

# WHEN DO INPUT PRICES MATTER FOR MAKE-OR-BUY DECISIONS?

DAVID M. MANDY\*

David M. Mandy  
Department of Economics  
University of Missouri  
118 Professional Building  
Columbia, MO 65211 USA  
Voice 573-882-1763; Fax 573-882-2697  
e-mail MandyD@missouri.edu

January 16, 2007

ABSTRACT. We investigate input pricing regimes that induce efficient make-or-buy decisions by entrants when there is constant returns in the production of the input(s) and simultaneous noncooperative price competition in downstream retail markets. A necessary and sufficient condition for efficient make-or-buy decisions is derived. This condition shows that input prices are relevant for make-or-buy decisions except under restrictive and often unverifiable assumptions on the demand structure, and that the least informationally-demanding way to ensure efficient make-or-buy decisions is to price inputs at marginal cost. The extent to which input prices can depart from marginal cost while still inducing efficient make-or-buy decisions depends on the relative efficiency of the incumbent and the demand displacement ratio, with significant departures possible even for modest efficiency differences when products are nearly homogeneous.

*Keywords:* Input Pricing Policy, Productive Efficiency.

*JEL Classifications:* L5, L9.

Many regulated industries have a vertically integrated dominant incumbent who produces critical inputs that could potentially be used by entrants to compete with the incumbent in downstream markets. Alternatively, entrants could produce the critical inputs and thereby bypass the incumbent's facilities. This structure is quite explicit in US telecommunications, where rival suppliers of long distance and other services often use the local switching and transmission facilities of the incumbent to deliver those services, and the incumbent is required by regulation to lease these critical inputs to rivals,<sup>1</sup> but entrants can and do sometimes install their own local switching and/or transmission facilities.<sup>2</sup> A similar structure arises in gas and electric distribution and railroad trackage rights, as well as in antitrust analysis of some unregulated industries.<sup>3</sup>

One central issue in these contexts is how the policy-maker should set the price of the dominant incumbent's critical input(s) to induce productively efficient make-or-buy decisions by entrants.<sup>4</sup> The critical input in many network industries is *access* to the network, and access price regulation is a contentious and high-stakes undertaking.<sup>5</sup> Although it is well-established theoretically that pricing access at marginal cost is not socially optimal in general,<sup>6</sup> marginal cost pricing has many merits and has become quite common in practice.<sup>7</sup> One argument offered in favor of marginal cost pricing is that an input price set equal to the incumbent's cost will cause the entrant to make its own inputs when its cost is below the incumbent's cost, and buy the input from the incumbent when its cost is above the incumbent's cost.<sup>8</sup> However, Sappington (2005) shows that input prices may have no effect on entrants' make-or-buy decisions once the strategic effect of make-or-buy decisions on subsequent retail competition is properly considered. Indeed, the literature

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<sup>1</sup>Section 251(c) of The Telecommunications Act of 1996 requires that incumbent local exchange carriers lease unbundled network elements to and interconnect with competing local exchange carriers.

<sup>2</sup>The US Federal Communications Commission (2006, Table 3) reports that 32% of the 32.6 million switched access lines sold by CLECs (competitive local exchange carriers, i.e., providers of local telephone service who were not the incumbent when the markets were opened to competition) in December 2005 were owned by the CLEC; the other 68% were sold under a lease or resale arrangement with the incumbent.

<sup>3</sup>Armstrong, Doyle, and Vickers (1996) p. 131.

<sup>4</sup>Vogelsang (2003) p. 844 notes that "... the price regulation of one-way access appears to be an indispensable policy instrument [that] ... is directed ... at productive efficiency."

<sup>5</sup>Laffont and Tirole (2000) p. 6.

<sup>6</sup>Laffont and Tirole (1994).

<sup>7</sup>Vogelsang (2003) pp. 837-8.

<sup>8</sup>See Armstrong (2001) p. 300 and Vogelsang (2003) pp. 840-841. This logic is partly responsible for the US Federal Communications Commission's (FCC) adoption of the Coalition for Affordable Local and Long Distance Service proposal on May 31, 2000, which moved local network access charges rapidly toward the marginal cost of supplying access in the US telecommunications industry (FCC, 2000). Paragraph 114 of this order states, in part: "Prices that are below cost reduce the incentives for entry by firms that could provide the services as efficiently, or more efficiently, than the incumbent LEC [Local Exchange Carrier]. Similarly, discrepancies between price and cost may create incentives for carriers to enter low-cost areas even if their cost of providing service is actually higher than that of the incumbent LEC. These findings and conclusions clearly support the proposed limited deaveraging of SLCs [Subscriber Line Charges]."

on bypass either does not consider the effect of make-or-buy decisions on subsequent retail competition, or formally considers the effect only on narrow forms of retail competition.<sup>9</sup>

The present paper considers efficiency of an entrant’s make-or-buy decision in a relatively general model of retail price competition with differentiated products. Differentiated products price competition is considered the most relevant setting by many observers.<sup>10</sup> A primary objective is to investigate the generality of Sappington’s (2005) “irrelevance” result. We derive a condition on the demand and cost structures, and the policy-maker’s pricing rule, that is necessary and sufficient for efficient make-or-buy decisions. This condition clarifies that the input price is irrelevant for make-or-buy decisions only under restrictive assumptions about demand that would be difficult to verify in practice. Laffont and Tirole’s (2000, chapter 4) admonishment to minimize reliance on detailed cost and demand information therefore argues for input pricing policies that do not attempt to establish whether the irrelevance assumptions hold. Instead, industrial policy is more reliably based on less informationally-demanding input pricing rules that still induce efficient make-or-buy decisions. Our necessary and sufficient condition is then exploited to show formally that marginal cost pricing of the incumbent’s critical input indeed ensures efficient make-or-buy decisions, and that marginal cost pricing is the only continuous input pricing rule that accomplishes this objective without relying on cost information about the entrant or general demand information. An example shows, however, that there may be considerable latitude for policy-makers to depart from marginal cost pricing and still obtain efficient make-or-buy decisions when there are differences in productive efficiency and products are close substitutes.

## I. THE MODEL

The standard input pricing model envisions a vertically integrated dominant incumbent who produces a critical upstream input that is required in fixed proportion (normalized to one) to produce the retail

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<sup>9</sup>Armstrong, Doyle, and Vickers’ (1996) extensive analysis of bypass assumes a price-taking competitive fringe, and they note (p. 149) that “... the nature of competition in the final product market – and therefore allocative efficiency – could well be influenced by the access pricing regime.” Armstrong (2001) does not explicitly consider competition in the retail market (the incumbent’s retail price is exogenous). Armstrong’s (2002, section 2) discussion of one-way access considers the same forms of retail competition as Armstrong, Doyle, and Vickers (1996) and Armstrong (2001). Laffont and Tirole’s (1994) seminal study of access pricing does not consider a model of strategic downstream interaction between the incumbent and entrant. Sappington (2005) assumes Hotelling competition. Gayle and Weisman (2006) examine both vertical differentiation and Cournot competition.

<sup>10</sup>See, for example, Armstrong (2002); Blank, Kaserman, and Mayo (1998); Gayle and Weisman (2006); Sappington (2005); and Weisman (1995). Although the first two of these papers consider a competitive fringe rather than simultaneous noncooperative price-setting, Armstrong (p. 303) is explicit that the price-taking fringe is an assumption of convenience “... to sidestep the issue of market power of entrants ...”.

(downstream) output. An entrant produces a differentiated retail product and competes via simultaneous noncooperative price competition against the incumbent. Before the price competition, the entrant chooses whether to make its own critical input or buy the critical input from the dominant incumbent at a preset (most likely by regulation) input price  $w$ .

Denote (retail) prices, quantities, costs, and profits by  $p$ ,  $Q$ ,  $C$ , and  $\Pi$ , respectively. These symbols carry superscripts  $I$  and  $E$  as needed to denote the incumbent and entrant, respectively, and subscripts  $u$  and  $d$  to denote upstream and downstream. Numerical subscripts denote partial derivatives. Fixed proportions for the critical upstream input means upstream and downstream costs are additively separable, with  $C_d^i(\cdot)$  the (twice differentiable) downstream cost function for firm  $i = I, E$  and  $c_u^i$  that firm's constant upstream marginal cost. The (twice differentiable) retail demand functions are  $Q^I(p^I, p^E)$  and  $Q^E(p^E, p^I)$ . A maintained assumption is that demands have the standard gross substitutes property.

**Assumption GS.**  $-Q_1^i > Q_2^i \geq 0$  when  $Q^i$  is positive, for  $i = I, E$ .<sup>11</sup>

The profit objectives for the downstream price competition are:

$$\max_{\{p^I\}} \Pi^I(p^I; p^E, w) = [p^I - c_u^I] Q^I(p^I, p^E) - C_d^I(Q^I(p^I, p^E)) + [w - c_u^I] Q^E(p^E, p^I) \quad (\text{II-I})$$

$$\max_{\{p^E\}} \Pi^E(p^E; p^I, c_u^E) = [p^E - c_u^E] Q^E(p^E, p^I) - C_d^E(Q^E(p^E, p^I)). \quad (\text{II-E})$$

The parameters  $w$  and  $c_u^E$  are of primary interest and are therefore included in the notation. A decision by the entrant to make the input is modeled by setting  $w$  equal to  $c_u^I$  (thereby eliminating the last term from  $\Pi^I$ ) and a decision to buy the input from the incumbent is modeled by setting  $c_u^E$  equal to  $w$ .

A second maintained assumption is that the model has the standard strategic complements structure.

**Assumption SC.**  $\Pi_{12}^i > 0$  for  $i = I, E$ .<sup>12</sup>

The price-setting game is supermodular under assumptions GS and SC, which ensures existence (but not uniqueness) of Nash equilibrium (Vives 1999, pp. 151-2). As in the extant models, we focus on interior

<sup>11</sup>Vives (1999) p. 144.

<sup>12</sup>Bulow *et al.* (1985). The derivatives are  $\Pi_{12}^I = Q_2^I + [p^I - c_u^I - C_d^I'] Q_{12}^I - C_d^{I''} Q_1^I Q_2^I + [w - c_u^I] Q_{12}^E$  and  $\Pi_{12}^E = Q_2^E + [p^E - c_u^E - C_d^E'] Q_{12}^E - C_d^{E''} Q_1^E Q_2^E$ , so sufficient conditions for  $\Pi_{12}^i > 0$  for  $i = I, E$  are that downstream costs are convex and the inverse demand facing each competitor becomes steeper as its rival's price increases (i.e.,  $Q_{12}^i \geq 0$  for  $i = I, E$ ), provided the price-cost margins are non-negative.

equilibria. Denoting equilibrium values with a circumflex, interior equilibrium prices  $\hat{p}^i(c_u^E, w)$  for  $i = I, E$  must satisfy the first order conditions

$$\Pi_1^I = Q^I(\hat{p}^I, \hat{p}^E) + \left[ \hat{p}^I - c_u^I - C_d^{I'}(Q^I(\hat{p}^I, \hat{p}^E)) \right] Q_1^I(\hat{p}^I, \hat{p}^E) + [w - c_u^I] Q_2^E(\hat{p}^E, \hat{p}^I) = 0 \quad (\text{FoC-I})$$

$$\Pi_1^E = Q^E(\hat{p}^E, \hat{p}^I) + \left[ \hat{p}^E - c_u^E - C_d^{E'}(Q^E(\hat{p}^E, \hat{p}^I)) \right] Q_1^E(\hat{p}^E, \hat{p}^I) = 0. \quad (\text{FoC-E})$$

Equilibrium profits are then

$$\hat{\Pi}^I(c_u^E, w) = \Pi^I(\hat{p}^I(c_u^E, w); \hat{p}^E(c_u^E, w), w) \quad (\hat{\Pi}\text{-I})$$

$$\hat{\Pi}^E(c_u^E, w) = \Pi^E(\hat{p}^E(c_u^E, w); \hat{p}^I(c_u^E, w), c_u^E). \quad (\hat{\Pi}\text{-E})$$

A third maintained assumption is that the entrant's equilibrium profit is a continuous function.

**Assumption C.**  $\hat{\Pi}^E(c_u^E, w)$  is a continuous function.<sup>13</sup>

Equilibrium profits following a ‘‘Make’’ decision are  $\hat{\Pi}^i(c_u^E, c_u^I)$  and equilibrium profits following a ‘‘Buy’’ decision are  $\hat{\Pi}^i(w, w)$ , for  $i = I, E$ . So the entrant chooses Make over Buy if and only if

$$\hat{\Pi}^E(c_u^E, c_u^I) \geq \hat{\Pi}^E(w, w). \quad (\text{MoB})$$

## II. COMPARATIVE STATICS

As the price-setting game is supermodular, if increases in the input price  $w$  or the entrant's upstream cost  $c_u^E$  systematically increase both firms' incremental returns from raising their prices then higher levels of these parameters correspond to higher equilibrium prices for both the incumbent and entrant.<sup>14</sup>  $\Pi^I$  does not depend directly on  $c_u^E$ , and  $\Pi^E$  does not depend directly on  $w$ , so the cross-partial derivatives that must be examined to determine whether each firm has increasing incremental returns are:

$$\Pi_{13}^I = Q_2^E \quad \text{and} \quad \Pi_{13}^E = -Q_1^E. \quad (1)$$

Assumption GS ensures both derivatives in (1) are positive, so supermodularity yields:

<sup>13</sup>This is not immediately implied by the Maximum Theorem because it involves changes in the rival's choice when a parameter changes. It holds, however, for standard functional forms of demands and costs.

<sup>14</sup>Milgrom and Roberts 1990; Topkis 1995; Vives 1999, p. 35. The monotonicity conclusion applies to the extremal equilibria if there is not a unique equilibrium. Strictly speaking, SC must hold on compact strategy spaces that do not depend on the comparative static parameters  $w$  and  $c_u^E$ . Little is lost by assuming existence of prices  $(\bar{p}^I, \bar{p}^E)$  above which both demands are zero, thereby providing upper bounds for the strategy spaces. Lower bounds are more problematic because  $C_d^{i'}$  varies with the prices, and  $c_u^E$  and  $w$  are comparative static parameters of interest, so a price-cost margin may be negative on parts of any strategy spaces that might be stated in terms of lower bounds on prices. If so, then  $Q_{12}^i \geq 0$  and convex costs are not sufficient for SC globally. However, both upstream price-cost margins are strictly positive at an interior equilibrium, so the problem can be handled by stating a bound slightly below the equilibrium price and considering local comparative statics.

**Lemma 1.**  $\hat{p}^i(c_u^E, w)$  is increasing in both of its arguments for  $i = I, E$ .

The comparative statics of  $\hat{\Pi}^E(c_u^E, w)$  are central in determining when (MoB) holds. Supermodularity does not generally determine the comparative statics of equilibrium payoffs. However, Dixit (1986, pp. 112-5) shows that  $c_u^E$  has an ambiguous effect on  $\hat{\Pi}^E$  because the direct and strategic effects work in opposite directions. Dixit's analysis is not directly applicable for determining the effect of  $w$  on  $\hat{\Pi}^E$  because the functional form of  $\Pi^I$  does not fit within Dixit's framework.<sup>15</sup> Direct evaluation of the derivatives, via the envelope theorem, yields

$$\hat{\Pi}_1^E(c_u^E, w) = \Pi_2^E \hat{p}_1^I + \Pi_3^E = \left[ \hat{p}^E - c_u^E - C_d^{E'}(Q^E(\hat{p}^E, \hat{p}^I)) \right] Q_2^E(\hat{p}^E, \hat{p}^I) \hat{p}_1^I - Q^E(\hat{p}^E, \hat{p}^I) \quad (2a)$$

$$\hat{\Pi}_2^E(c_u^E, w) = \Pi_2^E \hat{p}_2^I = \left[ \hat{p}^E - c_u^E - C_d^{E'}(Q^E(\hat{p}^E, \hat{p}^I)) \right] Q_2^E(\hat{p}^E, \hat{p}^I) \hat{p}_2^I > 0. \quad (2b)$$

(FOC-E) ensures that E's price-cost margin is positive at an interior equilibrium. This, along with Assumption GS and Lemma 1, establishes that the strategic effects  $\left[ \hat{p}^E - c_u^E - C_d^{E'}(Q^E(\hat{p}^E, \hat{p}^I)) \right] Q_2^E(\hat{p}^E, \hat{p}^I) \hat{p}_i^I$  for  $i = 1, 2$  in equations (2) are positive. The positive strategic effect of  $w$  establishes  $\hat{\Pi}_2^E > 0$ , but the direct effect  $-Q^E(\hat{p}^E, \hat{p}^I)$  of  $c_u^E$  in (2a) is negative, confirming Dixit's ambiguous sign for  $\hat{\Pi}_1^E$ .

### III. EFFICIENT MAKE-OR-BUY DECISIONS

The standard concept of an efficient Make-or-Buy decision is that the entrant chooses to make the input if and only if the entrant has lower upstream costs.<sup>16</sup> There are two ways for a policy-maker to implement this concept. First, a policy-maker could consider a cost pair  $(c_u^E, c_u^I)$  and ask: "Given these costs, for what values of  $w$  will (MoB) hold and for what values of  $w$  will (MoB) fail?" Second, a policy-maker could more generally ask: "What input pricing rule(s)  $w(c_u^I, c_u^E)$ , that map a cost pair into an input price, will ensure that (MoB) holds if and only  $c_u^E \leq c_u^I$ ?"

Gayle and Weisman (2006), and also Sappington's (2005, p. 1636) discussion of "partial displacement," take the first approach. This approach is information-intensive. It requires regulatory knowledge of both the incumbent's and the entrant's upstream marginal costs, and demand information as well so that profits can be calculated. Policy-makers struggle to obtain reliable cost information about incumbents. Accurate

<sup>15</sup>Specifically, the upstream profit term  $[w - c_u^I] Q^E(p^E, p^I)$  is not present in Dixit's model.

<sup>16</sup>See Sappington (2005) p. 1633 and the references cited in footnote 8 above.

cost or demand information about entrants is rarely available. Indeed, Laffont and Tirole (2000, chapter 4) pointedly argue for regulation that minimizes use of detailed demand and cost information because such information is rarely available in usable form.

The second approach poses an interesting mechanism design question. The answer provides general advice to policy-makers about how input pricing policy should be structured if the objective is to induce efficient Make-or-Buy decisions. At first, it might appear that designing the right mechanism would require at least as much information as choosing the right input price for a particular cost pair. Proposition 1, which is the main result of the paper, shows that this need not be the case.

**Proposition 1.** *Let  $\phi(x) = \widehat{\Pi}^E(x, x)$  denote the entrant's equilibrium profit when the entrant's upstream marginal cost and the incumbent's input price are both  $x$ . Within the class of continuous input pricing rules, (MoB) is equivalent to  $c_u^E \leq c_u^I$  if and only if the input pricing rule  $w(c_u^I, c_u^E)$  satisfies  $\phi(x) = \phi(w(x, x))$  for every relevant identical cost level  $x$ .*

*Proof.* Begin by assuming (MoB) is equivalent to  $c_u^E \leq c_u^I$ . One possible upstream cost configuration is equal productive efficiency:  $c_u^I = c_u^E = x$ . Equivalence of (MoB) and  $c_u^E \leq c_u^I$  for this cost configuration implies  $\phi(x) = \widehat{\Pi}^E(c_u^E, c_u^I) \geq \phi(w(x, x))$ . Moreover, this inequality cannot be strict. If the inequality were strict then continuity of  $\widehat{\Pi}^E$  and  $w$  yields  $\widehat{\Pi}^E(x, x - \varepsilon) > \phi(w(x, x - \varepsilon))$  for sufficiently small  $\varepsilon > 0$ , in which case the cost configuration  $(c_u^E, c_u^I) = (x, x - \varepsilon)$  satisfies (MoB) yet has  $c_u^E > c_u^I$ . Therefore efficiency of the Make-or-Buy decision implies  $\phi(x) = \phi(w(x, x))$  for every possible common upstream cost  $x$ .

Now consider the converse. If  $c_u^E > c_u^I$  then  $\widehat{\Pi}^E(c_u^E, c_u^I) < \widehat{\Pi}^E(c_u^E, c_u^E) = \phi(c_u^E) = \phi(w(c_u^E, c_u^E))$ , using (2b). If  $c_u^E \leq c_u^I$  then  $\widehat{\Pi}^E(c_u^E, c_u^I) \geq \widehat{\Pi}^E(c_u^E, c_u^E) = \phi(c_u^E) = \phi(w(c_u^E, c_u^E))$ . Hence  $c_u^E \leq c_u^I$  is equivalent to (MoB).  $\square$

There are two ways to ensure  $\phi(x) = \phi(w(x, x))$  across a range of  $x$  values. First,  $\phi$  could be a constant function. In this case the condition  $\phi(x) = \phi(w(x, x))$  is uninformative about the input pricing rule. Indeed, if  $\phi$  is a constant function then any pricing rule satisfies  $\phi(x) = \phi(w(x, x))$ , so Make-or-Buy decisions will be efficient under any pricing rule. Input prices are irrelevant for the efficiency of Make-or-Buy decisions in this situation.<sup>17</sup> Note that  $\phi'(x) = \widehat{\Pi}_1^E(x, x) + \widehat{\Pi}_2^E(x, x)$ . Using (FoC-E) to substitute for  $Q^E$  in (2a), using

<sup>17</sup>It is shown below that Sappington's (2005) Hotelling model has a constant  $\phi$  function.

(2b), and noting again that E's equilibrium price-cost margin is positive, yields

$$\phi'(x) \stackrel{s}{=} Q_1^E(\hat{p}^E, \hat{p}^I) + Q_2^E(\hat{p}^E, \hat{p}^I) [\hat{p}_1^I + \hat{p}_2^I], \quad (3)$$

where  $\hat{p}^i$  is evaluated at  $(x, x)$  for  $i = I, E$ . As might be expected from equations (2), this expression has ambiguous sign in general.  $\phi$  is constant if and only if

1. The direct effect dominates the strategic effect in  $\hat{\Pi}_1^E$ , making the entrant's equilibrium profit decreasing in its own cost, and
2. The magnitude of the negative effect in item 1 is exactly offset by the strategic effect on  $\hat{\Pi}^E$  of a change in  $w$  (i.e.,  $\hat{\Pi}_2^E$ ).

Verifying these items generally requires a lot of information about the entrant's equilibrium profit function. It is shown in the next section that one key determinant is the displacement ratio<sup>18</sup>  $-\frac{Q_2^E}{Q_1^E}$ , which measures the fraction of incumbent demand increase that displaces entrant demand when the incumbent lowers its retail price. However, the discussion below reveals that items 1 and 2 are determined exclusively by the magnitude of the displacement ratio only under strong assumptions about industry demand that would be difficult for a policy-maker to verify in practice.

The second way to ensure  $\phi(x) = \phi(w(x, x))$  is for the pricing rule to satisfy  $x = w(x, x)$ . One such rule is the marginal cost pricing rule  $w = c_u^I$ .

**Corollary 1.** *Marginal cost pricing of the incumbent's input induces efficient Make-or-Buy decisions.*

*Proof.* Marginal cost pricing is  $w(c_u^I, c_u^E) = c_u^I$ . So  $w(x, x) = x$ . Now apply Proposition 1.  $\square$

Proposition 1 reveals, however, that there are many other continuous pricing rules that induce efficient Make-or-Buy decisions. For example,  $w(c_u^I, c_u^E) = c_u^I + f(c_u^I - c_u^E)$  satisfies the necessary and sufficient condition for efficient Make-or-Buy decisions for any continuous function  $f$  with a fixed point at zero. Of course, all such rules, except marginal cost pricing, require that the input price depend on the entrant's upstream cost.

**Corollary 2.** *Marginal cost pricing of the incumbent's input is the only continuous input pricing rule that guarantees efficient Make-or-Buy decisions and does not require knowledge of the entrant's upstream cost or of the demand functions.*

<sup>18</sup>Armstrong et al. 1996; Armstrong 2002; Sappington 2005 p. 1636.

*Proof.* Proposition 1 requires  $w(x, x) = x$  or  $\phi'(x) = 0$ . Confirming the latter requires that items 1 and 2 above be confirmed, which requires demand information. So consider an input pricing rule that satisfies the former and does not depend on  $c_u^E$ . As the rule does not depend on  $c_u^E$ , a change in the second argument with no change in the first argument does not change  $w$ . Hence  $w(x, c_u^E) = x$  for every possible incumbent upstream cost  $x$ .  $\square$

Marginal cost pricing is much less informationally demanding than other possible efficiency-inducing rules. Policy-makers must know only the incumbent's upstream cost. No demand information, downstream cost information, or information about the entrant are needed.

#### IV. LINEAR DEMANDS

Two recent papers that have considered the efficiency of Make-or-Buy decisions are Sappington (2005) and Gayle and Weisman (2006). Both papers use models of the form considered above with linear demands.<sup>19</sup> Sappington assumes demands of the Hotelling form

$$Q^i = \frac{N [t + p^j - p^i]}{2t} \text{ for } i, j = I, E \text{ (} i \neq j \text{)}, \quad (\text{Hot})$$

where  $N$  is the number of consumers in the linear city and  $t$  is the linear transport cost per unit of distance.

Gayle and Weisman assume demands of the vertical differentiation form

$$Q^I = 1 - \frac{p^I - p^E}{\lambda^I - \lambda^E} \text{ and } Q^E = \frac{p^I}{\lambda^I - \lambda^E} - \frac{\lambda^I p^E}{\lambda^E(\lambda^I - \lambda^E)}, \quad (\text{VD})$$

where  $\lambda^I > \lambda^E$  are the quality parameters of the two firms.

It is straightforward to confirm that, when demands are linear, Assumption GS implies

1.  $\Pi_{12}^i = Q_2^i > 0$  for  $i = I, E$  (i.e., Assumption SC),
2.  $\Pi_{11}^i = 2Q_1^i < 0$  for  $i = I, E$  (i.e., second order conditions), and
3.  $J = \Pi_{11}^I \Pi_{11}^E - \Pi_{12}^I \Pi_{12}^E = 4Q_1^I Q_1^E - Q_2^I Q_2^E > 0$  (i.e., "stability").

Moreover, standard comparative statics analysis yields

$$\hat{p}_1^I = -\frac{Q_1^E Q_2^E}{J} \text{ and } \hat{p}_2^I = -\frac{2Q_1^E Q_2^E}{J}. \quad (4)$$

<sup>19</sup>Gayle and Weisman consider a Cournot model as well.

Substituting (4) into (3) and simplifying yields

$$\phi' \stackrel{s}{=} - [Q_1^I Q_1^E - Q_2^I Q_2^E] - [Q_1^I Q_1^E - (Q_2^E)^2]. \quad (3-L)$$

The first bracketed term in (3-L) is positive but approaches zero as the own-price and rival-price effects on demand become arbitrarily close in magnitude, and therefore cannot be relied upon in general to determine the sign of (3-L). The second bracketed term has ambiguous sign because it involves the magnitude of the own-price effect on firm I's demand relative to the rival-price effect on firm E's demand. This relative magnitude is the displacement ratio and its size is not addressed by Assumption GS since it is a comparison across incumbent and entrant demands.<sup>20</sup> Hence (3) has ambiguous sign even in the linear case and  $\phi$  need not be constant when demands are linear. Indeed, (3-L) shows that  $\phi'$  is negative when own-price and rival-price demand effects are not too close and own-price effects are generally larger in magnitude than rival-price effects.

Suppose, in particular, that the linear demands are symmetric. Letting  $Q$ (own price, rival price) denote a common linear demand that satisfies Assumption GS, (3-L) becomes

$$\phi' \stackrel{s}{=} -2 [(Q_1)^2 - (Q_2)^2]. \quad (3-LS)$$

Equation (3-LS) is negative under Assumption GS but degenerates to zero as rival-price effects approach own-price effects in magnitude (i.e., as  $Q_2$  approaches  $-Q_1$ , or the displacement ratio approaches 1). The Hotelling demands above are symmetric and are the limiting case of GS in which  $Q_2 = -Q_1$ . Hence  $\phi' = 0$  in a standard Hotelling model, which gives Sappington's (2005, p. 1636) "full displacement" explanation of irrelevance of input prices for the efficiency of Make-or-Buy decisions as an application of Proposition 1. Note, however, that this is a limiting case even when demands are linear and symmetric, and it implies a zero aggregate price elasticity of demand. Input prices are relevant for the efficiency of Make-or-Buy decisions in any linear symmetric demand structure that has own-price effects larger in magnitude than rival-price effects.

Gayle and Weisman's (2006) vertical differentiation model has linear but asymmetric demands. Differen-

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<sup>20</sup>Indeed, Assumption GS does not ensure the "displacement" ratio is less than one, even when demands are linear, unless the demands are symmetric.

tiating (VD) and substituting into (3-L) yields

$$\phi' \stackrel{s}{=} -\frac{2}{\lambda^E(\lambda^I - \lambda^E)} < 0.$$

Hence  $\phi$  is strictly decreasing in this model, which gives Gayle and Weisman's conclusion that the input pricing rule affects efficiency of Make-or-Buy decisions as an application of Proposition 1.

If  $\phi'(x) < 0$ , as suggested by the case of linear symmetric demands and by Gayle and Weisman's model, then the extent to which the input price can deviate from marginal cost while maintaining an efficient Make-or-Buy decision is depicted in Figure 1. If  $c_u^E$  exceeds  $c_u^I$ , as shown, then (2b) yields  $\widehat{\Pi}^E(c_u^E, c_u^I) < \widehat{\Pi}^E(c_u^E, c_u^E)$ , also as shown.  $\widehat{\Pi}^E(c_u^E, c_u^I)$  determines a critical input price,  $w^*$ , at which (MoB) is an equality. Any input price below this critical value will induce an efficient Make-or-Buy decision. Similarly, if the entrant's upstream cost lies below  $c_u^I$ , shown as  $\tilde{c}_u^E$  in the figure, then (2b) yields  $\widehat{\Pi}^E(\tilde{c}_u^E, c_u^I) > \widehat{\Pi}^E(\tilde{c}_u^E, \tilde{c}_u^E)$ , and  $\tilde{w}^*$  is the critical input price at which (MoB) is an equality. Any input price above this critical value will induce an efficient Make-or-Buy decision in this case. Note, however, that the position of the critical input price depends on the position of  $c_u^E$  relative to  $c_u^I$  and on the slope  $\phi'$ , which in turn depends on the demands.

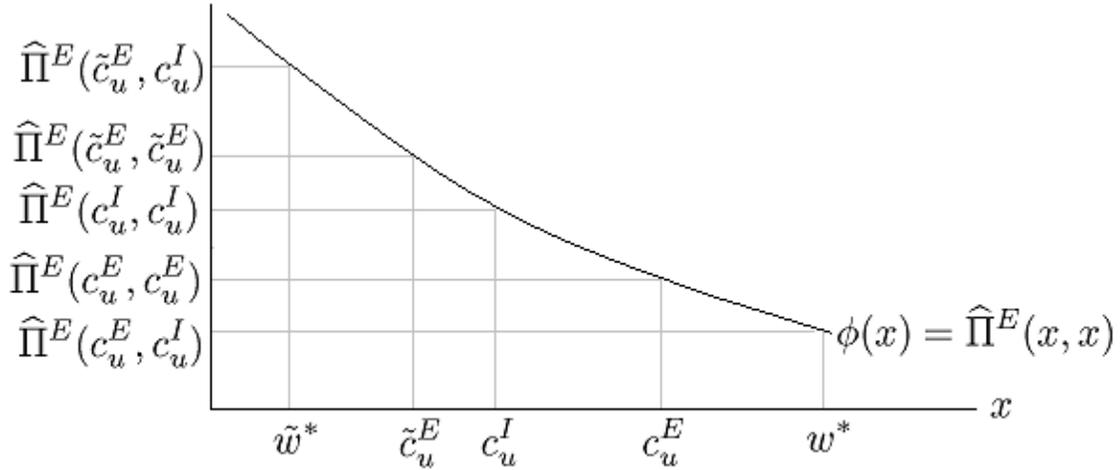


FIGURE 1. Input Prices and Efficient Make-or-Buy Decisions.

Note also that the entrant's participation decision can be affected by the value of  $w$  whenever  $\phi' \neq 0$ . In particular, if  $\phi' < 0$  then an increase in the input price above marginal cost can cause the entrant to either stay out of the market or enter but choose to make the input despite having an upstream cost disadvantage.

## V. AN EXAMPLE

A simple example provides a sense of how much the input price can deviate from marginal cost while still ensuring efficient Make-or-Buy decisions.<sup>21</sup>

Suppose demands are linear and symmetric as in Vives (1984, p. 75):

$$Q^i = \tilde{\alpha} - \beta p^i + \gamma p^j \text{ for } i, j = I, E \text{ (} i \neq j \text{)}. \quad (5)$$

Assumption GS is  $\beta > \gamma \geq 0$  and the displacement ratio is  $\delta = \frac{\gamma}{\beta}$ .

Suppose further that downstream costs are symmetric and constant returns, and suppress the constant downstream marginal cost henceforth by assuming it is incorporated into  $\tilde{\alpha}$ .

Then it is straightforward to calculate the interior equilibrium prices<sup>22</sup>

$$\hat{p}^I = \frac{[2 + \delta]\alpha + 2c_u^I + \delta c_u^E + 2\delta[w - c_u^I]}{4 - \delta^2} \quad (6-I)$$

$$\hat{p}^E = \frac{[2 + \delta]\alpha + \delta c_u^I + 2c_u^E + \delta^2[w - c_u^I]}{4 - \delta^2}, \quad (6-E)$$

where  $\alpha = \frac{\tilde{\alpha}}{\beta}$ .

Substituting these equilibrium prices into (II-E) and simplifying yields

$$\hat{\Pi}^E(c_u^E, w) = \frac{\beta}{[4 - \delta^2]^2} [[2 + \delta]\alpha + \delta c_u^I - [2 - \delta^2]c_u^E + \delta^2[w - c_u^I]]^2. \quad (\text{II-E}')$$

Evaluating this equilibrium profit at  $(c_u^E, c_u^I)$  and  $(w, w)$  reveals that (MoB) is

$$\frac{w}{c_u^I} \geq \frac{2\theta - \delta^2[1 + \theta]}{2[1 - \delta^2]}, \quad (\text{MoB}')$$

where  $\theta = \frac{c_u^E}{c_u^I}$  is the relative productive efficiency of the incumbent. (MoB') expresses a lower bound on the percent markup of input price over the incumbent's marginal cost in terms of the incumbent's relative efficiency and the demand displacement ratio. Markups above this bound will induce a Make decision by the entrant and markups below this bound will induce a Buy decision by the entrant.

Table 1 provides a few values for the bound when the incumbent is relatively efficient, in which case the bound is a maximum markup for an efficient Make-or-Buy decision. The bounds in Table 1 switch signs

<sup>21</sup>I am grateful to David Sappington for suggesting this analysis.

<sup>22</sup>A sufficiently large value of the (net of downstream cost) demand intercept  $\tilde{\alpha}$  ensures an interior equilibrium for all values of the other parameters considered herein.

for values of  $\theta$  less than one (i.e., a relatively inefficient incumbent), in which case the bounds are minimum markups for efficient Make-or-Buy decisions. Table 1 reveals that efficient Make-or-Buy decisions may occur even when the input price markup is large (as high as 15.66%) and the incumbent's efficiency advantage is small (i.e., 5%), provided the displacement ratio is close to one. A displacement ratio close to 1 corresponds to a relatively flat  $\phi$  function in Figure 1 (i.e.,  $\phi'$  close to zero).

		$\theta$					
		<u>1.01</u>	<u>1.025</u>	<u>1.05</u>	<u>1.10</u>	<u>1.15</u>	<u>1.20</u>
$\delta$	0.1	1.01%	2.51%	5.03%	10.05%	15.08%	20.10%
	0.2	1.05%	2.62%	5.25%	10.49%	15.74%	20.99%
	0.4	1.10%	2.74%	5.48%	10.95%	16.43%	21.90%
	0.5	1.17%	2.92%	5.83%	11.67%	17.50%	23.33%
	0.6	1.28%	3.20%	6.41%	12.81%	19.22%	25.63%
	0.7	1.48%	3.70%	7.40%	14.80%	22.21%	29.61%
	0.8	1.89%	4.72%	9.44%	18.89%	28.33%	37.78%
	0.9	3.13%	7.83%	15.66%	31.32%	46.97%	62.63%

TABLE 1. Maximum Input Price Markups for Efficient Make-or-Buy Decisions.

## VI. CONCLUSION

Pricing of critical inputs is an important and complicated issue in regulated, and even some unregulated, industries. The general problem involves many competing objectives; including the need to cover fixed costs across a bundle of services and the resulting Ramsey rules or efficient component rules; provision of incentives for innovation and cost-savings; control of potential non-price discrimination; coverage of stranded costs and, more generally, ensuring regulatory commitment; optimal use of asymmetric information; and optimal control of the significantly different strategic environment associated with two-way rather than one-way access.

This paper provides a definitive answer to the long-standing question of what input pricing regimes will induce efficient Make-or-Buy decisions by entrants, in a simplified environment in which many of these issues do not arise, but that improves upon the existing bypass literature by considering general retail price competition influenced by the Make-or-Buy decision. We find that input prices are irrelevant for Make-or-Buy decisions only when demands satisfy a restrictive and difficult-to-verify assumption. Otherwise, there is latitude in setting input prices that ensure efficient Make-or-Buy decisions, but the extent of that latitude depends on demand and cost information that is rarely available in practice. There can be considerable latitude for even modest differences in productive efficiency, however, when products are nearly homogeneous.

On the other hand, marginal cost pricing of inputs always ensures efficient Make-or-Buy decisions when there is constant returns upstream and simultaneous noncooperative price competition downstream.

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