

Horizontal Product Differentiation and the Irrelevancy of Input Prices for Make-or-Buy Decisions

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Abstract: *Mandatory network unbundling is one of the most important topics in regulatory economics today. The concept has crucial importance in the deregulation of many previously regulated industries including electricity, telecommunications, gas and railroads. Upon initial examination, determining the correct input prices would seem important for sending the correct price signals to the entrants for their efficient make-or-buy decisions. However, Sappington uses a standard Hotelling location model to show that input prices are irrelevant for an entrant's make or buy decision. In this study, it is shown that this result is closely related to the degree of product differentiation when firms are engaged in price competition. Specifically, it is shown that input prices are irrelevant when firms produce homogeneous products, but are relevant for make-or-buy decisions when the entrant and incumbent produce differentiated products. These results suggest that, in general, it is important for regulators to set correct prices in order to not distort the entrants' efficient make-or-buy decisions.*

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JEL Classification: L13, L49, L51, L97

1. Introduction

To introduce competition into the telecommunications industry, the 1996 Telecommunications Act requires incumbent providers to unbundle their networks and lease individual network elements to any requesting telecommunications carrier.¹ This concept is known as a mandatory unbundling policy and is prevalent in many network industries throughout the world. As a direct result of these unbundling policies, optimal access pricing for unbundled network elements has become a prominent issue in regulatory economics.² Moreover, mandatory unbundling and the price of unbundled network elements, known as access charges, have emerged as more prominent issues associated with the implementation of the 1996 Act. In general, the issue of access charges has attracted significant interest from researchers even before the implementation of the Act. As a result, a voluminous access pricing literature has emerged with the focus on optimal access charges.

Without question, 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.³ Their analyses depend on contestable markets which can be treated as part of a perfect competition framework. Based on the ECPR, the optimal

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access price of a bottleneck input 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.

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.

Laffont and Tirole (1994) investigate optimal access prices in a competitive fringe model using a principal-agent framework. 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 incumbent provider, competitors should contribute to the fixed cost of the network.

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' analysis suggests 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.

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. They show that the optimal access charge can be equal to the marginal cost of the bottleneck input depending on whether the incumbent's break-even constraint is binding or not at the social optimum.

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 based on different demand and supply conditions. The authors also investigate margin regulation. When the regulator's choice variable is margin between the retail price and the access price, they show that the optimal margin is fully consistent with the ECPR.

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.

Sappington and Unel (2005) examine privately negotiated input prices instead of access charges set by regulators. They observe that the number of successful input

negotiations between ILECs and their competitors has been increasing in the telecommunications industry. The authors examine the privately negotiated input prices under asymmetries in the bargaining power of the incumbents and their competitors within a theoretical framework. Assuming a homogenous product and no retail price regulation, a vertically integrated incumbent that has an upstream cost advantage and one competitor with a downstream cost advantage, they find that privately-negotiated input prices result in the full extraction of consumer surplus in the retail market. Their analysis also suggests that under retail price regulation, multiple potential competitors and product differentiation precludes the full exploitation of consumers.

The 1996 Act requires incumbent providers to supply unbundled network elements to rivals at cost-based prices. The pricing methodology implemented by the U.S. Federal Communications Commission (FCC) was initially based on total element long-run incremental cost (TELRIC).⁴ Note that both literature review in the access pricing issue and the FCC's initial position for the pricing methodology reflect the common view on the importance of level of access charges. Therefore, as Gayle and Weisman (2007, p.196) stated, "following the passage of the 1996 Act, the FCC and the individual state public service commissions engaged in efforts to determine costing standards that provide entrants with the right price signals to make or buy the input required for downstream production." However, the FCC has recently revisited this pricing methodology out of concern that the TELRIC methodology may yield prices that serve to distort the entrant's make-or-buy decision.⁵

Upon initial examination, establishing the correct costing standards and/or determining correct input prices would seem important for sending the correct price signals to entrants for their efficient make-or-buy decisions. This is not true in all cases, however. Sappington (2005), for example, uses a Hotelling location model for product differentiation to show that the entrant's efficient make-or-buy decision is independent of the price of the input. More specifically, Sappington's model reveals that the market entrants' decision for making or buying an input required for downstream production depends on a comparison between their cost and the incumbent's cost of making the input, rather than evaluation between their cost and the input price at which the input can be purchased from the incumbent. Sappington's conclusion is provocative since, if generally correct, it suggests that the efforts of the regulatory authorities to determine the correct prices for unbundled elements are largely pointless because input prices are irrelevant for efficient make-or-buy decisions.

Following Sappington (2005), Gayle and Weisman (2007) showed that, in the vertical Bertrand competition framework, input prices are not irrelevant and they concluded that "this line of research would benefit from a more general modeling framework as opposed to the rather specialized models that we employ in this paper and that Sappington employs in his article."^{6,7} The Hotelling framework for differentiated products is a horizontally differentiated approach, whereas Gayle and Weisman (2007) use a vertically differentiated approach in their analysis. In the vertically differentiated approach, the points in the characteristic space corresponding to the set of goods lie on the same ray vector through the origin representing higher quality farther out along this ray. Therefore, if these goods were sold at the same prices, every consumer would rank these goods in the same order. Conversely, in the horizontally differentiated models the goods cannot be ranked in terms of some quality index because preferences are diverse and asymmetric. Tastes follow some distribution across the characteristic space and each consumer determines her most preferred location. An alternative approach for product differentiation is to examine the case

where preferences are defined over the set of all possible goods where a central feature is preference symmetry. This approach makes extensive use of representative consumer models.⁸

Therefore, a natural question concerns whether contradictory results arise from inconsistencies in the definition of product differentiation. If this is the case, then a possible extension to address this inconsistency would enable us to produce more general rules for the relationship between the efficient make-or-buy decision and the irrelevancy of input prices.

This is the central idea motivating this line of research. The remainder of this essay is organized as follows. The general assumptions and definitions are outlined in Section 2. The Hotelling location model is reviewed and the drawbacks of this model in terms of product differentiation are also examined. One possible extension is suggested in Section 3. It is shown that product differentiation in the standard Hotelling location model is problematic when two firms' products are differentiated in only one characteristic. Section 4 summarizes the key findings and concludes.

2. General Assumptions and Definitions

An incumbent and an entrant are assumed to compete in a duopoly setting in the market for the downstream product. Each unit of downstream output requires one unit of the upstream input and one unit of the downstream input that is self-supplied by the individual firm. The entrant has an option to buy the upstream input from the incumbent at a price which is set by the regulator. Let w denote the wholesale price of the upstream input when the entrant purchases the upstream input from the incumbent. The constant unit cost of producing the upstream input for the incumbent and the entrant are denoted by c_u^I and c_u^E , respectively. In addition, c_d^I and c_d^E denote the constant unit cost of producing the downstream input for the incumbent and the entrant, respectively.

3. The Hotelling model

The assumptions and notation in this section are identical to Sappington (2005). Sappington employs a Hotelling location model of price competition for differentiated products.⁹ In this setting, 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 and each consumer buys one unit of the good and obtains utility v which is assumed to be sufficiently large so that each of N consumers purchases one unit of the retail product in equilibrium. Hence, demands are perfectly inelastic. A consumer at location $L \in [0, 1]$ incurs transportation cost (disutility) tL if the consumer purchases the product from the incumbent and $t(1-L)$ if the consumer purchases the product from the entrant. Each consumer purchases the product from the firm that offers the smallest sum of retail price and transportation cost, or the lowest delivered price. Of primary interest in Sappington's model is the level of w that induces the entrant to undertake the efficient make-or-buy decision. He concludes that 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 ($c_u^I < c_u^E$), and produces the upstream input itself whenever it is the least-cost supplier of the input ($c_u^E < c_u^I$). This result is stated formally in Proposition 1.

Proposition 1 (Sappington): *Regardless of the price (w) of the upstream input: (a) 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 (b) 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 the somewhat surprising result that the entrant's efficient make-or-buy decision is independent of the established input price (w). This is the basis for Sappington's principal finding that input prices are irrelevant for the entrant's make-or-buy decision.

The Hotelling location model is a widely used technique for modeling product differentiation as a form of spatial competition. In these models, product differentiation is captured by consumer's preferences in purchasing some homogenous product from sellers at different locations when transportation costs exist.¹⁰ In this sense, Hotelling type models imply product differentiation if both duopolists locate at distinct points and no product differentiation if firms locate at the same point.¹¹ On the other hand, the standard price and/or quantity duopoly models with negatively sloped demand curves—as a representative consumer model—require symmetric slopes of demand functions for homogeneous products and asymmetric slopes for differentiated products. The outstanding question therefore concerns the manner in which product differentiation in Hotelling models deviates from the representative consumer models. In other words, does fixing a firm's location at distinct points on an interval imply a consistent product differentiation framework within the confines of representative consumer models?

It is possible to show that Sappington's location model can be reduced to a slightly modified version of homogeneous Bertrand competition under special conditions. Thus, the solutions support the well-known Bertrand Paradox under special conditions.¹²

To see this, we use the Nash equilibrium prices and quantities obtained by Sappington (2005).¹³ When two firms have symmetric marginal costs ($c^i = c^j = c$), equilibrium prices, quantities and profits become $P = t + c$, $Q = N/2$ and $\Pi = Nt/2$. In words, both firms charge a price equal to constant marginal cost, and they share market demand equally.¹⁴

Consider, for example, two online sellers that produce some homogeneous product. Each firm incurs a cost c per unit of production. Moreover, assume that there are N consumers who purchase one unit of the product. Assume also that when a firm sells a unit of the homogeneous product there is a constant shipping cost s as an expense for the consumer as in the Hotelling model. When the prices of the two firms differ, all consumers buy from the low-price producer. Conversely when the prices of the two firms are equal, both firms are assumed to share the market equally. It is straightforward to show that the unique Nash equilibrium prices, quantities and profits of this game are: $P^i = P^j = s + c$, $Q^i = Q^j = N/2$ and $\Pi^i = \Pi^j = Ns/2$. This slightly modified version of the Bertrand Paradox produces the same results as Sappington's Hotelling model.

Two observations with respect to this analysis are instructive. First, this version of the Bertrand Paradox deviates from the classical Bertrand Paradox in terms of equilibrium values. This is due to the fact that prices differ for customers and firms. Hence $\Pi^I = \Pi^E = Ns/2$ could be evaluated as a normal profit level if one compares two possible cases that depend on the entity responsible for the unit shipping cost. Second, in these two models it is appropriate to set $s = t$, since in the Hotelling framework the total transportation cost expenditures for purchasing the two firms' product are the same if and only if the marginal consumer locates at the mid point of the $[0,1]$ interval. Therefore, s and t can be used interchangeably for the specific cases of Hotelling and Bertrand competition models, respectively.

An important observation is that the precise meaning of product differentiation in the Hotelling models diverges from the concept of product differentiation in standard price and competition models. In the Hotelling location models, fixing firms' locations at different points automatically implies product differentiation. That is to say, the products are differentiated by location only; they are homogeneous in all other respects. As shown above, however, when firms have symmetric constant marginal costs, the model can be reduced to a simple homogeneous product standard price competition model.¹⁵ This is not particularly surprising when one considers the assumptions underlying the Hotelling model. By assuming uniformly distributed consumers on a unit interval and requiring each consumer to consume one unit of the product, we might be oversimplifying the concept of product differentiation because any asymmetric tastes of consumers are ignored. In other words, the standard Hotelling model is restrictive in representing product differentiation since the model's assumptions do not allow consumers to pick their favorite location based on utility maximization. This is a drawback of the Hotelling type product differentiation models when the products of firms are differentiated in one dimension.

When firms have asymmetric marginal costs, the Hotelling model can no longer be reduced to the homogeneous good case since the prices of both firms' products differ under asymmetric marginal costs.^{16,17}

As we show above, under special conditions, namely symmetric constant marginal costs, the Hotelling setting yields a similar solution to the Bertrand paradox. This is the same case for homogeneous products in standard price competition models. Then the issue is whether we can eliminate this inconsistency in the models. As stated above, this contradiction occurs as a result of the first assumption of a homogeneous product in Hotelling type models. Then, assuming that the products of different firms are close but not perfect substitutes for consumers may serve to address this problem. In other words, we will allow the products of the firms to be differentiated in more than one characteristic.¹⁸ This modification also enhances the institutional realism of the model.

Let us assume that each customer incurs total cost $\psi^I P^I + tL$ if she buys the product from the incumbent and $\psi^E P^E + t(1-L)$ if she buys from the entrant. For every consumer, assume that $\psi^I < \psi^E$.^{19,20} For simplicity, each consumer has the same value for ψ^I and ψ^E . One explanation for the given relation between ψ^I and ψ^E is that of a loyalty effect. For example, the incumbent's product might be known and thus consumers tend to prefer the incumbent's product if the price difference is not too large. Another reason would be high switching costs. With positive switching costs, some consumers will accept a somewhat higher price for the incumbent's product.²¹

The settings wherein both the incumbent and entrant serve retail customers in equilibrium are the same as in Sappington (2005). To secure positive equilibrium quantities, we concentrate on interior solutions. Formally it is assumed throughout the analysis that:

Assumption 1: $\max \left\{ \left| \psi^I(w + c_d^I) - \psi^E(w + c_d^E) \right|, \left| \psi^I(c_u^I + c_d^I) - \psi^E(c_u^E + c_d^E) \right| \right\} < 3t.$

Following Sappington, our interest is limited to upstream input prices that leave the incumbent with nonnegative profit in equilibrium when the entrant chooses to buy the upstream input from the incumbent at unit price w .²² Formally, the assumption is given by:

Assumption 2: $(w - c_u^I)Q_B^E > -N \left[3t + \psi^E(w + c_d^E) - \psi^I(w + c_d^I) \right]^2 / 18\psi^I t$

or equivalently:

$$w > c_u^I - \frac{1}{3\psi^I} \frac{\left(3t - \psi^I(w + c_d^I) + \psi^I(w + c_d^E) \right)^2}{\left(3t - \psi^E(w + c_d^E) + \psi^I(w + c_d^I) \right)}$$

Under these assumptions, equilibrium price (P), output level (Q), and profits (Π) are characterized in Lemmas 1 and 2. The equilibrium values of the variables for the incumbent and the entrant are denoted by the superscripts I and E , respectively. The subscripts M and B , denote equilibrium values of the “make” and “buy” cases, respectively.

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

$$P_M^i = \frac{3t + 2\psi^i(c_u^i + c_d^i) + \psi^j(c_u^j + c_d^j)}{3\psi^i}; \tag{1}$$

$$Q_M^i = N \frac{3t - \psi^i(c_u^i + c_d^i) + \psi^j(c_u^j + c_d^j)}{6t}; \text{ and} \tag{2}$$

$$\Pi_M^i = N \frac{\left[3t - \psi^i(c_u^i + c_d^i) + \psi^j(c_u^j + c_d^j) \right]^2}{18\psi^i t}. \tag{3}$$

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

$$P_B^i = \frac{3t + 2\psi^i(w + c_d^i) + \psi^j(w + c_d^j)}{3\psi^i}; \tag{4}$$

$$Q_B^i = N \frac{3t - \psi^i(w + c_d^i) + \psi^j(w + c_d^j)}{6t}; \tag{5}$$

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

$$\Pi_B^I = \left[w - c_u^I\right] Q_B^E + N \frac{\left[3t - \psi^I (w + c_d^I) + \psi^E (w + c_d^E)\right]^2}{18\psi^I t}. \quad (7)$$

The entrant's efficient make-or-buy decision can be evaluated by using Lemma 1 and Lemma 2. The entrant prefers to buy the upstream input from the incumbent if $\Pi_B^E > \Pi_M^E$, and prefers to make the input itself if $\Pi_B^E < \Pi_M^E$. The entrant's make-or-buy decision is summarized in Proposition 2.

Proposition 2: *In the equilibrium of the Hotelling model for close substitutes: (a) the entrant prefers to buy the upstream input from the incumbent rather than make it if and only if $(w - c_u^I) > (\psi^E / \psi^I)(w - c_u^E)$; and (b) the entrant prefers to make the upstream input itself when $(w - c_u^I) < (\psi^E / \psi^I)(w - c_u^E)$.*

Proposition 2, part (a) reveals that $c_u^E > c_u^I$ is not a necessary condition for the entrant to buy the input from the incumbent. To see this, consider the case where the incumbent makes zero or negative profit from the upstream market, which implies that $w \leq c_u^I$. Then, the entrant's buy decision condition holds if and only if $c_u^E > c_u^I$. On the other hand, if the incumbent realizes positive profit from the upstream market ($w > c_u^I$), then the case where $c_u^I = c_u^E$ guarantees that $(w - c_u^I) > (\psi^E / \psi^I)(w - c_u^E)$ will hold since $(\psi^E / \psi^I) > 1$. Nevertheless, $c_u^E > c_u^I$ does not guarantee $(w - c_u^I) > (\psi^E / \psi^I)(w - c_u^E)$ when the incumbent makes a positive profit from the upstream market. Specifically, if both firms' upstream input production costs are not too disparate when the input price is high, then the specified condition is less likely to hold, depending on the value for (ψ^E / ψ^I) . In other words, even when $c_u^E > c_u^I$, but with a sufficiently large w , the entrant prefers to make the upstream input because $(w - c_u^I) < (\psi^E / \psi^I)(w - c_u^E)$. This case also contradicts Sappington's result for the efficient make-or-buy decision since it is possible for the entrant to have a higher upstream input production cost and yet still have the entrant prefer to make the upstream input rather than buy it from the incumbent provider. Hence, within the limits of the conditions specified here, the input price is not irrelevant for the entrant's make-or-buy decision.

Two observations regarding Proposition 2 are instructive. First, Proposition 2 is parallel to Proposition 2 of Gayle and Weisman (2007) who employ a Bertrand vertical differentiated model to investigate whether input prices are irrelevant. However, when we assume firms' products only differ in location and, except in the case where they produce identical products, then (ψ^E / ψ^I) becomes 1, and Proposition 2 reduces to Proposition 1. Hence, the framework suggests that the irrelevancy of input prices depends on the degree of product differentiation. Specifically, within the Hotelling framework, if the entrant's and

incumbent's products are identical, except for their differentiation along the location dimension, then input prices are irrelevant. In contrast, when both firms' products differ in more than one characteristic the input prices become relevant. In other words, Sappington (2005) result is a special case of more general framework.

4. Summary and Conclusion

The primary objective of this paper is to examine the relationship between horizontal product differentiation and the irrelevance of input prices for the entrants' make-or-buy decisions. We find that Sappington's main result on the irrelevance of input prices is sensitive to the particular level of product differentiation in the Hotelling model. Specifically, Sappington's results concerning the irrelevance of input prices depend on the limitations of the standard Hotelling location model for product differentiation. It is shown that even under the Hotelling framework, allowing for product differentiation in more than one characteristic undermines Sappington's main result concerning the irrelevance of input prices for make-or-buy decisions. Allowing product differentiation in more than one characteristic produces results similar to those of Gayle and Weisman (2007). Our findings serve to establish that input prices for make-or-buy decisions are irrelevant if the incumbent and the entrant produce identical products, and relevant if the firms produce differentiated products. The policy implications of these results are important. Unless the incumbent's and entrant's products are perfectly homogeneous, regulatory agencies should seek to set efficient prices to minimize efficiency distortions.

The models employed in this study treat product differentiation as independent from the actions of firms since the product differentiation definition relies on consumer preferences. However, in reality firms exert significant effort and go to great expense to differentiate their products from those of their rivals. Thus, employing models where the degree of product differentiation is endogenous to the firms may be a fruitful avenue for future research.

End Notes

¹47 U.S.C 251.

²See *Armstrong, Doyle and Vickers (1996) and Armstrong (2002) for a comprehensive analysis of access pricing. See Hausman and Sidak (1999) for the effects of unbundling policies on consumer welfare. See Crandall, Ingraham and Singer (2004) and Hazlett (2006) for the effect of mandatory network sharing on facilities-based investment.*

³See also Chapter 7 in *Baumol and Sidak (1994)*.

⁴TELRIC costs are determined based on the cost structure of an "ideally-efficient" provider. See *Weisman (2000) and Kahn, Tardiff and Weisman (1999) for comprehensive discussion of these issues.*

⁵See the *FCC(2005, para 220)*. The FCC continued this line of thinking when it removed mass market switching as an unbundled network element, in part, because TELRIC-based prices for switching discouraged investment in facilities-based networks.

⁶See *Gayle and Weisman (2007, p. 201)*.

⁷Following *Gayle and Weisman (2007)*, *Mandy (2009)* showed that input prices are relevant except for make-or-buy decisions except under restrictive assumptions on the demand structure in a more general setting.

⁸See *Beath and Katsoulacos (1991) for an extensive review of the literature on production differentiation.*

⁹See Sappington (2005, pp.1632-1633).

¹⁰Apart from transportation cost effect, there is no utility difference for consumers when they purchase the homogeneous product from either producer.

¹¹See Beath and Katsoulacos (1991, p. 13).

¹²The Bertrand paradox reaches the conclusion that when two firms produce identical products, they price at marginal cost and they make zero profit if they have symmetric constant marginal costs. In the asymmetric marginal cost case, the firm with lower marginal cost makes positive profit while the higher marginal cost firm makes zero profit because the equilibrium price is equal to the higher value of marginal cost.

¹³The equilibrium prices, quantities and profits of Lemma 1 obtained by Sappington are as follows:

$$(1) P^i = t + [2c^i + c^j] / 3;$$

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

$$(3) \Pi^i = N[3t + c^j - c^i]^2 / 18t$$

¹⁴The constant symmetric marginal cost of a firm could be evaluated as two firms that face the same conditions for obtaining inputs.

¹⁵This is natural because the standard Hotelling location model typically begins with a statement like: "assume two producers of a homogeneous product locate at different points on an interval."

¹⁶Asymmetric constant marginal cost may exist due to the result of different opportunities of obtaining inputs, the effects of learning curves, or different production technologies.

¹⁷ Under another special condition on marginal costs we can see some other similarities between the two models. When firms have different marginal costs ($c^i \neq c^j$), the equilibrium prices, quantities and profits are as given in footnote 13. If we assume that ($c^i < c^j$) and that marginal costs are very disparate, then firm i may have an opportunity to capture every consumer (even the consumer that shares the location with the firm j .) This situation creates a discontinuity in profit functions and reaction curves. The problem is solved by assuming that the marginal costs of two firms are not too disparate in the Hotelling models. For detailed information see Beath and Katsoulacos (1991, p. 17-22). The analogous problem in homogeneous Bertrand competition models is known as the openness problem. For a discussion of the openness problem, see Tirole (1989, p. 234).

¹⁸See Economides (1986) for an analysis of Hotelling's duopoly model when products are defined by two characteristics.

¹⁹Note that one approach for the assumption $\psi^i < \psi^E$ would be to add a vertical differentiation dimension to the model. However, the suggested version is still different from the vertical differentiation approach since when prices of both products are the same all consumers would not buy the same good. In other words, even though the prices are the same, the consumers pick their lower cost product based on their respective locations.

²⁰This assumption is reasonable given that switching costs and/or loyalty effects would tend to confer an advantage on the incumbent, *ceteris paribus*.

²¹ See Klemperer (1987), Fournier (1998), Lipman and Wang (2000), Delgado-Ballester and Munuera-Aleman (2001) and Chaudhuri and Holbrook (2002) for detailed review of loyalty effects and switching costs.

²²Following Sappington, very low values of input price are precluded since such an input price that is so low is impracticable for a meaningful make-or-buy decision. Hence, we exclude the case where $w < c_u^E < c_u^I$.

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