MATERIAL ON WEBSITE

The attached material provides background for the results in Reiffen, Schumann and Ward "Discriminatory Dealing with Downstream Competitors: Evidence from the Cellular Industry"

ATTACHMENT A - Additional Regressions Results

The following tables present the results of additional regression equations. These equations were estimated in order to test the robustness of the results in the paper. Tables V - A and V - B provide some evidence as to whether the observed relationship between the percentage of consumers having "satisfactory" or "favorable" opinions of their cellular carrier (relative to the percentage for their LEC) and the measures of physical asset concentration are due to multicollinearity between the two physical asset measure (end-offices switches and tandem switches). Table V - A shows the relationship between the percentage of consumers that have a favorable opinion of their cellular carrier and either of the two asset measures is robust to inclusion of the other asset measure. For example, in the 98 large markets the coefficient on tandem switches is -.031 when both measures are included on the right-hand side (column (3)), and -.027 when the end-office switch variable is omitted (column (2)). The end-office coefficient has a somewhat larger change, but the sign is the same, and the magnitudes are similar. Table V - B, presents the same evidence for "satisfactory" opinions.

Recall that the left-hand side variable in these regressions is the percentage of consumers who have these opinions of their cellular company divided by the percentage who hold the opinion in regard to their LEC. We normalized in this manner is order to adjust for cross-sectional differences in how consumers generally rate services. Tables V - C and V - D provide evidence relating to the importance of our decision to normalize consumers' opinions. The left-hand side variable in table V - C is the numerator from the left-hand side variable in table V (i.e, the percentage of consumer who are have satisfactory or favorable opinions of their cellular company), while the left-hand side variable in table V - D is the denominator from that variable. The results show that, as in table V, consumers' opinions of their cellular company is increasing in end-office concentration, and decreasing in tandem concentration. Conversely, table V - D demonstrates that there is virtually no relationship between consumers' perceptions of their LEC and these concentration measures.

Table VII - A presents additional price regression results. In this table, the left-hand side variable in each column is the average per-minute price for different monthly usage levels in the 98 large markets. (the left-hand side variable in table VII is the average of the rates for the 5 usage levels). Table VII - B presents the same regressions run for all markets. The coefficients are quite similar across usage levels in both tables. Finally, table VII - C regresses the difference between the affiliate's average price and its rivals average price in each market against the concentration variables. Proposition 1 shows that the two cellular companies' prices will increase by similar amounts when the access price rises. The theory implies also that the difference between the two companies' prices should be increasing in ownership concentration. Hence, if one finds a relationship between ownership concentration and the price difference, it suggests that the observed relationship between price levels and ownership concentration in table 7 is not due to the omission of the access price variable. As shown below, the relationships between the price difference and the ownership variables are quite similar to the relationship between levels and those variables depicted in the paper. Therefore, we conclude the results are not likely to be an artifact of the omission of the access price variable.

Table V - A

Consumer Opinion 'Favorable' Regression Results

Variables	98 Large Markets			All Markets		
Intercept	-0.107 (0.371)	0.257 (0.365)	0.304 (0.357)	0.072 (0.245)	0.245 (0.243)	0.359 (0.243)
Cellco Equity HHI	-0.006 (0.014)	0.014 (0.012)	0.003 (0.013)			
End Office HHI	0.015 (0.012)		0.025+ (0.013)	0.008 (0.007)		0.019* (0.007)
Tandem Switch HHI		-0.027* (0.008)	-0.031* (0.008)		-0.020* (0.005)	-0.025* (0.005)
Log Income	0.007 (0.020)	-0.003 (0.019)	-0.007 (0.019)	0.001 (0.012)	-0.001 (0.012)	-0.006 (0.012)
Log Population	0.007+ (0.004)	0.003 (0.004)	0.004 (0.004)	0.006* (0.002)	0.003 (0.002)	0.003 (0.002)
Log FIRE Employment	0.009* (0.003)	0.008* (0.003)	0.009* (0.003)	0.008* (0.002)	0.008* (0.002)	0.008* (0.002)
Log Vehicle Miles	0.077* (0.022)	0.053* (0.021)	0.060* (0.021)	0.066* (0.015)	0.055* (0.014)	0.055* (0.014)
Freeway Congestion	-0.005 (0.009)	0.002 (0.009)	0.002 (0.009)	-0.003 (0.005)	-0.000 (0.005)	-0.000 (0.005)
Log Commute Time	-0.075* (0.021)	-0.081* (0.020)	-0.079* (0.019)	-0.073* (0.014)	-0.073* (0.014)	-0.073* (0.013)
Log Housing Price	0.015 (0.011)	0.021+ (0.011)	0.022+ (0.010)	0.018* (0.006)	0.020* (0.006)	0.019* (0.006)
Log Tax Rate	0.010 (0.043)	0.000 (0.041)	-0.018 (0.041)	0.002 (0.030)	-0.002 (0.029)	-0.017 (0.029)
Observations	92	92	92	236	236	236
R^2	.400	.467	.497	.294	.333	.355

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 V - B
Consumer Opinion 'Satisfied' Regression Results

Variables	98 Large Markets			All Markets		
Intercept	-0.405 (0.554)	0.294 (0.517)	0.371 (0.502)	-0.134 (0.357)	0.187 (0.347)	0.394 (0.345)
Cellco Equity HHI	-0.000 (0.020)	0.035+ (0.017)	0.017 (0.018)			
End Office HHI	0.021 (0.018)		0.040+ (0.016)	0.014 (0.010)		0.033* (0.010)
Tandem Switch HHI		-0.053* (0.011)	-0.059* (0.011)		-0.037* (0.008)	-0.046* (0.008)
Log Income	-0.015 (0.030)	-0.034 (0.027)	-0.043+ (0.026)	-0.008 (0.017)	-0.013 (0.017)	-0.022 (0.017)
Log Population	0.019* (0.006)	0.013+ (0.005)	0.013+ (0.005)	0.018* (0.003)	0.014* (0.003)	0.013* (0.003)
Log FIRE Employment	0.012* (0.005)	0.011* (0.004)	0.012* (0.004)	0.010* (0.003)	0.010* (0.003)	0.011* (0.003)
Log Vehicle Miles	0.101+ (0.034)	0.057+ (0.030)	0.068+ (0.030)	0.078* (0.021)	0.057* (0.021)	0.058* (0.020)
Freeway Congestion	-0.006 (0.013)	0.008 (0.013)	0.008 (0.012)	-0.002 (0.008)	0.003 (0.007)	0.004 (0.007)
Log Commute Time	-0.146* (0.032)	-0.157* (0.028)	-0.154* (0.027)	-0.146* (0.020)	-0.145* (0.019)	-0.145* (0.019)
Log Housing Price	0.057* (0.017)	0.069* (0.015)	0.070* (0.015)	0.051* (0.009)	0.055* (0.009)	0.054* (0.009)
Log Tax Rate	-0.020 (0.065)	-0.042 (0.058)	-0.072 (0.057)	-0.030 (0.043)	-0.037 (0.041)	-0.064 (0.041)
Observations	92	92	92	236	236	236
R^2	.458	.566	.599	.392	.446	.474

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 V - C
Consumer Satisfaction Regression Results - Cellcos

Variables	98 Large Markets Cellular 'Favorable'	98 Large Markets Cellular 'Satisfied'	All Markets Cellular 'Favorable'	All Markets Cellular 'Satisfied'
Intercept	-0.003 (0.147)	0.080 (0.233)	0.003 (0.097)	0.062 (0.156)
Cellco Equity HHI	0.000 (0.005)	0.008 (0.008)		
End Office HHI	0.009+ (0.005)	0.015+ (0.007)	0.006+ (0.003)	0.013* (0.004)
Tandem Switch HHI	-0.012* (0.003)	-0.026* (0.005)	-0.011* (0.002)	-0.021* (0.004)
Log Income	0.020+ (0.008)	-0.007 (0.012)	0.022+ (0.005)	0.006 (0.008)
Log Population	0.001 (0.001)	0.006* (0.002)	0.000 (0.001)	0.006* (0.001)
Log FIRE Employment	0.001 (0.001)	0.003 (0.002)	0.001 (0.001)	0.003+ (0.001)
Log Vehicle Miles	0.029* (0.009)	0.036* (0.013)	0.025* (0.006)	0.031* (0.009)
Freeway Congestion	0.000 (0.003)	0.004 (0.006)	0.001 (0.002)	0.004 (0.003)
Log Commute Time	-0.046* (0.008)	-0.094* (0.013)	-0.042* (0.005)	-0.088* (0.009)
Log Housing Price	0.005 (0.004)	0.032* (0.007)	0.004 (0.003)	0.024* (0.004)
Log Tax Rate	-0.007 (0.017)	-0.026 (0.026)	-0.005 (0.011)	-0.022 (0.018)
Observations	92	92	236	236
R^2	.639	.657	.511	.534

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 V - D
Consumer Satisfaction Regression Results - LECs

Variables	98 Large Markets LEC 'Favorable'	98 Large Markets LEC 'Satisfied'	All Markets LEC 'Favorable'	All Markets LEC 'Satisfied'
Intercept	0.284* (0.089)	0.371* (0.088)	0.265* (0.061)	0.346* (0.060)
Cellco Equity HHI	-0.001 (0.003)	0.000 (0.003)		
End Office HHI	-0.002 (0.003)	-0.004 (0.003)	-0.002 (0.002)	-0.002 (0.002)
Tandem Switch HHI	-0.002 (0.002)	0.002 (0.002)	0.000 (0.001)	0.001 (0.001)
Log Income	0.028* (0.005)	0.015* (0.005)	0.029* (0.003)	0.019* (0.003)
Log Population	-0.001 (0.001)	-0.000 (0.001)	-0.001 (0.001)	-0.000 (0.001)
Log FIRE Employment	-0.003* (0.001)	-0.003* (0.001)	-0.003* (0.001)	-0.003* (0.001)
Log Vehicle Miles	0.003 (0.005)	0.005 (0.005)	0.002 (0.004)	0.004 (0.003)
Freeway Congestion	-0.001 (0.002)	0.000 (0.002)	0.002 (0.001)	0.003+ (0.001)
Log Commute Time	-0.014* (0.005)	-0.025* (0.005)	-0.013* (0.003)	-0.023* (0.003)
Log Housing Price	-0.005 (0.003)	-0.002 (0.003)	-0.005* (0.002)	-0.003 (0.002)
Log Tax Rate	0.001 (0.010)	0.010 (0.010)	0.003 (0.007)	0.010 (0.007)
Observations	92	92	236	236
R^2	.648	.719	.547	.615

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 VII - A
Additional Price Regression Results for 98 Large Markets

Variables	100 Minutes	200 Minutes	300 Minutes	400 Minutes	500 Minutes
Intercept	-3.810 (2.401)	2.292 (2.916)	0.418 (2.103)	0.339 (2.191)	-1.600 (2.158)
Equity HHI × 'B' License Dummy	0.325* (0.102)	0.272* (0.098)	0.312* (0.083)	0.272* (0.084)	0.265* (0.085)
End Office HHI × 'B' License Dummy	0.035 (0.113)	0.096 (0.113)	0.132 (0.092)	0.209^{+} (0.094)	0.238^{+} (0.095)
Tandem Switch HHI × 'B' License Dummy	-0.152^{+} (0.080)	-0.163^{+} (0.075)	-0.098 (0.068)	-0.114^{+} (0.064)	-0.132^{+} (0.065)
'A' License Dummy	0.254^{+} (0.117)	0.154 (0.132)	0.175^{+} (0.102)	0.162^{+} (0.104)	0.133 (0.104)
Equity HHI × 'A' License Dummy	-0.020 (0.096)	0.059 (0.130)	0.168^{+} (0.088)	0.160^{+} (0.090)	0.185^{+} (0.089)
End Office HHI × 'A' License Dummy	-0.094 (0.111)	0.015 (0.151)	-0.017 (0.101)	0.007 (0.105)	0.040 (0.101)
Tandem Switch HHI × 'A' License Dummy	-0.069 (0.074)	-0.073 (0.098)	-0.078 (0.066)	-0.072 (0.069)	-0.112 (0.068)
Log Income	0.114 (0.119)	0.076 (0.139)	0.064 (0.102)	0.176^{+} (0.104)	0.244^{+} (0.102)
Log Population	-0.073* (0.029)	-0.075^{+} (0.032)	-0.080* (0.025)	-0.063* (0.025)	-0.071* (0.025)
Log FIRE Employment	0.043* (0.018)	0.029 (0.020)	0.014 (0.016)	0.011 (0.016)	0.011 (0.015)
Log Vehicle Miles	-0.002 (0.152)	-0.398^{+} (0.178)	-0.235^{+} (0.132)	-0.254^{+} (0.138)	-0.231^{+} (0.136)
Freeway Congestion	0.061* (0.021)	0.055^{+} (0.022)	0.071* (0.018)	0.075* (0.018)	0.075* (0.018)
Log Commute Time	0.282^{+} (0.152)	0.249^{+} (0.179)	0.315^{+} (0.134)	0.216 (0.140)	0.250^{+} (0.136)
Log Housing Price	0.322* (0.076)	0.282* (0.083)	0.312* (0.064)	0.254* (0.063)	0.253* (0.063)
Log Tax Rate	0.563^{+} (0.277)	0.348 (0.326)	0.438^{+} (0.236)	0.470^{+} (0.243)	0.747* (0.233)
Log Months of Operation	-0.004 (0.041)	0.004 (0.046)	-0.021 (0.036)	-0.039 (0.039)	-0.050 (0.037)
Retail Regulation	-0.007 (0.031)	-0.046 (0.033)	-0.012 (0.025)	0.007 (0.026)	0.006 (0.026)
Observations	184	184	184	184	184
R^2	.410	.340	.487	.489	.525

To account for heteroskedasticity, an Aitken estimator was used. Standard errors are in parentheses. A plus sign indicates statistical significance at the 10% level and an asterisk indicates the 1% level.

Table VII- B
Additional Price Regression Results for All Markets

Variables	100 Minutes	200 Minutes	300 Minutes	400 Minutes	500 Minutes
Intercept	-0.099	3.450+	3.368+	3.847+	3.027+
	(1.553)	(1.641)	(1.461)	(1.507)	(1.696)
End Office HHI × 'B' License Dummy	0.044	0.103+	0.122+	0.136+	0.169+
	(0.060)	(0.058)	(0.054)	(0.056)	(0.064)
Tandem Switch HHI × 'B' License Dummy	-0.019	-0.048	-0.000	-0.016	-0.059
	(0.054)	(0.053)	(0.048)	(0.050)	(0.057)
'A' License Dummy	-0.021	0.005	0.019	0.019	0.006
	(0.065)	(0.070)	(0.061)	(0.062)	(0.071)
End Office HHI × 'A' License Dummy	0.004	0.038	0.083	0.106+	0.151+
	(0.061)	(0.068)	(0.057)	(0.059)	(0.065)
Tandem Switch HHI × 'A' License Dummy	-0.019	-0.044	-0.040	-0.056	-0.099+
	(0.053)	(0.060)	(0.051)	(0.052)	(0.057)
Log Income	0.216*	0.153+	0.127+	0.161+	0.150+
	(0.068)	(0.071)	(0.063)	(0.066)	(0.075)
Log Population	-0.023	-0.032+	-0.034+	-0.033+	-0.036+
	(0.016)	(0.017)	(0.015)	(0.016)	(0.018)
Log FIRE Employment	0.048*	0.033*	0.014	0.001	-0.010
	(0.011)	(0.011)	(0.011)	(0.011)	(0.012)
Log Vehicle Miles	0.098	-0.148	-0.200+	-0.306*	-0.302+
	(0.090)	(0.097)	(0.088)	(0.090)	(0.101)
Freeway Congestion	0.025+	0.015	0.025+	0.023+	0.028+
	(0.013)	(0.014)	(0.012)	(0.012)	(0.014)
Log Commute Time	0.024	0.204+	0.313*	0.292*	0.322*
	(0.092)	(0.098)	(0.087)	(0.091)	(0.102)
Log Housing Price	0.096*	0.076+	0.087*	0.095*	0.083+
	(0.032)	(0.032)	(0.028)	(0.030)	(0.033)
Log Tax Rate	-0.004	-0.075	0.101	0.190	0.448+
	(0.185)	(0.192)	(0.167)	(0.172)	(0.190)
Log Months of Operation	-0.024	-0.024	-0.043+	-0.040+	-0.039+
	(0.021)	(0.021)	(0.019)	(0.020)	(0.022)
Retail Regulation	0.016	0.006	0.020	0.032+	0.044+
	(0.019)	(0.020)	(0.018)	(0.019)	(0.021)
Observations	484	484	484	484	484
R^2	.164	.135	.209	.215	.205

To account for heteroskedasticity, an Aitken estimator was used. Standard errors are in parentheses. A plus sign indicates statistical significance at the 10% level and an asterisk indicates the 1% level.

Table VII - C

Difference in Average Price per Minute Regression Results

Variables	98 Large Markets	All Markets
Intercept	-0.105*	-0.009
	(0.028)	(0.014)
Equity HHI	0.096*	
	(0.034)	
End Office HHI	0.082+	0.026
	(0.036)	(0.018)
Tandem Switch HHI	-0.015	0.008
	(0.025)	(0.016)
Observations	92	242
R^2	.203	.013

To account for heteroskedasticity, an Aitken estimator was used. Standard errors are in parentheses. A plus sign indicates statistical significance at the 10% level and an asterisk indicates the 1% level.

ATTACHMENT B -
Example of an Equilibrium in which Downstream Firm Choose Quality

In the paper, we assume that the "quality" of both the affiliate and its rival is determined by the upstream firm. A more general version of this model allows the downstream firms to choose their levels of quality, given some cost of acquiring quality. We can incorporate the notions of discrimination and efficiency in such a model by allowing the cost of quality to differ between the affiliate and its rival.

Specifically, Choi and Shin (1992) show that in the model of interaction used in the text, the profits to the high (firm 1) and low (firm 2) quality firms can be written in terms of their qualities -

$$p_1(z_1) = \frac{4\bar{x}z_1^2(z_1 - z_2)}{(4z_1 - z_2)^2} \quad p_2(z_2) = \frac{\bar{x}z_1 z_2(z_1 - z_2)}{(4z_1 - z_2)^2} \qquad \textbf{(1)}$$

where, as in the paper, z_i is firm i's quality and $\bar{x}$ is the marginal value of quality to the consumer who values quality the most.

If we add the assumption that quality is costly to obtain, (as in Boom (1995)). then the net profits are the expressions in (1) minus the cost of acquiring quality. Let the cost of quality be F(Z, U), where U is the input supplied by the upstream firm. Following Boom, we assume $F(0,U) = 0$, $\partial F/\partial Z > 0$, $\partial^2 F/\partial Z^2 > 0$, and $\partial F/\partial U < 0$. In the model, we can think of discrimination as decreases in the rival's U, and efficiencies as increases in the affiliate's U.

Since $\partial^2 F/\partial Z^2 > 0$ and $\partial^2 p_1/\partial Z^2 < 0$ it follows that for any given Z_2, there is a unique profit-maximizing Z_1 and conversely. In fact, when the two firms have the same value of U, there are two equilibria; one in which where $Z_2 > Z_1$ and one in which $Z_1 > Z_2$. The comparative statics in the equilibria have the expected properties; e.g., $\partial Z_i/\partial U_i > 0$. In addition, in equilibrium, an exogenous fall in Z_i induces firm j to lower its quality as well.

What is most interesting for our purposes is that if U_A, the input provided by the upstream firm to the rival, is sufficiently smaller than U_B, there is a unique equilibrium. This occurs because as U_A falls, so does $Z_{A,}$ and if Z_A is sufficiently small, it cannot be maintained as the higher quality product (i.e., it will pay for B to "leapfrog" over A in quality). The following example illustrates:

Example 1:

Assume the conditions above hold, so that the profits (gross of the cost of acquiring quality) are as in (1) for quality levels z_1 and z_2 where $z_1 > z_2$. Let the cost of acquiring quality equal $F_U = (Z/U)^2$. For $\bar{x} = 3$, and $U_A = U_B = 5$, there are two equilibria, each characterized by one firm having quality $z_1 = 28.6$, and the other having quality $z_2 = 5.5$. As the upstream firm starts to discriminate (lowering U_A) quality of both firms fall in either equilibrium (i.e., in the equilibrium in which $z_A > z_B$ and the equilibrium in which $z_B > z_A$). This is illustrated in figures 1 and 2. Figure 1 shows the low-quality firm's quality choice, while figure 2 shows the high quality firm's quality choice. In either figure, discrimination shifts the rival's cost curve up. For example, $F_5(z)$ is the cost curve with no discrimination, and $F_4(z)$ represents firm A's cost of quality when the LEC discriminates by reducing U_A to 4. When $U_A = 4$, the equilibrium conditional on $z_A > z_B$, is $Z_A^H = 18.4$ and $Z_B^L = 4.75$. It is important to note that given $z_A = 18.4$, this choice of z_B does maximize B's profit. The other equilibrium for $U_A = 4$ is for $z_B > z_A$ is $Z_B^H = 28.3$, $Z_A^L = 3.8$. In both of these equilibrium, both firms' qualities are below the corresponding quality in the non-discrimination equilibrium. For further decrease in U_A, z_A continues to fall in either "equilibrium." However, for U_A sufficiently small, $z_A > z_B$ is no longer an equilibrium. For example with $U_A = 3$, the "equilibrium" conditional on $z_A > z_B$ is $Z_A^H = 10.62$ $Z_B^L = 3.66$. However, conditional on $z_A = 10.62$, the profit-maximizing strategy for firm B is to choose a quality level well in excess of z_A. Hence, for $U_A = 3$, the unique equilibrium has $z_B > z_A$ $(Z_B^H ' 28.1, Z_A^L ' 3.2)$.

References

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Choi, Chong Ju and Hyun Song Shin "A Comment on a Model of Vertical Product Differentiation" The Journal of Industrial Economics , 40 (1992), 229-232.

Figure 1: Low Quality Firm's Quality

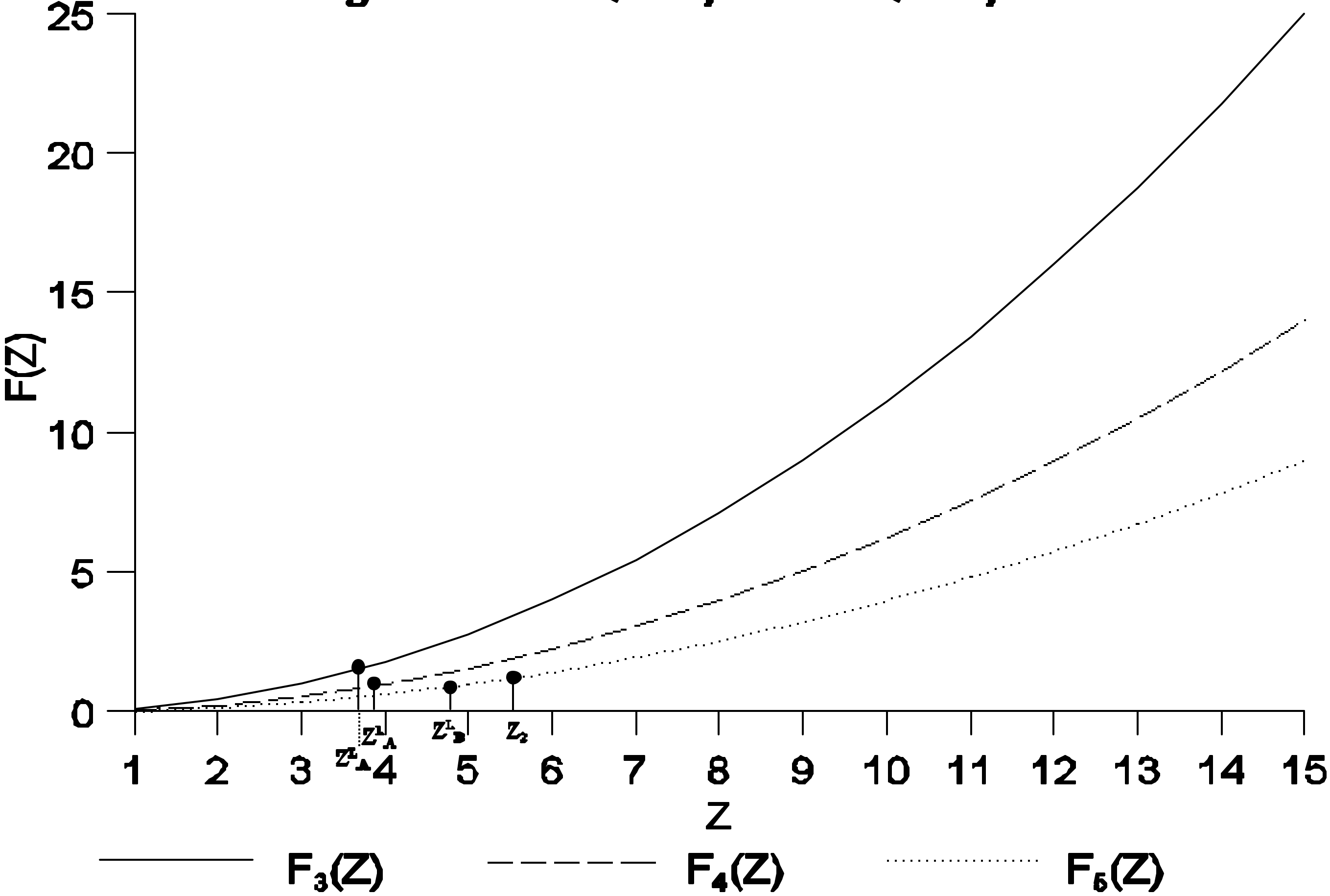
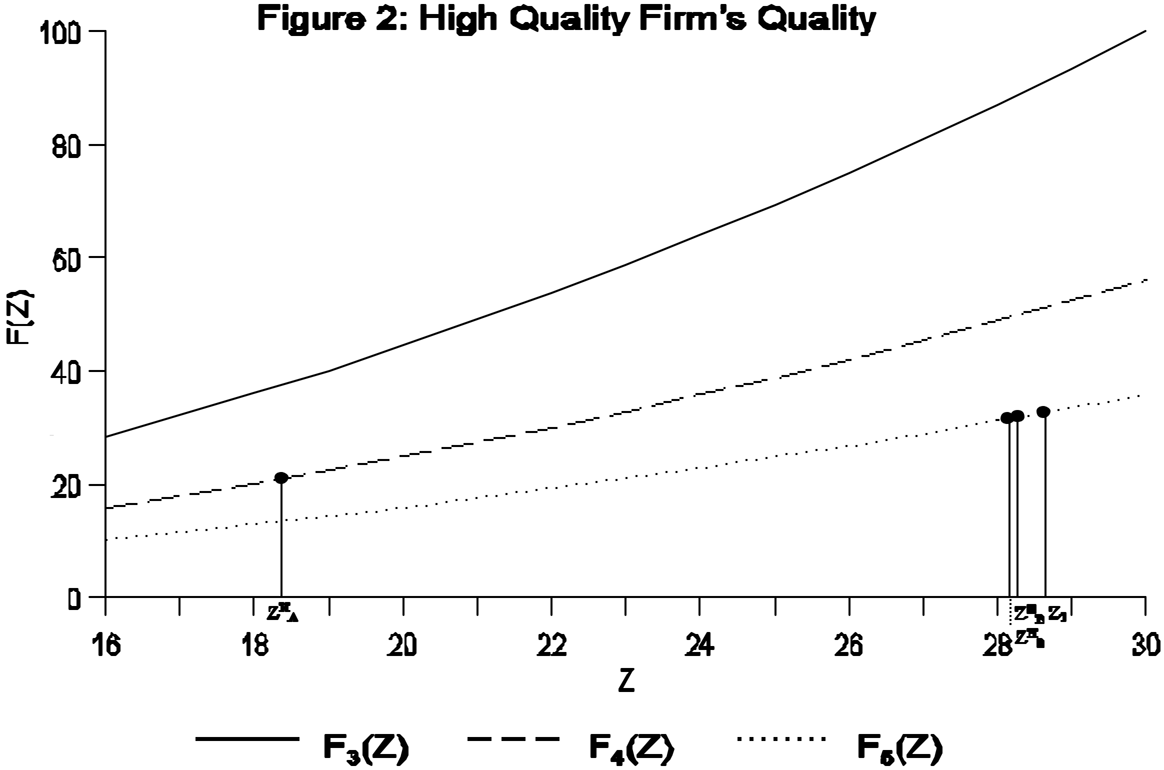


Figure 2: High Quality Firm's Quality



ATTACHMENT C - PROOF OF PROPOSITION 1

Proposition 1: Given the assumptions in the text,

a. $\partial P_B^*/\partial Z_B > \partial P_A^*/\partial Z_B \geq 0$. Also, $\partial P_A^*/\partial Z_B = 0$ implies $P_A^* = C$ for all Z_A, Z_B.

b. $\partial P_B^*/\partial Z_A < 0$, and $\partial(P_B^* - P_A^*)/\partial Z_A < 0$

c. $\partial P_A^*/\partial Z_A$ is non-monotonic, and $\partial^2 P_A^*/\partial Z_A^2 < 0$. In particular, if $(Z_B - Z_A)$ is small, $\partial P_A^*/\partial Z_A < 0$.

Proof: a. Let $f = 4Z_B - Z_A$. Then, $\partial P_B^*/\partial Z_B = [2\bar{x}(4Z_B^2 + Z_A^2 - 2Z_BZ_A) - 3Z_AC]/f^2$, which is positive since $Z_B > C/\bar{x}$ and $Z_B > Z_A > 0$. $\partial P_A^*/\partial Z_B = 3Z_A(\bar{x}Z_A - 2C)/f^2$. This takes the sign of $\bar{x}Z_A - 2C$. To sign this expression, note that in order that A's price exceeds his cost, it must be true that

$$P_A^* = \frac{\bar{x}Z_A(Z_B - Z_A) + (Z_A + 2Z_B)C}{f} \geq C \Rightarrow \bar{x}Z_A \geq 2C$$

That is, in equilibrium $\bar{x}Z_A \geq 2C$. If $\bar{x}Z_A = 2C$, then $P_A = C\ \forall Z_B$, and $\partial(P_B^* - P_A^*)/\partial Z_B > 0$ follows directly. Alternatively, if $\bar{x}Z_A > 2C$, then P_A is monotonically increasing in Z_B, and $\partial(P_B^* - P_A^*)/\partial Z_B = [\bar{x}(8Z_B^2 - Z_A^2 - 4Z_BZ_A) + 3Z_AC]/f^2 > 0$.

b&c. $\partial P_B^*/\partial Z_A = 3Z_B(C - 2\bar{x}Z_B)/f^2$, which is negative since $Z_B > C/\bar{x}$.

$$\frac{\partial P_A^*}{\partial Z_A} = \frac{\bar{x}[Z_A^2 + 4Z_B^2 - 8Z_AZ_B] + 6Z_BC}{f^2}$$

The sign of $\partial P_A^*/\partial Z_A$ is ambiguous. Unless $\bar{x}Z_A = 2C$, in which case $P_A = C\ \forall Z_B$, the expression will be negative when $Z_B - Z_A$ is small, since in the limit as Z_A approaches Z_B the numerator approaches $3(2C - \bar{x}Z_A)$ which is negative. As Z_A falls, the derivative rises, and eventually become positive. Evaluating the difference between the derivatives, we find that $(P_B^* - P_A^*)$ decreases in Z_A. ■

ATTACHMENT D - Discussion of the Price Data

Our price variables are calculated from posted cellular rates that were in effect in October, 1991. Rates were available for both licensees for 272 of 293 metropolitan areas. Each cellular provider offered a range of plans from which consumers can choose, each of which is non-linear. These plans vary by levels of monthly access fees, per-minute charges for peak and off-peak usage, and the minutes of airtime that are included in the monthly access fee. The average cost-per-minute of usage depends on the plan chosen, the average level of peak and off-peak usage, and the cellular provider's billing increment.

Our basic methodology was to calculate the total cost to the consumer of using a cellular phone for a given intensity (i.e., minutes/month), assuming the caller chose the plan which minimized the cost for that level of intensity. Specifically, among the plans offered by each provider, we determined which would lead to the lowest cost of using a cellular phone for 100, 200, 300, 400 and 500 minutes per month. The costs under the alternative plans were calculated on the assumptions that (1) 80% of usage was at peak rates and (2) calls averaged 2.5 minutes in length. Thus, for a cellular provider with, say, four rate plans, if the total cost of 100 minutes of monthly airtime was lowest under plan 2, then the plan 2 price was chosen as the appropriate price. If, for the same firm, plan 4 offered the lowest price for using 200 minutes of monthly airtime, then the 200 minute-per-month cost under plan 4 was used as that firm's price. We divide this cost by the number of minutes per month to arrive at a per-minute price for that level of usage.

ATTACHMENT E - Suggestive Evidence Regarding the Relative Importance of Time-Series vs. Cross-Sectional Variation

As table I indicates, we could not obtain data on all of the variables for a common year. This introduces some noise into the parameter estimates, and the magnitude of the problem is greater if the right-hand side variables change significantly over time. There is reason to believe, however, that the time-series variation in most (if not all) of the right-hand variables is small compared to the cross-sectional variation. Of course, we could not obtain data on all of the right-hand side variables (which is why not all the data is from a common year to begin with). We can, however, examine the relative cross-sectional and time-series variation in some of the variables. In particular, we compared the two kinds of variation in per-capita income. Our measure of cross-sectional variation is the standard deviation of per-capita income across the cities in our sample. Our measure of time-series variation is the standard deviation of the difference in per-capita income between 1991 and 1995 (i.e., the standard deviation of $X^* = X_{i2} - X_{i1}$, where X_{i1} is income in city i in 1991, and X_{i2} is income in 1995). The standard deviation of X_{i1} is $3,148, and the standard deviation of X_{i2} is $3,687, while the standard deviation of X^* is $882. That is, our measure of time-series variation is about 1/4 of the cross-sectional variation. As another measure of the stability of the cross-sectional variation over time, we note that the correlation between X_{i1} and X_{i2} is .98.

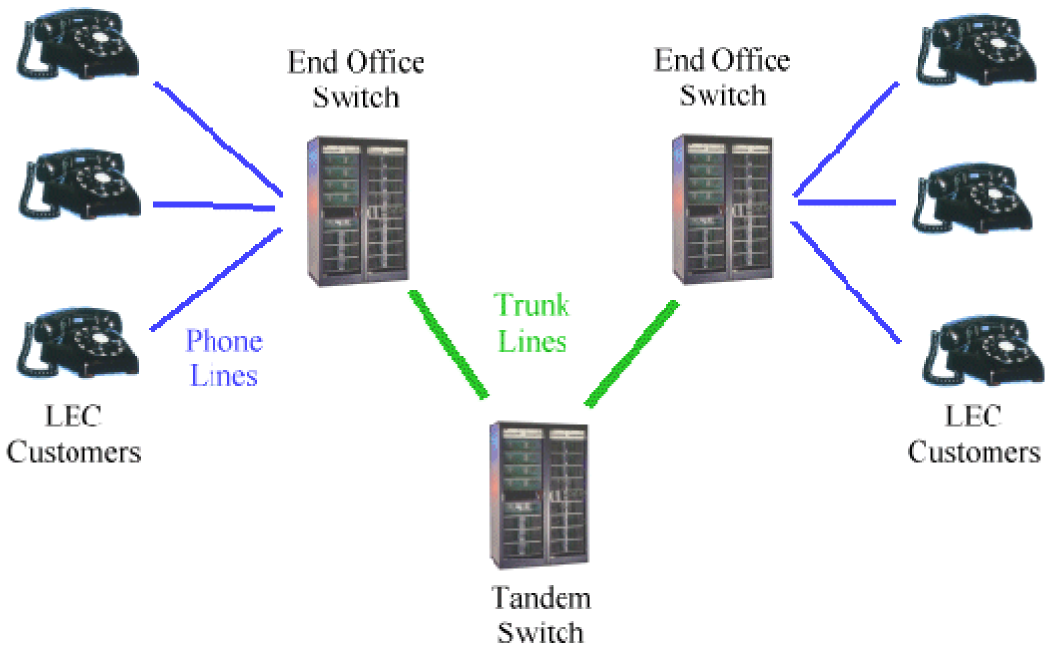
It also appears that the LECs' physical asset variables do not change much over time. While we cannot calculate how the time-series variation compares to the cross-sectional variation, we do have information about the average amount of time series variation. According to FCC data on switches, for the years 1991-1996, additions to the capital stock of switches represented one to two percent changes in the stock *(Status of Communication Common Carriers*, various years). This suggests that changes over time are small compared to the initial level of variation.

Finally, we obtained data on the number of cell towers per capita, and the share of those towers owned by the affiliate for 1998. Since this is a left-hand side variable, analysis of the relative importance of time-series and cross-sectional variation is not directly relevant to the question of the noisiness of our estimates. However, it does indicate the degree of stability of some of the cellular assets in this industry. Between 1991 and 1998, the total number of cell towers in the U.S. more than tripled. Given this level of growth, we would expect a much lower correlation between the 1991 and 1998 measures than for per-capita income. We find that the correlation between the number of affiliate cell towers per capita in the two years is about .52. This suggests that while time-series variation is important for this variable, cross-sectional variation is fairly stable.

ATTACHMENT F -Stylized Representation of Cellular and Landline Networks

Figure 1

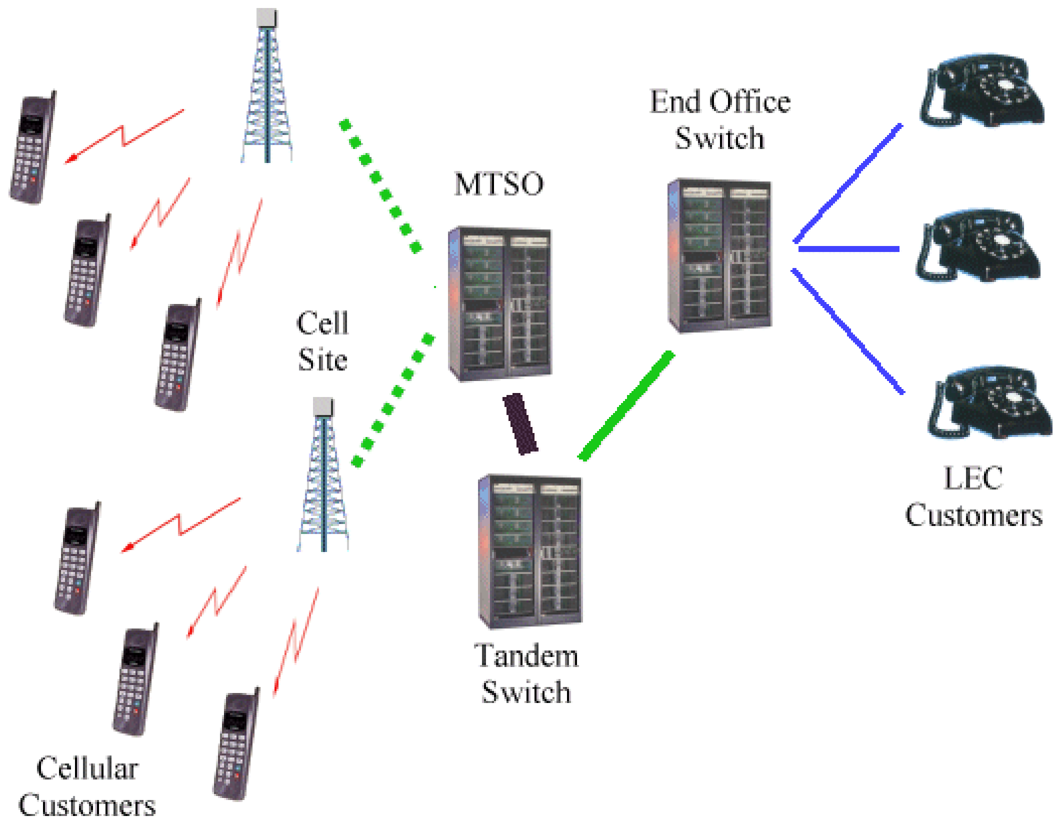
Typical Local Telephone Network Configuration



End Offices serve LEC customers in a part of town. Calls between LEC customers both served by the same end office are handled within this end office. Calls between LEC customers served by two end offices are routed through a tandem switch. Tandem switches act as a hub for end offices and connect to them via high capacity trunk lines.

Figure 2

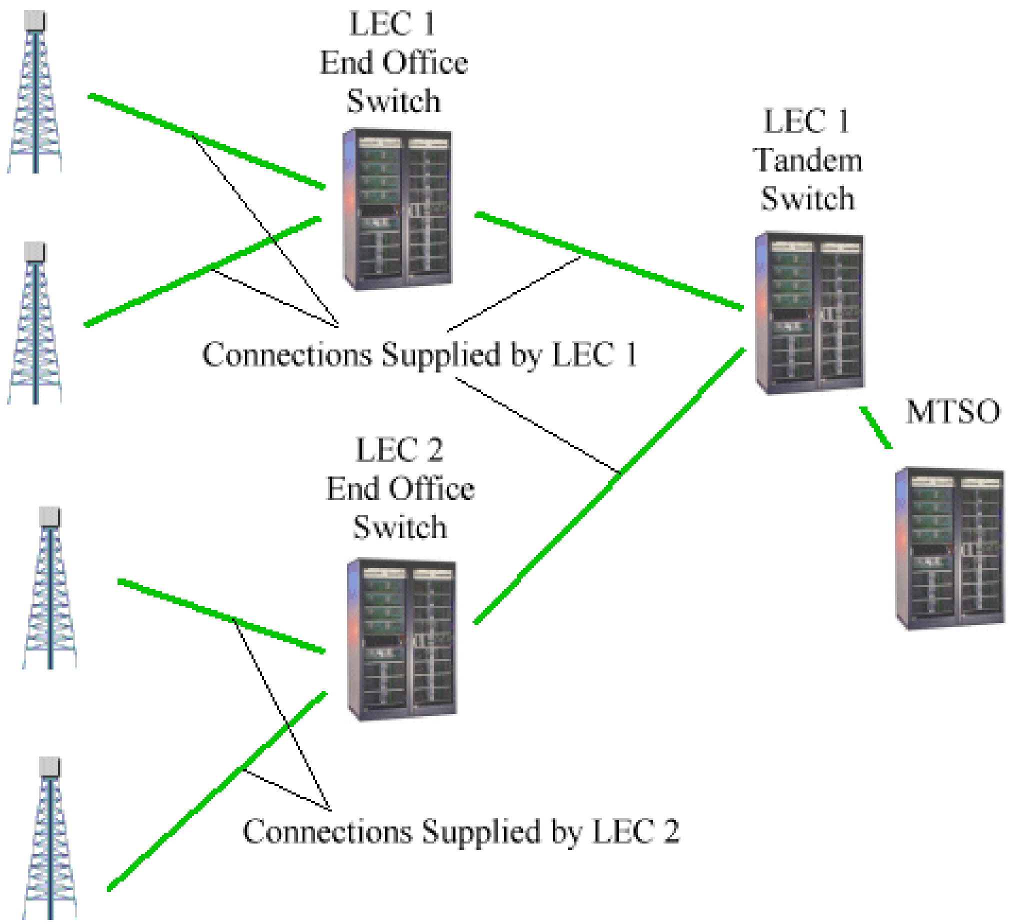
Typical Cellular Telephone Network Configuration



Antennae at cell sites serve cellular telephone customers in different parts of town. Calls from cellular customers to LEC customers (about 95% of all cellular calls during the sample period) are routed from the cell site to the MTSO, through a tandem switch onto a trunk line and finally onto the end office serving the called party. MTSOs act as hubs for cell sites and are connected to them via high capacity trunk lines. However, these trunk lines are usually leased by the cellular company from the LEC as described in figure 3.

Figure 3

Connections between Cell Sites and the MTSO



The high capacity lines connection cell sites to the MTSO are typically made up from two separate lines supplied by the LECs in the area. The first connection, from the cell site to the end office, is supplied by the LEC that serves the area and owns the end office. The second connection, from the end office to the tandem switch, is supplied by the LEC that provides inter-office connections, usually the owner of the tandem switch. The top two cell sites in figure 3 are connected to the MTSO by two connections supplied by LEC 1 who owns the tandem switch. The bottom two cell sites are connected to the MTSO by connections supplied by both LEC 1 and LEC 2.