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Trouble reports as an indicator of service quality: the influence of competition, technology, and regulation

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Abstract

Network trouble reports provide a proxy measure of service quality and network reliability. This paper analyzes the influence of local competition, state-level regulation, new technologies, automation, and mergers on RBOC reports of network trouble. Service quality discrimination between residential and business customers is also analyzed. Results indicate that (1) service quality discrimination between business and residential customers in response to competition may be occurring, (2) alternative regulation plans have not led to systematic increases in network trouble, and (3) merger and technology have a consistent impact on repeat trouble.

Keywords: Quality of service; Network reliability; Competition; Alternative regulation

1. Introduction

In competitive markets, service quality is determined by market forces. Some consumers may prefer high-quality services and be willing to pay to ensure the delivery of such services. Other consumers might prefer lower quality goods or services and may be unwilling to pay extra for a higher grade of service. It was not until 1996, when the Telecommunications Act provided guidelines to open local markets, that competition for local exchange service became possible in all areas of the United States. Service quality for local exchange carriers continues to be regulated in this environment of emerging local exchange competition by both the FCC and state public utility

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commissions. The impact of emerging competition on the quality of regulated services is an issue of concern to regulators and policymakers.

Service quality in the emerging competitive local exchange environment has become a highly contentious issue, with general perceptions of declining service quality. In Ohio, the staff of the public utilities commission recently suggested fines of $200 million be imposed on Ameritech as a penalty for its recalcitrance to improve service quality (Bischoff, 2000). Qwest, in its merger with US-West, has held out service quality improvements as a carrot for regulatory approval (Flash, 2000). Bell Atlantic has inherited NYNEX's poor service quality reputation in New York, and apparently has equal difficulty in fixing service quality problems (Sherman, 1999).

This paper examines the impact of local exchange competition on telephone service quality for Regional Bell Operating Companies (RBOCs). Additionally, we are able to study the impact of state-level regulation, automation, merger, and the deployment of fiber optic cable and digital switches on service quality. It is expected that with the emergence of competition there will be less need for regulation. This paper will provide some insight into that issue.

2. Existing literature on service quality

One of the first problems that a regulator will encounter in the process of regulating quality is determining the quality elements to use when evaluating a common carrier. Quality as an indicator is problematic because, as noted by Noam (1991) and by Lynch, Buzas, and Berg (1994), service quality is a multidimensional concept. Some indicators of quality can be technical in nature while others are related to the quality of customer service such as repair service, response time by operators, and directory assistance.

In spite of the fact that quality is an important indicator to assess a telecommunications company's performance, there have been few studies about quality of service for common carriers.

Pazner (1975) provided initial insights about the effects of regulation on the quality of products and services. His model predicted the typical monopoly outcome of reduced production of goods and services compared to a competitive environment. Quality on the other hand did not necessarily differ from that provided by firms under competition. The motivation for this conclusion is that an unregulated monopolist can have equally high quality but restrict supply and make profits equal to the difference between competitive and monopoly prices. When Pazner incorporated regulation into the model, rate-of-return regulation had an ambiguous impact on quality, while with price cap regulation, quality was expected to be lower.

Ai and Sappington (1998) address the impact of state incentive regulation on several aspects of local exchange carrier operations, including service quality. Their study finds that residential customers may have experienced decreased service quality under both price cap and incentive regulation plans. Our research supports this conclusion for some companies. However, the Ai and Sappington study does not control for important factors such as company influences, automation, emerging local exchange competition, and merger. By providing a broader examination of factors that influence service quality, our results show that competition and mergers also have a consistent impact on service quality.

Lewis and Sappington (1998) acknowledge that information about service quality is difficult for the regulatory agency to monitor. In telecommunications, quality measures are collected by the

firm, but are prohibitively costly for the regulator to monitor directly. Some of those indicators are, for example, the time it takes to get a connection, the quality of the transmission, and the time it takes the company to repair a problem in a customer's line. Lewis and Sappington do not address the issue of regulation type and quality of service. However, the authors point out that a regulator's ability to set welfare enhancing rates that take quality into account is heightened when information on service quality is available to regulators.

A study by Norsworthy and Tsai (1999) explores the effect of service quality and technology on demand. The study attests to the power that carriers have over their users if they do not have any alternatives. In their study they show that lower quality of service results in lower demand for service from business customers, but not from residential consumers. They interpret these results as the ability of business customers to use alternative means of communications, such as private networks and satellites. Since residential users do not have such choices, they cannot reduce their demand for services even if quality decreases.

Kridel, Sappington and Weisman (1996) cite Tardiff and Taylor (1993) as another study that addresses the issue of regulation and quality of service. Tardiff and Taylor assess the impact of regulation on multiple indicators, one of which was quality. Even though, as they pointed out, there is no clear evidence of the actual choice of quality by firms with market power, there is still a concern that inadequate regulation could result in the decline of quality. Borrowing from a study conducted by Mercer Management Consulting, Tardiff and Taylor concluded that, in general, states that impose regulations that included quality as a measure of performance had higher quality of service than those that did not. This study included 49 states over the 1990–1991 period. The study provides an indication of the correlation that may exist between regulation and quality of service. This study nonetheless did not provide a clear relation of causality between these two variables. Since the study does not take into consideration other variables, there may be an exaggeration of the effect of regulation on quality. Additionally, the study has a time span of only one year which makes it difficult to fully realize the effect of any regulatory decision over quality since adjustments by the firm with respect to any changes in regulation would not be reflected until a few years later.

The National Regulatory Research Institute has conducted a survey that identified 26 states that had undertaken service quality revisions since 1995, especially in response to alternative regulation (Witkind & Clements, 1999). This survey gives an indication of states' efforts to make carriers maintain the quality of their services.

As may be evident from the review of the literature, most of the research about quality of service has been done tangentially. This current study should therefore fill a gap in the literature, especially with regard to the impact of emerging local exchange competition on service quality.

3. Trouble reports as an indicator of network performance and service quality

As was stated before, there are multiple indicators to measure service quality. For the purpose of this paper, a specific problem is how to quantify service quality while avoiding the "Mandated vs. Motivated Pitfall" (Kridel et al., 1996). The Mandated vs. Motivated Pitfall recognizes that the level of service quality may be the result of explicit regulatory rules, while other changes in service quality may be the result of managerial decisions in response to broad regulatory incentives or

other influences. To help avoid the pitfall of measuring the impact of specific rules, the approach of this research is to examine reports of initial and repeat troubles. Trouble reports are tracked by the FCC for many Local Exchange Carriers (LECs) and all RBOCs. These trouble reports will provide both a measure of network reliability and a measure of service quality.

Initial trouble reports are the sum of the number of instances of two types of trouble. First, out-of-service trouble reports arise when the customer is totally without telephone service. The other type of trouble, categorized as "All Other Initial Trouble Reports", includes complaints about static and interrupted calls. Initial trouble will thus reflect the performance of network infrastructure (FCC, 1997, p. 11).

Repeat trouble reports are customer trouble reports concerning service quality that are received within 30 days after the resolution of an initial trouble report on the same line. These include both repeat out-of-service trouble reports and all other repeat trouble reports (FCC, 1997, p. 12). Telephone companies are required to track initial and repeat trouble reports and report this information to the FCC on an annual basis.

Telephone companies may face regulatory scrutiny regarding company performance based on trouble reports. Thus, it is important to consider whether an errors-in-variables problem might exist due to strategic misreporting of information relating to trouble reports. The potential for misreporting service quality information might interfere with the statistical analysis of service quality data. However, depending on how misreporting occurs, the possibility of statistically meaningful results continues. For example, suppose that trouble reports are being underreported in a systematic fashion, with a company underreporting trouble reports by 20% per year to improve its image in the eyes of regulators. In this case, variation in the data would still be captured in regression analysis. Absolute reports of trouble would be below their true levels, but changes in the level of trouble reports over time would be apparent. However, if a company were to "cook" their trouble report numbers to eliminate variation from year to year (i.e., to freeze report levels at or near some arbitrary values), the statistics would be affected as variation in the data would be eliminated. Alternatively, if the company were to simply "cook" their numbers to generate varying results that were designed to please regulators (e.g., improving service quality over time), the ability to place any confidence in statistical analysis would also be damaged.

To test the hypothesis that companies may "cook" trouble report levels, we performed regressions which separately utilized repeat and initial troubles as the dependent variables and a time trend as the independent variable. As will be discussed further below, companies in the Ameritech, Bell Atlantic, NYNEX, and SBC holding companies can be subject to the full statistical analysis conducted in this paper, thus these initial "time trend" regressions are performed on the data from these companies. Results from these regressions are shown in Tables 1 and 2.

Results for Bell Atlantic, NYNEX, and SBC show a statistically significant time trend relationship, with initial trouble reports showing a statistically significant decreasing trend over time and repeat trouble reports showing a statistically significant increasing trend over time. This would indicate that while it might be possible that the companies underreported trouble, that any manipulation must be systematic, and variation in the data still allows the observed trends to emerge. Additionally, as one of the statistically significant trends would be viewed as unfavorable by regulatory agencies (i.e., the increasing repeat trouble reports over time), this is evidence that the companies were not likely fabricating numbers to please regulators. It is noteworthy that these time trend results are consistent with the hypotheses of the paper with regard to technology

Table 1
Results of time trend regression with total initial trouble as the dependent variable

Company name	F of regression	R^2	Estimated coefficient of time trend variable	Standard error	T-ratio	Significance level
Ameritech	1.262	0.03	− 0.0029695	0.02635	− 1.123	0.27
Bell Atlantic	326.15	0.86	− 0.020862	0.001155	− 18.06	0.00
NYNEX	102.67	0.69	− 0.017451	0.001722	− 10.13	0.00
SBC	30.72	0.4471	− 0.014714	0.002655	− 5.543	0.00

Table 2
Results of time trend regression with total repeat trouble as the dependent variable

Company name	F of regression	R^2	Estimated coefficient of time trend variable	Standard error	T-ratio	Significance level
Ameritech	0.366	0.01	− 0.0018319	0.003029	− 0.6048	0.55
Bell Atlantic	152.63	0.74	0.028855	0.002336	12.35	0.00
NYNEX	15.59	0.25	0.0063019	0.001596	3.949	0.00
SBC	57.643	0.6027	0.010613	0.001398	7.59	0.00

improvements making networks generally more reliable, but more difficult to fix when trouble emerges.[1]

However, the same analysis performed on data from the Ameritech region does not show a statistically significant time trend for either initial or repeat trouble. Thus the underreporting that is more damaging to statistical results (i.e., "freezing" report levels from year to year) is a possibility. Ameritech has been criticized by the staff of the state regulatory commission in Ohio on precisely this account.[2] As a result, while reporting the results of the analysis for Ameritech, we believe that an errors-in-variables problem may exist for this company and thus do not offer interpretation of the Ameritech results.

[1] The time trend variable is not included in the regression analysis that follows as it is highly correlated with the technology variables, leading to a potential multicollinearity problem.

[2] "The PUCO staff accuses Ameritech of manipulating the customer service data to show the company in the best possible light. 'Ameritech generates numbers to show whatever it wants them to show at any particular time. They are meaningless,' the staff brief said." (Bischoff, 2000).

4. Factors that influence trouble reports

Initial and repeat trouble reports may be influenced by a number of factors. It is hypothesized that the following may influence instances of initial and repeat troubles.

4.1. Competition

Emerging local exchange competition may have an impact on instances of trouble for incumbent LEC customers. In order to measure competition, this study employs FCC reports that track the number of CLECs that are present in a state (FCC, 1999). Given that competitors have generally gravitated toward the business market, the intensity of competition in a state is measured by the number of competitors per business line, which is identified as the variable COMPETITORS.

However, the expected impact of competition is not certain. For example, increased competition might lead to pressure on the incumbent LEC to improve network reliability or response to trouble reports. Alternatively, the transition to competition, with unbundling of network elements, the admission of ILEC competitors into LEC central offices, and service order processing for both ILEC and competitor customers might lead to increased instances of trouble. The problems with regard to competition may be transitory, but certainly could be reflected in the data. Furthermore, there may be variation across ILECs with regard to managerial preparedness for competition. As a result, the expected impact of competition on service quality is not certain.

4.2. Regulation

The regulatory mechanism operative might have an impact on network reliability and service quality.[3] For the firms in the study, state-level regulatory constraints are categorized into one of three groups, namely, rate of return, price cap (PCAP), and other incentive (INCENTIVE). Rate of return is omitted from the regression to avoid the dummy variable trap. Thus, regression coefficients on PCAP and INCENTIVE are interpreted as the impact of changing from rate of return to the alternative plan. Following Roycroft (1999), price cap plans are defined as those that govern the regulated company's prices with an inflation index (like the GDPPI) and a productivity offset. The result of this classification is to exclude regulatory plans, such as rate freezes (that are sometimes referred to as price caps) from the price cap category and thus place rate freezes in the incentive category. This classification of price cap regulation is consistent with theoretical models of price caps (see, for example, Hillman & Braeutigam, 1989). Regulatory regimes that are neither price cap nor rate of return are classified as incentive. Earlier research has failed to produce evidence that price cap or incentive regulation has degraded service quality (Tardiff & Taylor, 1993), but earlier studies relied on relatively short time-series analysis. Tables 3–6 summarize the classification used in this paper of the regulatory plans for the Ameritech, Bell Atlantic, NYNEX, and SBC regions.

[3] Concerns about the initial switch to FCC price cap regulation were voiced in the industry press (see, Taff, 1991a, b). All firms in the study operated under FCC price cap regulation for the entire study period, thus changes in regulation are measured with state-level plans.

Table 3
Summary of state-level regulatory regimes (Ameritech region)[a]

Year	Illinois	Indiana	Michigan	Ohio	Wisconsin
1991	ROR	ROR	I	ROR	I
1992	ROR	ROR	I	ROR	I
1993	ROR	ROR	I	ROR	I
1994	ROR*	ROR*	I	ROR*	I
1995	PC	I	I	PC	I*
1996	PC	I	I	PC	PC
1997	PC	I	I	PC	PC
1998	PC	I	I	PC	PC

[a]ROR = rate of return; I = non-price-cap incentive; PC = price cap; * indicates transition year.

Table 4
Summary of state-level regulatory regimes (Bell Atlantic region)[a]

Year	Delaware	Maryland	New Jersey	Pennsylvania	Virginia	West Virginia
1991	ROR	I	I	ROR	ROR	I
1992	ROR	I	I	ROR	ROR	I
1993	ROR	I	I	ROR	ROR	I
1994	ROR*	I	I*	ROR*	ROR*	I
1995	PC	I	PC	PC	I	I
1996	PC	I	PC	PC	I	I
1997	PC	I	PC	PC	I	I
1998	PC	I	PC	PC	I	I

[a]ROR = rate of return; I = non-price-cap incentive; PC = price cap; * indicates transition year.

Table 5
Summary of state-level regulatory regimes (NYNEX region)[a]

Year	Maine	Mass.	New Hamp.	New York	Rhode Is.	Vermont
1991	ROR	ROR	ROR	ROR	I	I
1992	ROR	ROR	ROR	ROR*	ROR*	I
1993	ROR	ROR	ROR	I	PC	I*
1994	ROR	ROR	ROR	I	PC	ROR
1995	ROR*	ROR	ROR	I*	PC	ROR
1996	PC	ROR*	ROR	PC	PC	ROR
1997	PC	PC	ROR	PC	PC	ROR
1998	PC	PC	ROR	PC	PC	ROR

[a]ROR = rate of return; I = non-price-cap incentive; PC = price cap; * indicates transition year.

Table 6
Summary of state-level regulatory regimes (SBC region)[a]

Year	Arkansas	Missouri	Kansas	Oklahoma	Texas
1991	ROR	I	I	ROR	I
1992	ROR	I	I	ROR	I
1993	ROR	I	I	ROR	I
1994	ROR	ROR*	I	ROR	I
1995	ROR	I	I	ROR	I*
1996	ROR*	I	I	ROR	PC
1997	PC	I	I	ROR	PC
1998	PC	I	I	ROR	PC

[a]ROR = rate of return; I = non-price-cap incentive; PC = price cap; * indicates transition year.

4.3. Downsizing/automation

To measure the automation/downsizing influence, a variable that measures the number of lines per employee (LINE/EMP) at the state-level operating company was created. Most of the RBOCs experienced a period of downsizing in the early- to mid-1990s. These staff reductions may have been driven, in part, by changing regulation (Loube, 1995) and changing technology. The expected impact on trouble reports might be, at first glance, an increase. However, this logic may not be entirely clear cut. If increased automation is a driving factor in the workforce reductions, then trouble reports may actually decrease as automation increases. However, even with increased automation, how the downsizing is handled by the firm may impact trouble reports. For example, downsizing that was achieved through attrition might have a different impact on employee morale (and thus trouble reports) than downsizing that was achieved by pink-slipping employees at random. If downsizing is reflecting automation, it may be that the types of trouble reports tracked by the FCC, and used in this research, would behave differently. For example, increasing automation might lead to reduced initial trouble reports, but more difficultly with repeat trouble. Thus, with the impact of downsizing, the appropriate statistical tests will be two-tailed, as was the case for the earlier variables.

4.4. Technology

Technological change is also hypothesized to have an impact on trouble reports. The introduction of new technologies could, through the replacement of depreciated older equipment, lead to an improvement in network reliability and thus decreased trouble reports. However, new technologies could also generate problems. For example, the introduction of technologies such as fiber optics and digital switching could require substantial retraining of maintenance and repair staff and periods of learning by doing (see, Vandenbroeck & Montalti, 1998; Clingman, 1990; Lindstrom, 1997; Savich, 1994; Blymiller, 1985; Bult, 1986). To control for the impact of the introduction of these technologies two variables are used. The first measures the percentage of all carrier cable that

is fiber optic (FIBER). The second measures the percentage of all switches that are digital (SWITCHING). As was the case with the earlier variables, two-tailed tests are appropriate.

4.5. Merger

In the time frame of this study, mergers have been concluded for four RBOCs, namely, SBC and Pacific Telesis, and Bell Atlantic and NYNEX. Both of the mergers received final regulatory approval during 1997. Mergers could also have an impact on network reliability and service quality. Consolidation of operations could affect service quality as managerial control evolved in the merged entity. The transfer of "best practices" might lead to improved network reliability and reduced trouble reports. Alternatively, the impact on employee morale in the transitional period of a merger might lead to declining employee performance (see, Messmer, 1998). It is also possible that the integration of each of the two companies' networks could lead to disruptions that could be reflected in increased instances of trouble.

5. Description of the data set

The focus of this study is the RBOCs. Initial (INITIAL) and repeat (REPEAT) trouble reports are tracked by the FCC on a state-level basis for each RBOC. For this study, the trouble reports are converted to percentages, with initial trouble as a percentage of state access lines, and repeat trouble as a percentage of all initial trouble reports. Data on the type of state-level regulation are also available for each state from Abel and Clements (1998) and Roycroft (1999). Information on the number of competitors in a market area is available from FCC reports on local competition. Furthermore, data on deployment of fiber optics and digital switching, employee counts, and number of access lines are available from the FCC, through its Automated Reporting Management Information System (ARMIS). With regard to mergers, a dummy variable (MERGER) is utilized to designate years when the company was operating after the final approval of a merger. The data set consists of data for all seven RBOCs' operations in 48 states[4] over the eight-year period. The data set consists of both time-series and cross-sectional observations. A total of 384 observations make up the overall data set. Table 7 summarizes the availability of data.

Given the nature of the companies involved, some assumptions about the behavior of the error term of the regression must be made. Given the presence of time-series data, serial correlation is a concern. Tests on the data set reveal that serial correlation is a problem that will need to be corrected. Additionally, given that the companies are in the same industry, use similar technology, may be part of the same holding company, and in fact were all once part of the same company, it is reasonable to assume that cross-sectional correlation may be a problem. Tests on regression residuals bear out the presence of positive cross-sectional correlation.

A modeling approach well suited for pooled time-series and cross-section data that contain cross-sectional units that are not independent and when the data are autoregressive is Kmenta's

[4] All of the lower 48 states, excluding Connecticut and including the District of Columbia.

Table 7
Availability of state-level data

Type	Variable name	Ameritech	Bell Atlantic	Bell South	NYNEX	Pacific Bell	SBC	US-West
#	COMPETITORS	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dummy	PCAP	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dummy	INCENT	Yes	Yes	Yes	Yes	Yes	Yes	Yes
%	SWITCHING	Yes	Yes	Yes	Yes	Yes	Yes	Yes
%	FIBER	Yes	Yes	Yes	Yes	Yes	Yes	Yes
#	LINE/EMP[a]	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dummy	MERGER	NA[b]	Yes	NA	Yes	Yes	Yes	NA
%	INITIAL	Yes	Yes	Yes	Yes	Yes	Yes	Yes
%	REPEAT	Yes	Yes	Yes	Yes	Yes	Yes	Yes

[a] Data for the number of employees per state are available for Ameritech, Bell Atlantic, Pacific Bell and NYNEX's New York operations. Other holding companies report only overall employee counts. State-level employee counts are estimated for these companies.
[b] NA = not applicable.

(1986) cross-sectionally correlated and time-wise autoregressive model (Dielman, 1989). This model assumes

$E(\varepsilon_{it}^2) = \sigma_{ii}$ (heteroskedasticity),

$E(\varepsilon_{it}\varepsilon_{jt}) = \sigma_{ij}$ (mutual correlation),

$\varepsilon_{it} = \rho_i \varepsilon_{i,t-1} + u_{it}$ (autoregression),

where i indicates a cross-sectional observation and t indicates a time-series observation.

The limitation of this approach is the ability to apply the model to the aggregate data set, since this model requires that the number of cross-sectional units (states) be no greater than the number of time periods. With 48 cross-sectional units and only eight time periods, utilization of an aggregate approach that will address the cross-sectional correlation is not possible. Thus, several holding companies will be analyzed separately, so the full time-wise autoregressive, cross-sectionally correlated model can be applied. The holding companies that allow for the application of the appropriate model are Ameritech, Bell Atlantic, NYNEX, and SBC. While the correction for cross-sectional correlation may improve the efficiency of the estimators, the downside of this approach is the reduction in the degrees of freedom.[5]

6. Regression model

Separate regressions were run for the regional holding companies with total repeat trouble (REPEAT) and total initial trouble (INITIAL) as the dependent variables. The regression model

[5] While it is theoretically possible to perform this analysis on Pacific Bell, due to the small number of observations, an individual analysis of Pacific Bell is not performed.

has the following form for Bell Atlantic, NYNEX, and SBC:

$$\begin{aligned}\text{INITIAL}_{it} &= \beta_0 + \beta_1\,\text{COMPETITORS}_{it} + \beta_2\,\text{PCAP}_{it} + \beta_3\,\text{INCENT}_{it}\\ &\quad + \beta_4\,\text{LINES/EMP}_{it} + \beta_5\,\text{SWITCHING}_{it} + \beta_6\,\text{FIBER}_{it}\\ &\quad + \beta_7\,\text{MERGER}_{it} + \varepsilon_{it}\\ &\quad (i = 1,\ldots,n;\ t = 1,\ldots,8) \quad \text{(Model 1)},\end{aligned}$$

$$\begin{aligned}\text{REPEAT}_{it} &= \beta_0 + \beta_1\,\text{COMPETITORS}_{it} + \beta_2\,\text{PCAP}_{it} + \beta_3\,\text{INCENT}_{it}\\ &\quad + \beta_4\,\text{LINES/EMP}_{it} + \beta_5\,\text{SWITCHING}_{it} + \beta_6\,\text{FIBER}_{it}\\ &\quad + \beta_7\,\text{MERGER}_{it} + \varepsilon_{it}\\ &\quad (i = 1,\ldots,n;\ t = 1,\ldots,8) \quad \text{(Model 2)},\end{aligned}$$

where $n = 7$ for Bell Atlantic, $n = 6$ for NYNEX, and $n = 5$ for SBC.

The regression model has the following form for Ameritech:

$$\begin{aligned}\text{INITIAL}_{it} &= \beta_0 + \beta_1\,\text{COMPETITORS}_{it} + \beta_2\,\text{PCAP}_{it} + \beta_3\,\text{INCENT}_{it}\\ &\quad + \beta_4\,\text{LINES/EMP}_{it} + \beta_5\,\text{SWITCHING}_{it} + \beta_6\,\text{FIBER}_{it} + \varepsilon_{it}\\ &\quad (i = 1,\ldots,5;\ t = 1,\ldots,8) \quad \text{(Model 3)},\end{aligned}$$

$$\begin{aligned}\text{REPEAT}_{it} &= \beta_0 + \beta_1\,\text{COMPETITORS}_{it} + \beta_2\,\text{PCAP}_{it} + \beta_3\,\text{INCENT}_{it}\\ &\quad + \beta_4\,\text{LINES/EMP}_{it} + \beta_5\,\text{SWITCHING}_{it} + \beta_6\,\text{FIBER}_{it} + \varepsilon_{it}\\ &\quad (i = 1,\ldots,5;\ t = 1,\ldots,8) \quad \text{(Model 4)}.\end{aligned}$$

7. Regression results

7.1. Bell Atlantic

The results for Bell Atlantic with INITIAL as the dependent variable are shown in Table 8. With the exception of SWITCHING and MERGER, all variables are significant at 5%. For COMPETITORS the sign is positive, indicating an increase in initial trouble as competition increased. The sign of FIBER's coefficient is negative, indicating that deployment of fiber optics has decreased initial trouble reports. With regard to LINE/EMP, the sign of the coefficient is negative, indicating that for Bell Atlantic, reports of initial trouble decreased as the downsizing/automation process occurred. The coefficients of the regulatory variable both have negative signs, indicating that in the Bell Atlantic region, initial trouble reports decreased as alternative regulation plans at the state level were implemented.

For Bell Atlantic's REPEAT trouble, the results are shown in Table 9. All variables are significant at 5%. The sign of COMPETITORS is negative, indicating decreases in repeat trouble as the number of competitors increases. The signs of FIBER and SWITCHING's coefficients are positive, indicating that deployment of digital switching and fiber optics has coincided with an increase in repeat trouble reports. With regard to LINE/EMP, the sign of the coefficient is positive,

Table 8
Bell Atlantic — total initial trouble

Row no.	Variable name	Estimated coefficient	Standard error	*T*-ratio (48 df)	Significance level
1	COMPETITORS	388.81	194.7	1.997	0.05
2	PCAP	− 0.025869	0.003343	− 7.739	0.00
3	INCENT	− 0.025398	0.004009	− 6.335	0.00
4	LINE/EMP	− 0.00020295	0.00002779	− 7.303	0.00
5	SWITCHING	0.032055	0.02129	1.506	0.14
6	FIBER	0.86430	0.08570	− 10.09	0.00
7	MERGER	0.0086152	0.01162	0.7417	0.46
8	CONSTANT	0.38286	0.03085	12.41	0.00
$R^{2a} = 0.8591$, $F = 41.804$ (P value = 0.00)					

[a] R^2 is based on a statistic proposed by Buse (1973) for the GLS model.

Table 9
Bell Atlantic — total repeat trouble

Row no.	Variable name	Estimated coefficient	Standard error	*T*-ratio (48 df)	Significance level
1	COMPETITORS	− 1065.9	231.5	− 4.604	0.00
2	PCAP	− 0.030182	0.01055	− 2.862	0.01
3	INCENT	0.041560	0.006275	6.624	0.00
4	LINE/EMP	0.00035256	0.00003936	8.955	0.00
5	SWITCHING	0.17555	0.03359	5.226	0.00
6	FIBER	1.9579	0.2008	9.752	0.00
7	MERGER	− 0.13991	0.02895	− 4.833	0.00
8	CONSTANT	− 0.30596	0.03258	− 9.390	0.00
$R^2 = 0.9042$, $F = 64.734$ (P value = 0.00)					

indicating that for Bell Atlantic, reports of repeat trouble increased as the downsizing/automation process occurred. INCENT's coefficient has a positive sign, indicating that in the Bell Atlantic region, repeat trouble reports increased as alternative regulation plans at the state level were implemented. However, PCAP shows a negative sign, indicating that repeat trouble decreased where price cap plans were implemented. MERGER's coefficient is negative, indicating a decrease in repeat trouble for Bell Atlantic when operating as a merged entity.

In sum, results indicate that for Bell Atlantic the impact of alternative regulation has been mixed on trouble reports. The results for the impact of competition are consistent with the hypothesis that the transition to competition has created some difficulties for Bell Atlantic, with increased initial trouble reports. However, competition may have led to an improved response to initial trouble reports, leading to fewer instances of repeat trouble.

Table 10
NYNEX — total initial trouble

Row no.	Variable name	Estimated coefficient	Standard error	*T*-ratio (40 df)	Significance level
1	COMPETITORS	52.705	164.0	0.3214	0.75
2	PCAP	− 0.0083423	0.004990	− 1.672	0.10
3	INCENT	0.033631	0.006771	4.967	0.00
4	LINE/EMP	0.0000040758	0.00007119	0.05725	0.96
5	SWITCHING	− 0.45758	0.02636	− 17.37	0.00
6	FIBER	− 0.24098	0.1553	1.552	0.13
7	MERGER	0.026365	0.003996	6.606	0.00
8	CONSTANT	0.62208	0.02423	25.67	0.00

$R^2 = 0.9574$, $F = 128.488$ (P value = 0.00)

Table 11
NYNEX — total repeat trouble

Row no.	Variable name	Estimated coefficient	Standard error	*T*-ratio (40 df)	Significance level
1	COMPETITORS	− 588.91	131.3	− 4.485	0.00
2	PCAP	0.022352	0.003312	6.749	0.00
3	INCENT	− 0.014021	0.002998	− 4.667	0.00
4	LINE/EMP	− 0.000037711	0.00004754	− 0.7932	0.43
5	SWITCHING	0.031846	0.01965	1.620	0.11
6	FIBER	0.61854	0.07142	8.661	0.00
7	MERGER	− 0.0087148	0.004387	− 1.987	0.05
8	CONSTANT	0.085985	0.01752	4.907	0.00

$R^2 = 0.8549$, $F = 33.671$ (P value = 0.00)

7.2. *NYNEX*

The results for NYNEX with INITIAL as the dependent variable are shown in Table 10. Only the coefficients associated with INCENT, SWITCHING and MERGER are significant at 5%. For INCENT the sign is positive, indicating an increase in initial trouble as incentive regulation plans were introduced. The sign of SWITCHING's coefficient is negative, indicating that deployment of digital switching has decreased initial trouble reports. The coefficient for MERGER has positive sign, indicating that in the NYNEX region, initial trouble reports increased as NYNEX operated as part of a merged entity.

For NYNEX's REPEAT trouble, the results are shown in Table 11. All variables, with the exception of LINE/EMP and SWITCHING, are significant at 5%. The sign of COMPETITORS is negative, indicating decreases in repeat trouble as the number of competitors increases. The sign

Table 12
SBC — total initial trouble

Row no.	Variable name	Estimated coefficient	Standard error	*T*-ratio (32 df)	Significance level
1	COMPETITORS	− 1784.9	857.4	− 2.082	0.05
2	PCAP	− 0.0016525	0.02327	− 0.07102	0.94
3	INCENT	− 0.039996	0.01664	− 2.403	0.02
4	LINE/EMP	0.00010097	0.0003860	0.2616	0.80
5	SWITCHING	− 0.14370	0.03838	− 3.744	0.00
6	FIBER	− 0.39658	0.4167	− 0.9517	0.35
7	MERGER	− 0.014320	0.01257	− 1.139	0.26
8	CONSTANT	0.39279	0.08085	4.858	0.00
$R^2 = 0.9138$, $F = 48.461$ (P value = 0.00)					

of FIBER's coefficient is positive, indicating that deployment of digital switching has coincided with an increase in repeat trouble reports. The regulatory variable INCENT's coefficient has a negative sign, indicating that in the NYNEX region, repeat trouble reports also decreased as incentive regulation plans at the state level were implemented; however, for states with price cap regulation, the positive sign of the PCAP variable indicates increases in repeat trouble reports. The sign of MERGER's coefficient indicates that reports of repeat trouble decreased in the post-merger environment.

In sum, results indicate that for NYNEX the impact of incentive regulation has been to reduce repeat and increase initial trouble. Price cap regulation in the region may have led to an increase in repeat trouble. The results for the impact of competition are consistent with the hypothesis that competition may have led to an improved response to initial trouble reports, leading to fewer instances of repeat trouble.

7.3. SBC

The results for SBC with INITIAL as the dependent variable are shown in Table 12. Only the variables COMPETITORS, INCENT and SWITCHING are significant at 5%. For COMPETITORS the sign is negative, indicating decreased initial trouble as competition increased. The sign of SWITCHING's coefficient is negative, indicating that deployment of digital switching has decreased trouble reports. The coefficient of the regulatory variable INCENT has a negative sign, indicating that in the SBC region, initial trouble reports decreased as incentive regulation plans at the state level were implemented.

For SBC's REPEAT trouble, the results are shown in Table 13. All coefficients are significant at 5%. The sign of COMPETITORS is positive, indicating increases in repeat trouble as the number of competitors increases. Signs for both PCAP and INCENT are negative, indicating decreases in repeat trouble as alternative regulation plans were implemented. The signs for FIBER and SWITCHING are positive, indicating that deployment of digital switching and fiber optics has coincided with an increase in repeat trouble reports. The sign of MERGER is negative, indicating the repeat trouble decreased as SBC operated as a merged entity.

Table 13
SBC — total repeat trouble

Row no.	Variable name	Estimated coefficient	Standard error	*T*-ratio (32 df)	Significance level
1	COMPETITORS	3599.9	351.8	10.23	0.00
2	PCAP	− 0.033736	0.01137	− 2.967	0.01
3	INCENT	− 0.017156	0.006426	− 2.670	0.01
4	LINE/EMP	− 0.00029282	0.0000976	− 3.000	0.01
5	SWITCHING	0.069889	0.02716	2.573	0.02
6	FIBER	0.80472	0.1912	4.208	0.00
7	MERGER	− 0.024944	0.008360	− 2.984	0.01
8	CONSTANT	0.11114	0.01999	5.560	0.00
$R^2 = 0.9507$, $F = 88.237$ (P value = 0.00)					

Table 14
Ameritech — total initial trouble

Row no.	Variable name	Estimated coefficient	Standard error	*T*-ratio (33 df)	Significance level
1	COMPETITORS	70.885	2157.0	0.03287	0.97
2	PCAP	− 0.0076963	0.009924	− 0.7755	0.44
3	INCENT	− 0.00047651	0.008517	− 0.05595	0.96
4	LINE/EMP	0.00035211	0.00007947	4.431	0.00
5	SWITCHING	− 0.38794	0.06120	− 6.339	0.00
6	FIBER	− 0.16998	0.5454	− 0.3317	0.76
7	CONSTANT	0.43633	0.03462	12.6	0.00
$R^2 = 0.6873$, $F = 12.088$ (P value = 0.00)					

In sum, the results indicate that for SBC the impact of incentive regulation has been a reduction in initial trouble reports. The results for the impact of competition are consistent with the hypothesis that the transition to competition has created some difficulties for SBC with increased repeat trouble reports. However, competition may have led to improved network operations, as indicated by the decrease in initial trouble reports. Merger is associated with a decrease in repeat trouble.

7.4. Ameritech

The results for Ameritech with INITIAL as the dependent variable are shown in Table 14. With the exception of LINE/EMP and SWITCHING, no other variables are significant at 5%. The results for Ameritech with REPEAT as the dependent variable are shown in Table 15. With the exception of FIBER all variables are significant at 5%. As was discussed earlier, while reporting

Table 15
Ameritech — total repeat trouble

Row no.	Variable name	Estimated coefficient	Standard error	*T*-ratio (32 df)	Significance level
1	COMPETITORS	− 2254.1	837.9	2.69	0.01
2	PCAP	− 0.054085	0.007315	− 7.394	0.00
3	INCENT	− 0.043554	0.006996	− 6.225	0.00
4	LINE/EMP	− 0.00017923	0.00008774	− 2.043	0.05
5	SWITCHING	0.46334	0.07869	5.888	0.00
6	FIBER	0.19714	0.3272	0.6024	0.55
7	CONSTANT	− 0.15585	0.03687	− 4.227	0.00

$R^2 = 0.8591$, $F = 41.804$ (P value = 0.00)

Table 16
Summary of coefficient signs — total initial trouble

Variable name	BA	NYNEX	SBC
COMPETITORS	+ [a]	+	− [a]
PCAP	− [a]	−	−
INCENT	− [a]	+ [a]	− [a]
LINE/EMP	− [a]	+	+
SWITCHING	+	− [a]	− [a]
FIBER	− [a]	−	−
MERGER	+	+ [a]	−
CONSTANT	+ [a]	+ [a]	+ [a]

[a]Significant at 5%.

these results for completeness, the possibility of a damaging errors-in-variables problem exists for Ameritech; thus further interpretation of the Ameritech results is not offered.

8. Summary

Table 16 summarizes the results from the analysis of initial trouble. The results for the impact of emerging competition tend to be company specific. For Bell Atlantic, growing competition has led to growing initial trouble reports. However, for SBC the impact of growing competition has been the opposite, decreasing initial trouble. This difference might be attributed to how competitors are choosing to utilize the provisions of the Telecommunications Act for local market entry. In the Bell Atlantic region, use of unbundled loops by competitors is relatively much higher than in the SBC

region. By year-end 1998 Bell Atlantic sold 2.71 times as many loops as SBC.[6] Higher use of unbundled loops would imply a more complex local competition environment, which could result in higher initial trouble reports due to increased presence of competitors in Bell Atlantic switching centers and the greater level of intervention in Bell Atlantic's network facilities needed to provide unbundled loops. A larger competitor presence in Bell Atlantic switching centers is also borne out in the data. By year-end 1998, 55% of Bell Atlantic access lines were served by wire centers with collocated entrants. SBC had 39% of its access lines served by wire centers with collocated entrants during the same time period (FCC, 2000, Table 9.6).

With regard to the impact of regulation, the results are again company specific. For Bell Atlantic, initial trouble decreased as incentive and price cap plans were implemented. Decreased initial trouble was also the case for SBC incentive plans. For NYNEX, however, the introduction of incentive regulation is associated with increased initial trouble. It should be noted, however, that the results for the NYNEX region with regard to incentive regulation are heavily weighted with the results of NYNEX's New York operations. Recalling Table 5, during the study period incentive regulation existed in the NYNEX region for only six observations, three from New York and three from Vermont. Given NYNEX New York's notoriously poor service quality problems during this period, it is not surprising to find that incentive regulation is associated with an increase in initial trouble reports.[7]

For the technology variables, SWITCHING shows a significant reduction in two of three cases. The signs associated with FIBER are all negative, but only significant in one case. The impact of downsizing/automation is associated with a decrease in initial trouble for Bell Atlantic. Merger shows a statistically significant result for NYNEX alone, an increase in initial trouble.

Table 17 summarizes the results from the analysis of repeat trouble. For Bell Atlantic and NYNEX, growing competition has led to fewer repeat trouble reports, but SBC shows an increase in repeat trouble. This difference might be influenced by the fact that SBC faced a higher level of local service resale than did Bell Atlantic and NYNEX. As of December 1998, SBC was reselling approximately 3.17% of its access lines under total service resale arrangements with competitors, as opposed to 2.17% for NYNEX states and 0.90% for Bell Atlantic (FCC, 2000, Table 9.5). Furthermore, about 67% of SBC resale lines were sold in one state, Texas. The higher level of local service resale could be contributing to higher repeat trouble due to increased complexity in processing initial trouble reports that arises in a resale environment, with trouble reports being passed from the CLEC to the ILEC for resolution, thus leading to a higher likelihood of repeat trouble.

With regard to the impact of regulation, the results are company specific, but a majority of the cases show reduced repeat trouble. The exceptions to this are NYNEX with price cap and Bell Atlantic with incentive regulation plans. With regard to NYNEX, ironically the increase in repeat trouble under price caps corresponds to a specific plan adopted by the New York Public Service

[6] Bell Atlantic had about 1.39 times as many total loops as SBC, indicating that proportionally it still was selling about twice as many unbundled loops as SBC (FCC, 2000).

[7] New York continues to be dogged by a reputation for service quality problems, especially in the New York City metro area (see, for example, Sherman, 1999).

Table 17
Summary of coefficient signs — total repeat trouble

Variable name	BA	NYNEX	SBC
COMPETITORS	−[a]	−[a]	+[a]
PCAP	−[a]	+[a]	−[a]
INCENT	+[a]	−[a]	−[a]
LINE/EMP	+[a]	−	−[a]
SWITCHING	+[a]	+	+[a]
FIBER	+[a]	+[a]	+[a]
MERGER	−[a]	−[a]	−[a]
CONSTANT	−[a]	+[a]	+[a]

[a]Significant at 5%.

Commission to address poor service quality.[8] NYNEX New York paid $72 million in fines related to poor service quality in the first year of the plan's operation (Sherman, 1999). For SBC, incentive and price cap regulation have resulted in fewer repeat trouble reports.

The impact of downsizing/automation leads to mixed results for repeat trouble with SBC showing statistically significant decreases and Bell Atlantic showing statistically significant increases.

Merger is associated with a consistent decrease in repeat trouble. This may reflect company response to an expected higher level of scrutiny by regulators in the aftermath of a merger. Technology shows a consistent impact with the deployment of digital switching and fiber optics leading to statistically significant increases in repeat trouble reports in the majority of cases. This growth would lend support to the hypothesis that the deployment of these technologies has led to greater difficulty in solving network problems once they arise.

8.1. Service quality discrimination

Another interesting question is whether service quality discrimination is emerging in response to competition. The results reported above are for company-wide trouble reports. However, data are also available for initial and repeat trouble reports for business and residential customers, allowing for additional analysis of service quality discrimination. The emergence of local exchange competition has been primarily affecting the business market segment. Thus, if service quality discrimination is occurring, one would expect a disaggregated analysis to reveal differences in the sign and significance levels associated with the COMPETITORS variable. In order to explore this issue, separate regressions were run on the business and residential trouble reports. The structure of the regression models was the same as Models 1–4 above, with the exception of the dependent variable.

[8] Proceeding on Motion of the Commission to Investigate Performance-based Incentive Regulatory Plans for New York Telephone … Case 92-C-0665; Case 92-C-0001; Case 92-C-0150; Case 92-C-0228; Case 92-C-0342; Opinion No. 94-2. New York Public Service Commission, January 28, 1994.

Table 18
Coefficient summary of the COMPETITORS variable (disaggregated total initial trouble)

Company	Aggregate result		Business segment		Residential segment	
	Sign	Sig. level	Sign	Sig. level	Sign	Sig. level
Bell Atlantic	+	0.05	−	0.54	+	0.00
NYNEX	+	0.75	+	0.38	+	0.70
SBC	−	0.05	−	0.00	−	0.09

Table 19
Coefficient summary of the COMPETITORS variable (disaggregated total repeat trouble)

Company	Aggregate result		Business segment		Residential segment	
	Sign	Sig. level	Sign	Sig. level	Sign	Sig. level
Bell Atlantic	−	0.00	−	0.00	−	0.00
NYNEX	−	0.00	−	0.00	−	0.28
SBC	+	0.00	+	0.00	+	0.00

For each holding company, the dependent variable was replaced with either business initial trouble, business repeat trouble, residential initial trouble, or residential repeat trouble. All regression results yielded statistically significant F statistics, and R^2 values that were similar to the aggregate results reported above. Table 18 summarizes the results for the COMPETITORS coefficients in the disaggregated analysis of initial trouble, focusing on the sign and significance level of the coefficients. SBC shows that an increasing number of competitors resulted in a statistically significant decrease in initial trouble reports for business customers, but not for residential customers. Bell Atlantic residential customers show a statistically significant increase in initial trouble, while Bell Atlantic business customers saw an insignificant impact. Neither NYNEX residential nor business customers show statistically significant changes.

A similar analysis was conducted to explore service quality discrimination for repeat trouble. Table 19 summarizes the disaggregated analysis of repeat trouble. The disaggregated analysis of repeat trouble shows a divergence of results between the business and residential markets only for NYNEX. For NYNEX, the decrease in repeat trouble is only significant in the business segment.

9. Conclusions

As was discussed above, service quality is a multi-dimensional concept. This paper has focused on two metrics that reflect service quality and network reliability, initial and repeat trouble reports and sheds light on multiple factors that may influence service quality.

The results from Bell Atlantic, NYNEX and SBC show that the introduction of competition may be having some impact on network reliability and service quality as measured by trouble reports, with repeat trouble showing fairly consistent decreases. Bell Atlantic, however, shows a significant increase in initial trouble in response to competition and the disaggregated analysis indicates that increases in initial trouble in the residential market segment alone are driving this increase. Evidence of differential service quality in response to competition that is apparent from the disaggregated analysis of business and residential customer segments may be troubling news for policymakers. It is natural that an incumbent firm would respond to a competitive threat by improving service quality to the customers that face competition. However, the evidence of increasing initial trouble reports for residential customers in the Bell Atlantic region raises concern. This impact may be a passing phenomenon related to the learning by doing associated with the introduction of local competition, but it is an area for regulators and policymakers to keep monitoring. Continued regulatory oversight of residential service quality would seem prudent.

Technology has had a consistent impact on network reliability and service quality as reflected in trouble reports. Deployment of fiber optics and digital switching has led to more reliable network performance, with generally fewer instances of initial trouble. However, when trouble arises, it is more difficult to resolve, as indicated by increased repeat trouble.

Another conclusion is that there is not any compelling evidence in the data that price cap and incentive regulation have led to systematic degradation of network reliability and service quality, as measured by trouble reports. Results indicate that some alternative regulation plans that were implemented in the NYNEX and Bell Atlantic regions were associated with increased instances of trouble. This points to a future research direction, analysis of the specific components of alternative regulation plans in order to identify common features that may lead to decreased service quality.

Finally, the analysis of Ameritech trouble reports, with the lack of statistically significant time trends and the possibility of the errors-in-variables problem, highlights a dilemma faced by regulators that has been highlighted by Lewis and Sappington (1998), namely, the asymmetry of information between regulators and the companies that they regulate.

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