DISCRIMINATORY DEALING WITH DOWNSTREAM COMPETITORS: EVIDENCE FROM THE CELLULAR INDUSTRY*

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ABSTRACT

Concern over regulated monopolies entering unregulated vertically-related markets is grounded in the incentives for such firms to cross-subsidize their unregulated enterprises or discriminate against competitors in the unregulated market. However, a prohibition against regulated monopolies offering related goods may forfeit the benefits of production by the most efficient provider. We take advantage of cross-sectional variation across geographic cellular markets to examine the empirical importance of these discrimination and efficiency effects. This cross-sectional variation takes three forms; differences in the percentage of interconnection facilities in a cellular market owned by each phone company, in the percentage of wireline end customers served by each local phone company, and in the percentage of the cellular companies' equity owned by each local telephone company. Consistent with the discrimination hypothesis, greater ownership of interconnection facilities is associated with lower quality and lower output of cellular phone service. However, consistent with the efficiency hypothesis, a greater fraction of customers served is associated with higher cellular quality and greater output. The estimated magnitudes of these effects imply that discrimination and efficiency effects of greater integration tend to be offsetting. Higher equity ownership in the cellular company by the phone company leads to higher prices (which is consistent with either hypothesis) and no discernable effect on quality or quantity.

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[1]The literature on vertical integration to evade regulation is distinct from motivations discussed in the general literature on vertical integration (for a review of the latter see Perry (1989)). The rationale for integration in the regulated context is most closely related to an older literature on tying as a means of

hypothesis and of efficiencies from integration in two ways. First, we develop a framework for formalizing the notion of discrimination, and show that discrimination increases the profitability of the unregulated affiliate of a regulated firm. We use this framework to generate implications of the discrimination hypothesis, and also of the hypothesis that integration lowers the cost of improving quality. Second, we empirically examine an industry in which conditions for discrimination exist. In providing cellular phone service to consumers, cellular phone companies use an input supplied by the local phone company (or *exchange carrier*[2]) to produce its product (a phone call between a customer served by the cellular company and one served by the local exchange carrier). That is, connection to, and use of, the local exchange carrier's (LEC) facilities is necessary to the production of a call between subscribers of the two networks. The price that the LEC can charge for the use of its facilities is regulated. In addition, there are exaclty two cellular phone providers in each market, and the local exchange carrier is permitted to own equity in one of the two. In fact, the dominant local land-line carrier almost always holds a majority equity interest in one of the two cellular carriers. Thus, under the discrimination hypothesis, there is an incentive for the regulated firm to offer different terms to its affiliate and the affiliate's rival.

A feature of this industry that makes it useful for evaluating the discrimination hypothesis is that the extent of vertical integration between the LEC and its affiliated cellular company varies across geographic markets. In particular, there is considerable cross-sectional variation in the share of the cellular company's equity owned by the dominant LEC and also in the share of the relevant physical assets (land lines, switches, etc.) owned by the dominant LEC.[3] These differences can be thought of as differences in the extent of vertical integration across geographic areas. We show that one prediction of the discrimination hypothesis is that as the LEC's equity interest in its cellular affiliate falls, its incentive to discriminate decreases. Similarly, as the ownership of the relevant physical assets becomes more diffuse, the ability to discriminate falls. Increased discrimination leads to higher prices, while the efficiency hypothesis implies that (holding quality constant) increased concentration of ownership of the cellular company, and of the relevant physical assets, should reduce price. Because of the variation in both types of ownership concentration, we are able to test whether higher concentration is associated with higher prices and lower average quality as predicted by the discrimination hypothesis. Moreover, to the

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[2]The common industry parlance for a local telephone company is a local exchange company (LEC) because they operated the various community-level telephone exchanges.

[3]That is, in some geographic areas, there are multiple, non-competing land-line carriers. For example, the same two cellular companies cover the entire Los Angeles metropolitan area. However, the monopolist LEC is different in different parts of the area; both Pacific Telesis and GTE served significant numbers of land-line customers in the area during the period we examined.

extent that both discrimination and efficiency occurs from integration between cellular companies and land-line monopolists, policy-makers would be interested in the net effect on cellular phone prices and quality. Our analysis indicates whether on net the two effects increase or decrease prices and quality, and hence addresses a central policy question.

We find that, consistent with the discrimination hypothesis, prices increase with the share of the cellular company's equity held by the dominant land-line provider. Similarly, prices increase with the share of the relevant physical facilities controlled by the dominant LEC. While this evidence is consistent with the discrimination hypothesis, it could also be consistent with integration leading to efficiencies if quality increases were associated with integration, and if those increases more than offset the effect of higher prices (at least to the marginal consumer). To test whether the higher prices reflect higher quality, we examine the relationship between several (subjective) indices of customer "satisfaction" and the ownership measures. The evidence implies that, controlling for other factors, satisfaction is increasing in one measure of the degree of land-line ownership (the percentage of lines served by the dominant LEC) and decreasing in the other (the dominant LEC's share of interconnection facilities). The effect of financial ownership on satisfaction is small. This seems to suggest that both discrimination and efficiencies result from greater integration. The quantity regressions yield similar implications; quantity increases with the dominant LEC's share of lines served. This suggests that, despite higher prices associated with integration, consumers' perception of quality is increased by greater integration. At the same time, quantity falls as the dominant LEC's share of interconnection facilities rises, suggesting that some of the price increase is due to discrimination.

The issue of whether to allow regulated firms to enter related, unregulated businesses has emerged in several regulated industries. Probably the most prominent example involves the regional Bell operating companies. Under the 1982 Modified Final Judgement in the AT&T antitrust case, these providers of local phone service have been prohibited from entering long-distance phone service.[4] One of the reasons for the prohibition was a concern that these firms would discriminate against rival long distance carriers (see Brennan (1987)). These companies recently petitioned the FCC to vacate this order.[5] The regional Bell operating companies presented a significant amounindiNc 0 Tw 374.28 0ulong-6pan imination.

[4]U.S. v. AT&T 552 F. Supp 131 (1982). The 1996 Telecommunications Act provides for eventual Bell operating company integration into long distance services. Currently, they are allowed to compete in long-distance carriage between local markets they do not serve. The discussion in the text relates to long- distance carriage in which one party to the call resides in the local market in which the regional operating company is the local monopolist.

[5]See "Motion of Bell Atlantic Corporation, BellSouth Corporation, NYNEX Corporation, and Southwestern Bell Corporation to Vacate the Decree," Civil Action No. 82-0192 (July 6, 1994).

[6]See for example, “AT&T’s Opposition to the Four RBOCs’ Motion to Vacate the Decree,” (Dec. 7, 1994), Civil Action No. 82-0192.

[7]*In the Matter of an Inquiry Into the Use of the Band 825-845 MHZ and 870-890 MHZ for Cellular Communications Systems; and Amendments of Parts 2 and 22 of the Commission’s Rules Relative to Cellular Communications Systems*

market, represented a compromise between the benefits of issuing relatively few licenses, and allowing firms to realize potential economies of scale within the limited spectrum available, and the benefits of competition from issuing a large number of licenses.[9]

One of the two licenses in each market (typically, the B license) was reserved for a local provider of land-line phone service. The FCC required the cellular licensee to be run separately from the land-line company (ies) that own it. In some markets there was a single such landline provider, and it was awarded the license. In other markets, there were multiple (non-competing) providers, and the FCC's choice of licensee among these candidates was to be made through "comparative hearings."[10] However, the FCC encouraged the LECs in each geographic area to reach a settlement, whereby all but one of the candidates withdrew from consideration. Such a settlement was reached in all of the 30 largest markets (which were the first markets for which licenses were awarded). In other markets, settlements were also common. Typically, the company receiving the license was jointly owned by all of the relevant local LECs.[11] Award of the other, "non wireline" licenses was also initially determined by comparative hearings, and settlement among the candidates often occurred here as well.

Each cellular service area is divided into a honeycomb of geographic areas, referred to as "cells." Within each cell, there is a "cell site" where radio signals are transmitted to and received from mobile units. Because these broadcasts are made at low power, the same channel of spectrum can be used simultaneously in nearby (but not adjacent) cells without interference. The signals received by each cell are transmitted to the Mobile Telephone Switching Office, via a land-line or microwave link. For most calls, the signal is then linked through a tandem switch to the land-line network. In this way, interconnection to LECs is a necessary input for completion of most cellular calls (over 90% of cell calls are completed on wireline networks). Local exchange carriers are usually regulated in regard to the pricing of this input. In particular, there is a maximum price that the LEC can charge for interconnection, and also a requirement that the LEC deal with the two cellular services on a nondiscriminatory basis.

An issue we address in some detail is whether the quality of cellular service differs between

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service.

[9]For a detailed discussion of the technological and regulatory history of cellular telephony, see Calhoun (1988).

[10]Our discussion of the history of FCC licensing derives primarily from Rosston (1994).

[11]Given the potential for side-payments between the parties, it would seem that ownership of the new company would be determined so as to maximize the joint profits of the LECs. As discussed in Section III, profit-maximization would dictate that the distribution of the cellular firm's equity would reflect the distribution of physical assets within the geographic area.

cellular companies in each market, and across markets. The source of these difference is not primarily differences in broadcasting technology; the analog technology used to transmit cellular calls duringour data period was the same for all cellular systems in our sample. Rather, cellular service quality differs primarily in call blockage rates (due to system congestion) and call interference (due to gaps in system coverage).

Two common problems that reduce the quality of cellular service are "dead spots" and "hot spots" within cells. Dead spots are areas within cells in which cellular transmissions can experience noise and interference leading to the transmission being "dropped." One can be talking on a cellular car phone while driving through a city and suddenly hear substantial static or interference and lose the transmission. This problem can be a result of such things as local topography or physical obstructions such as tall buildings.[12] Hot spots are small, localized areas of a city from which an unusually large number of cellular calls originate. Hot spots typically develop at freeway exits and entrances or busy intersections. Radio engineers designing cellular systems have often had difficulty predicting where hot spots will appear. Roadway construction or repair can sometimes permanently remove or create "hot spots," and random events such as traffic accidents can suddenly create temporary ones. Hot spots can strain a cell's capacity, blocking the transmission of calls or causing calls to be dropped during the "hand-off" as a car moves into a cell that is experiencing an unexpected "hot spot." The common solution to "dead spots" and "hot spots" is splitting these cells in order to create more channels. In general, the greater the number of cells per system subscriber, the less frequent will be these types of problems, and the better will be the overall quality of the cellular system.

Since competing cellular providers may make different decisions regarding the number and location of cells in a market, differences in transmission quality may arise. Moreover, the nature of hot spots and dead spots is such that the optimal location and number of cells in a particular system change over time. Adding cells to the system can require coordination between the LEC and the cellular company, since a new cell requires trunk lines connecting it with the land-line network. The coordination problems may give rise to differences between affiliated and independent cellular companies. In particular, if integration mitigated these coordination problems, one would anticipate differences between how affiliated and unaffiliated cellular companies route their calls to the LEC network. For example, industry sources tell us that unaffiliated cellular companies tend to build their own link between their cell sites and their Mobile Telephone Switching Office, whereas affiliated cellular companies tend to lease a high capacity line from the LEC. As discussed in Section III these differences may be evidence of a more

[12]Calhoun (1988, p. 96) discusses an actual case in which the appearance of leaves on trees in the spring created a "dead spot" along Philadelphia's Schuykill Expressway.

efficient production procedure or of discrimination.

III. A Model of Quality Differences

As noted above, the existence of an unregulated affiliate may cause a regulated firm to change its actions so as to increase the profits of its unregulated business. In particular, if regulation is less than perfect, then subtle forms of discrimination may persist, such as reducing the quality of the interchange services provided to non-affiliated firms.[13] Alternatively, quality differences between the affiliate and its rivals could be due to efficiencies from integration. For example, integration may reduce the transaction cost of contracting for the construction of new trunk lines to connect a new tower. These lower transaction costs allow the affiliate to be more responsive to changes in demand for cellular services.

To formally evaluate these two potential sources of differentiation between affiliates and non-affiliates, and to derive empirical implications of each, we model the difference between the firms as a difference in unambiguously defined "quality." This type of "vertical differentiation" seems a natural way to capture potential differences between telephone service providers. In particular, it provides an intuitive way of thinking about the effects of LEC ownership of cellular companies on quality. Given this characterization of potential differences between firms, we consider a two-stage game. In the first stage, each LEC determines the quality of interconnection it will provide each cellular company. In the second stage, the two cellular companies simultaneously choose prices, given the interconnection quality from stage 1.[14] We solve for the equilibrium using backward induction. That is, we first solve for the equilibrium cellular prices as functions of the firms' qualities. This allows us to calculate comparative static derivatives to demonstrate how prices and output vary with quality, and to discuss the implications for profits. Given these relationships between quality and cellular company profits, we then consider LEC's decisions regarding quality determination. In particular, we formally analyze how the incentive to discriminate varies with observable characteristics of ownership structure. Using the comparative static

[13]Here, we use the term "interchange services" to refer to any service provided by the LEC to the cellular phone companies that can alter the quality of cellular service. Hence interchange services include the speed of a cellular customer obtaining a dial tone, the sound quality of a call between a wireline and cellular customer, or the delay and negotiation cost faced by the cellular company in obtaining new trunk lines to connect a new cell to its system.

[14]The model described here essentially assumes that the LEC's decision regarding interconnection quality completely determines cellular quality. In a more general model, we could allow an intermediate stage, in which the two cellular companies simultaneously choose the quality of their products, given the quality of interconnection services from stage 1. The cellular companies would then choose prices in the third stage, given these qualities. This generalization would better reflect the cellular companies' decisions as characterized in section II, but would not change the basic results of our model.

relationships, we then derive implications for the relationships between LEC ownership structure and prices, output, and quality. Finally, we contrast these to the empirical predictions of the hypothesis that vertical integration leads to efficiencies.

[15]This contrasts with a model of "horizontal differentiation", in which consumers differ in their ordinal ranking of products, so that even if the goods had the same price, all consumers would not choose to buy the same product.

$$q_B = \int_{\frac{P_B - P_A}{Z_B - Z_A}}^{X} \int_{P_B - x Z_B}^{\bar{\theta}} q(x, P_B)\, g(\theta, x)\, d\theta\, dx \qquad (1)$$

where g(θ, x) is the joint distribution of θ and x, where x varies from 0 to X, and θ2

$$q_B = \int_{\frac{P_B - P_A}{Z_B - Z_A}}^{1} f(x)\, dx = 1 - \frac{P_B - P_A}{Z_B - Z_A}.$$

$$\pi_B = \left(1 - \frac{P_B - P_A}{Z_B - Z_A}\right)(P_B - C), \qquad (2)$$

[16] S&S also assume a uniform distribution, and our characterization of the distribution of consumers is equivalent to theirs when $\theta_i = \theta$ for all i. We relax this assumption in Appendix A.

[17] In fact, we assume that the cost of providing cellular service, C $\geq \theta$, so that not all customers are served in equilibrium.

$$P_B\,(P_A) \;=\; \frac{P_A + Z_B - Z_A + C}{2} \qquad \textbf{(3)}$$

$$A_A \;' \left(\frac{P_B}{\;} \quad m \qquad \right)$$

[18] As noted above, we do not formally model the determination of Z_A and Z_B by the downstream firms. Rather, we assume that they are completely determined by the actions of the LEC(s). In a more general model, the actions of the LECs change the cellular companies' cost of increasing quality, and consequently change equilibrium values of Z_A and Z_B.

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$$P_A^{(} \; ' \; \frac{Z_A(Z_B \& Z_A) \; \% \; Z_A C \; \% \; 2Z_B C \; \% \; 22(Z_B \& Z_A)}{4Z_B \& Z_A} \; \$ \; C \;] \; Z_A \; \$ \; 2C \& 22$$

$$\frac{8Z_B^2 \& Z_A^2 \& \; 2 \; \; 2Z^{\& \; 2}}{}$$

$$\frac{\partial q}{\partial Z_A} = \frac{\partial q_A}{\partial Z_A} + \frac{\partial q_B}{\partial Z_A} = -\frac{(P_B - P_A)}{(Z_B - Z_A)^2} + \left[\frac{P_A - \theta}{Z_A^2} + \frac{P_B - P_A}{(Z_B - Z_A)^2}\right] = \frac{P_A - \theta}{Z_A^2} > 0.$$

Hence, a reduction in Z_A reduces the number of customers buying the product. ∎

Although discrimination reduces aggregate sales, it increases q_B. Hence, increased discrimination allows the affiliate to increase both its price and its number of subscribers, and hence its profits. While increasing discrimination reduces the number of customers, in this version of the model, efficiencies do not increase the number of customers buying the good. The reason is that in equilibrium, any consumer who prefers to not buy the good (i.e., consumers with x_i sufficiently low that $x_i Z_j + \theta < P_j$ for all j), necessarily prefers product A to product B (i.e., $x_i Z_A - P_A > x_i Z_B - P_B$). In that case, increases in Z_B induce some of A's customers to switch to B, but does not induce any non-customers to buy the good. In the more general model presented in the Appendix A, however, we show that increases in Z_B will induce some customers to begin buying from B. In either case, increasing Z_B increases the affiliate's profits.

To summarize, increases in the affiliate's quality increases both prices, and in the more general model, aggregate subscribership. Decreases in the rival's quality increase the affiliate's price and reduce subscribership, and may either increase or decrease the rival's price. The model presented in the Appendix B presents similar results for intensity of use: increases in the affiliate's quality increases both prices and increases aggregate intensity of use, while decreases in the rival's quality increases the affiliate's price, and decreases aggregate intensity of use.

B. Upstream Equilibrium

Having characterized the relationship between increased discrimination (or increased efficiency) and prices and output, we now turn to the question of the relationship between the degree of vert2(0.009 Tc -0.0258 areas served by the cellular companies. In some markets, different portions of the market are served by different monopolist LECs. Fewer than 5% of the geographic markets (as delineated by the cellular licenses) are served by a single LEC providing local land-line service to all consumers. On average, about 3/4 of the end offices in a cellular market were owned by the largest LEC in the market, although the figure ranged from a low of 27% up to 100%. This suggests that the ability of the largest LEC to affect the quality of the unaffiliated cellular company will vary across markets. At the same time, as discussed in section II, in areas with multiple LECs, ownership of the affiliated cellular company is often shared among the LECs. For about 1/3 of the top 100 cellular markets in our sample (we only have equity ownership data for these 100) one LEC owned all of the equity in the affiliated cellular company. On average, the dominant LEC owned about 88% of the cellular company's equity, ranging down to a low of 28%.[19]

These cross-sectional differences allow for empirical examination of the importance of both the incentives to discrimination created by integration, and the efficiency effects of integration. In particular, if discriminatory incentives exist, they will be greatest in markets characterized by the dominant firm owning a large share of the equity in the cellular company, and also a large share of the land lines used for interconnection. Conversely, if integration lead to lower operating cost or higher quality for cellular affiliates (e.g, through reduced scope for opportunism), we would expiect that such markets will have less expensive or higher quality cellular service.

i. The Discrimination Hypothesis

To formally analyze the relationship between ownership structure the incentive to discriminate, we consider the incentives of LECs. As noted above, each cellular market is served by one or more LECs, each a regulated monopolist over some portion of the geographic area covered by the cellular license. LEC j owns a fraction, "$_j$, of the facilities used to interconnect cellular end users to wireline end users in that cellular market, and a fraction, ($_j$, of the equity interest in the affiliated cellular firm (firm B). The discrimination hypothesis is that LEC j can manipulate Z_A^j in order to adv 0 Tc1anse.

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[19]One can think of these differences as difference in the degree of vertical integration in that the kinds of incentives created by integration are also created by owning a share of the equity in the cellular affiliate. The greater the ownership interest, the closer the relationship becomes to full integration.

$$\Pi_j = W\left[q_B^j(W, Y, Y_j) + q_A^j(W, Y, Y_j)\right] + \gamma_j q_B(W, Y)(P_B(W,Y) - C).$$

$$0 = \alpha_j \gamma_j \left[\qquad \right]$$

[20]In this model, the incentive to discriminate derives, at least in part, from the existence of price regulation. To see this, note that $\partial Y_j^*/\partial W < 0$ (where Y_j^* is LEC j's choice of Y_j) i.e., as the regulated price rises, the incentive to discriminate falls.

Proposition 3: If $\gamma_j = 0$, LEC j does not discriminate

Proof: Equation (6) implies that if γ_j = 0, LEC j chooses

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$$\Pi_1 + \Pi_2 - \Pi_L = W \sum_{i=1}^{2}\left(q_B^i(W,Y) + q_A^i(W,Y)\right) + (\gamma_1 + \gamma_2) q_B(W,Y)\left(P_B(W,Y) - C\right) \qquad \textbf{(7)}$$

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$$((_1\%(_2)''_1(P_B\&C)\left(\frac{Mq_B}{MY}\%\frac{Mq_B}{MP_A}\frac{MP_A}{MY}\right)\%W\left(\frac{dq_B}{dY_1}\%\frac{dq_A}{dY_1}\right)$$ [redacted]

$$((_1\%(_2)''_1(P_B\&C)\left(\frac{Mq_B}{MY}\%\frac{Mq_B}{MP_A}\frac{MP_A}{MY}\right)\%W\left(\frac{Mq_B^1}{MY_1}\%\frac{Mq_A^1}{MY_1}\right)\%$$ [redacted]

$$''_1\mathrm{E}_{i'1}^{2}W\left[\frac{MP_B}{MY}\left(\frac{Mq_B^i}{MP_B}\%\frac{Mq_A^i}{MP_B}\right)\%\frac{MP_A}{MY}\left(\frac{Mq_B^i}{MP_A}\%\frac{Mq_A^i}{MP_A}\right)\right]$$

$$(_1''_1(P_B\&C)\left(\frac{Mq_B}{MY}\%\frac{Mq_B}{MP_A}\frac{MP_A}{MY}\right)\%W\left[\frac{Mq_B^1}{MY_1}\%\frac{Mq_A^1}{MY_1}\right]\%''_1W\left[\frac{MP_B}{MY}\left(\frac{Mq_B^1}{MP_B}\%\frac{Mq_A^1}{MP_B}\right)\%$$ [redacted]

$$''_1(_2(P_B\&C)\left(\frac{Mq_B}{MY}\%\frac{Mq_B}{MP_A}\frac{MP_A}{MY}\right)\%''_1W\left[\frac{MP_B}{MY}\left(\frac{Mq_B^2}{\quad}$$ [redacted] $$\right)\right]$$

in the area. As the number of such LECs in the market falls, the cellular company will have to deal with with fewer parties, and it seems reasonable that the cost of contracting (e.g., to add cells) will decline. This implies that greater concentration of " will be associated with lower transactions costs of creating a cellular network.

The second kind of transactions costs are those emphasized in the literature on the theory of the firm. In particular, the literature emphasizes that in many contractual relationships, there are assets whose value is significantly higher within that relationship than outside of it. Klein, Crawford, & Alchian (1978) refer to the difference between the values within and outside the relationship as the *appropriable quasi-rents* of the relationship. As Klein, Crawford, & Alchian and Grossman & Hart (1986) show, the

[21] Hansen and Lott (1996) argue that partial ownership interests often serve to harmonize the incentives of the contracting parties.

the unaffiliated cellular company will have a greater incentive to use substitute inputs for interconnection. This latter prediction appears to be true, since, according to industry sources, unaffiliated cellular companies tend to build their own connections between their towers and switches, whereas the affiliated cellular companies lease a line from the LEC for this connection.

If the greater efficiency associated with higher (led to lower costs of providing service of any specific quality, but did not change the costs of increasing quality, then under the efficiency hypothesis, we would expect greater concentration of ownership to reduce prices. Alternatively, if efficiency took the form of reducing the cost of providing quality, then we would expect a positive relationship between Z_B and (or ", although prices could be higher in markets with greater integration. As discussed in Section II, one important means of increasing the quality of cellular service is through the addition of more cells. Therefore, if integration primarily affects the cost of adding cells, it is plausible that efficiency will be reflected in higher quality rather than lower prices.

iii. Empirical Implications

In section A, we described how changes in quality parameters, Z_B and Z_A, affect prices and quantity. We then showed how these quality parameters vary with market characteristics under the discrimination and efficiency hypotheses. The analysis demonstrated that under the discrimination hypothesis, higher concentration of physical asset ownership will lead to higher concentration of ownership of equity in cellular company B, and both types of concentration lead to lower quality for the affiliate's rival (greater discrimination). Combining this with the results from Proposition 2 on downstream effects of discrimination implies that quality and quantity will be lower in markets with high ownership concentration. Proposition 1 implies that affiliate prices would be higher in such markets, and non-affiliate prices may be higher.

The implications of the efficiency hypothesis are more ambiguous. However, if one is willing to assume that integration leads to higher quality, rather than lower production costs, the above analysis clearly predicts a positive relationship between the affiliate's quality and the ownership concentration measures. In this case, the efficiency hypothesis has some similar implications to the discrimination hypothesis in that both predict a positive relationship between ownership concentration and the quality difference between the cellular firms. Combining this conclusion with Proposition 1, we find that under either hypothesis, higher prices for both firms, and a greater difference between the two firms' prices will be associated with greater concentration of land-line ownership and equity ownership in the cellular company. The two hypotheses differ in their predictions regarding the effects of ownership concentration on quality and quantity. The efficiency hypothesis predicts that both quantity and quality will be higher in markets with higher ownership concentration.

One word of caution about these conclusions. The cost-shifting hypothesis discussed above yields similar

Demand- and Cost-Related Factors

Six demand-related exogenous variables are included in the regression equations. These are: per capita income in each metropolitan area; the population of each metropolitan area; per capita state employment in finance, insurance, and real estate; vehicle miles per capita by state; a qualitative measure of freeway congestion in each metropolitan area compiled by the Federal Highway Administration; and the average time spent commuting to work in each metropolitan area as determined by the U.S. census. The last three variables are included to account for the frequent use of cellular telephone service by users of cellular car phones. Employment in finance, insurance, and real estate is intended to capture demand by measuring employment in industries that might have greater than average demands for cellular service. We anticipate that demand, hence price and quantity, will be increasing in these demand variables.

Three cost-related exogenous variables could help explain differences in cellular markets.[25] The median housing price in each metropolitan area is used as a measure of relative land values across the metropolitan areas, which can be a factor affecting the costs of installing base stations. This can also be a proxy for a cost-of-living index,[26] that might arguably affect cellular rates as a factor of both demand and supply. Since the cellular telephone industry is relatively young, it is likely that it exhibits learning-by-doing, as information about efficient production techniques is obtained only through experience. To account for this possibility, the price regressions include a variable for the number of months that each system was in operation, to proxy for declining marginal costs due to learning-by-doing. Finally, since taxes vary across states and localities, we include a cost variable equal to the sum of the marginal tax rates of state corporate income taxes, sales taxes, excise taxes, and other taxes that apply to cellular providers.

V. Empirical Results

The issues of primary interest are the relationships between the degree of vertical integration and market outcomes (price, quantity, and quality). These relationships could be estimated in a structural (i.e., demand and supply) model. However, structural estimates often require strong *a priori* behavioral restrictions. Because structural parameters are not our primary interest, we instead restrict our attention to reduced form regressions of price, quantity and quality on variables measuring the degree of vertical

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[25]Another relevant aspect of costs are the access fees that cellular systems pay to the local wireline telephone company in order to connect cellular calls to the wireline system. (See Kaestner and Kahn (1990)). However, consistent measures of access charges are not available.

[26]The consumer price index (CPI) is available by MSA, but only for relatively large MSAs. Using median housing prices as a measure of the cost of living rather than the CPI allows us to include many smaller cities and some states, and reduce sample selection biases.

[27]OLS results are qualitatively similar. For a discussion of theTwo Staged Aitken estimator, see Johnston (1984), p. 303.

[28]Since

Another implication of both the discrimination and the efficiency hypotheses is that price difference between the A and B licensees should increase with the degree of vertical integration Table 4 reports regressions of this price difference regressed against ownership measures. The regressions do not include the available independent variables measuring differences in demand and costs because those variables measure market characteristics common to both cellular companies. However, because the dependent variable is the price difference, the regression controls for any market-level effects on demand and costs omitted from the price level regressions. This provides a means of determining the importance of omitted variables, such as access charges. The results mimic those in table 3 in that price differences increase with both cellular company equity integration and end office ownership, with the first effect being much larger, and that there is no discernable ownership effect in the expanded sample. The fraction of tandem ownership tends to decrease the price difference in the top 100 markets, but this effect is much smaller than the others and is significant at the 5% level, rather than the 1% level of the other two variables. While these regressions do not distinguish between the discrimination and efficiency hypotheses, they do tend to support the vertical differentiation model. Specifically, that model implies that efficiency and discrimination both lead to the price effects observed in tables 3 and 4 (e.g., the affiliate's price increases more with financial ownership than does its competitor's price).

To distinguish between the discrimination hypothesis and the hypothesis that efficiencies led to higher quality, it is necessary to examine the relationship between ownership and measures of quality and quantity. Table 5 reports regression results for total transaction quantity in a market from the ServQuest survey; individual firm data were not available. Columns (1) and (3) report regression results using the fraction of households subscribing to cellular service as the dependent variable, which corresponds to the "extensive margin" model discussed in Section III and Appendix A. Columns (2) and (4) use average monthly expenditures as the dependent variable, and hence correspond to the "intensive margin" model discussed in Appendix B. Since the construction of these variables induces heteroskedasticity, observations are weighted by the number of households in the market.[30] The obvious limitation of the expenditure variable is that it confounds the effects of quantity and price. In the intensive margin model, efficiencies which increase quality increase both the quantity purchased and the total expenditure of each consumer. Discrimination decreases quantity and has an ambiguous effect on total expenditure. As a result, an increase in total expenditure would be consistent with both explanations, while a decrease would

[30]For example, the variable measuring the fraction of households subscribing will have a smaller standard error in markets where more respondents answered the survey. Since the survey attempted to be nationally representative, the number of respondents is roughly proportional to the number of households.

be consistent only with the discrimination hypothesis.

The two physical ownership measures are generally statistically significant in these regressions; subscribership and expenditures per household are increasing in end-office ownership and decreasing in tandem ownership. These effects are typically similar in magnitude, so a simultaneous, equal-sized increase in both forms of ownership would have little effect on either quantity measure.[31] An increase in tandem ownership reduces expenditures and subscribership, effects which are consistent with the discrimination hypothesis. Conversely, an increase in end-office ownership increases subscribership (despite higher prices), as suggested by the efficiency hypothesis. One potential interpretation of these results is that an increase in tandem switch ownership (the essential interconnection facility) does not lead to efficiencies, but rather enables the dominant firm to reduce the quality of cellular company A's service. Conversely, the positive signs on the percentage of end-offices variables suggests that there are efficiencies from coordination; a more extensive phone network reduces cellular company B's cost of negotiating interconnections and/or obtaining locations to construct transmitters, and hence reduces B's cost of creating a higher quality network.

Other demand and cost variables generally have the expected sign, or are not statistically significant. The exceptions to this are FIRE employment, commute time and housing prices. One interpretation of the positive coefficient on housing prices is that in addition to measuring marginal costs as we initially thought, housing prices are a demand shifter; e.g., housing prices reflect wealth in a way not reflected in per-capita income. Estimated coefficient values are qualitatively unchanged between the two samples, but standard errors tend to decrease with the larger sample size.

Table 6 represents the same regression equations as table 5, replacing the dependent variables constructed from the ServQuest data with those from the Bill Harvesting II data. As noted above, the Bill Harvesting II data contains fewer observations, and we therefore anticipate less precise coefficient estimates than in table 5. We have included the regression results for this data set primarily to test the robustness of the results in table 5. As anticipated, the standard errors of the coefficients are larger and, because

[31]These results do not appear to be the result of possible multicollinearity between the dominant firm's fraction of end offices and the fraction of tandem switches. The correlation between the two is less than 0.5 and deleting one does not appreciably change the coefficient of the other. Leamer (1978, at 170-81) suggests that when prior information on other variables does not significantly affect the parameter estimate of interest, the interpretation problem caused by multicollinearity is not severe.

Table 7 presents regression results on the subjective quality measures. Since the quality measures are based on subjective perceptions of cellular phone service, some care is required interpreting the results. In particular, the “favorable” or “satisfied” measures may reflect both “quality” and price, in that, holding "quality” constant, fewer consumers are likely to be satisfied in markets with higher prices. Hence, if we observe a higher percentage of consumers with “satisfactory” or “favorable” perceptions of their cellular service in markets with greater integration (despite the higher prices in such markets), then we would conclude that integration increases quality. If, however, price increases with integration, but satisfaction seems to be unaffected by integration, then it would indicate that quality rose with integration, but that increase was offset by the higher price. Finally, evidence that satisfaction declined with integration would support the discrimination hypothesis, and may mean greater integration is associated with both lower quality and higher prices.

As was the case for quantity, we only have observations on average quality for both cellular companies in each geographic area. Columns (1) and (3) report regression results using the ratio of respondents who view cellular service ’favorably’ to a,ower quiceLEClar seprice ’favorably s was of271) and4(1us
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industries.

Estimation results also indicate that a relatively clear picture of an industry emerged only from

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Table 1
Data Sources

Variables	**Source**	**Year**
Dependent Variables		
Cellco Price	Cellular Price and Marketing Database (CPMD), Information Enterprises	1991
Cellco Subscribership, Avg. Bill	ServQuest Survey, Equifax NDS	1995
Cellco Subscribership, Avg. Bill	Bill Harveting II, PNR and Associates	1995
Satisfactied, Favorable Opinion	ServQuest Survey, Equifax NDS	1995
Ownership Variables		
Ownership of End Offices	Local Exchange Routing Guide (LERG), Bellcore	1996
Ownership of Tandem Offices	Local Exchange Routing Guide (LERG), Bellcore	1996
Ownership of Cellco Equity	Cellular Ownership Report, Donaldson, Lufkin & Jenrette	1995[32]
Demand Variables		
Income	Survey of Current Business, BEA	1991
Population	State and Metropolitan Area Data Book, U.S. Census Bureau	1991
Finance, Insurance and Real Estate Employment per Capita	Employment and Earnings, BLS	1991
Vehicles Miles per Capita	Selected Highway Statistics and Charts, FHA	1991
Freeway Congestion	FHA	1991
Average Commute Time	1990 Census of Population and Housing, U.S. Census	1990
Cost Variables		
Median Housing Price	FHA Trends of Home Mortgage Characteristics, HUD	1991
Marginal Tax Rate	State and Local Taxation of the Cellular Industry, CTIA	1991
Months of Cellco Operation	Cellular Telephone Industry Association (CTIA)	1991

[32] As modified to reflect PacTel's Divestiture of its Cellular Phone Asset.

Table 2
Summary Statistics - Means (Standard Deviations)

	Top 100 Markets		All Markets	
Variables	License A	License B	License A	License B
Firm-Specific Variables				
Price 100 Minutes	58.01 (13.43)	59.99 (13.42)	56.05 (12.51)	58.41 (12.72)
Price 200 Minutes	92.29 (18.69)	93.75 (22.52)	89.36 (18.07)	91.20 (19.92)
Price 300 Minutes	124.06 (25.46)	126.77 (29.96)	119.95 (24.27)	122.12 (26.38)
Price 400 Minutes	154.87 (31.80)	158.25 (38.91)	150.24 (31.62)	151.64 (34.35)
Price 500 Minutes	182.92 (39.47)	189.44 (46.95)	177.75 (39.94)	180.69 (42.62)
Market Specific Variables				
ServQuest Subs. (%)	17.0	(1.8)	16.0	(1.9)
ServQuest Avg. Bill	45.43	(4.63)	46.64	(4.56)
Bill Harv. Subs. (%)	13.6	(8.0)	12.2	(14.0)
Bill Harv. Avg. Bill	47.36	(26.97)	43.66	(24.99)
Celco/Telco Favor.	0.811	(0.032)	0.810	(0.034)
Celco/Telco Satisfied	0.829	(0.051)	0.817	(0.052)
Cellco Equity (%)	84.7	(18.7)		
End Office (%)	73.8	(17.7)	69.7	(20.0)
Tandem Switch (%)	71.3	(26.6)	77.6	(26.9)
Income ($1,000)	17.88	(3.31)	16.41	(3.14)
Popl. (1,000,000)	1.34	(1.51)	0.61	(1.06)
FIRE Empl. (%)	2.79	(2.59)	2.49	(2.36)
Veh. Miles (1,000)	8.72	(0.98)	8.85	(0.96)
Freeway Congestion	2.85	(0.79)	2.15	(0.98)
Commute Time	21.15	(2.90)	19.09	(2.90)
House Price ($1,000)	77.9	(23.8)	68.8	(20.6)
Tax Rate	12.5	(5.8)	13.0	(5.4)

Table 3
Price Regression Results

	Top 100 Markets		All Markets	
Variables	A License	B License	A License	B License
Cellco Ownership	0.127* (0.045)	0.236* (0.054)		
End Office Ownership	0.029 (0.067)	0.205* (0.071)	-0.073 (0.044)	-0.013 (0.041)
Tandem Switch Ownership	-0.049 (0.036)	-0.041 (0.042)	0.001 (0.030)	0.024 (0.029)
Log Income	-0.114+ (0.056)	-0.015 (0.073)	0.069 (0.047)	0.154* (0.045)
Log Population	-0.035+ (0.016)	-0.033 (0.023)	-0.029+ (0.013)	-0.033+ (0.014)
Log FIRE Employment	0.030* (0.011)	0.048* (0.012)	0.018+ (0.008)	-0.001 (0.007)
Log Vehicle Miles	-0.184+ (0.093)	-0.164 (0.104)	-0.280* (0.071)	-0.379* (0.066)
Freeway Congestion	0.029+ (0.012)	0.038* (0.014)	0.034* (0.010)	0.045* (0.009)
Log Commute Time	0.253* (0.095)	0.127 (0.107)	0.201* (0.074)	0.190* (0.072)
Log Housing Price	0.292* (0.041)	0.263* (0.045)	0.123* (0.022)	0.091* (0.021)
Log Tax Rate	0.087* (0.017)	0.015 (0.022)	0.037* (0.014)	0.023+ (0.014)
Log Month of Operation	-0.018 (0.021)	0.104 (0.080)	-0.036+ (0.016)	-0.021 (0.029)
Observations	420	435	905	1000
R^2	.884	.828	.812	.801

To account for heteroskedasticity, an Aitken estimator was used. An intercept term and dummy variables for each calling volume plan were included in regressions but are not reported. Standard errors are in parentheses. A plus sign indicates statistical significance at the 10% level and an asterisk indicates the 1% level.

Table 4
Price Difference Regression Results
(Affiliate Price minus Independent Firm Price)

Variables	Top 100 Markets	All Markets
Cellco Ownership	18.90* (2.88)	
End Office Ownership	11.93* (3.58)	2.71 (2.19)
Tandem Switch Ownership	-5.07+ (2.24)	1.30 (1.52)
Observations	445	935
R^2	.140	.004

An intercept term and dummy variables for each calling volume plan were included in regressions but are not reported. Standard errors are in parentheses. A plus sign indicates statistical significance at the 10% level and an asterisk indicates the 1% level.

Table 5
ServQuest Quantity Regression Results

Variables	Top 100 Markets: Cellular Subscribership	Top 100 Markets: Cellular Expenditures per Capita	All Markets: Cellular Subscribership	All Markets: Cellular Expenditures per Capita
Intercept	-1.025* (0.168)	-67.557* (17.737)	-0.956* (0.109)	-61.915* (12.628)
Cellco Ownership	-0.002 (0.009)	1.189 (0.915)		
End Office Ownership	0.021+ (0.009)	1.042 (0.908)	0.016* (0.005)	0.262 (0.587)
Tandem Switch Ownership	-0.016* (0.005)	-1.774* (0.582)	-0.012* (0.004)	-1.005+ (0.412)
Log Income	0.068* (0.011)	2.185+ (1.127)	0.072* (0.007)	3.828* (0.765)
Log Population	0.003 (0.002)	0.822* (0.231)	0.003+ (0.001)	0.861* (0.154)
Log FIRE Employment	-0.002 (0.002)	0.081 (0.177)	-0.002 (0.001)	0.023 (0.117)
Log Vehicle Miles	0.050 (0.013)	3.006+ (1.356)	0.044* (0.008)	2.180+ (0.967)
Freeway Congestion	0.004 (0.005)	-0.013 (0.548)	0.005+ (0.003)	-0.097 (0.350)
Log Commute Time	-0.040* (0.012)	-6.275* (1.276)	-0.038* (0.008)	-6.027* (0.919)
Log Housing Price	0.014+ (0.006)	5.131* (0.637)	0.009+ (0.004)	3.866* (0.408)
Log Tax Rate	0.002 (0.003)	-0.504+ (0.267)	0.002 (0.002)	-0.401+ (0.197)
Observations	89	89	198	198
R^2	.658	.710	.647	.662

To account for heteroskedasticity, observations are weighted by population. Standard errors are in parentheses. A plus sign indicates statistical significance at the 10% level and an asterisk indicates the 1% level.

Table 6
Bill Harvesting Quantity Regression Results

Variables	Top 100 Markets: Cellular Subscribership	Top 100 Markets: Cellular Expenditures per Capita	All Markets: Cellular Subscribership	All Markets: Cellular Expenditures per Capita
Intercept	-1.678+ (0.884)	-166.033* (58.317)	-1.410+ (0.692)	-161.248* (48.823)
Cellco Ownership	-0.023 (0.046)	0.373 (3.039)		
End Office Ownership	0.156* (0.045)	7.224+ (2.915)	0.151* (0.032)	6.441* (2.301)
Tandem Switch Ownership	-0.060+ (0.029)	-4.366+ (1.937)	-0.073* (0 . 0 4 6) 1.93787 T0Td (0.1	

(0.029 .0187 Tc -3.72 -9.36 End Office 8032)

Table 7
Surveyed Quality Regression Results

	Top 100 Markets		All Markets	
Variables	Ratio of Cellular to LEC 'Favorable'	Ratio of Cellular to LEC 'Satisfied'	Ratio of Cellular to LEC 'Favorable'	Ratio of Cellular to LEC 'Satisfied'
Intercept	0.398 (0.333)	0.351 (0.493)	0.425* (0.222)	0.349 (0.332)
Cellco Ownership	0.009 (0.017)	0.026 (0.025)		
End Office Ownership	0.032 + (0.017)	0.055^{+} (0.025)	0.025^{+} (0.010)	0.039^{+} (0.015)
Tandem Switch Ownership	-0.034* (0.011)	-0.064* (0.016)	-0.027* (0.007)	-0.048* (0.011)
Log Income	-0.044^{+} (0.021)	-0.099* (0.031)	-0.031^{+} (0.013)	-0.059* (0.020)
Log Population	0.005 (0.004)	0.016^{+} (0.006)	0.005^{+} (0.003)	0.017* (0.004)
Log FIRE Employment	0.009^{+} (0.003)	0.010^{+} (0.005)	0.007* (0.002)	0.008* (0.003)
Log Vehicle Miles	0.057^{+} (0.025)	0.057 (0.038)	0.050* (0.017)	0.045^{+} (0.025)
Freeway Congestion	-0.006 (0.010)	-0.003 (0.015)	-0.005 (0.006)	-0.004 (0.009)
Log Commute Time	-0.077* (0.024)	-0.151* (0.035)	-0.074* (0.016)	-0.149* (0.024)
Log Housing Price	0.038* (0.012)	0.096* (0.018)	0.030* (0.007)	0.073* (0.011)
Log Tax Rate	0.001 (0.005)	-0.002 (0.007)	0.001 (0.003)	-0.001 (0.005)

00126 3.003)406.018 /TT0 0.36 Td (-0n087 Tc 0m6)Tj 056 l.367/TT0 0.36 Td (109)Tj 0.f4.003-0m60.009)

Appendix A - A Generalized Extensive Margin Model

In this appendix, we generalize the model in the text by allowing variation in 2_i (consumer i's reservation value for the good). Although a fully generalized model would allow for a continuum of 2_i, the important properties of that model are contained in a simpler model in which 2_i takes on one of two values. The reason that considering only two values of 2 is sufficient to capture the heterogeneity is that for any given 2, consumers will segment themselves on the basis on their x_i in one of two ways. Hence, if we allow sufficient heterogeneity that some consumers fall into each category, then we have captured the essential feature of the more general model.

Specifically, for a given 2, one possibility is that consumers with x_i sufficiently high will buy from firm B (the high-qu729w -0.0348 Tc 184c 0 Tw -330.96 -15irs72(smod0471iTj i -1-0.9896 Tw (for a giDeTc (8tsuspen
fo79.6 Tfr565cient hashemsnt themse7i1.04 Tf a fully -1 Tw (-1.

$$q_B \; ' \; D \int_{\frac{P_B\&P_A}{Z_B\&Z_A}}^{1} dx \; \% \; (1\&D) \int_{\frac{P_B\&2_2}{Z_B}}^{1} dx \; ' \; D\left(1\&\frac{P_B\&P_A}{Z_B\&Z_A}\right) \; \% \; (1\&D)\left(1\&\frac{P_B\&2_2}{Z_B}\right) \qquad \text{(A.1)}$$

$$A_B \; ' \; \left[D\left(1 \; \& \; \frac{P_B\&P_A}{Z_B\&Z_A}\right) \; \% \; (1\&D)\left(1 \; \& \; \frac{P_B\&2_2}{Z_B}\right)\right]\left(P_B\&C\right)$$

[33]? must be small in the sense that all consumers who prefer A's product to B's prefer no product to either firms' product. This requires

$$\frac{P_B\&2}{Z_B} \; > \; \frac{P_B\&P_A}{Z_B\&Z_A}, \; so \; that \; 2 \; < \; P_B\&\frac{Z_B}{Z_B\&Z_A}(P_B\&P_A).$$

$$P_B\ (P_A)\ \ '\ \ \frac{\mathrm{D}Z_B P_A\ \%\ (Z_B \& Z_A)\big(Z_B\ \%\ C\ \%\ (1\&\mathrm{D})\mathbf{2}_2\big)\%\mathrm{D}Z_A C}{2\,(Z_B\%\mathrm{D}Z_A\&Z_A)}\,. \qquad \text{(A.2)}$$

$$P_A\ (P_B)\ \ '\ \ \frac{(P_B\&\mathbf{2}_1)Z_A}{2Z_B}\ \%\ \frac{C\%\mathbf{2}_1}{2}\,.$$

$$\lceil$$

$$P_A^{(}\ \ '\,\mathrm{P}_B^{(}$$

$$q_B = \left(1 - \frac{P_B - P_A}{Z_B - Z_A}\right)(Z_B - P_B).$$

So that its objective function is

$$\pi_B = \left(1 - \frac{P_B - P_A}{Z_B - Z_A}\right)(Z_B - P_B)(P_B - C).$$

and its first-order condition with respect to P_B is

$$0 = 3P_B^2 - 2P_B(2Z_B - Z_A + C + P_A) + CZ_B + (Z_B + C)(Z_B - Z_A + P_A).$$

It can be shown that the derivative of P_B with respect to Z_B is positive and the derivative with respect to Z_A is negative (i.e., B's best-response function is increasing in Z_B and decreasing in Z_A).

Because all customers are assumed to buy the good,

$$q_A = \int_0^{\frac{P_B - P_A}{Z_B - Z_A}} (Z_A - P_A)\, dx = \left(\frac{P_B - P_A}{Z_B - Z_A}\right)(Z_A - P_A)$$

so that A's objective function is

$$\pi_A = \frac{P_B - P_A}{Z_B - Z_A}(Z_A - P_A)(P_A - C)$$

and its first-order condition with respect to P_A is

$$0 = 3P_A^2 - 2P_A(Z_A + C + P_B) + Z_A C + (Z_A + C)P_B.$$

Proposition A.2: Let P_i^* be the equilibrium value of firm i's price, then $\partial P_B^*/\partial Z_B > \partial P_A^*/\partial Z_B > 0$. Proof: Using the implicit function theorem, we note that the derivative of P_A with respect to Z_B is zero, while an increase in Z_B shifts out B's best-response function. Therefore, as long as both best-response functions are upward sloping, and the slopes are less than one, an equilibrium exists whereby both prices are increasing in Z_B. The slope of A's best response function is

$$\frac{MP_A(P_B)}{MP_B} \; ' \; \frac{2P_A\&}{}$$

Z_A as Z_A approaches Z_B. Figure A1 presents a simulation of the effect of Z_A on prices. This simulation suggests that the predictions of the discrimination hypothesis for prices will not distinguish between the two hypotheses. That is, a finding that both prices are increasing in the degree of integration is consistent with both the discrimination and efficiency hypotheses. However, there is a difference between the hypotheses in regard to the effect of integration on output.

Proposition A.4: Greater discrimination leads to a reduction in aggregate sales.

Proof: Taking the derivative of $q_B + q_A$ with respect to Z_A, we get $Mq/MZ_A = (P_B - P_A)^2/(Z_B - Z_A) > 0$. Hence, greater discrimination reduces sales.**#**

Figure A1
The Effect of Discrimination on Prices (for C = 1, Z_B = 10)