Technical Appendix to Accompany
"Incentive Regulation and Telecommunications Service Quality"

by

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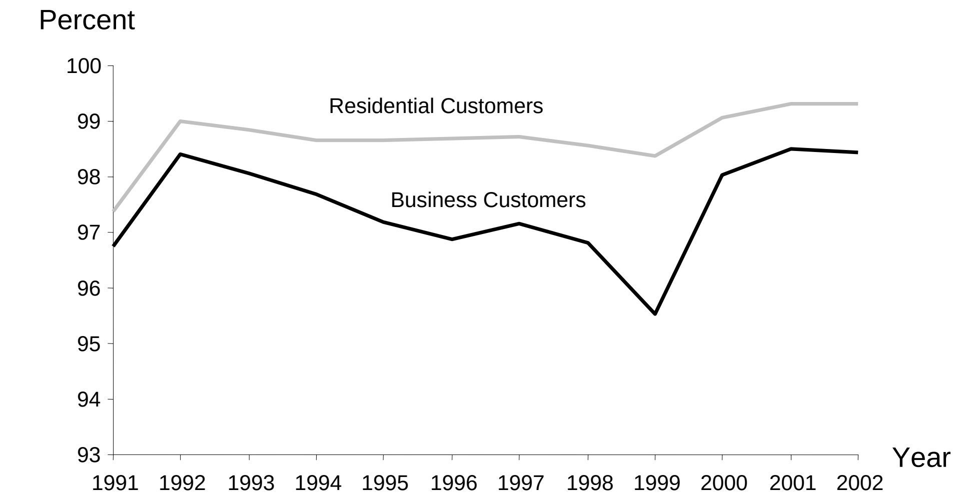


Figure 1. Percent of Installation Commitments Met

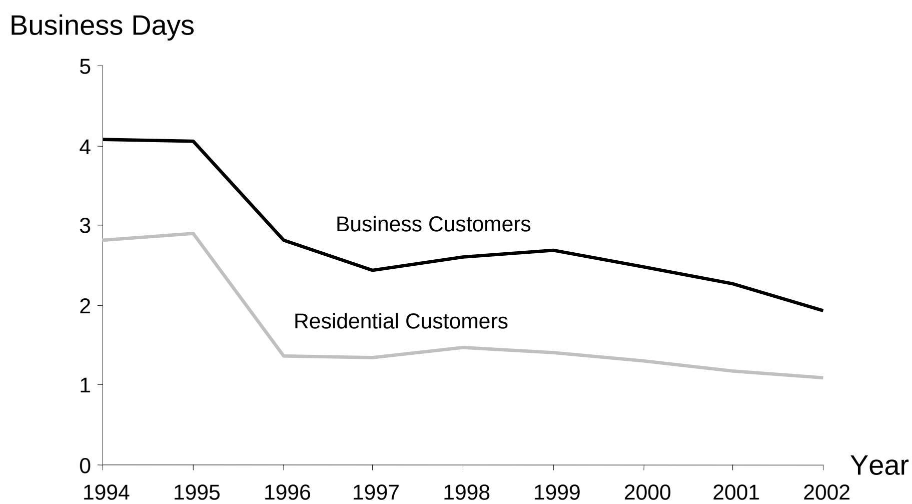


Figure 2. Time Required to Install New Telephone Service

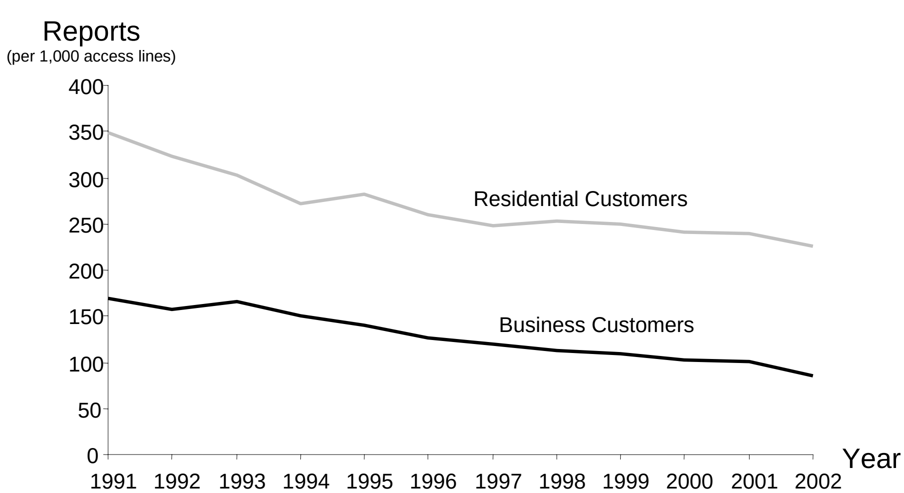


Figure 3. Number of Initial Trouble Reports

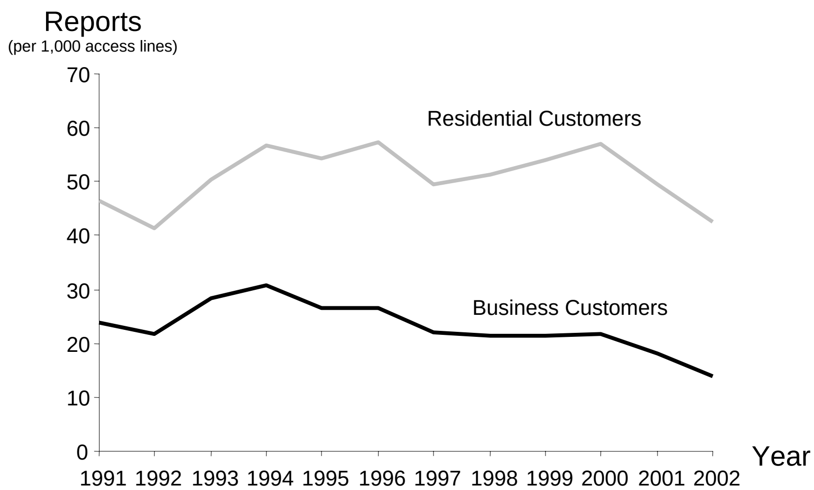


Figure 4. Number of Repeat Trouble Reports

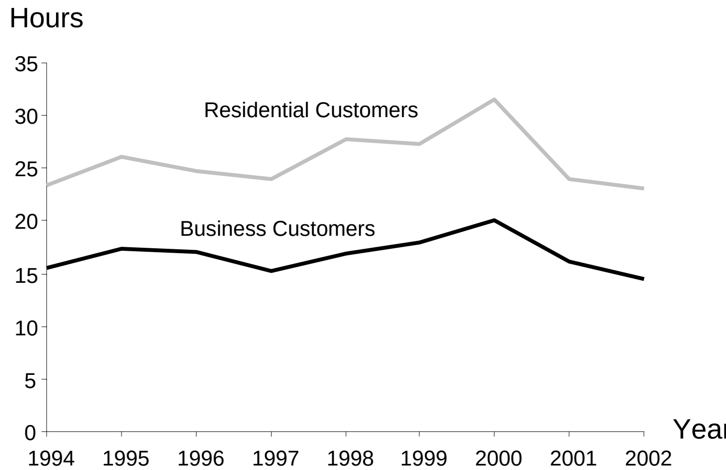


Figure 5. Time Required to Resolve Trouble Reports

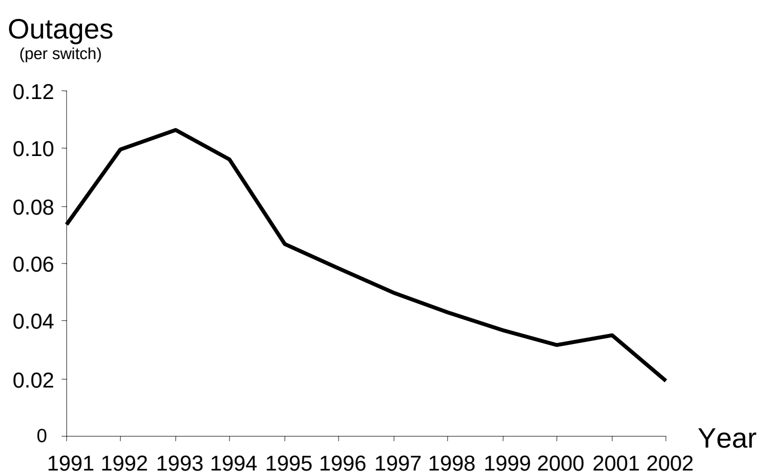
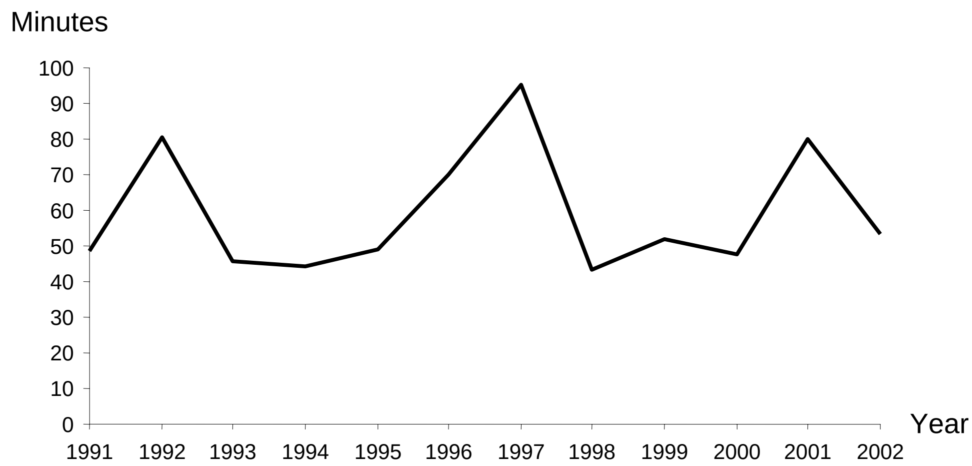


Figure 6. Unscheduled Switch Outages ≥ 2 Minutes



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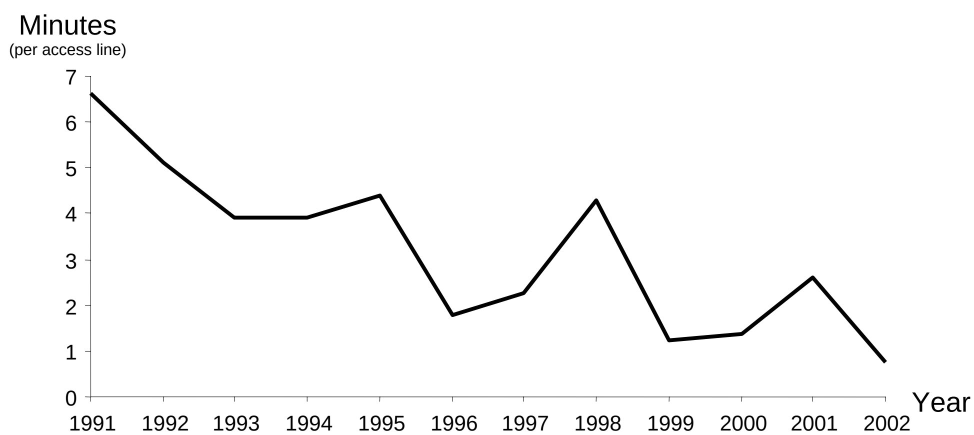

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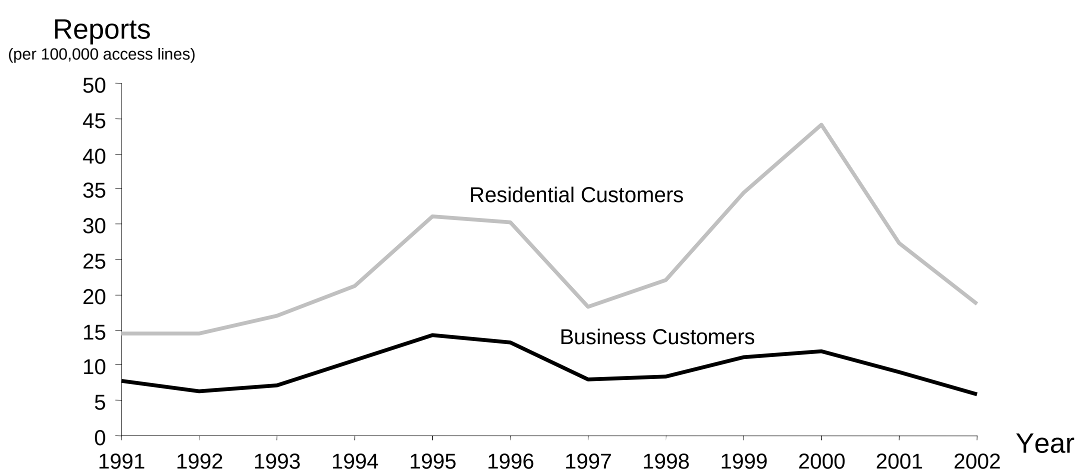

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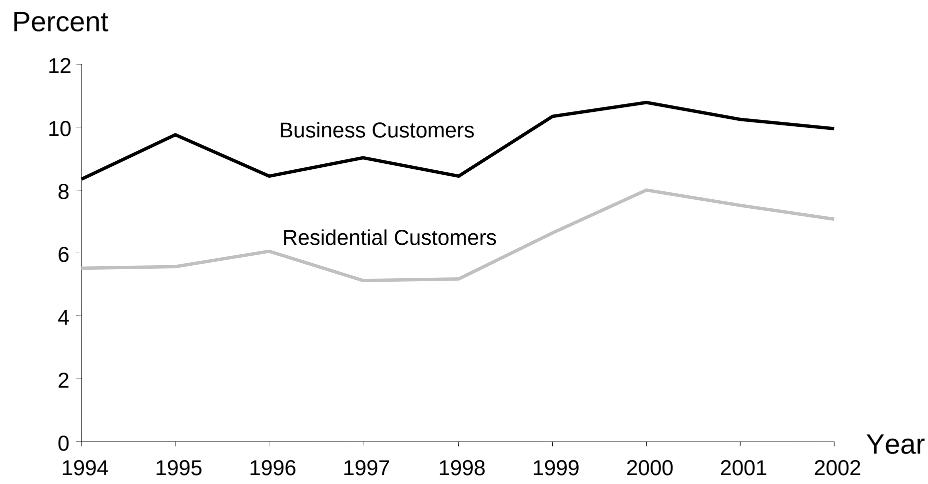

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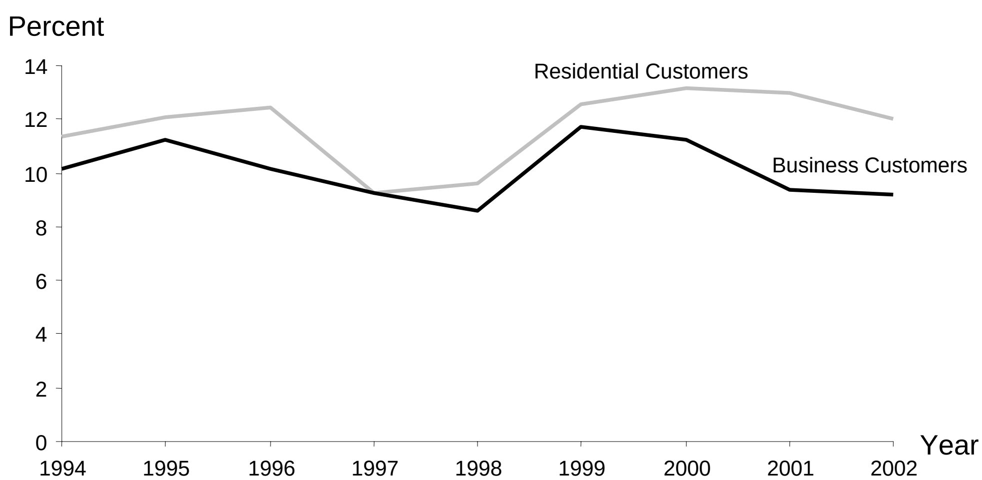

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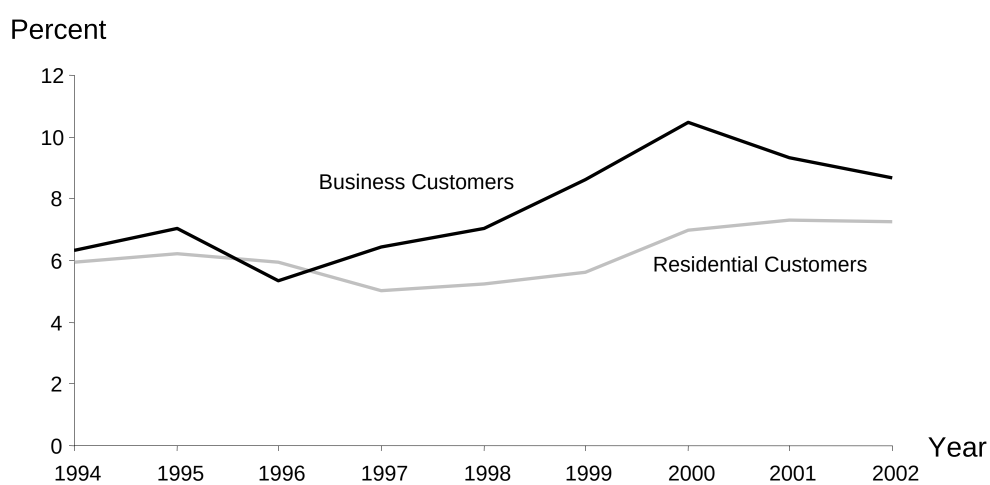

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SECTION 2. CONTROLS FOR ENDOGENEITY.

To control for the possible endogeneity of key explanatory variables, we created instruments for these variables. The instruments for the ESR, PR, TOLL COMP, LDAPPLY, MERGER1, and MERGER2+ were constructed as follows. First, these variables were employed as the dependent variable in a probit regression. Second, the estimated probabilities were employed as the instruments. The instruments for LOCAL COMP, MODERN, MODERN^2, ESR*LCOMP, and PR*LCOMP were constructed in analogous fashion, except that ordinary least squares was employed.

The explanatory variables employed in these regressions were mainly political and regulatory variables that might primarily influence the choice of regulatory regime. The political variables were the political affiliation of the governor and the fraction of the popular vote (s)he achieved in the most recent election. The regulatory variables were the salary of the chairman of the state public service commission (PSC), the number of PSC staff members, the method by which the PSC commissioners are selected (e.g., elected vs. appointed), and the length of a commissioner's term in office. We also employed the following demographic variables: state size, the metropolitan and rural populations in the state, state population density, the unemployment rate in the state, the average educational attainment of state residents, and the total state government expenditures on education. Interaction terms were also employed.

The correlation between the dependent variables and their instruments are as follows: ESR (.95), PR (.0.90), LOCAL COMP (.88), ESR*LCOMP (.87), PR*LCOMP (.86), LDAPPLY (.0.86), MERGER1 (.89), MERGER2+ (.88), MODERN (.92), MODERN^2 (.92), and TOLL COMP (.95).

The effects of controlling for the potential endogeneity of the key explanatory variables can be inferred by comparing the findings in Tables 3 through 6 in the text with the findings reported below in Tables 3A through 6A. These latter tables present coefficient estimates when instruments are not employed for any explanatory variables. As expected, because the instruments for the regulatory regime variables are not perfect instruments, the regime variables are significant less frequently when the instruments are employed.

Explanatory Variable	Dependent Variable					
	COMMIT MET		INSTALL TIME		DISSAT INSTALL	
	Business	Residential	Business	Residential	Business	Residential
ESR	-.0498 (-0.89)	-.1096* (-1.98)	-1.320** (-3.04)	-1.490** (-2.73)	-.1399** (-2.95)	-.1343** (-3.06)
PR	-.0179 (-0.42)	-.0228 (-0.62)	-1.049** (-2.85)	-1.345** (-2.88)	-.1055** (-2.87)	-.1029* (-2.51)
LOCAL COMP	.2186 (1.47)	.3600* (2.48)	-3.922** (-2.73)	-3.566** (-3.17)	-.3546** (-3.80)	-.5880** (-5.43)
ESR*LCOMP	-.7962** (-2.75)	-.5650* (-2.06)	4.985** (3.00)	4.538** (3.58)	.2650* (1.96)	.1649 (0.93)
PR*LCOMP	-0.2997** (-2.63)	-.3560** (-3.28)	3.442* (2.49)	2.830** (2.75)	.2030* (2.40)	.2888** (3.18)
TOLL COMP	.0127 (0.18)	.0041 (0.06)	1.038 (1.43)	1.136 (1.42)	.1180 (1.03)	.0605 (0.43)
LDAPPLY	.0311 (0.46)	.0700 (1.13)	-.2188 (-1.04)	-.2081 (-1.18)	-.0280 (-1.09)	-.0064 (-0.21)
MERGER1	-.1174 (-1.52)	-.2136** (-3.10)	-1.491** (-4.25)	-1.196** (-2.93)	-.1862** (-4.50)	.0138 (0.23)
MERGER2+	-.1034 (-1.02)	-.2146* (-2.15)	-1.930** (-4.68)	-2.007** (-3.60)	-.3534** (-7.66)	-.2120** (-3.14)
MODERN	.2316 (0.33)	$-1.227^{\dagger}$ (-1.84)	25.60** (4.56)	16.91** (3.35)	2.589** (3.84)	$1.414^{\dagger}$ (1.65)
MODERN^2	-.2045 (-0.41)	.7210 (1.49)	-17.16** (-4.87)	-10.90** (-3.49)	-1.759** (-4.00)	$-1.071^{\dagger}$ (-1.90)
LINES	-1.10×10^{-7} (-0.77)	-2.16×10^{-8} (-0.14)	-1.94×10^{-6}* (-2.55)	-5.76×10^{-7} (-0.77)	-2.09×10^{-7}* (-2.33)	-8.82×10^{-8} (-0.80)
LINES^2	1.58×10^{-15} (0.35)	$7.39 \times 10^{-15\dagger}$ (1.72)	7.33×10^{-14}** (3.23)	$4.23 \times 10^{-14\dagger}$ (1.81)	7.79×10^{-15}* (2.50)	5.36×10^{-15} (1.25)
ORDER^+	-1.66×10^{-7} (-1.11)	-2.16×10^{-7}** (-6.10)	-1.52×10^{-6}* (-2.00)	-1.43×10^{-7} (-1.33)	-5.89×10^{-8} (-0.63)	-6.76×10^{-8}** (-3.07)
ORDER^-	2.43×10^{-7} (0.90)	-4.17×10^{-8} (-0.86)	-4.62×10^{-7} (-0.60)	9.22×10^{-9} (0.03)	-1.51×10^{-7} (-1.08)	8.61×10^{-8} (1.47)
DAMAGE	-8.49×10^{-5}* (-2.24)	-5.93×10^{-5} (-1.56)	-.0002 (-1.03)	-.0002 (-0.97)	3.61×10^{-5} (0.59)	3.2×10^{-5} (0.46)
DAMAGE^2	$2.87 \times 10^{-9\dagger}$ (1.88)	1.67×10^{-9} (1.09)	7.37×10^{-8} (1.32)	5.98×10^{-8} (1.02)	-1.22×10^{-8} (-0.93)	-1.10×10^{-8} (-0.77)
911	-.0121 (-0.10)	-.1040 (-1.07)	$-.9893^{\dagger}$ (-1.74)	.2959 (0.73)	-.0922 (-1.06)	-.2565* (-2.36)
Adjusted R^2	.45	.43	.54	.49	.68	.48

** = 1%; * = 5%; † = 10% significance level.

Table 3A. Speed and Reliability of New Service Installation. [OLS Estimates]

Explanatory Variable	Dependent Variable							
	Trouble 1		Trouble 2		Clear Time		Dissat Repair	
	Business	Residential	Business	Residential	Business	Residential	Business	Residential
ESR	-.0071 (-1.14)	-.0209 (-1.40)	-.0021† (-1.74)	-.0053* (-1.97)	1.437 (1.16)	1.679 (0.81)	-.1095* (-2.25)	-.1148** (-2.85)
PR	.0007 (0.15)	-.0215 (-1.64)	-.0015 (-1.45)	-.0013 (-0.57)	-1.559 (-1.44)	-.3775 (-0.21)	-.0723 (-1.64)	-.1029** (-2.65)
Local Comp	.0076 (0.69)	-.0077 (-0.24)	.0042 (1.40)	.0079 (1.15)	-8.471** (-2.58)	-12.96* (-2.40)	-.4061** (-3.65)	-.4592** (-3.55)
ESR*LComp	-.0662** (-2.60)	-.0886* (-2.32)	-.0176* (-2.28)	-.0258 (-1.33)	7.702† (1.81)	18.01 (2.62)	.4035** (2.63)	.3564* (2.33)
PR*LComp	-.0120 (-1.38)	-.0111 (-0.65)	-.0017 (-0.63)	-.0066 (-1.04)	9.261** (3.18)	12.62* (2.53)	.2417* (2.48)	.2688* (2.25)
Toll Comp	.0028 (0.33)	.0172 (1.06)	.0010 (0.61)	.0043 (1.23)	4.382† (1.68)	3.527 (0.64)	.0533 (0.53)	.1841** (2.67)
LDApply	.0066 (1.57)	.0037 (0.49)	.0009 (0.77)	.0007 (0.32)	1.055 (1.26)	1.546 (1.28)	.0142 (0.46)	-.0015 (-0.05)
Merger1	.0135* (2.09)	-.0024 (-0.21)	.0008 (0.67)	.0013 (0.45)	6.505** (3.33)	6.269* (2.07)	-.0590 (-1.24)	-.0358 (-0.58)
Merger2+	.0124† (1.72)	-.0014 (-0.08)	.0013 (0.88)	-.0053† (-1.66)	2.112 (1.63)	-2.975 (-1.50)	-.2587** (-5.06)	-.2999** (-4.89)
Modern	.2277** (2.82)	-.0367 (-0.15)	.0811** (5.38)	.1212** (3.68)	-35.54† (-1.75)	-68.49* (-2.21)	.0289 (0.05)	-.8986 (-1.32)
Modern^2	-.1588** (-2.81)	-.0101 (-0.06)	-.0611** (-5.43)	-.1000** (-4.07)	15.58 (1.21)	32.86 (1.64)	-.1782 (-0.42)	.3329 (0.73)
Lines	-1.33×10^{-8} (-0.96)	2.08×10^{-8} (0.49)	-3.80×10^{-9} (-1.42)	-3.11×10^{-9} (-0.52)	6.12×10^{-6}* (1.99)	6.15×10^{-6} (1.21)	1.06×10^{-7} (1.03)	1.19×10^{-7} (1.14)
Lines^2	4.68×10^{-16} (1.04)	-6.16×10^{-16} (-0.48)	2.49×10^{-17} (0.28)	3.26×10^{-17} (0.16)	-1.59×10^{-13} (-1.57)	6.66×10^{-14} (0.41)	-3.97×10^{-15} (-1.15)	2.44×10^{-15} (0.60)
Order	-4.12×10^{-9} (-0.46)	-4.53×10^{-9} (-1.45)	-3.58×10^{-9}* (-2.10)	-3.55×10^{-9}** (-3.15)	1.75×10^{-6} (1.03)	-3.73×10^{-7} (-0.75)	-1.12×10^{-7}† (-1.77)	-4.40×10^{-8}** (-3.23)
Damage	4.10×10^{-6} (0.99)	1.53×10^{-5}** (3.01)	1.48×10^{-6}† (1.86)	3.95×10^{-6}* (2.15)	.0010 (0.89)	.0040 (1.63)	-1.15×10^{-5} (-0.16)	1.38×10^{-5} (0.21)
Damage^2	-1.05×10^{-10} (-0.63)	-4.96×10^{-10}* (-2.29)	-3.42×10^{-11} (-1.08)	-1.13×10^{-10} (-1.54)	3.39×10^{-7} (1.23)	-2.36×10^{-7} (-0.45)	2.98×10^{-9} (0.19)	-1.61×10^{-9} (-0.12)
911	-.0299 (-1.61)	-.1100** (-3.25)	-2.38×10^{-5} (-0.01)	-.0102* (-2.17)	4.057* (2.26)	5.140† (1.83)	-.0585 (-0.70)	-.1273† (-1.71)
Adjusted R^2	.78	.63	.74	.57	.57	.41	.57	.59

** = 1%; * = 5%; † = 10% significance level

Table 4A. Network Service Problems and Their Resolution. [OLS Estimates]

Explanatory Variable	Dependent Variable		
	OUTAGES	AVG DOWNTIME	LINE LOSS
ESR	-.0104 (-1.06)	-.2929 (-0.01)	-.2647 (-0.17)
PR	-.0250** (-2.89)	34.76 (1.30)	1.497 (0.99)
LOCAL COMP	.0219 (0.82)	74.62 (1.31)	3.865 (0.92)
ESR*LCOMP	.0137 (0.40)	-18.94 (-0.33)	-.3160 (-0.07)
PR*LCOMP	-.0198 (-0.81)	-30.28 (-0.72)	-2.764 (-0.77)
TOLL COMP	-.0262† (-1.84)	44.20 (1.34)	1.226 (0.94)
LDAPPLY	-.0122 (-1.61)	17.67 (0.89)	-.0823 (-0.06)
MERGER1	.0002 (0.02)	39.01 (1.25)	.1098 (0.07)
MERGER2+	-.0024 (-0.22)	.3848 (0.01)	-.2748 (-0.17)
MODERN	.3393* (2.54)	301.8 (1.35)	25.31 (1.44)
MODERN^2	-.2503* (-2.43)	-110.4 (-0.66)	-21.99 (-1.62)
LINES	$-2.64\text{x}10^{-8}$ (-1.27)	$-1.6\text{x}10^{-5}$ (-0.37)	$2.64\text{x}10^{-6}$ (1.45)
LINES^2	$2.94\text{x}10^{-16}$ (0.33)	$2.02\text{x}10^{-13}$ (0.18)	$-5.59\text{x}10^{-14}$ (-1.02)
DAMAGE	$-5.56\text{x}10^{-6}$ (-0.92)	.1174* (2.16)	.0035* (2.02)
DAMAGE^2	$2.08\text{x}10^{-10}$ (0.85)	$-3.75\text{x}10^{-6}$† (-1.74)	$-1.34\text{x}10^{-7}$* (-1.96)
911	.0173 (1.42)	2857.2** (91.85)	173.15** (104.29)
Adjusted R^2	.32	.70	.57

** = 1%; * = 5%; † = 10% significance level.

Table 5A. Switch Outages and Downtime. [OLS Estimates]

Explanatory Variable	Dependent Variable			
	COMPLAINTS		DISSAT OFFICE	
	Business	Residential	Business	Residential
ESR	-2.31×10^{-5} (-1.10)	-2.02×10^{-5} (-0.52)	-.1203* (-2.13)	-.1485** (-2.79)
PR	-7.73×10^{-5}** (-3.76)	-15.1×10^{-5}** (-3.87)	-.1091* (-2.32)	-.0751† (-1.66)
LOCAL COMP	-6.12×10^{-5} (-1.10)	-17.5×10^{-5} (-1.30)	-.2229* (-1.98)	-.3203** (-2.78)
ESR*LCOMP	6.38×10^{-5} (0.90)	29.5×10^{-5} (1.63)	.1116 (0.56)	.1585 (0.80)
PR*LCOMP	9.9×10^{-5}† (1.87)	34.3×10^{-5}** (2.76)	.2812** (2.72)	.2710** (2.68)
TOLL COMP	-3.61×10^{-5}† (-1.65)	-4.46×10^{-5} (-1.05)	.1245* (2.10)	.0010 (0.01)
LDAPPLY	-1.71×10^{-6} (-0.10)	-5.15×10^{-5} (-1.23)	-.0244 (-0.68)	.0125 (0.40)
MERGER1	1.49×10^{-5} (0.50)	13.0×10^{-5} (1.49)	-.1209* (-2.13)	-.0364 (-0.65)
MERGER2+	-3.73×10^{-5} (-1.37)	-14.1×10^{-5}* (-2.21)	-.3910** (-6.26)	-.1876** (-2.69)
MODERN	54.0×10^{-5}† (1.91)	85.0×10^{-5} (1.60)	-2.213** (-3.44)	-2.387** (-3.00)
MODERN^2	-55.0×10^{-5}** (-2.61)	-90.9×10^{-5}* (-2.19)	1.065* (2.46)	1.385** (2.69)
LINES	7.56×10^{-12} (0.21)	5.61×10^{-11} (0.68)	2.29×10^{-7}* (2.06)	1.27×10^{-7} (1.11)
LINES^2	-1.14×10^{-18} (-0.86)	-4.35×10^{-18} (-1.45)	-5.44×10^{-15} (-1.51)	-1.12×10^{-15} (-0.27)
DAMAGE	1.12×10^{-8} (1.31)	3.38×10^{-8} (1.16)	6.88×10^{-6} (0.07)	7.89×10^{-5} (1.11)
DAMAGE^2	-3.04×10^{-13} (-0.87)	-1.09×10^{-12} (-0.94)	-9.67×10^{-10} (-0.05)	-1.74×10^{-8} (-1.18)
911	-14.7×10^{-5}* (-2.17)	-.0003† (-1.80)	-.1481 (-1.44)	-.2940* (-2.25)
Adjusted R^2	.57	.53	.54	.64

** = 1%; * = 5%; † = 10% significance level.

Table 6A. Customer Complaints and Dissatisfaction with Office Services.
[OLS Estimates]

SECTION 3. STATISTICAL TESTS.

To assess whether a regulatory regime is associated with a significantly higher or lower level of service quality, one must consider the coefficient estimates on both the regime variable and its interaction with LOCAL COMP.

In the case where the dependent variable is not bounded between 0 and 1, the analysis is relatively straightforward. The model in this case is:

$$y_{it} = \alpha_0 + \alpha_1 ESR_{it} + \alpha_2 PR_{it} + \gamma Z_{it} + \beta X_{it} + \mu_i S_i + \delta_t T_t + \varepsilon_{it} . \qquad \text{(A1)}$$

Recall that Z_{it} is a vector of explanatory variables other than ESR and PR that may be endogenous. The Z_{it} vector includes the interactions between the regulatory regime variables and LOCAL COMP. Write:

$$\gamma Z_{it} = \gamma_1 [\mathit{LOCAL\ COMP}_{it}] \cdot ESR_{it} + \gamma_2 [\mathit{LOCAL\ COMP}_{it}] \cdot PR_{it} + \gamma_3 Z_{it}^0 , \qquad \text{(A2)}$$

where Z_{it}^0 denotes the remaining other endogenous explanatory variables. It follows from (A1) and (A2) that the impact of a change from ROR regulation to earnings sharing regulation (ESR) on the expectation of y, given the explanatory variables, is $\alpha_1 + [\mathit{LOCAL\ COMP}_{it}] \cdot \gamma_1$. Consequently, the average effect is:

$$\alpha_1 + 0.1918 \cdot \gamma_1 , \qquad \text{(A3)}$$

where 0.1918 is the mean value of LOCAL COMP in our sample, from Table 2 in the text. The corresponding impact of a change from ROR regulation to price regulation (PR) is:

$$\alpha_2 + 0.1918 \cdot \gamma_2 . \qquad \text{(A4)}$$

To determine the statistical significance of the effect of a change in regulatory regime, one must estimate the effects of the regime changes and compute their standard errors. To do so, use (A2) – (A4) to rewrite (A1) as:

$$\begin{aligned} y_{it} = {} & \alpha_0 + [\alpha_1 + 0.1918 \cdot \gamma_1] ESR_{it} + [\alpha_2 + 0.1918 \cdot \gamma_2] PR_{it} + \\ & \gamma_1 [\mathit{LOCAL\ COMP}_{it} - 0.1918] \cdot ESR_{it} + \gamma_2 [\mathit{LOCAL\ COMP}_{it} - 0.1918] \cdot PR_{it} + \\ & \gamma_3 Z_{it}^0 + \beta X_{it} + \mu_i S_i + \delta_t T_t + \varepsilon_{it} . \end{aligned} \qquad \text{(A5)}$$

The effects of a switch from ROR regulation to ESR and PR are the coefficients on ESR and PR in (A5), respectively. These effects are estimated by applying instrumental variable estimation to (A5). The relevant *t*-statistics are the usual *t*-statistics for the estimates of these coefficients.

The analysis is a bit more complicated for variables that are bounded between 0 and 100. In this case, the model is:

$$y_{it}/100 \ = \ F(\alpha_0 + \alpha_1\, ESR_{it} + \alpha_2\, PR_{it} + \gamma\, Z_{it} + \beta\, X_{it} + \mu_i\, S_i + \delta_t\, T_t + \varepsilon_{it}), \qquad \text{(A6)}$$

where $F(\cdot)$ denotes the cumulative distribution function for a standard normal variable. The model is estimated by first inverting $F(\cdot)$:

$$F^{-1}(y_{it}/100) \ = \ \alpha_0 \ + \ \alpha_1\, ESR_{it} \ + \ \alpha_2\, PR_{it} \ + \ \gamma\, Z_{it} \ + \ \beta\, X_{it} \ + \ \mu_i\, S_i \ + \ \delta_t\, T_t \ + \ \varepsilon_{it}\ , \quad \text{(A7)}$$

and then applying instrumental variables estimation to (A7).

Define: $$v_{it} \ = \ \alpha_0 \ + \ \gamma_3\, Z_{it}^0 \ + \ \beta\, X_{it} \ + \ \mu_i\, S_i \ + \ \delta_t\, T_t \ + \ \varepsilon_{it} \ . \qquad \text{(A8)}$$

The value of v_{it} can be determined by replacing the coefficients in (A8) with their estimates and replacing ε_{it} with the regression residuals from (A8). The effect on $y_{it}/100$ of a change from ROR regulation to ESR is:

$$F(\hat{\alpha}_1 + [\textit{Local Comp}_{it}] \cdot \hat{\gamma}_1 + v_{it}) \ - \ F(v_{it}) \ . \qquad \text{(A9)}$$

Notice that the magnitude of this effect varies with the values of other regressors. We compute the effect at the mean values:

$$F(\hat{\alpha}_1 + \ 0.1918 \cdot \hat{\gamma}_1 + \ \bar{v}\,) \ - \ F(\bar{v}) \ , \qquad \text{(A10)}$$

where $\bar{v}$ is the sample mean of the estimated v_{it} in (A8), and where $\hat{\alpha}_1$ and $\hat{\gamma}_1$ are estimated coefficients. Notice that the effect in (A10) is zero if and only if $\hat{\alpha}_1 + 0.1918 \cdot \hat{\gamma}_1$ is zero. Therefore, the significance of the estimated impact of the regulatory regime is determined by the significance of $\hat{\alpha}_1 + 0.1918 \cdot \hat{\gamma}_1$. This significance is inferred from the *t*-statistic of the estimated coefficient on the ESR variable in the following regression:

$$\begin{aligned} F^{-1}(y_{it}/100) \ = \ & \alpha_0 \ + [\alpha_1 + \ 0.1918 \cdot \gamma_1]\, ESR_{it} \ + \ [\alpha_2 + 0.1918 \cdot \gamma_2]\, PR_{it} \ + \\ & \gamma_1 [\textit{Local Comp}_{it} - 0.1918] \cdot ESR_{it} \ + \ \gamma_2 [\textit{Local Comp}_{it} - \ 0.1918] \cdot PR_{it} \ + \\ & \gamma_3 Z_{it}^0 \ + \ \beta\, X_{it} \ + \ \mu_i\, S_i \ + \ \delta_t\, T_t \ + \ \varepsilon_{it} \ . \qquad \text{(A11)} \end{aligned}$$

Similarly, the effect of a change from ROR regulation to PR at the mean values of the regressors is:

$$F(\hat{\alpha}_2 + 0.1918 \cdot \hat{\gamma}_2 + \bar{v}) - F(\bar{v}) \quad . \tag{A12}$$

The statistical significance of the estimated effect is the significance of the coefficient on the PR variable in (A11).

The percentage change reported in the last column of Table 7 is computed using the sample mean from Table 2. To illustrate, the percentage change in COMMIT MET for residential customers associated with a change from ROR regulation to ESR is:

$$100 \cdot [F(\hat{\alpha}_1 + 0.1918 \cdot \hat{\gamma}_1 + \bar{v}) - F(\bar{v})] \;/\; 0.9885 \quad .$$