THREE ESSAYS ON REGULATORY ECONOMICS

by

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B.A., Gazi University, 1999
M.A., Akdeniz University, 2003

AN ABSTRACT OF A DISSERTATION

submitted in partial fulfillment of the requirements for the degree

DOCTOR OF PHILOSOPHY

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Abstract

Mandatory network unbundling is one of the foremost topics in regulatory economics today. The concept has crucial importance in the deregulation of many previously regulated industries including telecommunications, gas, electricity and railroads. Moreover, the topic has emerged as one of the more prominent issues associated with the implementation of the 1996 Telecommunication Act in the United States. Upon initial examination, establishing the correct costing standards and/or determining the correct input prices would seem important for sending the correct price signals to the entrants for their efficient make-or-buy decisions. Sappington (AER, 2005) uses a standard Hotelling location model to show that input prices are irrelevant for an entrant's make or buy decision. In this first essay, we show 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.

The second essay investigates optimal access charges when the downstream markets are imperfectly competitive. Optimal access charges have been examined in the literature mainly under the condition where only the incumbent has market power. However, network industries tend to exhibit an oligopolistic market structure. Therefore, the optimal access charge under imperfect competition is an important consideration when regulators determine access charges. This essay investigates some general principles for setting optimal access charges when

downstream markets are imperfectly competitive. One of the primary objectives of this essay is to show the importance of the break-even constraint when first-best access charges are not feasible. Specifically, we show that when the first-best access charges are not feasible, the imposition of the break-even constraint on only the upstream profit of the incumbent is superior to the case where break-even constraint applies to overall incumbent profit, where the latter is the most commonly used constraint in the access pricing literature. Bypass and its implications for optimal access charges and welfare are also explored.

The third essay is empirical in nature and investigates two primary issues, both relating to unbundled network element (UNE) prices. First, as Crandall, Ingraham, and Singer (2004) suggested, we will empirically test the stepping stone hypothesis using a state-level data set that spans multiple years. To do this, we will explore the effect of UNE prices on facilities-based entry. Second, in light of those findings, we will investigate whether the form of regulation (e.g. price cap and rate of return regulation) endogenously affects the regulator's behavior with respect to competitive entry. Lehman and Weisman (2000) found evidence that regulators in price cap jurisdictions tend to set more liberal terms of entry in comparison with regulators in rate-of-return jurisdictions. This paper investigates whether their result is robust to various changes in modeling, including specification and econometric techniques.

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Dedication

To my dad and mom, who were always patient in allowing me to develop my interests and encouraged me.

CHAPTER 1 - Product Differentiation and the Irrelevancy of Input Prices for Make-or-Buy Decisions

1.1 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] 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).[3] As Gayle and Weisman (2007a, 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." The FCC has recently revisited this pricing methodology out of

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[1] 47 U.S.C 251.
[2] See 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.
[3] TELRIC 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.

concern that the TELRIC methodology may yield prices that serve to distort the entrant's make-or-buy decision.[4]

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.[5] 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 (2007a) 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,

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[4] See 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.
[5] Sappington employs a Hotelling model with a simultaneous game structure in his analysis. One possible extension is to evaluate how Sappington's conclusion changes when the game structure is changed from simultaneous to sequential. The results of the Hotelling location model with a sequential game structure are provided in Appendix B.
[6] See Gayle and Weisman (2007a, p. 201).
[7] Following Gayle and Weisman (2007a), 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.

whereas Gayle and Weisman (2007a) 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 1.2. 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 1.3. It is shown that product differentiation in the standard Hotelling location model is problematic when two firms' products are differentiated in only one characteristic. To compare the results provided in Section 1.3, the Bertrand price competition model, as a representative consumer model, for

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

homogeneous and differentiated products is employed and evaluated in a yardstick framework in Section 1.4.[9] Section 1.5 summarizes the key findings and concludes.

1.2 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.

1.3 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.[10] 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

[9] It is not possible to use the vertical differentiation model as a complete yardstick model since the homogeneous product case cannot be examined using this framework.
[10] See Sappington (2005, pp.1632-1633).

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.[11]

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* $(i.e., \Pi_B^E > \Pi_M^E \text{ if } c_u^I < c_u^E)$; *and (b) the entrant prefers to make the upstream input itself when it is the least-cost supplier of the input* $(i.e., \Pi_M^E > \Pi_B^E \text{ if } c_u^E < c_u^I)$.

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

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[11] Proofs of all lemmas and propositions are provided in Appendix A.

captured by consumer's preferences in purchasing some homogenous product from sellers at different locations when transportation costs exist.[12] 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.[13] 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.[14]

To see this, we use the Nash equilibrium prices and quantities obtained by Sappington (2005).[15] When two firms have symmetric marginal costs ($c^i = c^j = c$), equilibrium prices,

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[12] Apart from transportation cost effect, there is no utility difference for consumers when they purchase the homogeneous product from either producer.
[13] See Beath and Katsoulacos (1991, p. 13).
[14] The 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.
[15] The equilibrium prices, quantities and profits of Lemma 1 obtained by Sappington are as follows:

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

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

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

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.[16]

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 $\Pi^i = \Pi^j = Ns/2$ 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.

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

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.[17] 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.[18, 19]

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[17] This 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."

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

[19] 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

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.[20] 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 $\psi^I < \psi^E$.[21, 22] 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.

(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).

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

[21] Note 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.

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

With positive switching costs, some consumers will accept a somewhat higher price for the incumbent's product.[23]

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

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.[24] Formally, the assumption is given by:

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

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

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[23] 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.
[24] Following 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 $w < c_u^E < c_u^I$.

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* $i, j = I, E,\ \ j \neq i$*):*

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

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

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

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

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

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

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

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

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* $\left(w-c_u^I\right)>\left(\psi^E/\psi^I\right)\left(w-c_u^E\right)$; *and (b) the entrant prefers to make the upstream input itself when* $\left(w-c_u^I\right)<\left(\psi^E/\psi^I\right)\left(w-c_u^E\right)$.

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 $w \le c_u^I$. 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 $\left(w-c_u^I\right)>\left(\psi^E/\psi^I\right)\left(w-c_u^E\right)$ will hold since $\left(\psi^E/\psi^I\right)>1$. Nevertheless, $c_u^E > c_u^I$ does not guarantee $\left(w-c_u^I\right)>\left(\psi^E/\psi^I\right)\left(w-c_u^E\right)$ 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 $\left(\psi^E/\psi^I\right)$. 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 $\left(w-c_u^I\right)<\left(\psi^E/\psi^I\right)\left(w-c_u^E\right)$.

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 (2007a) 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 $\left(\psi^E/\psi^I\right)$ 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.

1.4 Bertrand Price Competition

In the previous section, we showed that Sappington's (2005) main result concerning input price irrelevance is sensitive to the underlying assumptions regarding product differentiation. When the firms' products are differentiated in more than one characteristic, input prices are no longer irrelevant. Since the vertical differentiation model cannot allow modeling the homogeneous product case, we require a somewhat different modeling framework to determine the relevance of input prices for intermediate cases between homogeneous and differentiated products. We then apply the representative consumer approach to determine whether the irrelevance of input prices exhibits a similar pattern in the cases of homogeneous and differentiated products. In this respect, a simple Bertrand price competition model for homogeneous and differentiated product cases is employed to investigate efficient make-or-buy decisions. First a duopoly setting with homogeneous products is considered. The analysis is then extended to the differentiated products case.

1.4.1 Homogeneous Products Bertrand Competition

We first note that Bertrand price competition for homogeneous products results in what has become known as the Bertrand Paradox. The Bertrand Paradox reaches the conclusion that under the assumption of two firms producing goods that are "non-differentiated" in that they are perfect substitutes in consumers' utility functions, the two firms price at marginal cost and they do not make positive profits when firms have symmetric constant costs in equilibrium.[25] In the asymmetric cost case, however, both firms set a price equal to the higher marginal cost and the firm with lower marginal cost makes a profit whereas the higher marginal cost firm realizes zero profit. However, the proof for the asymmetric marginal cost case is not as straightforward as the symmetric case. The asymmetric case gives rise to the "openness problem," and cannot be solved unless some additional assumptions are made.[26]

To keep the analysis simple, the downstream input cost for both firms is assumed to be zero. This assumption does not affect our model's qualitative results and yet greatly reduces non-

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[25] See Tirole (1989, p. 209-211).

[26] In the asymmetric cost case, the firm with lower marginal cost actually wants to set a price ε below the high-cost firm's marginal cost to secure the entire market. It wants to choose ε infinitesimally close to 0, but such an ε does not exist. See Tirole (1989, p. 234).

substantive mathematical complexities. Similarly, in the Hotelling model, the incumbent is not allowed to have negative profit if the entrant prefers to buy the input from incumbent. Hence the case where $c^I > w$ is excluded. Otherwise, the incumbent firm would incur negative profits and would therefore not be financially viable.

Assume the incumbent and the entrant produce an identical product, and each firm incurs a marginal cost c^i where $i = I, E$. The market demand function is given by

$$D_i(p_i, p_j) = \begin{cases} D(p_i) & if \;\; p_i < p_j \\ \frac{1}{2} D(p_i) & if \;\; p_i = p_j \\ 0 & if \;\; p_i > p_j. \end{cases}$$

The firms choose prices simultaneously. As stated above, the unique Nash equilibrium of this game is that both firms charge the price equal to the higher marginal cost. Therefore, the unique Nash price will be $\max\{c^I, c^E\}$ if each firm individually provides the input, and w if the entrant buys the input from the incumbent.

Under the specified assumptions, whenever the entrant buys the input from the incumbent, it earns zero profit since $\Pi_B^E = (w - w)\frac{1}{2}D(w) = 0$. Hence the entrant's profit is invariant to the buy decision. Notice that the incumbent's viability condition plays a crucial role here.[27] Related to this, there is an interesting feature of the specified game structure that should be noted. Under the specified conditions, if the entrant purchases the input from the incumbent, the openness problem may disappear since the incumbent may not need to undercut its price in order to secure the entire market. In other words, the incumbent may find that not undercutting

[27] Since $w \geq c^I$ whenever the entrant buys the input, both firms charge $p = w$, so the entrant makes zero profit in equilibrium.

its price is more profitable in this case. Specifically, if the entrant purchases the input, the incumbent's profit is $\Pi_B^I = (w - c^I)\frac{1}{2}D(w) + (w - c^I)\frac{1}{2}D(w)$ which is equivalent to $\Pi_B^I = (w - c^I)D(w)$. However, if the incumbent undercuts its price by ε to ensure that it secures the entire market, its profit will be $\hat{\Pi}_B^I = (w - \varepsilon - c^I)D(w - \varepsilon)$ which is lower than the previous profit if the demand function is sufficiently inelastic. The less elastic the demand function, the more likely the openness problem will disappear. Hence the incumbent will not have any incentive to secure the entire market under the specified conditions.

Let us turn our attention to the entrant's efficient make-or-buy decision. The following proposition asserts that in the homogeneous products case, the incumbent's viability constraint binds and the entrant's make-or-buy decision is independent of input prices.

Proposition 3: *In the equilibrium of the homogeneous products Bertrand game: (a) the entrant prefers to make the input if and only if* $c^I > c^E$ *and (b) otherwise the entrant is indifferent between buying and making the input.*

Proposition 3 reveals that the entrant's make-or-buy decision is irrelevant to the input price. The entrant makes the input whenever it is the least-cost supplier of the input. However, when it is not the least-cost supplier the entrant is indifferent to either case. To see the irrelevancy of the input price for part (b), consider the following two cases: *(i)* $c^E > w \geq c^I$ and *(ii)* $w > c^E \geq c^I$. First, in the case where $c^E > w \geq c^I$, if the entrant makes the input both firms will charge price $p = c^E$, and the entrant makes zero profit while the incumbent makes positive profit, $\Pi_M^I = (c^E - c^I)\frac{1}{2}D(c^E)$. Conversely, in the case where $c^E > w \geq c^I$, if the entrant makes the input, then the market price $p = c^E$, the firms' profits are $\Pi_M^E = (c^E - c^E)\frac{1}{2}D(c^E) = 0$ and $\Pi_M^I = (c^E - c^I)\frac{1}{2}D(c^E)$. Hence, in the case where $c^E \geq c^I$, the entrant is indifferent to the make-or-buy decision. Comparing the cases ($c^E \geq w$) and ($w > c^E$) reveals that the entrant's equilibrium profit is not affected. In words, whether the entrant's marginal cost exceeds the input price that is set by the regulator or not, the entrant realizes zero profit in equilibrium. Observe that the viability condition of the incumbent plays a crucial role for the irrelevancy of input prices in the homogeneous products Bertrand framework. However this assumption plays the same role as the financial viability assumption in the standard Hotelling model.

1.4.2 Differentiated Products Bertrand Competition

As shown in the previous sub-section, input prices are irrelevant in the homogeneous products Bertrand framework. The next logical question concerns whether this property of input prices is sensitive to the degree of product differentiation. As discussed in the introduction, there are three commonly used methods to model product differentiation. The representative consumer based product differentiation models are the most commonly used models in the literature. The following simple Bertrand competition model is one of these types of product differentiation models. Gayle and Weisman (2007b) examine the entrant's make-or-buy decision in the two-stage game framework. In the first stage, the incumbent chooses investment in innovation and competes against an entrant in the second stage. Although their model is similar to ours, they do not examine the irrelevance of input prices.

Let inverse market demand functions be given by $P^i = \alpha_i - \beta_i Q^i - \gamma Q^j$ where $i = I, E$ and $i \neq j$.[28] Note that the cross-price effects are symmetric as required for well-behaved consumer demand functions. Using this inverse demand system, the direct demand system can be expressed as: $Q^I = a_I - b_I P^I + dP^E$ and $Q^E = a_E + dP^I - b_E P^E$. Note that the relation between the parameters in the two systems can be expressed as $a_i = (\alpha_i \beta_j - \alpha_j \gamma)/\delta$, $b_i = \beta_j / \delta$ for $i \neq j$, $i = I, E$ and $d = \gamma / \delta$ where $\delta = \beta_I \beta_E - \gamma^2$.

Equilibrium price (*P*), output level (*Q*), and profits (Π) of the entrant are characterized in Lemmas 3 and 4. The equilibrium values of the variables for the entrant are denoted by the superscript *E*, and the subscript *M* and *B* are used to denote the equilibrium values of the make-and-buy cases, respectively.

Lemma 3: *If the entrant chooses to produce the upstream input itself, its equilibrium retail prices, outputs, and profits are given, respectively, by:*

$$P_M^E = \frac{\left(2a_E b_I + a_I d\right) + 2b_I b_E \left(c_u^E + c_d^E\right) + b_I d \left(c_u^I + c_d^I\right)}{\left(4b_I b_E - d^2\right)}; \tag{8}$$

$$Q_M^E = b_E \frac{\left(2a_E b_I + a_I d\right) - \left(2b_I b_E - d^2\right)\left(c_u^E + c_d^E\right) + b_I d \left(c_u^I + c_d^I\right)}{\left(4b_I b_E - d^2\right)}; \text{ and} \tag{9}$$

[28] These linear inverse demand functions are obtained from Singh and Vives (1984). Singh and Vives model an economy with a monopolistic sector with two firms, each one producing a differentiated good, and a competitive numeraire sector. In their linear model, there is a continuum of consumers of the same type with a utility function separable and linear in the numeraire good, implying there are no income effects on the monopolistic sector. The representative consumer maximizes $U(q_1, q_2) - \sum_{i=1}^{2} p_i q_i$. The utility of the consumer is assumed to be quadratic and strictly concave $U(q_1, q_2) = \alpha_1 q_1 + \alpha_2 q_2 - \left(\beta_1 q_1^2 + 2\gamma q_1 q_2 + \beta_2 q_2^2\right)/2$, where α_i and β_i are positive, $i = 1, 2$, $\beta_i \beta_j - \gamma^2 > 0$, and $\alpha_i \beta_j - \alpha_j \gamma > 0$ for $i \neq j$, $i = 1, 2$. Hence, this utility function yields a linear demand structure with inverse demands given by $P^i = \alpha_i - \beta_i q_i - \gamma q_j$.

$$\Pi_M^E = b_E \left[\frac{\left(2a_E b_I + a_I d\right) - \left(2b_I b_E - d^2\right)\left(c_u^E + c_d^E\right) + b_I d\left(c_u^I + c_d^I\right)}{\left(4b_I b_E - d^2\right)} \right]^2. \tag{10}$$

Lemma 4: *If the entrant chooses to buy the upstream input from the incumbent, its equilibrium retail prices, outputs, and profits are given respectively by:*

$$P_B^E = \frac{\left(2a_E b_I + a_I d\right) + 2b_I b_E\left(w + c_d^E\right) + \left(b_I - d\right)d\left(c_u^I + c_d^I\right) + d^2\left(w + c_d^I\right)}{\left(4b_I b_E - d^2\right)}; \tag{11}$$

$$Q_B^E = b_E \frac{\left(2a_E b_I + a_I d\right) - \left(2b_I b_E - d^2\right)\left(w + c_d^E\right) + \left(b_I - d\right)d\left(c_u^I + c_d^I\right) + d^2\left(w + c_d^I\right)}{\left(4b_I b_E - d^2\right)}; \text{ and} \tag{12}$$

$$\Pi_B^E = b_E \left[\frac{\left(2a_E b_I + a_I d\right) - \left(2b_I b_E - d^2\right)\left(w + c_d^E\right) + \left(b_I - d\right)d\left(c_u^I + c_d^I\right) + d^2\left(w + c_d^I\right)}{\left(4b_I b_E - d^2\right)} \right]^2. \tag{13}$$

The following proposition asserts that in the differentiated product case, the entrant's make-or-buy decision is not independent of the level of the input prices.

Proposition 4: *In the equilibrium of the differentiated products Bertrand model: (a) the entrant prefers to buy the upstream input from the incumbent rather than make it if and only if* $\left(w - c_u^I\right) > \left(\frac{2b_I b_E - d^2}{d^2}\right)\left(w - c_u^E\right)$; *and (b) the entrant prefers to make the upstream input itself when* $\left(w - c_u^I\right) < \left(\frac{2b_I b_E - d^2}{d^2}\right)\left(w - c_u^E\right)$.

Proposition 4, part (a) reveals that $c_u^E > c_u^I$ is a not a necessary condition for the entrant to buy the input from the incumbent. When the incumbent makes zero or negative profit from the upstream market, thereby implying that $w \leq c_u^I$, the entrant's buy decision condition holds if and only if $c_u^E > c_u^I$. However, when the incumbent earns positive profit from the upstream market ($w > c_u^I$), if the firms have symmetric upstream marginal costs ($c_u^I = c_u^E$), the specified inequality in the Proposition 4, part (a) holds since $\left(\dfrac{2b_I b_E - d^2}{d^2}\right) > 1$.

However, the case where the incumbent is the least-cost supplier ($c_u^E > c_u^I$) is ambiguous. In this case, the entrant may or may not buy the upstream input. Specifically, as the firms upstream production costs converge to one another and when $\left(\dfrac{2b_I b_E - d^2}{d^2}\right)$ is sufficiently close to 1, the entrant is less likely to buy the upstream input. In other words, when $c_u^E > c_u^I$, the entrant would prefer to make the input for a sufficiently large input price *w,* implying that $\left(w - c_u^I\right) < \left(\dfrac{2b_I b_E - d^2}{d^2}\right)\left(w - c_u^E\right)$ is a possibility in this case. This case also underscores the relevancy of input prices because it is possible for the entrant to have a higher upstream input production cost and still prefer to make the upstream input instead of buying it from the incumbent. Hence, within the limits of the model specified here, the input price is not irrelevant for the entrant's make-or-buy decision.

Note that Proposition 4 is a slightly different version of Proposition 2. Both propositions have similar qualitative results. However, the conditions of Proposition 4 moves toward the homogeneous products case when $\left(\dfrac{2b_I b_E - d^2}{d^2}\right)$ approaches 1 since $\left(\dfrac{2b_I b_E - d^2}{d^2}\right)$ measures the degree of product differentiation. When $\left(\frac{2b_I b_E - d^2}{d^2}\right)$ equals 1, this implies that $b_I = b_E = d$, and the demand system may not be well-defined. However, it is possible to say that as $\left(\frac{2b_I b_E - d^2}{d^2}\right)$ approaches 1 in the limit, the products of the firms become more homogeneous and the greater the degree of homogeneity, the less relevant are input prices in equilibrium. Hence, this framework suggests that the irrelevancy of input prices depends on the degree of product differentiation. Specifically, in similar fashion to the Hotelling framework, within the Bertrand competition setting, if the entrant's and incumbent's products are homogeneous, then the input prices are irrelevant. Conversely when both firms' products are differentiated, the input prices become relevant.

1.5 Summary and Conclusion

The primary objective of this paper is to examine the relationship between 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 (2007a). The representative consumer approach also provides similar qualitative results. 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.

Appendix A - Proofs for Lemmas and Propositions

Proof of Proposition 1:

See Sappington (2005, pp. 1632-1633).

Proof of Lemma 1:

The location of the consumer that is indifferent between purchasing from the incumbent and the entrant satisfies the following equation:

$$\psi^I P_M^I + tL = \psi^E P_M^E + t(1-L) \tag{A1}$$

Solving (A1) for L yields:

$$\hat{L} = \frac{t - \psi^I P_M^I + \psi^E P_M^E}{2t}\text{; and} \tag{A2}$$

$$1 - \hat{L} = \frac{t - \psi^E P_M^E + \psi^I P_M^I}{2t}. \tag{A3}$$

The profits of the incumbent and the entrant are given, respectively, by

$$\Pi_M^I = \left(P_M^I - c_u^I - c_d^I\right) N \frac{t - \psi^I P_M^I + \psi^E P_M^E}{2t}\text{; and} \tag{A4}$$

$$\Pi_M^E = \left(P_M^E - c_u^E - c_d^E\right) N \frac{t - \psi^E P_M^E + \psi^I P_M^I}{2t}. \tag{A5}$$

Maximizing (A4) and (A5) with respect to P_M^I and P_M^E, respectively, then solving the first order conditions simultaneously yields

$$P_M^I = \frac{3t + 2\psi^I\left(c_u^I + c_d^I\right) + \psi^E\left(c_u^E + c_d^E\right)}{3\psi^I}\text{; and} \tag{A6}$$

$$P_M^E = \frac{3t + 2\psi^E\left(c_u^E + c_d^E\right) + \psi^I\left(c_u^I + c_d^I\right)}{3\psi^E}. \tag{A7}$$

Substituting (A6) and (A7) into (A2) and (A3), respectively, then multiplying the resulting equations by N yields:

$$Q_M^I = N\,\frac{3t - \psi^I\left(c_u^I + c_d^I\right) + \psi^E\left(c_u^E + c_d^E\right)}{6t};\text{ and} \tag{A8}$$

$$Q_M^E = N\,\frac{3t - \psi^E\left(c_u^E + c_d^E\right) + \psi^I\left(c_u^I + c_d^I\right)}{6t}. \tag{A9}$$

Substituting (A6) and (A8) into (A4), and (A7) and (A9) into (A5) yields:

$$\Pi_M^I = N\,\frac{\left[3t - \psi^I\left(c_u^I + c_d^I\right) + \psi^E\left(c_u^E + c_d^E\right)\right]^2}{18\psi^I t};\text{ and} \tag{A10}$$

$$\Pi_M^E = N\,\frac{\left[3t - \psi^E\left(c_u^E + c_d^E\right) + \psi^I\left(c_u^I + c_d^I\right)\right]^2}{18\psi^E t}. \tag{A11}$$

Proof of Lemma 2:

The proof follows steps similar to those of Lemma 1. The difference arises from the definition of profits. For the buy decision, the incumbent makes profits from the production of the upstream input which is basically a function of the entrant's quantity and its downstream production. On the other hand, when the entrant buys the upstream input, *w* replaces c_u^E as the entrant's upstream marginal cost. Therefore, if the entrant buys the upstream input from the incumbent, the incumbent's profits are:

$$\Pi_B^I = \left[w - c_u^I\right]Q_B^E + \left(P_B^I - c_u^I - c_d^I\right)N\,\frac{t - \psi^I P_B^I + \psi^E P_B^E}{2t};\text{ and} \tag{A12}$$

$$\Pi_B^E = \left(P_B^E - w - c_d^E\right) N \frac{t - \psi^E P_B^E + \psi^I P_B^I}{2t}. \tag{A13}$$

Maximizing (A12) and (A13) with respect to P_B^I and P_B^E, respectively, then solving the first-order conditions simultaneously yields:

$$P_B^I = \frac{3t + 2\psi^I\left(w + c_d^I\right) + \psi^E\left(w + c_d^E\right)}{3\psi^I}; \text{ and} \tag{A14}$$

$$P_B^E = \frac{3t + 2\psi^E\left(w + c_d^E\right) + \psi^I\left(w + c_d^I\right)}{3\psi^E}. \tag{A15}$$

Substituting (A14) and (A15) into (A2) and (A3), respectively, then multiplying the resulting equations by N yields:

$$Q_B^I = N \frac{3t - \psi^I\left(w + c_d^I\right) + \psi^E\left(w + c_d^E\right)}{6t}; \text{ and} \tag{A16}$$

$$Q_B^E = N \frac{3t - \psi^E\left(w + c_d^E\right) + \psi^I\left(w + c_d^I\right)}{6t}. \tag{A17}$$

Substituting (A14) and (A16) into equation (A12) and (A15) and (A17) into equation (A13) yields:

$$\Pi_B^I = \left(w - c_u^I\right) Q_B^E + N \frac{\left[3t - \psi^I\left(w + c_d^I\right) + \psi^E\left(w + c_d^E\right)\right]^2}{18\psi^I t}; \text{ and} \tag{A18}$$

$$\Pi_B^E = N \frac{\left[3t - \psi^E\left(w + c_d^E\right) + \psi^I\left(w + c_d^I\right)\right]^2}{18\psi^E t}. \tag{A19}$$

Proof of Proposition 2:

A comparison of (A11) and (A19) reveals that the condition for the entrant's efficient make-or-buy decision,

$$\Pi_M^E \overset{<}{\underset{>}{=}} \Pi_B^E \tag{A20}$$

$$\Leftrightarrow \quad \left[3t - \psi^E\left(c_u^E + c_d^E\right) + \psi^I\left(c_u^I + c_d^I\right)\right]^2 \overset{<}{\underset{>}{=}} \left[3t - \psi^E\left(w + c_d^E\right) + \psi^I\left(w + c_d^I\right)\right]^2 \tag{A21}$$

$$\Leftrightarrow \quad \psi^E\left(w - c_u^E\right) \overset{<}{\underset{>}{=}} \psi^I\left(w - c_u^I\right). \tag{A22}$$

Hence, the entrant buys the upstream input from the incumbent when $\Pi_B^E > \Pi_M^E$, or

$$\left(w - c_u^I\right) > \frac{\psi^E}{\psi^I}\left(w - c_u^E\right). \tag{A23}$$

The entrant prefers to make the upstream input when $\Pi_B^E < \Pi_M^E$, which implies that

$$\left(w - c_u^I\right) < \frac{\psi^E}{\psi^I}\left(w - c_u^E\right). \tag{A24}$$

Proof of Proposition 3:

The proof is straightforward. As stated in the body of the essay, for $w \geq c^I$, the entrant earns zero profit if it chooses to buy the input. In the case where $c^I > c^E$ the entrant makes the input, and both firms charge a price of $p=c^I$, and the entrant's profits are $\Pi_M^E = (c^I - c^E)\frac{1}{2}D(c^I) > 0$. Hence, the entrant prefers to make the input if it is the least-cost supplier. This establishes part (a). In the case where $c^E \geq c^I$ the entrant is indifferent to either option. To show this in the case where $c^E \geq c^I$, observe that if the entrant chooses to make the input both firms will charge price $p=c^E$, and the entrant makes zero profit while the incumbent makes positive profit of $\Pi_M^I = (c^E - c^I)\frac{1}{2}D(c^E)$. However, if the entrant buys the input, then the market price is p=w, the entrant's profit is once again zero and the incumbent's profit is $\Pi_I^B = (w - c^I)D(w)$. Hence the entrant is indifferent to the make-or-buy decision. This establishes part (b).

Proof of Lemma 3:

If the entrant makes the upstream input itself, the profits of the incumbent and the entrant are:

$$\Pi_M^I = \left(P_M^I - c_u^I - c_d^I\right)\left(a_I - b_I P_M^I + dP_M^E\right); \text{ and} \quad \text{(A25)}$$

$$\Pi_M^E = \left(P_M^E - c_u^E - c_d^E\right)\left(a_E + dP_M^I - b_E P_M^E\right). \quad \text{(A26)}$$

Maximizing (A25) and (A26) with respect to P_M^I and P_M^E, respectively, then solving the first-order conditions simultaneously yields:

$$P_M^I = \frac{\left(2a_I b_E + a_E d\right) + 2b_I b_E\left(c_u^I + c_d^I\right) + b_E d\left(c_u^E + c_d^E\right)}{\left(4b_I b_E - d^2\right)}; \text{ and} \quad \text{(A27)}$$

$$P_M^E = \frac{\left(2a_E b_I + a_I d\right) + 2b_I b_E\left(c_u^E + c_d^E\right) + b_I d\left(c_u^I + c_d^I\right)}{\left(4b_I b_E - d^2\right)}. \quad \text{(A28)}$$

Substituting (A27) and (A28) into the demand system provides:

$$Q_M^I = b_I \frac{\left(2a_I b_E + a_E d\right) - \left(2b_I b_E - d^2\right)\left(c_u^I + c_d^I\right) + b_E d\left(c_u^E + c_d^E\right)}{\left(4b_I b_E - d^2\right)}; \text{ and} \quad \text{(A29)}$$

$$Q_M^E = b_E \frac{\left(2a_I b_E + a_E d\right) - \left(2b_I b_E - d^2\right)\left(c_u^E + c_d^E\right) + b_E d\left(c_u^I + c_d^I\right)}{\left(4b_I b_E - d^2\right)}. \quad \text{(A30)}$$

Substituting (A27) and (A29) into (A25) and (A28), and (A30) into (A26) yields:

$$\Pi_M^I = b_I \left[\frac{\left(2a_I b_E + a_E d\right) - \left(2b_I b_E - d^2\right)\left(c_u^I + c_d^I\right) + b_E d\left(c_u^E + c_d^E\right)}{\left(4b_I b_E - d^2\right)} \right]^2; \text{ and} \tag{A31}$$

$$\Pi_M^E = b_E \left[\frac{\left(2a_E bI + a_I d\right) - \left(2b_I b_E - d^2\right)\left(c_u^E + c_d^E\right) + b_I d\left(c_u^I + c_d^I\right)}{\left(4b_I b_E - d^2\right)} \right]^2. \tag{A32}$$

Proof of Lemma 4:

The proof follows steps similar to those of Lemma 3. As before, the difference derives from the definition of profits. For the buy decision the incumbent makes profits from both the production of the upstream input which is basically a function of the entrant's quantity and its downstream production. However, when the entrant buys the upstream input, *w* replaces c_u^E as the entrant's upstream marginal cost. Hence, if the entrant buys the upstream input from the incumbent, the profits are:

$$\Pi_B^I = \left(w - c_u^I\right)Q_B^E + \left(P_B^I - c_u^I - c_d^I\right)\left(a_I - b_I P_B^I + dP_B^E\right); \text{ and} \tag{A33}$$

$$\Pi_B^E = \left(P_B^E - c_u^E - c_d^E\right)\left(a_E + dP_B^I - b_E P_B^E\right). \tag{A34}$$

Maximizing (A33) and (A34) with respect to P_M^I and P_M^E, respectively, then solving the first order conditions simultaneously yields,

$$P_B^I = \frac{\left(2a_I b_E + a_E d\right) + 2b_E\left(b_I - d\right)\left(c_u^I + c_d^I\right) + 2b_E d\left(w + c_d^I\right) + b_E d\left(w + c_d^E\right)}{\left(4b_I b_E - d^2\right)}; \text{ and} \tag{A35}$$

$$P_B^E = \frac{\left(2a_E b_I + a_I d\right) + 2b_I b_E\left(w + c_d^E\right) + \left(b_I - d\right)d\left(c_u^I + c_d^I\right) + d^2\left(w + c_d^E\right)}{\left(4b_I b_E - d^2\right)}. \tag{A36}$$

Substituting (A35) and (A36) into the demand system yields:

$$Q_B^I = \frac{b_I\left(2a_Ib_E + a_Ed\right) - \left(2b_Ib_E - d^2\right)\left(b_I - d\right)\left(c_u^I + c_d^I\right) - \left(2b_Ib_E - d^2\right)\left(w + c_d^I\right) + b_Ib_Ed\left(w + c_d^E\right)}{\left(4b_Ib_E - d^2\right)}; \text{ and} \tag{A37}$$

$$Q_B^E = b_E \frac{\left(2a_Ib_E + a_Ed\right) - \left(2b_Ib_E - d^2\right)\left(w + c_d^E\right) + \left(b_I - d\right)d\left(c_u^I + c_d^I\right) + d^2\left(w + c_d^I\right)}{\left(4b_Ib_E - d^2\right)}. \tag{A38}$$

Substituting (A35), (A37) and (A38) into (A33), and (A36) and (A38) into (A34) yields:

$$\Pi_B^I = \left(w - c_u^I\right)Q_B^E + \frac{1}{b_I}\left[\frac{b_I\left(2a_Ib_E + a_Ed\right) - \left(2b_Ib_E - d^2\right)\left(b_I - d\right)\left(c_u^I + c_d^I\right) - \left(2b_Ib_E - d^2\right)\left(w + c_d^I\right) + b_Ib_Ed\left(w + c_d^E\right)}{\left(4b_Ib_E - d^2\right)}\right]^2; \tag{A39}$$

$$\Pi_B^E = b_E\left[\frac{\left(2a_Ib_E + a_Ed\right) - \left(2b_Ib_E - d^2\right)\left(w + c_d^E\right) + \left(b_I - d\right)d\left(c_u^I + c_d^I\right) + d^2\left(w + c_d^I\right)}{4b_Ib_E - d^2}\right]^2. \tag{A40}$$

Proof of Proposition 4:

A comparison of (A32) and (A40) reveals that the condition for the entrant's efficient make-or-buy decision.

$$\Pi_M^E \overset{<}{\underset{>}{=}} \Pi_B^E \tag{A41}$$

or,

$$\Pi_M^E = b_E\left[\frac{\left(2a_Eb_I + a_Id\right) - \left(2b_Ib_E - d^2\right)\left(c_u^E + c_d^E\right) + b_Id\left(c_u^I + c_d^I\right)}{\left(4b_Ib_E - d^2\right)}\right]^2$$

$$\overset{<}{\underset{>}{=}} \tag{A42}$$

$$\Pi_B^E = b_E\left[\frac{\left(2a_Ib_E + a_Ed\right) - \left(2b_Ib_E - d^2\right)\left(w + c_d^E\right) + \left(b_I - d\right)d\left(c_u^I + c_d^I\right) + d^2\left(w + c_d^I\right)}{4b_Ib_E - d^2}\right]^2$$

$$\Leftrightarrow \left[-\left(2b_I b_E - d^2\right)\left(c_u^E\right)\right] \begin{matrix} < \\ = \\ > \end{matrix} \left[-\left(2b_I b_E - d^2\right)\left(w\right) - d^2\left(c_u^I - w\right)\right] \tag{A43}$$

$$\Leftrightarrow \left(2b_I b_E - d^2\right)\left(w - c_u^E\right) \begin{matrix} < \\ = \\ > \end{matrix} d^2\left(w - c_u^I\right). \tag{A44}$$

Hence, the entrant buys the upstream input from the incumbent when $\Pi_B^E > \Pi_M^E$, which implies that

$$\left(w - c_u^I\right) > \frac{\left(2b_I b_E - d^2\right)}{d^2}\left(w - c_u^E\right). \tag{A45}$$

The entrant prefers to make the upstream input when $\Pi_B^E < \Pi_M^E$ which implies that

$$\left(w - c_u^I\right) < \frac{\left(2b_I b_E - d^2\right)}{d^2}\left(w - c_u^E\right). \tag{A46}$$

Appendix B - The Irrelevancy of Input Prices in a Sequential Game

Sappington (2005) employs the Hotelling model to demonstrate the irrelevance of input prices in a simultaneous game framework. One possible extension would be to examine the concept in a sequential game framework. In the sequential framework, we assume that the incumbent firm is the leader and the entrant is the follower. The remaining assumptions are identical to those in Sappington (2005).

We will present the entrant's equilibrium values only. When the entrant makes the upstream input, the entrant's equilibrium price, output, and profit are given by:

$$P_M^E = \frac{5t + 3\left(c_u^E + c_d^E\right) + \left(c_u^I + c_d^I\right)}{4}; \tag{B1}$$

$$Q_M^E = N\frac{5t - \left(c_u^E + c_d^E\right) + \left(c_u^I + c_d^I\right)}{8t}; \text{ and} \tag{B2}$$

$$\Pi_M^E = N\frac{\left[5t - \left(c_u^E + c_d^E\right) + \left(c_u^I + c_d^I\right)\right]^2}{32t}. \tag{B3}$$

Conversely, when the entrant chooses to buy the upstream input from the incumbent, the entrant's equilibrium price, output, and profit are given by:

$$P_B^E = \frac{5t + 3\left(w + c_d^E\right) + \left(w + c_d^I\right)}{4}; \tag{B4}$$

$$Q_B^E = N\frac{5t - \left(w + c_d^E\right) + \left(w + c_d^I\right)}{8t}; \text{ and} \tag{B5}$$

$$\Pi_B^E = N\frac{\left[5t - \left(w + c_d^E\right) + \left(w + c_d^I\right)\right]^2}{32t}. \tag{B6}$$

A comparison of (B3) and (B6) reveals the conditions for the entrant's efficient make-or-buy decision. Specifically, the entrant prefers to make the upstream input itself if $\Pi_M^E > \Pi_B^E$ and buy the input from the incumbent if $\Pi_M^E < \Pi_B^E$. Therefore the entrant makes the upstream input when $c_u^I > c_u^E$, and the entrant prefers to buy the upstream input from the incumbent if and only if $c_u^I < c_u^E$. Hence, in comparison with the simultaneous game framework, the sequential game structure affects only the equilibrium values, but not the irrelevance of the input prices. Hence, Sappington's result on input irrelevance is robust to the change from a simultaneous-move to a sequential-game framework.

CHAPTER 2 - Access Pricing Under Imperfect Competition

2.1 Introduction

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

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

Access pricing is not a new issue in regulatory economics. Its roots derive from the essential facilities doctrine that dates back to a U.S. Supreme Court decision for railroads in the early 20th century. In 1912 the Supreme Court forced the Terminal Railroad Association to allow its competitors to use its terminal facilities.[29,30] As Sherman (2008, p. 266) observed following the Supreme Court decision, when a firm has monopolistic power over a facility that is required by other firms in order to compete, it has been argued that other suppliers should have access to the facility on non-discriminatory terms and conditions. [31]

Access pricing became the main policy instrument for regulators after vertically integrated monopolies were deregulated. Increased criticism of regulation in the 1970s and 1980s led to network unbundling with the goal of increased competition. For example, in Britain before privatizing the national railway in 1994, the railways were sold to approximately seventy companies and the most important company, Railtrack, owned and maintained the infrastructure.[32]

In the United States, the most recent example of unbundling as an industrial policy is the 1996 Telecommunications Act.[33] Section 251(d)(2) of the 1996 Telecommunications Act directs the Federal Communications Commission (FCC) to determine the specific network elements that incumbent local exchange carriers (ILECs) must provide to their competitors on an unbundled

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

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

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

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

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

(A) access to such network elements as are proprietary in nature is necessary; and

(B) the failure to provide access to such network elements would impair the ability of the telecommunications carrier seeking access to provide the services that it seeks to offer.

basis at "cost-based" rates.[34] Nevertheless, the ILECs and the competitive local exchange carriers' (CLECs) are at odds with respect to the pricing of unbundled network elements (UNEs) at cost-based rates. The ILECs contend that economic efficiency requires that prices for UNEs be based on the actual, forward-looking costs. Conversely the CLECs contends that economic efficiency demands that prices for UNEs be based on the forward-looking costs of an ideally efficient ILEC as this standard is consistent with the competitive market structure that the 1996 Telecommunications Act envisioned.[35]

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

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

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[34] See Kahn,Tardiff and Weisman (1999) for a comprehensive discussion of the economics underlying the 1996 Telecommunications Act.
[35] See Weisman (2002) and Weisman (2000).

cost minimization, and create an efficient amount of entry into infrastructure, and do all this at a reasonable regulatory cost.

Realizing all of these objectives simultaneously with a single policy instrument is complex. High access prices not only prevent society from reaching a desired level of competition by raising barriers to entry and perhaps allowing the incumbents to sustain their monopoly power in the potentially competitive segments of the industry, but also lead potential competitors to engage in socially inefficient bypass and/or duplication of facilities. Conversely, low access prices might create socially inefficient entry and discourage competitors from investing in their own facilities. Low access prices may also discourage the incumbents from maintaining and upgrading their facilities. As Laffont and Tirole (2001, p. 99) point out, the access price is critical in order to give incumbents the correct signals for their choices of investment in infrastructure and induce potential competitors to enter into socially desirable segments.

Optimal access pricing has become one of the central topics in modern regulatory economics. In the access pricing literature, there is a distinction between one-way access pricing and two-way access pricing. In one-way access, pricing only competitors require vital inputs from the monopolistic incumbent. In the case of two-way access pricing, all firms in the market need to purchase critical inputs from each other. In this study we focus on one-way access pricing.[36]

The purpose of this study is to examine optimal access charges under an oligopolistic market structure. Although formerly regulated industries post-deregulation exhibit properties that are closer to an oligopolistic market structure, most of the optimal access pricing literature

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

focuses on contestable/perfect competition models. In this respect, we study key characteristics of optimal access charges in a simple Cournot competition model where only one input is necessary for the downstream production. This is a simple framework and many complicated real-word issues such as asymmetric information, investment decisions, and dynamics are suppressed. Nonetheless, this analysis provides a useful starting point for the analysis and future research.

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

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

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

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

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

The organization of the remainder of this essay is as follows. Section 2.2 provides a literature review. Although there is a voluminous literature on the topic, the focus here is primarily on studies that explore optimal access charges. Section 2.3 discusses the main elements of the model. The first–best and second–best access prices in an oligopolistic market structure are derived in Section 2.4. This section also includes the welfare comparisons of two possible policies regarding the non-negativity constraint of the vertically integrated provider. In Section 2.5, the possibility of bypass and its effects on optimal access charges are examined. Section 2.6 contains the conclusion. The proofs for all lemmas and propositions are contained in Appendix C.

2.2 Literature Review

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

Perhaps one of the most important results in the optimal access charge literature is known as the Baumol-Willig efficient component pricing rule (ECPR). Willig (1979) and Baumol (1983) advocate the ECPR.[37] Their analyses depend on contestable markets which can be treated as part of a perfect competition framework. The optimal access price of a bottleneck input based on the ECPR should be equal to the direct incremental cost of access plus the opportunity cost borne by the integrated access provider in supplying access. The opportunity cost is the decrease in the incumbent's profit caused by the provision of the bottleneck input to a rival. Therefore, the access charge can be higher than the direct incremental cost by a substantial margin. The ILECs

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

generally favor such an access pricing policy. However, the fact that previously regulated industries are far from being competitive is a serious point of criticism. Moreover, the inclusion of the opportunity cost term in this form of access pricing means that less-efficient incumbents will receive higher prices for their input, ceteris paribus.

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

Laffont and Tirole (1994) investigate optimal access prices in a competitive fringe model using a principal-agent framework. In their analysis, the key assumption is that the regulator can make up any possible earnings deficiency for the incumbent using public funds. However, they also examine optimal access pricing in the absence of government transfers. 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. The authors state that the contribution takes the form of an access charge exceeding the marginal cost of the input. With this contribution, it is possible to reduce public funds and/or the price distortions related to the incumbent's budget constraint. It is noteworthy that their results also suggest that when taxation of the competitive downstream products is feasible, the access price can be equal to marginal cost.[38]

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

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

[38] Although both the first-best optimal access charge and the optimal access charge (when taxation of the competitive downstream products is feasible) can be set equal to marginal cost, the authors state that the two access charges have differing marginal costs since the firm's effort is lower in the first best case. See Laffont and Tirole (1994, p. 1699).

even constraint is binding at the social optimum, the optimal access price should exceed marginal cost. Moreover, their results reveal that the latter benchmark case with price regulation implies an optimal charge fully consistent with the ECPR. Their model reveals that within a contestable market framework, a homogenous downstream product, a fixed coefficient production function, and no bypass possibility, the ECPR is equivalent to the simple margin rule.[39] This implies that the simple margin should be set equal to the incumbent's average incremental cost in the competitive activity. In addition, they show that the opportunity cost term in the ECPR formula is lower when product differentiation, bypass, and a variable proportions technology are allowed.

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

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,

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[39] The simple margin rule is simply the margin between the incumbent's retail price and the access price.

and partial deregulation models, Armstrong examines topics such as the foreclosure problem, fixed retail prices, unregulated prices and bypass. In this study, he sheds light on topics such as access charges, dynamic issues and two-way access pricing in the telecommunications industry.

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. This study casts doubt on the wisdom of the FCC's policy of encouraging private negotiations over input prices.

2.3 Model

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

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

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

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

where Π^I and Π_i are profits of the incumbent and the representative competitor. The first term in (1) is the upstream profit that the incumbent realizes from selling the essential input to the competitors. The second term is the incumbent's profit from its downstream operations. The essential input cost is assumed to be identical for the incumbent's upstream and downstream affiliates.[40]

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

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

2.4 Main Findings

Assuming an interior solution, the first order necessary conditions of the incumbent and the representative competitor for the profit maximization are the equality of marginal revenue and marginal cost: $P' q_1^I + P = c$ and $P' q_i + P = w$. Totally differentiating the first-order conditions and allowing for an infinitesimal change in the price of essential input yields: $P' dq_1^I + P'(\cdot).\left(dq_1^I + \sum_{i=2}^{n} dq_i\right) = 0$ and $P' dq_i + P'(\cdot).\left(dq_1^I + \sum_{i=2}^{n} dq_i\right) = dw$. Solving the previous *n* equation system yields:

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

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

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

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

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

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

Two observations are instructive regarding the first-best optimal access charge. First, when price equals marginal cost, the incumbent's downstream production is zero according to the necessary first-order condition for the incumbent.[41] This result is consistent with Vickers (1995).[42] Second, based on the first-order condition of the competitor, its downstream production is positive if and only if the optimal access charge is lower than the marginal cost of access.[43] Based on these observations and Proposition 1, it follows that the regulator uses the upstream markup to achieve the first-best output level in the retail market. In other words, by charging less than the marginal cost for the bottleneck input, the regulator is subsidizing access to harmonize the downstream product price with the marginal cost of production. The key point here is that the regulator compensates for downstream market power by reducing the critical input price below marginal cost to increase output in the retail market.

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

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

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

[43] This result is identical to Spencer and Brander (1983). They showed that in the case of first-best pricing of a publicly produced input with imperfect downstream competition, the input price should be lower than marginal cost of the input and downstream product price equals marginal cost. See Spencer and Brander (1983) Proposition 1.

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

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

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

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

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

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

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

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

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

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

Total welfare (*W*) is assumed to be the unweighted summation of (7), (8) and (9). The optimal access charge (w^*) for the essential input can be found by maximizing total welfare (*W*) with respect to the access price (w). Hence, the optimal access charge is given by $w^* = (nc - \alpha)/(n-1)$.[44] Note that w^* is the access charge that allows the market price for the downstream product to equal the marginal cost of the input. This is the first-best access pricing policy and $w^* = (nc - \alpha)/(n-1)$ is lower than marginal cost of the input. Hence at the first-best access price the incumbent makes negative profit from the upstream market. In addition, as previously stated, the optimal access charge leads the incumbent's downstream affiliate to not produce any output in the downstream market. Therefore, the vertically integrated producer makes negative profit at the essential input price w^* since the incumbent's break-even constraint will bind at the social optimum. In the case where no lump-sum transfers are available to cover the incumbent's losses, this access charge is not feasible.

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

> *"It has been assumed that the participation constraint for M (vertically integrated incumbent) applies to its profits overall,*

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

including profits from the downstream competitive activity... Indeed, it is more in the spirit of deregulation to allow the firm independently to take it chances along with other competitors in deregulated activities, and not to prejudge the outcome of competition there... This suggests that a more realistic formulation might be to require that M at least break even in its upstream regulated activities."

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

$$\max \; G = CS + \sum_{i \neq 1}^{n} \Pi_i + (1+\lambda)\left(\Pi_{1u}^{I} + \theta \Pi_{1d}^{I}\right) \tag{10}$$

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

Finding the optimal access charge for the incumbent's profit constraint requires solving the regulator's constrained maximization problem in (10). In other words, the optimal access price can be found by setting the derivative of the Lagrange function equal to zero and solving it for the access charge (w).[45] The optimal access charge is given by:

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

The optimal access charge in (11) is the second-best access charge. Notice that the optimal access charge exceeds the marginal cost of access.[46] This implies that the second-best optimal access price allows the incumbent's downstream production to be positive.

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

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

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

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[45] The second-order conditions are assumed to hold, hence, the focus is on an interior solution.

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

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

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

Equations (12) – (14) define total social welfare under the optimal access charge. Specifically, when $\theta = 1$, equations (12) – (14) denote total welfare under the second-best optimal access charge when the break even constraint applies to the incumbent's overall profit. Conversely, when $\theta = 0$, equations (12) – (14) define total social welfare under the second-best optimal access price when the break-even constraint for the incumbent applies to its upstream profit only. Proposition 2 provides a comparison of the two possibilities regarding the break-even constraint for the incumbent.

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

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

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

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

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

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

2.5. Bypass

It is common in the access pricing literature to consider the effect of the entrants' ability to substitute away from the incumbent's network. This concept is generally referred to as bypass. Armstrong, Doyle and Vickers (1996) state two reasons why the fringe is able to bypass the incumbent's access service: (i) the fringe may supply the access service itself or purchase it from a third party; and (ii) the technology used by the fringe is a variable-coefficient technology and for high access charges the fringe may use proportionately less of the bottleneck input. The competitive fringe model of Armstrong, Doyle and Vickers reveals that the possibility of bypass reduces the optimal access charge compared to the non-bypass scenerio by reducing the displacement ratio.[47] Additionally, Armstrong (2002) suggests that when competitors have bypass opportunities, both the market price for the final product and the access charge are priced above marginal cost.[48]

We assume that m of $n-1$ firms make their own input, and hence $n-1-m$ firms buy the bottleneck input from the incumbent. Note that the number of firms that make the input is exogenous. Furthermore, for simplicity, we assume that the marginal cost of producing the input is also c for the competitors who bypass the incumbent (i.e., make their own input). One possible explanation for having the same marginal cost with the incumbent would be the marginal cost is

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[47] See Armstrong, Doyle and Vickers (1996, p. 142-143).
[48] See Armstrong (2002, pp. 323-324).

the result of cost minimizing production technology of the bottleneck input. Therefore, the profit function for the incumbent, one of *m* firms and one of *n-m-1* firms are given as follows.

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

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

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

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

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

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

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

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

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

Summation of expressions (18) – (21) yields total social welfare. It is straightforward to show that the optimal access charge when the incumbent's budget constraint is not binding at the social optimum.[49] Therefore, this optimal access charge would be the first-best optimal access price in this case, and once more the first best optimal access charge equates the market price to the marginal cost of the input, or c. However, the first-best optimal access charge leads to the same qualitative results as in the non-bypass case. In other words, at the first-best optimal access charge, the downstream production of the incumbent–and the competitors that make the key input–is zero, since the optimal access charge is lower than the marginal cost of the access. Hence, the incumbent's financial viability is threatened in the bypass case as well.

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

$$\max \; G = CS + \sum_{i \neq 1}^{n} \Pi_i + \Pi_{1d}^{I} + (1+\lambda)\Pi_{1u}^{I} \tag{22}$$

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

[49] The first best optimal access charge is $w^* = \frac{(n-m)c-\alpha}{n-m-1}$ in the bypass case. First, notice that when the number of firms that make the input (m) is zero, w^* is equal to the first-best access charge when bypass is not feasible. See page 48. Second, $w^* = \frac{(n-m)c-\alpha}{n-m-1}$ decreases with the number of firms that can bypass.

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

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

The expression in (23) characterizes the second-best access charge. Notice that the second-best access price exceeds the marginal cost of the input.[50] Hence, the incumbent and the competitors that provide their own input realize positive downstream production at the second-best access price.

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

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

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

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

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

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

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

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

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

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

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

2.6 Summary and Conclusion

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

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

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

Appendix C - Proofs for Lemmas and Propositions

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

$$dW = dCS + \sum_{i=2}^{n} d\Pi_i + d\Pi_1^I \tag{C1}$$

$$dCS = -P'(\cdot)\left(dq_1^I + (n-1)dq_i\right)\left(q_1^I + (n-1)q_i\right) \tag{C2}$$

$$\sum_{i=2}^{n} d\Pi_i = (n-1)\Big(P'(\cdot)\left(dq_1^I + (n-1)dq_i\right)q_i - (n-1)q_i dw + (P-w)dq_i\Big) \tag{C3}$$

$$d\Pi_1^I = (n-1)\left(q_i dw + (w-c)dq_i\right) + P'(\cdot)\left(dq_1^I + (n-1)dq_i\right)q_1^I + (P-c)dq_1^I \tag{C4}$$

Substituting (C2), (C3) and (C4) into (C1) by making use of (3) and (4) yields

$$dW = (P-c)\left(dq_1^I + (n-1)dq_i\right) = (P-c)\frac{(n-1)}{(n+1)P'}dw \tag{C5}$$

and therefore

$$\frac{dW}{dw} = (P-c)\frac{(n-1)}{(n+1)P'} = 0\,. \tag{C6}$$

Equation (C5) characterizes the welfare optimizing access price in our simple Cournot model, one that equates the market price with the marginal cost of access. This completes the proof part (a). To prove part (b), note that the first-order conditions for the profit maximization condition of a representative competitor is $P'q_i + P = w$. The first-order condition with $P = c$ implies that $q_i > 0$ if and only if $w < c$. This completes the proof of part (b).

Proof of Lemma 1: Assuming an interior solution, the necessary first-order conditions for profit maximization for the incumbent and each of the symmetric competitors is found by taking the derivative of (5) with respect to q_1^I and (6) with respect to q_i. Therefore, the first-order conditions are given by:

$$\alpha - 2\beta q_1^I - \beta \sum_{i \neq 1}^{n} q_i - c = 0 \text{ ; and} \tag{C7}$$

$$\alpha - 2\beta q_i - \beta \sum_{j=1, j \neq i}^{n} q_j - w = 0 . \tag{C8}$$

The first-order conditions for the profit maximization yields the equilibrium market output level:

$$Q = \frac{n\alpha - c - (n-1)w}{\beta(n+1)} \cdot \tag{C9}$$

Substituting (C9) into (C7) and (C8) and solving for q_1^I and q_i yields the equilibrium output levels for the incumbent and the entrant, respectively. Hence,

$$q_1^I = \frac{\alpha - nc + (n-1)w}{\beta(n+1)} \text{ ; and} \tag{C10}$$

$$q_i = \frac{\alpha + c - 2w}{\beta(n+1)} \cdot \tag{C11}$$

Assumption 1 and (C9) yields the equilibrium market price of

$$P = \frac{\alpha + c + (n-1)w}{n+1} \cdot \tag{C12}$$

Expressions (C10), (C11) and (C12) along with expressions (5) and (6) define the equilibrium profits of the incumbent and the *n* symmetric competitors, or

$$\Pi_1^I = (w-c)(n-1)\frac{\alpha+c-2w}{\beta(n+1)} + \frac{\left(\alpha - nc + (n-1)w\right)^2}{\beta(n+1)^2} \text{ ; and} \tag{C13}$$

$$\sum_{i=2}^{n} \Pi_i = \frac{(n-1)\left(\alpha+c-2w\right)^2}{\beta(n+1)^2}. \tag{C14}$$

Consumer surplus is defined by $CS = \int_0^Q P(x)dx - P(Q)Q$. Therefore (C9) and (C12) are used to determine consumer surplus, or

$$CS = \frac{\left(n\alpha - c - (n-1)w\right)^2}{2\beta(n+1)^2}. \tag{C15}$$

Proof of Lemma 2: Substituting (11) into (7) – (9) is sufficient to prove Lemma 2. However, it is useful to examine the effect of the optimal access charge on the other endogenous variables in the model. Substituting (11) into (C10) and (C11) gives the incumbent's and one of the *(n-1)* competitors' equilibrium production levels. Hence, equilibrium downstream production of the incumbent and a representative competitor are given by:

$$q_1^I = \frac{1}{\beta}\frac{\lambda\left(n+3\right)(\alpha-c)}{(n-1)\left(3-2\theta(1+\lambda)\right)+4\lambda(n+1)} \text{ ; and} \tag{C16}$$

$$q_i = \frac{1}{\beta}\frac{\left(3+2\lambda-2\theta(1+\lambda)\right)(\alpha-c)}{(n-1)\left(3-2\theta(1+\lambda)\right)+4\lambda(n+1)}. \tag{C17}$$

Notice that the downstream production of the incumbent is positive. This is a direct result of the positive mark-up on the optimal access charge given in equation (11). Equations (C16) and (C17) can be used to obtain the equilibrium level of downstream production; coupled with Assumption 1, this yields the equilibrium market price. Therefore, the equilibrium market quantity and price are given by

$$Q=\frac{1}{\beta}\frac{\left[(n-1)\big(3-2\theta(1+\lambda)\big)+\lambda(3n+1)\right](\alpha-c)}{(n-1)\big(3-2\theta(1+\lambda)\big)+4\lambda(n+1)} \text{ ; and} \tag{C18}$$

$$P=\frac{\lambda(n+3)\alpha+\left[(n-1)\big(3-2\theta(1+\lambda)\big)+\lambda(3n+1)\right]c}{(n-1)\big(3-2\theta(1+\lambda)\big)+4\lambda(n+1)}\cdot \tag{C19}$$

The components of economic welfare are obtained by using (C16) – (C19) in combination with the optimal access charge in (11). Hence the incumbent's profit, competitors' profit and consumer surplus at the optimal access charge are given, respectively, by:

$$\begin{aligned}\Pi_1^I=&\frac{n-1}{\beta}\frac{\big(2\theta(1+\lambda)+\lambda(n+1)-3\big)\big(3+2\lambda-2\theta(1+\lambda)\big)}{\left[(n-1)\big(3-2\theta(1+\lambda)\big)+4\lambda(n+1)\right]^2}(\alpha-c)^2\\ &+\frac{1}{\beta}\left[\frac{\lambda(n+3)(\alpha-c)}{(n-1)\big(3-2\theta(1+\lambda)\big)+4\lambda(n+1)}\right]^2\end{aligned} \text{ ;} \tag{C20}$$

$$\sum_{i=2}^{n}\Pi_i=\frac{n-1}{\beta}\left[\frac{\big(3+2\lambda-2\theta(1+\lambda)\big)(\alpha-c)}{(n-1)\big(3-2\theta(1+\lambda)\big)+4\lambda(n+1)}\right]^2 \text{ ; and} \tag{C21}$$

$$CS=\frac{1}{2\beta}\left[\frac{\left[(n-1)\big(3-2\theta(1+\lambda)\big)+\lambda(3n+1)\right](\alpha-c)}{(n-1)\big(3-2\theta(1+\lambda)\big)+4\lambda(n+1)}\right]^2. \tag{C22}$$

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

$$\frac{\partial\Pi_1^I}{\partial\theta}=\frac{2\lambda(1+\lambda)(n-1)(n+3)^2(\alpha-c)^2\big(3-2\theta(1+\lambda)+2\lambda\big)}{\beta\left[(n-1)\big(3-2\theta(1+\lambda)\big)+4\lambda(n+1)\right]^3}>0\cdot \tag{C23}$$

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

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

$$\frac{\partial\left(\sum_{i=2}^{n}\Pi_i\right)}{\partial\theta}=-\frac{8\lambda(1+\lambda)(n-1)(n+3)(\alpha-c)^2\left(3-2\theta(1+\lambda)+2\lambda\right)}{\beta\left[(n-1)\left(3-2\theta(1+\lambda)\right)+4\lambda(n+1)\right]^3}<0\cdot \tag{C24}$$

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

$$\frac{\partial CS}{\partial\theta}=-\frac{2\lambda(1+\lambda)(n-1)(n+3)(\alpha-c)^2\left[(n-1)\left(3-2\theta(1+\lambda)\right)+\lambda(3n+1)\right]}{\beta\left[(n-1)\left(3-2\theta(1+\lambda)\right)+4\lambda(n+1)\right]^3}<0\cdot \tag{C25}$$

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

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

$$\frac{\partial W}{\partial\theta}=-\frac{2\lambda^2(1+\lambda)(n-1)(n+3)^2(\alpha-c)^2}{\beta\left[(n-1)\left(3-2\theta(1+\lambda)\right)+4\lambda(n+1)\right]^3}<0. \tag{C26}$$

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

Proof of Lemma 3: Assuming an interior solution, the first-order conditions for the profit maximization for the incumbent, each competitor that makes the essential input, and each of the symmetric competitors that buys the input from the incumbent are found by taking the derivative of (15) – (17) with respect to their corresponding quantities. Therefore, the first-order conditions are given by:

$$\alpha - 2\beta q_1^I - \beta\sum_{i\neq 1}^{n} q_i - c = 0 \;; \tag{C27}$$

$$\alpha - 2\beta q_i^M - \beta \sum_{j=1,\, j\neq i}^{n} q_j - c = 0 \;; \text{ and} \tag{C28}$$

$$\alpha - 2\beta q_i^B - \beta \sum_{j=1,\, j\neq i}^{n} q_j - w = 0 \cdot \tag{C29}$$

The first-order necessary conditions for profit maximization yield the equilibrium market output level:

$$Q = \frac{n\alpha - (m+1)c - (n-m-1)w}{\beta(n+1)} \cdot \tag{C30}$$

Substituting expression (C30) into (C27) – (C29) and solving for q_1^I, q_i^M and q_i^B, respectively, yields the equilibrium output levels for the incumbent, a representative entrant that makes the essential input, and a representative entrant that buys the input, respectively. Hence,

$$q_1^I = \frac{\alpha - (n-m)c + (n-m-1)w}{\beta(n+1)} \;; \tag{C31}$$

$$q_i^M = \frac{\alpha - (n-m)c + (n-m-1)w}{\beta(n+1)} \;; \text{ and} \tag{C32}$$

$$q_i^B = \frac{\alpha + (m+1)c - (m+2)w}{\beta(n+1)} \cdot \tag{C33}$$

Assumption 1 and expression (C30) yields the market price:

$$P = \frac{\alpha + (m+1)c + (n-m-1)w}{n+1} \cdot \tag{C34}$$

Expressions (C31) – (C33) and (C34) in combination with (15) – (17) define the equilibrium profits for the incumbent and its competitors, or

$$\Pi_1^I = (w-c)(n-m-1)\frac{\alpha+(m+1)c-(m+2)w}{\beta(n+1)} + \frac{1}{\beta}\frac{\left[\alpha-(n-m)c+(n-m-1)w\right]^2}{(n+1)^2}; \tag{C35}$$

$$\sum_m \Pi_i^M = \frac{m}{\beta}\frac{\left[\alpha-(n-m)c+(n-m-1)w\right]^2}{(n+1)^2} \text{ ; and} \tag{C36}$$

$$\sum_{n-m-1} \Pi_i^B = \frac{n-m-1}{\beta}\frac{\left[\alpha+(m+1)c-(m+2)w\right]^2}{(n+1)^2}. \tag{C37}$$

Consumer surplus can be defined as $CS = \int_0^Q P(x)dx - P(Q)Q$. Therefore (C30) and (C34) are used to determine consumer surplus:

$$CS = \frac{1}{2\beta}\frac{\left[n\alpha-(m+1)c-(n-m-1)w\right]^2}{(n+1)^2}. \tag{C38}$$

Proof of Lemma 4: Substituting (23) into (18) – (21) is sufficient to prove Lemma 4. Substituting (23) into (C30) yields:

$$Q = \frac{1}{\beta}\frac{(n-m-1+\lambda(3n+m+2mn+1))}{(n-m-1)+2\lambda(n+1)(m+2)}(\alpha-c)\cdot \tag{C39}$$

Similarly, substituting (23) into expressions (C31) – (C33) yields the downstream equilibrium production for the incumbent, one of *m* firms that makes its own input, and one of *n-m-1* firms that buys the critical input from the incumbent. Therefore,

$$q_1^I = \frac{1}{\beta}\frac{\lambda(n+m+3)(\alpha-c)}{(n-m-1)+2\lambda(n+1)(m+2)} ; \tag{C40}$$

$$q_i^M = \frac{1}{\beta}\frac{\lambda(n+m+3)(\alpha-c)}{(n-m-1)+2\lambda(n+1)(m+2)} \text{ ; and} \tag{C41}$$

$$q_i^B = \frac{1}{\beta}\frac{(\lambda(m+2)+1)(\alpha-c)}{(n-m-1)+2\lambda(n+1)(m+2)}. \tag{C42}$$

Assumption 1 and expression (C39), or equivalently substituting (23) into (C34) yields the market price, or:

$$P = \frac{\lambda(n+m+3)\alpha + ((n-m-1)+(m+3n+2mn+1))c}{(n-m-1)+2\lambda(n+1)(m+2)}. \tag{C43}$$

Expressions (C40) – (C42) and (C43) in combination with (15) – (17) and (23) characterize the equilibrium profits for the incumbent and its competitors:

$$\begin{aligned}\Pi_1^I = {} & \frac{n-m-1}{\beta}\frac{\big(\lambda(n+1)-1\big)\big(\lambda(m+2)+1\big)}{\left[(n-m-1)+2\lambda(n+1)(m+2)\right]^2}(\alpha-c)^2 \\ & +\frac{1}{\beta}\left[\frac{\lambda(n+m+3)(\alpha-c)}{(n-m-1)+2\lambda(n+1)(m+2)}\right]^2;\end{aligned} \tag{C44}$$

$$\sum_M \Pi_i^M = \frac{m}{\beta}\left[\frac{\lambda\big(m+n+3\big)(\alpha-c)}{(n-m-1)+2\lambda(n+1)(m+2)}\right]^2 \text{ ; and} \tag{C45}$$

$$\sum_B \Pi_i^B = \frac{n-m-1}{\beta}\left[\frac{(\lambda\big(m+2\big)+1)(\alpha-c)}{(n-m-1)+2\lambda(n+1)(m+2)}\right]^2. \tag{C46}$$

Consumer surplus can be defined as $CS = \int_0^Q P(x)dx - P(Q)Q$. Therefore (C39) and (C43) are used to determine consumer surplus, or

$$CS = \frac{1}{2\beta}\left[\frac{\left[(n-m-1)+\lambda(3n+m+2mn+1)\right](\alpha-c)}{(n-1)\big(3-2\theta(1+\lambda)\big)+4\lambda(n+1)}\right]^2. \tag{C47}$$

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

$$\frac{\partial w}{\partial m} = -\frac{(\lambda(n+1)-1)(2\lambda(n+1)-1)}{(n-m-1)+2\lambda(n+1)(m+2)}(\alpha-c) < 0. \tag{C48}$$

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

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

$$\frac{dW}{dm}=\frac{2}{\beta}\frac{\lambda^{2}(n+1)(\lambda+n\lambda-1)(m+n+3)}{\left((n-m-1)+2\lambda(n+1)(m+2)\right)^{3}}(\alpha-c)^{2}>0 \tag{C49}$$

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

CHAPTER 3 - The Political Economy of Unbundled Network Element Pricing

3.1 Introduction

The passage of the 1996 Telecommunications Act was important on many different levels. One important policy objective of the Act was to create facilities-based entry for local telecommunications services. To achieve this policy objective, the Act implemented mandatory unbundling of network elements (UNEs). Thus, the incumbent local exchange carrier (ILEC) was required to lease inputs to the competitive local exchange carriers (CLECs) at a price set by the regulator. In a report released in 1999, the Federal Communications Commission defended their implementation of policy objectives by stating the following: "We find our decision to unbundle [certain local network elements] is consistent with the 1996 Act's goals of rapid introduction of competition and the promotion of facilities-based entry." By taking this position, the FCC clearly advocated the so-called stepping-stone hypothesis. This hypothesis contends that in order for CLECs to build their own facilities, they first need to gain access to the market by leasing UNEs. The stepping-stone hypothesis predicts that lower UNE prices will ultimately lead to more facilities based entry. In other words, the stepping-stone hypothesis conjectures that CLECs will transition naturally over time from reselling the services of the incumbent providers to investing in their own facilities-based networks. The implication being that lower UNE prices today will lead to higher rates of deployment of competitive facilities-based networks tomorrow.

Industry changes following the Act provided researchers with an opportunity to test whether or not the stepping-stone hypothesis holds. To date, even though the FCC advocates policies (i.e. liberalized UNE prices) derived from the validity of the theory, empirical research has not always supported their position. Studies by Eisner and Lehman (2001), Crandall, Ingraham, and Singer (2004), and Hazlett (2006) found evidence refuting the stepping stone hypothesis. Willig et al. (2002) and Hasset and Kotlikoff (2002) contend that lower UNE prices tend to increase competition and this increase in competition leads to higher levels of investment. Robinson and Weisman (2008) contend that the weight of the credible empirical evidence fails to support the stepping stone hypothesis. Crandall et al (2004) stated that areas for fruitful research remain if the researcher could access better data sources.

This research will investigate two primary issues, both relating to UNE prices. First, as Crandall et al (2004) suggested, we empirically test the stepping-stone hypothesis using a state-level data set that spans multiple years. To do this, we explore the effect of UNE prices on facilities-based entry. Second, in light of those findings, we investigate the determinants of the level of UNE prices. This inquiry will extend primarily the work of Lehman and Weisman (2000). They show that regulators set different UNE prices under price cap regimes than they do under rate-of-return regulation. Utilizing a new dataset, we seek to test whether regulators are influenced by the particular form of regulation in place. Additionally, we will empirically test whether elected regulators behave differently than appointed regulators. More broadly, our aim is to test whether regulators are active participants in the competitive games or merely serve as passive referees. Our results shed important light on the political economy of regulation in the U.S. Telecommunications industry.

The remainder of this essay is organized as follows. Section 3.2 presents an empirical test of the stepping-stone hypothesis. Section 3.3 examines the political economy of regulatory behavior with respect to UNE prices. Section 3.4 concludes.

3.2 An Empirical Test of the Stepping-Stone Hypothesis

3.2.1 A Literature Review of the Stepping-Stone Hypothesis

According to Hausman and Sidak (2005), mandatory unbundling is defended by both regulators and entrants. These defenders argue that UNEs are a complement to facilities-based entry. If UNEs and facilities-based entry are in fact complementary, then a decrease in the price of UNEs today will increase investment in facilities by CLECs tomorrow. In turn, the CLEC's cross-price elasticity of investment with respect to access-based entry is negative. In anecdotal support of the stepping stone hypothesis, Hausman and Sidak (2005) cite MCI as an example of an access-based provider transitioning into a facilities-based provider. The overarching objective of the FCC in mandating unbundling was to stimulate facilities-based competition. Dynamic efficiency, as explained by Robinson and Weisman (2008), can be expected to confer greater consumer benefits than a focus on static efficiency. Pindyck agrees with this long run view in arguing that

> *"the Telecom Act envisioned a world of independent physical networks competing with each other to provide telecommunications services in local markets. Unbundling was intended to help facilitate entry so this goal could be reached. The intent was not to have permanent regulation, but rather to transition from regulation to free market rivalry."* [51]

[51] See Pindyck (2004, p. 2).

In 1999, UNE-P lines were less numerous than lines owned by CLECs.[52] When regulation changed in 1999, CLECs could lease UNE-P lines at more favorable rates. According to Hazlett (2006), this presented an ideal opportunity to test the stepping-stone hypothesis. The hypothesis predicts that a decrease in UNE-P rates will increase CLEC-owned lines. Results by Hazlett (2006) unambiguously contradict this hypothesis. As UNE-P lines increased by 300%, CLEC-owned lines experienced a markedly decreased rate of growth. In fact, the number of non-cable CLEC-owned lines decreased by 28% from the years 2000 to 2003. Most notably, the correlation between UNE-P lines and non-cable CLEC-owned lines was -0.997. In light of this evidence, Hazlett (2006) concludes that "rather than provide a stepping stone to new entry, the UNE-P regulatory offering appears to crowd out new investment."[53] In their survey of five industrialized countries, Hausman and Sidak (2005) find little evidence in support of the stepping-stone hypothesis. In Canada, for example, even though the absolute number of lines owned by CLECs increased substantially from 1999-2002, CLECs became increasingly dependent on unbundled loops. In effect, the Canadian CLECs substituted away from resale and towards local unbundled loops. It is noted that Canada had a less expansive unbundling policy than did many other countries. However, evidence from the other four countries in the Hausman-Sidak study was equally unambiguous, and the stepping stone hypothesis did not appear to hold.

In perhaps the most frequently cited work on the stepping stone hypothesis, Crandall et al. (2004) investigate the hypothesis in the U.S. by utilizing a model of factor demand. Using data from 2000 and 2001, their dataset contained 56 state-level observations. Using ordinary

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[52] UNE-P is the platform that allows the CLECs to deliver a complete service without the need for their own facilities. Weisman and and Lehman write (2000, p. 344) that "UNE platforms enable a complete service to be provided solely through the use of UNEs."
[53] See Hazlett (2005, p. 488).

least squares, they find a strong positive relationship between the log of UNE average rates and the log of the ratio of facilities based lines to UNE lines. These results also appear to contradict the stepping stone hypothesis.

3.2.2 Data and Econometric Models

Our dataset includes the years 2002-2006. Data sources are as follows: Survey of Unbundled Network Element Prices by Billy Jack Gregg, NECA study results, USAC data from FCC filings, FCC local telephone competition reports, U.S. Census Bureau, State Retail Rate Regulation of Local Exchange Providers Reports, and the National Association of Regulatory Utility Commissioners (NARUC). The data are state-level and includes every state except for Hawaii. *"CLEC-owned"* is the dependent variable for all regressions and is the number of facilities-based lines owned by CLECs in a state during a given year. Independent variables that potentially influence *CLEC-owned* are as follows: (1) The *UNE price* per loop that is determined by the state regulatory process; this is the primary independent variable of interest. (2) *BUSRES* is a variable that measures the retail price distortion in local telephone markets. It is measured as the ratio of the flat-rate local telephone price charged to business customers to the flat-rate price charged to residential customers. (3) *Elect* is a dummy variable that is equal to one when regulators are elected and is equal to zero when regulators are appointed. (4) *Cost* is the monthly cost per local loop. (5) *Price cap* is a dummy variable equal to one if the state is regulated under a price cap regime and is equal to zero otherwise. (6) *Population* is the population of a state in the given year.

In most regressions, year effects are taken into account. Our econometric models use the log version for all non-dummy variables. Table 1 includes summary statistics for each variable in both log and non-log form.

The econometric models that are estimated are expressed as follows:

Pooled OLS:

$$y_{it} = \alpha + X'_{it}\beta + \mu_{it} \tag{1}$$

Between Effects:

$$\bar{y}_i = \alpha + \bar{X}'_i\beta + (\alpha_i - \alpha + \bar{\varepsilon}_i) \tag{2}$$

Random Effects:

$$y_{it} = \alpha_{it} + X'_{it}\beta + \varepsilon_{it} \tag{3}$$

where *i* and *t* represent state and time, respectively, and ε represents the error term.

3.2.3 Results

In terms of simple correlation, "UNE prices" and "CLEC-owned" have a negative relationship of -0.38 that is illustrated by Figure 1. Without a more sophisticated econometric approach, the stepping-stone hypothesis appears validated by the data. The negative correlation indicates that CLEC owned-lines are decreasing with UNE prices; however, a more sophisticated statistical approach is required. The first OLS regression appears in Table 2 and contains the identical set of independent variables as Crandall et al (2004). As shown in Table 2, the coefficient of *log (UNE price)* is negative in our regression and appears to confirm the stepping-stone hypothesis. This contrasts sharply with the findings of Crandall et al's (2004) study that estimate the same coefficient as being positive and statistically significant.

However, when theoretically important control variables are added (as shown in table 2) the *log (UNE price)* coefficient is not statistically different from zero. This result holds for the OLS, between effects, and random effects models, suggesting that the predictions of the stepping-stone hypothesis are not robust to alternative model specifications. Since the coefficient of *log (UNE prices)* is not statistically different from zero, the number of facilities-based lines owned by the CLEC is not influenced by changes in UNE prices while the stepping-stone hypothesis predicts a statistically significant negative coefficient. While the stepping-stone hypothesis is not validated by these results, neither are the results of Crandall et al (2004). The results from these specifications imply UNE and facilities-based entry are not substitutes as Crandall et al (2004) suggests, nor are they complements as the stepping-stone hypothesis predicts.

However, when the square of *log (UNE price)* is included to capture any non-linear relationship between UNE prices and CLEC-owned facilities, statistically significant coefficients emerge. This non-linearity implies one range of UNE prices where the stepping-stone hypothesis holds and another range of UNE prices where the hypothesis does not hold. Table 3 shows that both *log (UNE price)* terms are statistically significant at the 1% level. For all regressions, the coefficient of the linear term of *log (UNE price)* is positive while the coefficient of the squared term is negative. Given the absolute size of each coefficient, estimates indicate that as UNE prices are lowered, the number of facilities-based CLEC lines only decrease when UNE prices are very low. For most levels of UNE prices found in our sample, there is a negative relationship between UNE prices and CLEC-owned facilities. That is to say, we find some support for the stepping-stone hypothesis.

One possible explanation for the non-linear relationship is that when UNE prices are low retail markups tend to be high. This attracts facilities-based entry in the local telephone market. Conversely, higher UNE prices indicate lower retail markups caused by an increase in marginal costs for providing local telephone service. In this case, new firms are less willing to enter the market as facilities-based providers of local telephone service.

In other words, the statistically significant non-linear relationship between CLEC-owned lines and UNE prices imply that when UNE prices are at a low level, an increase in UNE prices will boost the percentage of CLEC-owned lines. However, at higher levels of UNE prices, any increase the UNE price level will actually decrease the percentage of CLEC-owned lines. The estimates of our coefficients serve to reveal the levels for which higher UNE prices will lead to fewer facilities-based lines, *ceteris paribus*. This critical value occurs where log (UNE price) is equal to 2.623 (based on estimates from the RE model found in table 3.3). According to these estimates, there is a positive relationship between UNE price and CLEC-owned lines when the UNE price is less than $13.78 as shown by Figure 2.[54] When UNE prices are less than $13.78, the stepping-stone hypothesis is rejected. Conversely, there is a negative relationship between UNE price and CLEC-owned lines when the UNE price is greater than $13.78. Given that over half of our sample has UNE prices exceeding this critical value of $13.78, there is some evidence in support of the stepping-stone hypothesis.

Until now, researchers have not been able to test whether contemporaneous UNE price changes affect the facilities-based entry of CLECs in subsequent years. Our dataset facilitates the opportunity to test whether or not changes in UNE prices influence entry over time. As shown in Table 4, the affect of current UNE price changes on CLEC-owned facilities *does* persist intertemporally. Thus, a change in the UNE price in year *t* will affect the number of CLEC-owned facilities in year *t+1* in much the same fashion as in the contemporaneous case. This result holds true even when UNE prices are lagged for up to three years (the maximum number of years that our dataset allows).

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[54] This critical value for UNE price is $13.84 for between model and $13.54 for OLS.

Our estimates suggest that UNE prices and facilities-based entry appear as complements to each other. These results are opposite those of Eisner and Lehman (2001), Hausman and Sidak (2005), Crandall et al. (2004), and Hazlett (2006). We conclude, based on our estimations, that increasing UNE prices can actually hinder facilities-based competition both within the same year and through time.

The signs from the control variable coefficients are not sensitive to the inclusion of the non-linear log (UNE price) term and are discussed as follows. The ELECT coefficient is statistically significant at conventional levels in some regressions. The positive value suggests that there are more facilities-based CLEC lines in states where regulators are elected rather than appointed, *ceteris paribus*. This implies that conditions are relatively favorable for facilities-based CLECs in states where regulators are subjected to the traditional electoral process. That is, entry is more attractive in states where regulators are elected, even controlling for relevant factors. This suggests elected regulators are more accommodating towards competitive entry via UNEs than are appointed regulators, *ceteris paribus*.

Interestingly, the price cap coefficient shows a statistically significant relationship in most of the regressions. States with price cap regulation–in contrast to rate of return regulation–have fewer facilities-based CLEC lines, *ceteris paribus*. Therefore, business conditions for CLECs appear less favorable in states with price cap regulation. One explanation for this result is that incumbent firms in states with price cap regulation are simply more efficient. As Lehman and Weisman (2000) note, price cap regulation (at least in theory) provides strong incentives for the incumbent to discover more efficient ways to operate. This increased efficiency could conceivably reduce the profit opportunities for CLECs, thereby reducing incentives to build their own facilities-based lines. Our estimates for the price cap coefficient are both statistically and economically significant. The range of estimates for this coefficient is -0.241 to -0.784. This coefficients may be interpreted as follows: when other variables are held constant, the introduction of a price cap regime decreases the percentage of CLEC lines anywhere from 21.4% to 54.3%.

3.3 UNE Access, Price Cap Regulation, and the Regulator

3.3.1 A Review of the Effects of Liberalized UNE Access

In a dynamic setting, according to Hausman and Sidak (2005), lowering the price of unbundled network elements is likely to decrease investment in multiple ways. First, new infrastructure development by the ILEC is likely to decrease since the returns from the new investment are diminished because CLECs may lease the input from the incumbent or invest in their own facilities.[55] In support of this view, Waverman et al. (2007) found that lower UNE prices lead to less investment in alternative access platforms such as broadband. Second, CLECs will choose a UNE-based entry approach rather than build their own facilities since lower UNE prices increase the relative returns of UNE-based entry relative to facilities-based entry, *ceteris paribus*. Hausman and Sidak (2005) show that CLECs are increasingly dependent on UNEs over time. In 1999, CLECs used UNEs for 23.9 percent of their lines. By 2003, that number increased to 58.5 percent as a result of liberalized access to UNEs.[56] Waverman et al. (2007), and Hazlett and Havener (2003) state that proponents of lower UNE prices believe competition stemming from CLECs will be increased by these lower rates. This competition comes initially through

[55] See also Pindyck (2007). This is also discussed in Robinson and Weisman (2008).
[56] Our dataset reveals that the share of UNE lines fell to 43.6% by 2006.

UNE-based entry and later through building new facilities that compete directly with the incumbent's existing networks. Conversely, opponents of low UNE rates argue that CLECs will substitute away from facilities based entry and toward UNEs. Regardless of the particular point of view, decreased UNE prices will unambiguously favor UNE-based entrants. For example, Ros and McDermott (2000) find that lower UNE prices lead to increased entry by CLECs.

Using data provided by CLECs and collected by the FCC, Eisner and Lehman (2001), test how UNE prices affect competitive entry in several ways. They note that "the effect of regulatory policy on competitive entry is uniquely suited to the American environment, given the large number of state jurisdictions reaching independent determinations on wholesale and retail rates."[57] Although they find evidence that facilities-based entry is decreased with lower UNE-prices, their empirical results for other types of entry do not match their prior expectations. For example, the number of CLECs is not influenced statistically by a change in UNE prices. An even more puzzling finding is that in some of their specifications, lower UNE prices appear to decrease UNE-based entry.

3.3.2 The Political Economy of Price Cap Regulation

Price cap regulation can potentially offer gains to all interest groups including the firm, regulator, and consumer. Incumbent firms might prefer price cap regulation for several reasons. The firm's earnings are no longer limited as they were under rate-of-return regulation (ROR). Under ROR, the firm could only earn a normal profit that was determined by the regulator. With price cap regulation in place, the regulator does not limit profit once the price cap has been set. The incumbent firm can now potentially secure higher profits than in the ROR case. One way to achieve these higher profits is to take on risky investments that have high upside potential. If

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[57] See Eisner and Lehman (2001, p. 5).

these risky investments turn out well, then the firm has a secure property right on these earnings. ROR presents the firm with limited incentives to take on high risk projects. The incumbent firm values the opportunity to increase economic profit in a manner that is independent of the regulator. Another reason why incumbents might value price cap regulation is that the firm now has increased pricing flexibility. For example, the incumbent can cut prices as the industry grows more competitive. The incumbent can now compete with new rivals in terms of price. When the regulator determines the price cap, the firm has flexibility in determining the price; however the firm cannot charge a price that exceeds the level of the price cap.

A price cap regime, at least theoretically, provides the firm with increased incentives to reduce production costs to maximize profits. Ideally, with price cap regulation, the regulator will allow the firm to enjoy any increased profits that are the result of decreased costs. Under a price cap regime, the opportunity for the firm to capture increased profits as a result of increases in efficiency is fundamentally different than that under traditional rate-of-return regulation where profits are limited to a "normal" level. Under a price cap regime, the firm has increased incentives to maximize efficiency relative to rate-of-return regulation. Because of this, the incumbent firm naturally prefers price cap regulation to ROR regulation, *ceteris paribus*. To secure a price cap regulatory regime, Lehman and Weisman (2000) note that firms agreed to pay up-front entry fees. These payments took the form of rate freezes, bill credits, refunds, and commitments to invest in new infrastructure and modernization.[58]

One drawback of price cap regulation, from the firm's point of view, is that they are no longer shielded by outcomes in which they earn less than normal economic profit (perhaps due to increased competition). However, the perceived benefits of price cap regulation outweigh the

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[58] See also Sappington and Weisman (1996) for a review of incentive regulation regimes, including price caps.

perceived costs, as revealed when firms sought regime shifts away from ROR regulation and towards price cap regulation. From a societal standpoint, it is a beneficial that firms are exposed to downside risk, since incumbent firms now have strong incentives to become efficient. Increased efficiency will also clearly benefit consumers in the form of lower prices.

The success of price cap regulation in practice relies heavily on the commitment of regulators to not adjust prices in response to the success of the regulated firm. For example, if a firm reports higher than expected earnings, the regulator could potentially appropriate these gains and transfer them back to consumers in the form of lower rates. As explained below by Braeutigam and Panzar (1989, p. 389), this type of regulatory behavior is called regulatory opportunism:

> *"A regulatory agency is likely to be subjected to considerable political pressure to change the price cap or price cap formula over time. If a firm regulated by price caps begins to earn large profits, consumers will no doubt petition the regulator to lower the price in the core market."*

According to Guthrie (2006), regulators are regularly pressured by firms, consumers, and other interested parties. Regulatory commitment is a much more complex problem when investigated in a dynamic sense. If the regulated firm fears that its "excess" profits could be transferred back to consumers, then the incentive to innovate or build costly infrastructure is reduced. Price cap regulation in practice could produce the same results as ROR regulation did previously. Thus, firms must be assured of regulatory commitment in order for the efficiency gains predicted in theory to hold in reality. For price cap regulation to work effectively, the behavior of the regulator must be unaffected by the success/failure of the regulated firm.

The passage of the 1996 Telecommunications Act increased the complexity of the regulator's control over competition since the Act mandated a new form of "regulator-assisted" competitor entry. Regulators were given the responsibility of pricing UNEs leased by incumbents to market entrants. As UNE prices are lowered, entry into the market becomes easier. Thus, the Act provides regulators with an important tool to influence the dynamics of competitive entry. Since the Act applies to states regardless of regulatory regime, testing whether or not UNE pricing is systematically affected by the regulatory regime is an important policy issue. Testing this proposition relates directly to the issue of regulatory commitment discussed above.

When a state switches from ROR to price cap regulation, the incentives that regulators face will change markedly. First, even if the regulator commits to the level of a price cap, s/he can still reduce the price of UNEs and increase competition. So even though the firm still has a property right to its future earnings, the value of these earnings could be lessened due to increased competition in the industry. Because competition can be affected by the regulator through UNE prices, Lehman and Weisman (2000) note that the price cap commitment is an example of an incomplete contract. Since the regulator's utility is decreasing with market prices, we can expect more liberal competition policies (through lower UNE prices) when the regulator does not share in the financial gains/losses of the incumbent firm. Under a price cap regime, the regulator typically is not committed to ensure a normal rate of return for the incumbent. Moreover, a regulator operating under price caps is not concerned with the profit level of the firm per se since the incumbent's earnings are allowed to fluctuate. However, under traditional ROR regulation, the regulator will often allow the incumbent provider to increase prices in the event of an earnings deficiency. Lehman and Weisman (2000) suggested that with rate freeze under price-cap regimes, regulators are fully insured against the adverse effects of competition. They stated that the absence of earning sharing under price caps leads to a moral hazard problem in which the regulator may induce excessive competitive entry. According to Lehman and Weisman, the reason for this moral hazard problem is the nature of the regulators' utility function which is decreasing in market prices and increasing in competitive entry. Lehman and Weisman (2000, p.346) give the following example:

> *"In a recent open meeting of the Texas Public Utility Commission, the record indicates that the Commissioners noted (i) the absence of competition in local telephone service markets in Texas; (ii) the inclusion of contribution and subsidies in wholesale prices of network inputs; and (iii) the fact that since Southwestern Bell "freely elected into" price cap regulation, it has no recourse before the Commission in the event of under-earnings should the contribution and subsidies embedded in these wholesale rates be reduced or eliminated entirely. The implication being that because price caps are in place, the Commission can move unilaterally to reduce subsidies and contribution levels in wholesale rates to encourage competition without any adverse consequences."*

Lehman and Weisman (2000) test the hypothesis that regulator behavior is affected by the particular form of the regulatory regime. Predicting that UNE prices would be lower under the price cap regime relative to rate of return regulation, their econometric results supported their hypothesis as they found a statistically significant negative relationship between price cap regime and the UNE price. Their UNE price data came from arbitration hearings that occurred after the 1996 Telecommunications Act but before April 15, 1997. Using ordinary least squares, they concluded that price cap regulation led regulators to adopt lower UNE prices. Since their research had access to a limited number of arbitration hearings and had only 36 observations, they were restricted in the number of independent variables they could include. Also, their research only utilized ordinary least squares regression. As a result of these limitations, the negative coefficient on their price cap variable could be biased due to an omission of relevant variables. For example, if price caps are correlated with state effects that are unobserved, estimates could be biased. A larger dataset and additional control variables could conceivably alleviate this issue. Since we have access to 215 observations, we are not limited econometrically by any issues with degrees of freedom. Additionally, since our dataset spans 5 years, we can test whether the relationship between the price cap regime and UNE prices holds through time. If our results subsequently show a negative relationship between price caps and UNE prices that theory suggests, then the empirical evidence in support of the theoretical argument will increase substantially.

The potential for differences in UNE pricing based purely on politics has also been explored in the literature. For example, Quast (2008) examines the possibility that political considerations affect UNE prices. Using data that ranges from 1996 to 2004, he finds that Democrats that are elected (rather than appointed) set systematically higher prices. Also, Republican commissioners were found to set lower UNE prices relative to Democrats. According to Quast (2008), since Democrats tend to favor lower retail prices, they can potentially compensate for this lower retail prices policy position by granting incumbents higher prices for UNEs. Studies by Lehman and Weisman (2000), Beard and Ford (2004), and de Figueiredo and Edwards (2004) all found that UNE prices are higher in states with elected public utility commissioners. Interestingly, de Figueiredo and Edwards (2004) also found that a one standard deviation increase in the percentage of contributions in an electoral cycle by entrants to the industry is associated with a decrease of approximately three-tenths of a standard deviation in the regulated local loop price (approximately $1.36 per month).

3.3.3 Data and Empirical Analysis

Our dependent variable for this analysis is the UNE loop price. In total, we have 245 state-level observations from 2002 to 2006. Following Lehman and Weisman (2000), we wish to isolate the factors that influence the UNE loop price that is set by the state regulatory process. Departing from their research, we utilize regulator determined UNE prices instead of prices set by the arbitration process. These UNE prices reflect an agreement between the ILEC and CLEC that do not challenge the regulator's decision. In other words, if the incumbent and entrant both agree on the UNE price set by the regulator, then an agreement is met in the first stage. If one party challenges the regulator's decision through the regulatory process, then agreement is not met until the second stage. Our dataset includes only first-stage agreements while Weisman and Lehman (2000) focus solely on second stage agreements. Both approaches are expected to reveal similar results; however, our approach increases the size of our dataset without sacrificing relevant information. Our independent variables were chosen on the basis of theoretical importance. The independent variables that potentially influence UNE prices include the following: (1) *Political* represents the share of the state house and senate that have Republican Party affiliation. We assume that the house and senate both have equal influence. (2) *Loops per square mile* is the total number of loops in a state divided by the geographical area of the state. (3) *CLEC market share* is the share of the market currently served by competitive local exchange carriers. (4) *Elect* is a variable that is equal to one if state regulators are elected and equal to zero if state regulators are appointed. (5) *Total lines* is a variable that equals the total number of lines in a state. This is the sum of wireless, wireline and cable lines in a state. (6) *Interlata* is a variable that relates to Section 271 of the 1996 Telecommunication Act. The Act allows for Regional Bell Operating Companies (RBOCs) to compete in the interLATA long distance market once certain market-opening requirements are met. *Interlata* is a dummy variable that is equal to 1 if the state's incumbent carrier completes the filing that allows for long distance service. It is 0 before the completion of the filing date, and 1 after it. (7) *SBC 2005 merger*. SBC merger is the only merger that we control since this merger is the only incumbent related merger that took place in the time span of our dataset. This variable is equal to one in after 2004 in states where SBC was the largest incumbent. For states where SBC was not the largest incumbent or before 2005 this dummy variable is set equal to zero. (8) *Deregulation* is a dummy variable which is equal to one for the states where there is no regulation. (9) *Price Cap* is a dummy variable which is equal to one if the state is regulated under a price cap regime, otherwise it is equal to zero. (10) When both the *deregulation* and *price cap* variables are equal to zero, the state is operating under a ROR regulatory regime.

Ai and Sappington (2002) and Ai, Martinez, and Sappington (2004) note that in the telecommunications industry, controlling for all relevant factors requires the complete use of a panel data set. Following Ai and Sappington (2002) and Ai, Martinez, and Sappington (2004), we employ an approach that introduces dummy variables of two distinct types. This approach is designed to decrease the systematic variation in our econometric specifications. In the random effects model, we use state-specific dummy variables that are designed to control for differences that are not directly observed by the researcher but still influence UNE prices. For example, state-specific laws may influence UNE prices. We are not able to employ a fixed effects approach because the price cap variable is time-invariant for many states.

3.3.4 Results- Political Economy of Price Cap Regulation

The primary independent variable of interest is *Price Cap*. It is a dummy variable that is equal to one when a state utilizes price cap regulation and is equal to zero when rate of return regulation is utilized. As noted in Lehman and Weisman (2000), the price cap variable could be endogenous. We tested for endogeneity for the price cap variable by performing a Hausman test and endogeneity was rejected. We also ran the same test for total lines and CLEC market share and endogeneity was also rejected for these variables. As shown in Table 6, we ran a specification using four distinct econometric models and we were able to control for various relevant factors.[59] As economic theory predicts, the coefficient on the price cap variable is negative for each econometric model; additionally, the price cap variable was negative and statistically significant at the 1% level for three out of the four models. Thus, our econometric results provide evidence that regulators behave differently when operating under price cap regulation than they do under other alternative forms of regulation. Estimated coefficients for the price cap variable range from -1.530 using an instrumental variable approach to -1.979 when between effects estimation is performed. In terms of dollars, the between effects estimate suggests that the introduction of a price cap regime leads to $1.98 decrease in the UNE price, ceteris paribus. Since the mean UNE price is $15.37 in our sample, the price cap coefficient in each model is economically significant.

These estimates strongly suggest the presence of regulatory moral hazard. If the incumbent experiences an earnings deficiency under ROR regulation, then the regulator will typically be required to raise retail prices in the future. To guard against this event, the regulator will keep UNE rates sufficiently high to ensure a normal rate of return for the incumbent. Conversely, under price cap regulation, the regulator is less concerned about setting UNE prices too low since a normal profit for the incumbent is no longer guaranteed. The concerns about the incumbent's return are alleviated with price cap regulation, and the regulator responds by setting lower UNE prices. As the following analysis indicates, regulators also respond to other incentives.

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[59] Specification 2 in Table 6 uses an instrumental variable for total lines. The instrument was the population served by the non-UNE lines provided by the CLEC.

As CLEC market share increases, UNE prices decrease. This result is large and statistically significant in each model. We considered the possibility that the variable CLEC share could be endogenous with UNE prices. However, when we ran instrumental variables estimation, endogeneity was rejected. The reason behind the inverse relationship between CLEC share and UNE prices can be explained through a political economy framework. As the share of the market possessed by CLECs increase, *ceteris paribus*, the relative strength between the ILEC and CLEC is altered in favor of the latter. This will tend to increase the bargaining power that the CLEC possesses. Additionally, a relatively stronger CLEC will be able to exert more lobbying pressure on the regulator. These effects will tend to decrease the UNE price as the CLEC's market share increases.

One way to test the sensitivity of the regulator to the market share of the CLEC is to include an interaction term in our regression analysis. When ELECT is included in the regression (both as a dummy variable and as an interaction term with CLEC share), the results suggest that UNE prices are dependent on the appointment process and on CLEC market share. Since the interaction variable of ELECT and CLEC market share is statistically significant and negative, we conclude that UNE prices are more sensitive to CLEC share when the regulator is elected (instead of appointed). This is consistent with public choice theory in that elected (relative to appointed) regulators are more easily captured by the firms they regulate since elected regulators depend on campaign contributions to retain their elected position. Hence, as CLECs increase their market share, elected regulators set lower UNE prices than do their appointed counterparts, *ceteris paribus*. In other words, CLECs have more to gain from lower UNE prices as their market share increases and they secure these gains in part through capturing the elected regulator. Using our estimates, we can investigate the size of the impact that CLEC share has on

UNE prices while setting the ELECT variable equal to one. The mean value of CLEC share is 0.159 with a standard deviation of 0.064. Based on the pooled OLS estimation results and assuming the regulator is elected, a one standard deviation increase in CLEC share from the mean will decrease the UNE price by $1.88. In contrast, when the regulator is appointed and the ELECT variable is equal to zero, the same increase in CLEC market share decreases UNE price by only $0.58. Hence, consistent with economic theory, an increase in CLEC share will have more of an impact when the regulator is elected– a $1.88 decrease in price– than when the regulator is appointed –a $0.58 decrease in price.

Alternatively, we can treat the CLEC share as constant at the mean and use our estimates to calculate the change in the UNE price when the method of selecting the regulator is changed. When the regulator selection a process changes from one in which s/he is appointed to a process where s/he is elected, UNE prices are estimated to *increase* by $0.55.[60] Hence, when the CLEC share is constant at its mean (0.159), moving from an appointment process to an electoral process will tend to favor the incumbent. This makes intuitive sense because at this mean level of CLEC market share, the ILEC is still relatively more powerful and can be expected to exert relatively more control in the form rent-seeking behavior than the CLEC. As our estimates suggest, the elected official is more likely to be captured by the ILEC than by the CLEC at the mean of CLEC share.

A number of other observations follow directly from our findings. First, the political coefficient is negative in all of the models, however it is statistically insignificant. Abel (2002) contends that Republican politicians are relatively more supportive of free-market tendencies than their Democratic counterparts. This leads him to hypothesize that regimes with Republican

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[60] Calculation is based on the mean of CLEC share.

tendencies will tend to support increases in both CLEC entry and the size of fringe competition in local telephone markets. The estimates from Abel (2002) support both of these hypotheses, albeit weakly. Our results are similar in spirit to those of Abel (2002) as we find that as states become more Republican, other things equal, UNE rates tend to fall (although close, these estimates are not statistically significant). This seems to suggest that a pro-Republican legislature leads to a decrease in rates that favor competitors at the expense of incumbents. Another reason for this effect could be that lobbying efforts by CLECs could have more effect when the legislature is dominated by Republicans.

Second, loops per square mile are negatively related with UNE prices. This result is statistically significant for each model. One explanation is that as loops per mile increase, additional political pressure is exerted on regulators to decrease the price. Alternatively, urban environments are able to achieve economies of scale and density that allow the regulator to lower UNE prices while sparsely located loops in rural states are associated with higher prices.

Third, the coefficient for total lines (wireless lines plus wireline) is negative and significant while the coefficient for total lines squared is positive and significant. With this non-linear relationship between total lines and the UNE price, the relationship between these two variables depends on the number of total lines. The mean number for total lines in our sample is 7.43 million. When total lines exceed 39.25 million in a state, there is a positive relationship between total lines and UNE price (based on the estimates from the RE model found in table 3.6).[61] When total lines are less than 39.25 million, there is a negative relationship between total lines and UNE price. For the most relevant values, our estimates suggest that an increase in total lines will lead to an increase in the UNE price, *ceteris paribus*.

[61] This critical value for total lines is 29.9 million for OLS, 29.75 million for IV and 26.5 million for between model.

Fourth, Interlata is a dummy variable that is equal to 1 if the state's incumbent carrier completes the filing that allows it to provide InterLATA long distance service. It is 0 before the completion of the filing date. The coefficient for this variable is positive and statistically significant in three of the models. With the introduction of InterLATA, incumbents not only received access to the InterLATA long distance market, but they also received higher UNE prices. One possible explanation for this result is that ILCECs were willing to "bribe" regulators in the form of lower UNE prices in order to secure access to the lucrative InterLATA long distance markets.

Fifth, the SBC 2005 variable is equal to one after 2004 in states where SBC was the largest incumbent. The coefficient estimates for this variable are mixed. In two of the models the coefficient is negative and significant, in one model the coefficient is positive and significant, and in one model the coefficient is statistically insignificant. Therefore, the effect of SBC Merger gives different results for different specification

3.4 Conclusion

The passage of the 1996 Telecommunications Act provided regulators with additional instruments through which to control outcomes, including the intensity of competition, in local telephone industry. The FCC envisioned that lower regulated UNE prices would increase facilities based entry by CLECs. However, most research found that lower UNE prices actually led to less facilities-based entry. Using a panel data set, we find evidence in *support* of the stepping stone theory that appears to contradict much existing research. Over the set of most relevant UNE prices, our estimates suggest that facilities-based entry increases as a result of lower UNE prices. Utilizing our unique panel data set, we find our results hold intertemporally and also when UNE prices are lagged by one year. Our estimates provide evidence that the FCC may have been correct with the stepping-stone hypothesis.

After investigating how UNE prices affect facilities-based entry, we analyze how the regulator determines UNE prices in general. Our estimates reveal two primary conclusions. 1) Regulators are subject to regulatory moral hazard. That is to say, they set lower UNE prices under a price cap regime because they are shielded from the adverse consequences of raising local rates. 2) Elected (relative to appointed) regulators grant increasingly lower UNE prices as CLEC market share increases. Since the incentive to engage in rent-seeking behavior increases with market share, our results suggest that elected regulators are more easily influenced by lobbying when CLEC market share increases.

Our results reveal that regulators are not passive actors in the telecommunications industry in which they regulate. Rather than being referees of the game, their behavior provides evidence that they are in fact "players" in the game. Future changes in telecommunication policy should consider the fact that regulatory behavior is likely to be endogenous rather than exogenous to changes in policy variables of interest.

Figure 3.1 Correlation between ln(CLEC-Owned) and ln(UNE price)

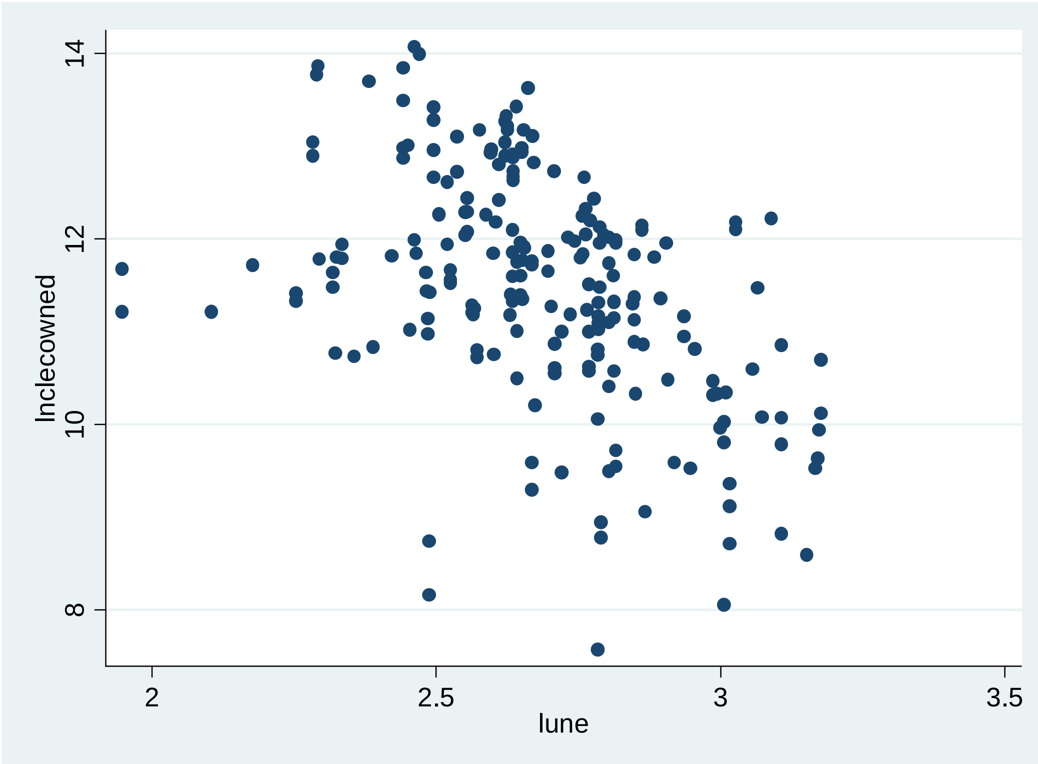

Figure 3.2 Relationship between CLEC-Owned Lines and UNE Prices

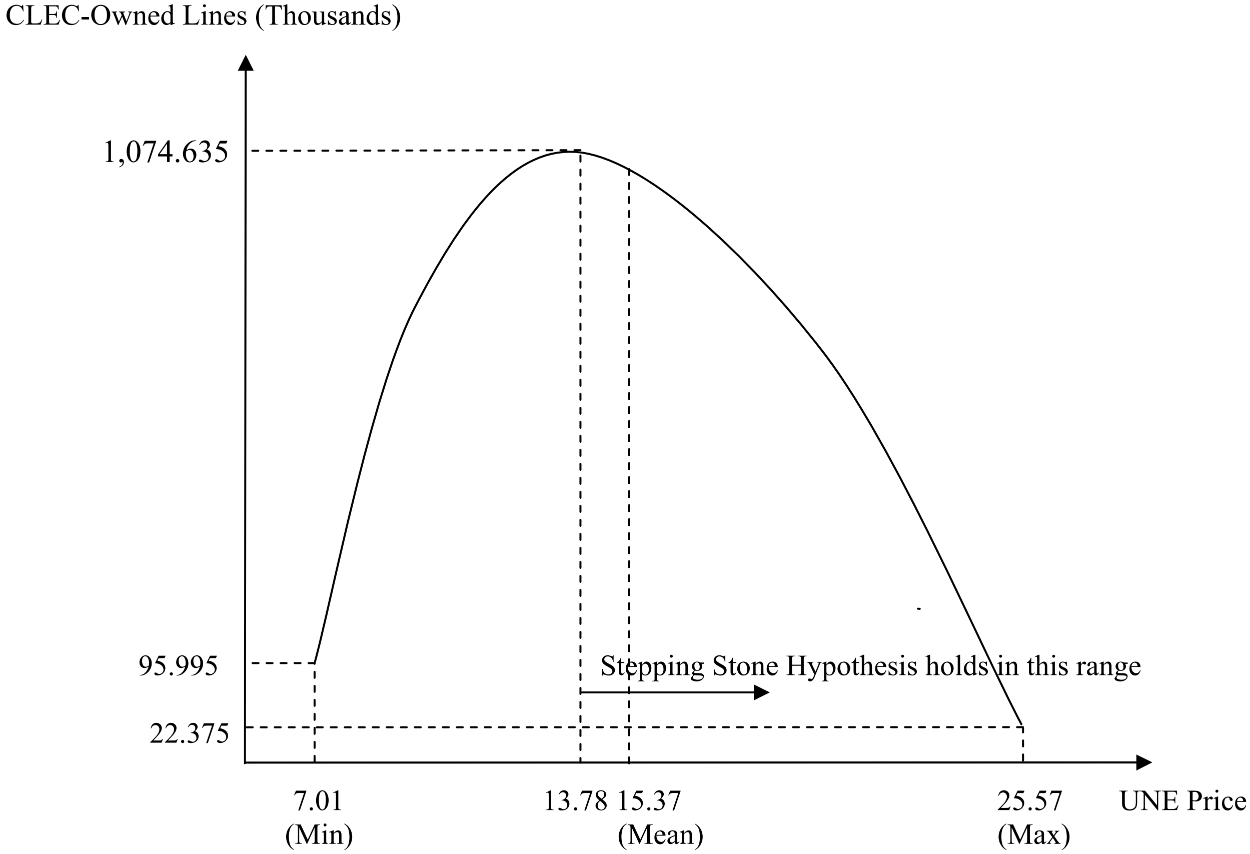

Table 3.1 Summary Statistics for the Stepping-Stone Hypothesis (2002-2006)

Variable	Observations	Mean	Std.Dev	Min	Max
CLEC Owned	218	184,444.7	219,923.1	1944.1	1,284,951
UNE Price	245	15.372	3.633	7.01	25.565
Loop Cost/Mo	243	21.94396	5.305445	13.324	35.263
BUSRES	245	1.778	0.476	0.596	2.828
Population	245	5,946,944	6,482,289	497,204	36,200,000
log (CLEC Owned)	218	11.489	1.235	7.573	14.066
log (UNE price)	245	2.705	0.236	1.947	3.241
Log (UNE) squared	245	7.373	1.273	3.792	10.506
Log(Loop Cost/Mo)	239	3.084	0.205	2.575	3.563
log (BUSRES)	245	0.534	0.306	-0.517	1.039
log (population)	245	15.11	1.014	13.112	17.406
Elect	240	0.250	0.434	0	1
Price Cap	245	0.735	0.433	0	1

Table 3.2 Testing the Stepping-Stone Hypothesis

Dependent variable: the log of CLEC-Owned lines.

Variable	OLS (i)	OLS (ii)	Between Effect	Random Effect
ln (UNE price)	-2.202*** (0.388)	-0.286 (0.590)	-0.522 (0.751)	0.115 (0.353)
ln (cost)	-0.641 (0.435)	-0.429 (0.495)	-0.378 (0.754)	-0.515 (0.406)
ELECT	-------	0.342 (0.260)	0.417 (0.259)	0.324 (0.268)
ln (BUSRES)	-------	-0.206 (0.299)	-0.316 (0.374)	0.127 (0.235)
ln (population)	-------	1.041*** (0.144)	1.057*** (0.132)	1.114 (0.126)
Price Cap	-------	-0.306 (0.239)	-0.517* (0.301)	-0.164 (0.139)
Constant	19.384 (1.177)	-1.826 (3.829)	-1.708 (3.502)	-4.338** (2.779)
Observations	213	213	213	213
R-squared	0.224	0.631	0.733	0.590

*** Statistically significant at 1% level
** Statistically significant at 5% level
* Statistically significant at 1% level

Table 3.3 Testing the Stepping-Stone Hypothesis by Including Non-linearity in UNE Prices.

Dependent variable: the log of CLEC-Owned lines.

Variable	OLS	Between Effect	Random Effect
ln (UNE price)	18.865*** (4.286)	23.229*** (8.095)	15.722*** (3.656)
ln (UNE price) squared	-3.620*** (0.842)	-4.420*** (1.501)	-2.997*** (0.699)
ln (cost)	-0.396 (0.448)	-0.324 (0.692)	-0.494 (0.385)
ELECT	0.359 (0.241)	0.415* (0.238)	0.380 (0.244)
ln (BUSRES)	-0.330 (0.264)	-0.528 (0.370)	-0.042 (0.225)
ln (population)	1.005 (0.135)	1.066*** (0.121)	1.040*** (0.116)
Price Cap	-0.496** (0.190)	-0.784*** (0.291)	-0.290** (0.136)
Constant	-26.328*** (4.766)	-33.357*** (11.218)	-23.236 (5.148)
Observations	213	213	213
R-squared	0.680	0.780	0.643

*** Statistically significant at 1% level

** Statistically significant at 5% level

* Statistically significant at 1% level

Table 3.4 Testing the Stepping-Stone Hypothesis by Lagging UNE Prices.

Dependent variable: the log of CLEC-Owned lines.

Variable	OLS	Between Effect	Random Effect
lagged log (UNE price)	17.766*** (4.541)	21.132***	17.353*** (3.737)
lagged log (UNE price squared)	-3.411*** (0.902)	-4.062*** (1.344)	-3.369*** (0.710)
ln (cost)	-0.585 (0.448)	-0.376 (0.690)	-0.819** (0.381)
ELECT	0.490** (0.231)	0.514** (0.237)	0.534** (0.238)
ln (BUSRES)	-0.319 (0.269)	-0.516 (0.367)	0.036 (0.230)
ln (population)	1.033*** (0.141)	1.069*** (0.120)	0.981*** (0.115)
Price Cap	-0.443** (0.193)	-0.762** (0.294)	-0.241* (0.136)
Constant	-24.844*** (4.726)	-30.188*** (9.817)	-23.045*** (5.323)
Observations	176	176	176
R-squared	0.711	0.788	0.686

*** Statistically significant at 1% level
** Statistically significant at 5% level
* Statistically significant at 1% level

Table 3.5 Summary Statistics for the Political Economy of UNE Prices (2002-2006)

Variable	Observations	Mean	Std. Deviation	Min	Max
UNE Price	245	15.372	3.633	7.010	25.565
Loop cost/mo	243	21.943	5.305	13.324	35.263
Loops/sq. mi.	245	102.978	141.310	3.184	794.245
Political	240	0.508	0.145	0.136	0.893
CLEC share	223	0.159	0.064	0.030	0.445
Elect	240	0.250	0.434	0	1
Elect*CLEC share	223	0.039	.076	0	.315
Total Lines	234	7.43	8.28	.436	50.783
Total Lines Squared	234	123.43	330.82	.191	2578.89
Interlata	240	0.838	0.370	0	1
SBC 2005	245	0.106	0.309	0	1
Deregulation	245	.116	0.313	0	1
Price Cap	245	0.735	0.433	0	1

Table 3.6 Political Economy of UNE Prices.

Dependent variable: UNE prices.

Variable	OLS	IV	Between Effect	Random Effect
Loop Cost/Mo	0.152*** (0.038)	0.153*** (0.039)	0.141* (0.078)	0.055* (0.033)
Loops per sq mi.	-0.005*** (0.001)	-0.006*** (0.001)	-0.007** (0.003)	-0.007*** (0.002)
Political	-1.247 (1.306)	-1.931 (1.401)	-1.643 (2.352)	-1.962 (1.840)
CLEC Share	-9.022*** (3.317)	-9.892*** (3.714)	-10.027 (6.642)	-6.924** (3.049)
ELECT	3.874*** (0.979)	3.685*** (1.267)	4.152* (2.136)	2.751*** (1.048)
ELECT*CLEC share	-20.344*** (5.829)	-19.288*** (6.107)	-22.965* (12.648)	-9.686** (4.865)
Total Lines	-0.299*** (0.054)	-0.238*** (0.089)	-0.212** (0.104)	-0.314*** (0.083)
Total Lines squared	0.005*** (0.001)	0.004* (0.002)	0.004 (0.003)	0.004** (0.002)
Interlata	1.151* (0.638)	1.253* (0.650)	3.887* (2.272)	-0.179 (0.307)
SBC 2005	-0.486 (0.562)	-0.533 (0.568)	-3.271* (1.701)	1.822*** (0.335)
Deregulation	0.723 (0.806)	0.877 (0.851)	2.468 (1.789)	0.263 (0.664)
Price Cap	-1.577*** (0.491)	-1.530*** (0.498)	-1.979* (0.999)	-0.143 (0.487)
Constant	16.555*** (1.463)	16.629*** (1.471)	14.505*** (3.043)	18.472*** (1.449)
Observations	214	208	214	214
R-squared	0.60	0.60	0.79	0.48

*** Statistically significant at 1% level
** Statistically significant at 5% level
* Statistically Significant at 1% level

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