumbent's effective cost advantage, the entrant can decide to purchase the input from the incumbent. Doing so effectively equalizes the upstream unit costs of the two competitors because: (1) the entrant's unit cost of the upstream input is w when it chooses to purchase the input at this price; and, as explained above, (2) the incumbent acts as if its upstream unit cost is w when the entrant decides to purchase the input from the incumbent at unit price w . By effectively equalizing upstream costs, the entrant improves its position in the downstream pricing competition, and thereby secures higher profit in equilibrium.

In contrast, the entrant prefers to produce the upstream input itself when it can do so at lower cost than the incumbent. The decision to produce the upstream input itself in this setting secures the entrant's upstream cost advantage when it competes downstream against the incumbent. In contrast, a decision to buy the input from the incumbent would effectively eliminate the entrant's upstream cost advantage, and thereby reduce its retail market share and profit.

Proposition 1. Regardless of the established price (w) of the upstream input: (1) the entrant prefers to buy the upstream input from the incumbent when the incumbent is the least-cost supplier of the input (i.e., $\Pi_B^E > \Pi_M^E$ if $c_u^I < c_u^E$); and (2) the entrant prefers to make the upstream input itself when it is the least-cost supplier of the input (i.e., $\Pi_M^E > \Pi_B^E$ if $c_u^E < c_u^I$).

Proposition 1 reveals that the entrant always makes the efficient make or buy decision in the setting considered here. Most importantly, the entrant makes the efficient decision regardless of the established price (w) for the upstream input. Thus, although a price set equal to the upstream unit cost of the (efficient) incumbent supplier will induce the efficient make or buy decision, so will any price that ensures the solvency of the incumbent supplier.¹⁶

Before concluding, it should be noted that the entrant's industry participation decision also is not affected by the price of the upstream input (w). Equation (6) reveals that the entrant's equilibrium profit is strictly positive and invariant to w under the maintained assumptions. Therefore, provided it does not face too severe a downstream cost disadvantage (i.e., provided $c_d^E - c_d^I < 3t$),¹⁷ the entrant will find it profitable to operate in the industry, regardless of the price it must pay to purchase the upstream input from the incumbent.^{18,19}

III. Summary, Discussion, and Conclusions.

The finding that the entrant's make or buy decision is largely insensitive to the price at which it can purchase the upstream input from the incumbent may seem counterintuitive at first blush. One might expect the entrant to be systematically more likely to buy the upstream input from the incumbent when the price of the input is low and to produce the input itself when the

price at which the entrant can buy the input from the incumbent is high. This simple logic, though, ignores the ensuing strategic interaction between the incumbent and the entrant.

As explained above, when it decides to purchase the upstream input from the incumbent, the entrant creates for the incumbent an opportunity cost of increasing its retail output. The opportunity cost is the profit the incumbent forgoes on sales of the upstream input when the incumbent's increased retail output induces the entrant to reduce its retail output and thus its demand for the upstream input. The combination of the incumbent's opportunity cost and physical production cost induce the incumbent to act as if its upstream unit cost of production is w , the price at which it sells the upstream input to the entrant. Therefore, the decision to buy, rather than make, the upstream input enables the entrant effectively to reduce any innate upstream cost disadvantage it may face. The reduced cost disadvantage enables the entrant to increase its retail market share and profit. Consequently, the entrant prefers to purchase the upstream input from the incumbent rather than produce the input itself whenever the incumbent is the least-cost supplier of the upstream input. Thus, in the present setting, any price for the upstream input induces the efficient make or buy decision, not just the price that reflects the cost of the (efficient) incumbent supplier.

The finding that the entrant's make or buy decision is completely insensitive to the price at which the entrant can purchase the upstream input from the incumbent stems in part from the form of retail competition analyzed here. However, the conclusion that the upstream input price can have limited impact on the entrant's make or buy decision holds more generally. In the simple, standard model of price competition analyzed here, each consumer always purchases one unit of the retail product. Consequently, any increase in retail sales by the incumbent results in an identical decrease in the entrant's retail sales, and thus its demand for the upstream input. This

“full displacement” of the entrant’s retail output ensures that the incumbent’s marginal opportunity cost of increasing its retail sales is $w - c_u^I$, the difference between the price of the upstream input and the incumbent’s unit cost of producing the input.

Other models of retail competition could result in less than full displacement. For example, suppose a unit increase in the incumbent’s retail sales is systematically associated with a decline of $\alpha \in (0, 1)$ units in the entrant’s retail sales.²⁰ In this case, the incumbent’s marginal opportunity cost of increasing its retail output would be $\alpha [w - c_u^I]$. The sum of this marginal opportunity cost and the incumbent’s marginal physical production cost would be $\alpha w + [1 - \alpha]c_u^I + c_u^I$. If the incumbent therefore perceived its effective upstream marginal cost to be $\alpha w + [1 - \alpha]c_u^I$ when setting its retail price, the entrant could ensure an effective upstream cost disadvantage of $w - [\alpha w + (1 - \alpha)c_u^I] = [1 - \alpha][w - c_u^I]$ if it chose to buy the upstream input from the incumbent, compared to a cost disadvantage of $c_u^E - c_u^I$ if it chose to produce the input itself. The entrant could thus reduce its effective upstream cost disadvantage and thereby improve its downstream competitive position whenever $w < c_u^I + [c_u^E - c_u^I]/[1 - \alpha]$.²¹ Under these conditions, then, the entrant would make the efficient make or buy decision as long as the price for the upstream input (w) were not too far (i.e., less than $[c_u^E - c_u^I]/[1 - \alpha]$) above the incumbent’s unit cost of producing the upstream input.

Although the price at which the entrant is permitted to purchase the upstream input from the incumbent may have limited impact on the entrant’s make or buy decision both in the simple model analyzed formally here and more generally, the upstream input price can have an important impact on other dimensions of industry performance. It is apparent from equations (4) and (7), for example, that industry prices and the incumbent’s profit increase as the upstream

input price increases, given the entrant's decision to purchase the upstream input from the incumbent.²² This fact and the finding that the entrant's make or buy decision is relatively insensitive to the price of the upstream input suggest that regulators may have substantial flexibility to structure input prices to achieve other important social goals while ensuring efficient make or buy decisions. For instance, regulators may be able to structure input prices to enhance consumer surplus, to promote innovation and cost reduction, or to induce efficient industry participation.²³ The optimal manner in which to structure input prices to pursue such goals is an important topic for future research.²⁴

APPENDIX

Proof of Lemma 1.

Let $\hat{L} \in [0, 1]$ denote the location of the customer that is indifferent between purchasing from the incumbent and the entrant. Thus:

$$(A1) \quad p_M^I + t\hat{L} = p_M^E + t[1 - \hat{L}].$$

Solving equation (A1) for \hat{L} provides:

$$(A2) \quad \hat{L} = [t + p_M^E - p_M^I] / [2t].$$

It follows from equation (A2) that when the entrant decides to make the upstream input, the profit of the entrant and the incumbent are, respectively:

$$(A3) \quad \Pi_M^E = [p_M^E - c_u^E - c_d^E]N[t + p_M^I - p_M^E] / [2t], \text{ and}$$

$$(A4) \quad \Pi_M^I = [p_M^I - c_u^I - c_d^I]N[t + p_M^E - p_M^I] / [2t].$$

Maximizing equation (A3) with respect to p_M^E and maximizing equation (A4) with respect to p_M^I , and then solving the resulting equations simultaneously provides:

$$(A5) \quad p_M^E = t + [2(c_u^E + c_d^E) + c_u^I + c_d^I] / 3, \text{ and}$$

$$(A6) \quad p_M^I = t + [2(c_u^I + c_d^I) + c_u^E + c_d^E] / 3.$$

Equations (A2), (A5), and (A6) reveal that the equilibrium output levels for the entrant and incumbent, respectively, are:

$$(A7) \quad Q_M^E = N[3t + c_u^I + c_d^I - (c_u^E + c_d^E)] / [6t]; \text{ and}$$

$$(A8) \quad Q_M^I = N[3t + c_u^E + c_d^E - (c_u^I + c_d^I)] / [6t].$$

Substituting the equilibrium prices in equations (A5) and (A6) into equations (A3) and (A4) provides:

$$(A9) \quad \Pi_M^E = N [3t + c_u^I + c_d^I - (c_u^E + c_d^E)]^2 / [18t]; \text{ and}$$

$$(A10) \quad \Pi_M^I = N [3t + c_u^E + c_d^E - (c_u^I + c_d^I)]^2 / [18t].$$

Proof of Lemma 2.

The proof parallels the proof of Lemma 1. The central difference is that because the incumbent can secure profit both from sales of the upstream input to the entrant and from sales of the final product to downstream retail customers, the incumbent's profit is:

$$(A11) \quad \Pi_B^I = [w - c_u^I]Q_B^E + [p_B^I - c_u^I - c_d^I]Q_B^I.$$

The counterpart to equation (A2) can then be employed to derive an expression for the incumbent's profit as a function of p_B^E and p_B^I . Maximizing this expression with respect to p_B^I , performing an analogous exercise to derive the entrant's profit-maximizing retail price as a function of p_B^I , and then solving the two expressions simultaneously provides:

$$(A12) \quad p_B^E = t + w + [2c_d^E + c_d^I] / 3, \text{ and}$$

$$(A13) \quad p_B^I = t + w + [2c_d^I + c_d^E] / 3.$$

Substituting these equilibrium prices into equation (A11) and the corresponding expression for the entrant's profit provides the following expressions for equilibrium profit for the entrant and incumbent, respectively:

$$(A14) \quad \Pi_B^E = N [3t + c_d^I - c_d^E]^2 / [18t];$$

$$(A15) \quad \Pi_B^I = N [w - c_u^I] + N [3t + c_d^E - c_d^I]^2 / [18t].$$

Proof of Proposition 1.

From equations (3) and (6) in the text:

$$(A16) \quad \Pi_M^E \begin{array}{c} > \\ \equiv \\ < \end{array} \Pi_B^E$$

$$(A17) \quad \Leftrightarrow \quad [3t + c_u^I + c_d^I - (c_u^E + c_d^E)]^2 \begin{array}{c} > \\ \equiv \\ < \end{array} [3t + c_d^I - c_d^E]^2$$

$$(A18) \quad \Leftrightarrow \quad 3t + c_u^I + c_d^I - (c_u^E + c_d^E) \begin{array}{c} > \\ \equiv \\ < \end{array} 3t + c_d^I - c_d^E$$

$$(A19) \quad \Leftrightarrow \quad c_u^I \begin{array}{c} > \\ \equiv \\ < \end{array} c_u^E.$$

Expression (A18) follows from expression (A17), given the maintained assumption that

$$\text{maximum} \left\{ |c_d^I - c_d^E|, |c_u^I + c_d^I - (c_u^E + c_d^E)| \right\} < 3t.$$

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Footnotes

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¹ Pub. L. No. 104-104, 100 Stat. 56 (codified at 47 U.S.C. §§ 151 *et seq.*).

² *Verizon Communications Inc. v. FCC et al.*, 122 S. Ct. 1646 (2002).

³ Federal Communications Commission (FCC) (1996). More accurately, under the FCC's methodology, prices for key inputs reflect the costs an efficient incumbent supplier would incur if it employed the best available technology. In the ensuing analysis, the incumbent's production costs are taken to be exogenous, and can be viewed as the costs of an efficient incumbent supplier.

⁴ The pricing methodology implemented by the FCC is known as the TELRIC methodology. TELRIC denotes "total element long-run incremental cost". The FCC (1996, ¶ 630) argues that "prices based on forward-looking long-run incremental costs (LRIC) ... ensure efficient entry and utilization of the telecommunications infrastructure."

⁵ Although many experts question elements of the FCC's methodology for assessing an incumbent supplier's (efficient) cost of producing network elements, most experts appear to agree that regulated prices for network elements influence an entrant's make or buy decision. As David Kaserman and John Mayo (2002, p. 128) summarize the argument, "... the ILECs and their supporters have argued that relatively high ... prices [for network elements] are more likely to promote the necessary network-stage investment. Low resale and lease prices, they argue, will cause investment in facilities to be unattractive, as entrants can purchase these inputs from incumbents more cheaply than they can build them." Jerry Hausman (1997, p. 36) observes that "By setting network prices below competitive levels,

the FCC has ... discouraged new entrants from investing in their own infrastructure because they can buy the services at below-competitive prices and less risk from the carriers.”

⁶ Railroad companies often sell track rights to their competitors, for example. Similarly, gas and electric companies provide access to their distribution systems to their competitors for a fee. Furthermore, many vertically-integrated firms (e.g., soft-drink producers, cereal manufacturers, and gasoline refiners) supply key inputs both to their own downstream affiliates and to downstream competitors.

⁷ The ensuing analysis differs from standard analyses of access pricing in part by examining a setting with unregulated retail price competition. When the incumbent’s retail price is regulated, an input price equal to the incumbent’s (efficient) cost of producing the upstream input typically is required to ensure efficient make or buy decisions. See Mark Armstrong (2001, 2002).

⁸ For simplicity, consumers are assumed to incur the same unit transportation cost whether they purchase the product from the incumbent or the entrant. The key qualitative conclusions drawn below continue to hold if a consumer’s unit transportation cost differs according to whether she purchases the product from the incumbent or the entrant.

⁹ In the telecommunications industry, the upstream input might include the local loop, for example. The local loop is the wire that runs from the supplier’s central office to the customer’s premise.

¹⁰ Although the present analysis is motivated by recent experience in the U.S. telecommunications industry, the analysis clearly abstracts from key issues in the industry. Relevant issues that warrant consideration in a more comprehensive model include scale economies, start-up costs, retail price regulation, universal service concerns, dynamic investment decisions, and innovation. Hausman (1997), Alfred Kahn et al. (1999), Gary Biglaiser and Michael Riordan (2000), Armstrong (2001, 2002), David Mandy (2002), Dennis Weisman (2002), Mandy and William Sharkey (2003), and Sappington (2005), among others, consider some of these issues.

- ¹¹ Conceivably, the incumbent might also be authorized to purchase the upstream input from the entrant at some specified wholesale price. This possibility is not considered formally here, in part to focus on current practice in the U.S. telecommunications industry, which only requires incumbent suppliers of local exchange services to make key inputs available to competitors at regulated wholesale rates.
- ¹² This timing reflects a setting where unregulated retail prices can be changed more quickly than can the source from which the entrant secures the upstream input. In practice, negotiating the (non-price) terms of a contract with an outside supplier can be time-consuming, as can the process of implementing an internal supply operation.
- ¹³ Notice that when the transportation cost (t) increases, consumers find it more attractive to purchase from the closest producer. Consequently, as t increases, a producer can experience a larger cost disadvantage before it loses all customers to its rival.
- ¹⁴ Formally, it is assumed that $w > c_u^I - [3t + c_d^E - c_d^I]^2 / [18t]$.
- ¹⁵ Armstrong et al. (1994, pp. 135-6), David Sibley and Weisman (1998), Yongmin Chen (2001), and Armstrong (2002), among others, observe that a vertically-integrated producer faces an opportunity cost that reflects changes in upstream profit when it expands its retail output.
- ¹⁶ Of course, an upstream input price that is so low as to induce the incumbent supplier to terminate its operations will preclude a meaningful make or buy decision by the entrant.
- ¹⁷ If the entrant's operation required a fixed cost of production, the entrant's variable profit – which is invariant to w – would need to exceed its fixed cost in order to ensure the entrant's market participation.
- ¹⁸ Higher levels of w do not necessarily limit the entrant's industry participation because a higher price for the upstream input reduces the intensity of retail price competition. It does so because a higher

input price increases the incumbent's opportunity cost of increasing its retail output, and thereby increases the incumbent's profit-maximizing retail price. Because prices are strategic complements (Jeremy Bulow et al., 1985) in the present setting, the entrant will increase its price in response to a price increase by the incumbent. (Notice from equation (4) that increases in w are reflected fully in higher equilibrium retail prices.)

¹⁹ This finding raises questions about the common intuition that upstream input prices necessarily affect entry decisions. This intuition seems implicit, for example, in Gregory Rosston and Roger Noll's (2002, pp. 84-5) observation that "[upstream input] prices [that] are too high (or too low) ... will distort the development of future competition in local access. Adopting a price for [upstream inputs] ... that enable incumbents to recover uneconomic costs will ... send inefficient entry signals."

²⁰ See Armstrong et al. (1996) and Armstrong (2002) for more detailed discussions of the importance of displacement ratios in setting access prices in network industries.

²¹ As is apparent, this inequality holds when $c_u^E - c_u^I > [1 - \alpha][w - c_u^I]$.

²² Input price levels also may affect incentives for non-price discrimination against downstream rivals. See, for example, Nicholas Economides (1998), T. Randolph Beard et al. (2001), and Irina Kondaurova and Weisman (2003).

²³ Notice, for example, that as long as the input price (w) is below the level that induces the entrant to produce the input itself, increases in w provide increased revenue for the incumbent that can cover the fixed costs incumbents typically incur in practice. Furthermore, an input price that does not simply track the incumbent's realized upstream unit cost can enhance the incumbent's incentives to reduce its upstream production costs. See Sappington (2005), for example, for an analysis of the optimal design of input prices when the incumbent's production costs are endogenous.

²⁴ Future research also should consider alternative downstream interactions, including nonlinear price competition.