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Competition, Regulatory Policies and Productivity Growth in the U.S. Local Telecommunications*

- First Draft -

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ABSTRACT

It is widely accepted that competition and incentive regulation have positive effects on the performance of telephone operating companies. In addition, substitution of fixed telephone services with mobile and broadband services may affect the productivity of telephone companies through their impact on output growth and investments. The study attempts to examine the effects of competition and incentive regulation on changes in the total factor productivity (TFP) of U.S. local exchange carriers (LECs) and more importantly, to investigate into the key sources for a recent slowdown in the TFP across large incumbent LECs. The empirical analysis is carried out with a panel data of 28 incumbent LECs for the period 1991-2004. The estimation results indicated that competition had clear positive effects on both TFP change and technical change, while incentive regulation led to industry-wide technical change and not to carrier-specific TFP growth. Also, the results showed that fixed-mobile substitution had a detrimental effect on the performance of ILECs through its negative impacts on the demand for fixed telephone services and the quality of capital inputs. On the other hand, broadband services were found to have little relationship with the performance of ILECs so far. In sum, active intra-modal competition and the introduction of incentive regulation may no longer be a sufficient means for promoting the productivity growth of LECs.

Key words: Local Telecommunications, Productivity, Competition, Incentive Regulation, Fixed-Mobile Substitution

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Ⅰ. Introduction

While competition is currently under way in the U.S. local telecommunications markets, traditional rate-of-return (ROR) regulation has been gradually replaced with incentive regulation. Without doubt, one of main objectives of both competition and incentive regulation is to provide local exchange carriers (LECs) or local operating companies with incentives to improve their productive efficiency and to achieve higher productivity growth. On the other hand, despite the gradual progress of competition and the proliferation of various incentive regulations, reporting incumbent local exchange carriers (ILECs) are found to have suffered from a substantial slowdown in the productivity growth in the 2000s. To take labor productivity as an example, the annual average change rate of telephone calls per employee for 28 reporting ILECs dropped from 13.8% for the period 1992-1996 to 4.4% for the period 2001-2004.

One of the main causes of this slowdown may be found in the growth of mobile services (or wireless services) and broadband services (or high-speed services for internet access). At first, both mobile and broadband services served primarily as a complement to fixed telephones (or wireline services). However, as the two services become widely spread, they began to compete directly with fixed telephones, first for usage and then for access. Currently mobile telephones are increasingly substituting fixed telephones. Also the potential for broadband services to become a substitute for, and directly compete with, fixed telephones by providing a platform for voice over IP (VoIP) has become clear. As a result, many LECs have suffered from a declining fixed telephone market, which may lead to bad performance, and lower productivity than before.

Another factor explaining the slowdown may be the tight wholesale regulation on ILECs, including unbundled network elements (UNE) or local loop unbundling obligations. Some economists argue that this type of access regulation may suppress ILEC's readiness to invest.[1] It is widely accepted that the purchase of new capital goods is one of the main driving forces behind technical change and productivity growth.

The study attempts to examine the effects of competition and incentive regulation on the total factor productivity (TFP) of ILECs and more importantly, to investigate into the main sources of the recent slowdown in their change in TFP. The empirical analysis is carried out with panel data of 28 ILECs for the period 1991-2004. The study is divided into three parts. In the first part, the TFP growth rates of sample ILECs are determined using the data envelopment analysis (DEA) technique. A slowdown in the TFP change will be identified. Then the TFP growth rates are used as the dependent variable in the TFP regression models in which the explanatory variables capture the differences in competition, regulatory regimes, the state of technology, and firm-level characteristics across ILECs. At the last stage, the study investigates into the main sources of the recent slowdown in the change in TFP, examining the effects of rapid diffusion in mobile and broadband services on fixed telephone demand and the quality of capital.

Many studies have dealt with the effects of competition and incentive regulation on productivity. In general, they can be divided into international comparison studies and country-specific studies.[2] One of the typical international studies is Boylaud and Nicolletti (2000), which examined the effects of competition and privatization on the productivity,

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[1] For example, refer to Hazlett (2005).

[2] Besides, many studies on the effects of public telecommunications policies on other performance measures have been reported as well. For example, Jha and Majumdar (1999) suggested that mobile telephone diffusion contributed to productivity growth in OECD telecommunications sector. Wallsten (2002) argued that the establishment of independent regulator is more important than privatization at least in promoting the diffusion of fixed telephones.

prices, and service qualities in long-distance and mobile services markets by using 23 OECD member states data over the period 1991-1997. Boylaud and Nicolletti confirmed only a positive effect of competition. On the other hand, using 74 countries data over the period 1991-1997, Madden and Savage (1999) argued that privatization promoted technical change, while market concentration had no close relationship with technical change. Bortolotti *et al*. (2002) showed that 31 telecom operators obtained better performance results when privatization kept pace with regulatory reforms. Based on major European telephone operator data, Fraquelli and Vannoni (2000) concluded that the introduction of incentive regulation and competition resulted in efficiency improvements and price reductions, respectively.

Most of the country-specific productivity studies used the U.S. market data, partly because the FCC has provided plenty of publicly available data, especially data on telephone plants and equipments. For example, Gort and Sung (1999) showed a markedly faster change in the productivity of AT&T Long Lines, operating in a competitive market, than for 8 local telephone monopolies over the period 1951-1999. Resende (1999) indicated that incentive regulation had no causal relationship with difference in productivity across LECs for the period 1989-1994. Several studies, using the U.S. data, examined the effects of incentive regulation on technical efficiency.[3] Technical efficiency improvements, along with technical change and scale economies, are the key factor affecting productivity growth. For example, Majumdar (1997) estimated efficiency scores by applying DEA to a panel data of 45 LECs, which were collected for the period 1988-1993. Majumdar showed that the introduction of pure price-cap regulation did positively and significantly affect the technical efficiency of LECs after a 2-period lag. Using similar

[3] Ai and Sappington (2002) and Sappington (2003) offer a brief summary of empirical studies on various effects of incentive regulation in the U.S. telecommunications markets.

methods, Uri (2001) reached the opposite conclusion that price-cap regulation had no significant effects on technical efficiency.

These past studies reveal some drawbacks, including a poor measure of productivity and unreliable data. Also, few studies consider the effects of both competition and incentive regulation on the productivity. More importantly, none of these studies pay attention to the slowdown in the TFP and the effects of inter-modal competition as its key factor.

The study proceeds as follows. In section 2, the study provides a snapshot of regulatory and institutional environments in the U.S. local telecommunications markets. In section 3, the study present TFP changes of sample ILECs and estimates TFP regression equations to examine the effects of competition and incentive regulation on the TFP change. In section 4, the study searches for the key factors which may lead to the slowdown in the TFP change. Both the regression equations for telephone calls demand and capital quality are estimated. Conclusions are drawn in the final section.

Ⅱ. Regulatory and Institutional Environments in the U.S. Local Telecommunications Markets

Proliferation and Ubiquitousness of Incentive Regulation

Incentive regulation has been increasingly popular in the U.S. local telecommunications markets as more state commissions began to recognize the drawback of traditional rate-of-return regulation and the function of incentive regulation.[4] Table 1

[4] Numerous studies have tackled the principle, function and effects of incentive regulation, especially price-cap regulation, in telecommunications markets. For example, Sappington

shows change in the dominant form of retail rate regulation in the U.S. local telecommunications markets. Note that Table 1 does not report the number of rate regulation forms which state commissions adopted but that which 28 sample ILECs faced. For example, if a sample ILEC operated in a state adopting price-cap regulation, its type of rate regulation is simply price-capping. For a multi-state operating ILEC, the dominant form of rate regulation is regarded as its type. To calculate regulatory score, the study classifies seven regulatory forms from the baseline case of traditional rate-of-return regulation to deregulation through several regulatory plans that incrementally provide greater flexibility to LEC.[5] Then a regulatory form that allows more flexibility is given a higher score.[6] For a multi-state operating ILEC, the regulatory score is derived by weighting state regulatory scores by proportion of access lines that each state contributes to the total access lines owned by the ILEC.

Table 1 indicates that various forms of incentive regulation including price-capping were already widely adopted in the early 1990s. For example, the number of sample ILECs operating under any form of incentive regulation was 18 out of 28 sample ILECs in 1991. Rate-of-return (ROR) regulation, however, was not dead in many states. Still, 10 ILECs operated under ROR regulation at that time. As soon as price-cap regulation and its variants gained popularity, they became the most frequently adopted form of retail rate regulation around 1995. In 2004, price-cap regulation was not applicable only to 5 ILECs.[7] The

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and Weisman (1996a, 1996b) and Sappington (2003) made a close inspection of incentive regulation.

5 This classification is mainly based on Abel and Clements (1998).

6 In particular, the study gives score 1 to rate-of-return regulation, 2 to banded rate-of-return regulation, 3 to rate case moratoria, 4 to earnings-sharing, 5 to revenue sharing, 6 to indexed price cap regulation, 7 to social contracts and rate freezes, and 8 to deregulation. For convenience' sake, the last three forms of regulation are grouped into price-cap regulation (PC) and deregulation in Table 1. The remaining forms excluding rate-of-return regulation, PC and deregulation are classified as other forms of incentive regulation (IC).

7 In 2004, Hawaiian Telephone Company and Puerto Rico Telephone Company were still

popularity of price-cap regulation is based on the notion that it gives stronger incentive toward cost reduction and innovation, is more suitable for competitive markets, and bears less regulatory costs than any other forms of incentive regulation.

< Table 1 inserted here >

Gradual Progress of Local Competition

New facility-based carriers, mainly competitive access providers (CAPs), had entered into the local telecommunications markets since the 1980s, but its presence was at most immaterial before the Telecommunications Act of 1996. The Act was aimed at eliminating legal barriers that had suppressed technically feasible local competition. In particular, the Act built a road to local competition by enforcing existing LECs to resell local services and to lend their network on the basis of UNEs. The Act added service-based competition to the sprouting facility-based competition, ultimately promoting serious local competition.[8]

Table 2 shows key measures of competitiveness for sample ILECs. In Table 2, local service competitors (LSCs) do not include only competitive local exchange carriers (CLECs), but also other forms of entrants such as CAPs. Table 2 indicates that a sample ILEC, on the average, competed only against 0.29 carriers in 1994, but against 9.47 carriers in 1999. The average number of reporting CLECs increased from 8.58 in 1999 to 15.62 in 2004. As competition proceeded, CLECs gradually took more subscribers from ILECs so that their market share increased to 17.7% in 2004. In Table 2, the ratio of CLEC resold

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regulated on the basis of rate-of-return. Other forms of incentive regulation were applied to Verizon-Northwest, Verizon-New England, and Qwest.

[8] The 1996 Act eliminated state-mandated exclusive local franchises, thereby opening local markets to competitive entry via one or a combination of methods. The 1996 Act provided for several modes of local telephone competition: resale of ILEC retail services, lease of ILEC UNEs, and interconnection of facilities-based networks (Rosenberg, 2007, p. 3)

lines and CLEC UNEs to total access lines owned by ILECs represents the extent of service-based competition. It appears that CLEC market share increased together with the two ratios, which indicates that service-based competition was of great assistance for CLECs to increase their market share. Irrespective of the form of competition, serviced-based or facility-based competition, competition is expected to raise productivity growth.

< Table 2 inserted here >

Inter-modal Competitive Pressure from Mobile and Broadband Services

The competitiveness of a market depends on the availability of reasonable substitutes for the relevant product. In markets for basic local telephone service, wireless services (and broadband services) are becoming more important as competitive platforms or technologies (Rosenberg, 2007, p. 1). Mobile services at the start were designed to give the additional feature of mobility, were conceived as a luxury good, and were peripheral or complementary to fixed telephone services. Thus mobile and fixed services served different segments of telecommunication needs. Consumers, however, began to perceive mobile services as substitutes for fixed telephone services for some uses, as soon as mobile prices dropped to a comparable level. It did not take too much time for the inter-modal competition between mobile and fixed telephone services to be formed and even to be transformed into direct rivalry at least in some markets. It is a matter of course that this fixed-mobile substitution has led to a gradual drop in fixed telephone calls and lines, which in turn has a bad influence on the productivity of LECs. Table 3 indicates that the U.S. has experienced rapid diffusion in mobile services as in many developed countries. In particular, a sample ILEC, on the average, has experienced a dramatic increase in mobile subscriptions per 100 persons from 28.7 in 1999 to 63.1 in 2004.

Broadband services may be a potential threat for fixed telephone services because they can provide a platform to VoIP as a cost effective alternative to fixed telephone services. VoIP becomes increasingly an alternative method of sending and receiving telephone calls. On the other hand, it appears that it takes more time for VoIP to act as a complete substitute for fixed telephone services, especially for residential customers, partly because of technological constraints and partly because the density of high-speed lines is still relatively low.[9] Table 4 indicates that the density of high-speed lines per 100 persons for an average sample ILEC is 12.9 in 2004.

< Table 3 inserted here >

Ⅲ. Change in TFP and Technical Change

Measuring TFP Growth Rates

The study estimates the Malmquist TFP change index (MPI) and decomposes the MPI into efficiency change and technical change. The MPI is a productivity index based on a distance function. Distance function is defined as the factor by which inputs can be decreased while still remaining within the input requirement set for a given output level.[10] The MPI reflects the distance from the current period observation to previous period technology. Technical efficiency score is defined as the distance from the current period

[9] Moreover, the subscription price for the VoIP service may be too high for customers that do not already have broadband access service, since it should include the subscription fee to obtain broadband access.

[10] Alternatively, distance function can be defined as the inverse of the factor by which outputs can be increased while still remaining within the production possibility set for a given input level. This is called output-oriented distance function. The definition in the text corresponds to input-oriented distance function. Similarly, output- or input-oriented MPI is defined. The study used input-oriented MPI because LECs had the ability to control the quantity of inputs at their discretion rather than the quantity of outputs.

observation to current period technology, and thereafter, improvement in the efficiency is measured by the ratio of the current period efficiency score to the previous period efficiency score. Technical change is measured by a shift in the input requirement set between two periods, *i.e.* the distance from the previous period technology to the current period technology. Then it is easy to show that the MPI is equal to the product of efficiency improvement and technical change. The study applies the DEA technique to estimate various distance functions.[11]

The empirical analysis of TFP is carried out with panel data for 28 ILECs.[12] Appendix Table gives a list of the 28 carriers, and the appendix itself gives a detailed explanation of the methods used to measure inputs, outputs and technology variables. When the DEA was applied, two outputs and three inputs were assumed. The two outputs are access lines and telephone calls and the three inputs are labor, capital and materials. In particular, the net stock of capital inputs is aggregated by using the conventional perpetual inventory method.

Table 4 shows the average annual change rates of various productivity indexes for sample ILECs. In Table 4, it is worth noticing a substantial decrease in both technical change and TFP change from the first two periods (1992-1996 and 1997-2000) to the last

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[11] DEA is a widely used non-parametric technique to estimate distance functions. In particular, DEA avoids problems faced by index numbers (*e.g.* Törnqvist TFP index) and econometric methods (*e.g.* stochastic frontier model) when price data are not available. The DEA technique estimates the shape of a production frontier based on all available observations, and calculates the distance from observations to targets (the best virtual firm) on the production frontier by solving a linear programming problem for each firm. Many DEA textbooks, including Coelli et al. (1998), Thanassoulis (2001), and Cooper et al. (2002), provide a detailed explanation of the DEA and the MPI. The study calculated the MPI by applying the DEA-Solver of Cooper et al. (2002).

[12] The sample carriers was chosen for continuity of data filed with the Federal Communications Commission (FCC). The sample carriers consist of all regional Bell operating companies (RBOCs), former GTE operating companies, and Puerto Rico Telephone Company.

period (2001-2004). In particular, the average annual change rate of TFP dropped from 6.9% for the period 1997-2000 to 0.63% for the period 2001-2004. On the other hand, no systematic changes in efficiency over time are found, which indicates that efficiency improvement might not be affected by any pre-determined policy variables. When the average cost (AC), which equals the ratio of total costs to the quantity of output, was computed, it showed the same change pattern as the TFP. The AC, on the average, decreased for the first two periods, but increased for the last period.

The calculation of TFP requires the construction of capital stocks and this raises many problems. Thus, labor productivity changes were examined in order to confirm the robustness of the findings using capital. The study used the average annual growth rate in labor productivity, measured by access lines per employee (LP1) and telephone calls per employee (LP2). In Table 4, it is easy to confirm no systematic change in access lines per employee, but a sharp decline in telephone calls per employee in the 2000s. For example, the average annual growth rate of telephone calls per employee, on the average, dropped from 13.8% for the period 1992-1996 to 4.4% for the period 2001-2004.

< *Table 4 inserted here* >

TFP Regression Equations

Many factors, including scale effects, technological advance, regional characteristics, competitive pressure and regulatory scheme, may have effects on the productivity of LECs. A matter of primary concern in the paper is to confirm the effects of these factors on the TFP and technical change in the U.S. local telecommunications markets, especially the effects of competition and incentive regulation among them. Thus the TFP level indexes are regressed on these factors. The econometric specification of the TFP level regression is expressed as follows.

$$TFP = \beta_0 + \beta_1 \ln MQ + \beta_2 \ln LQ + \beta_3 \ln KQ + \beta_4 \ln AL + \beta_5 \ln RS + \beta_6 COM + \beta_7 IR1 + \beta_8 IR2 \quad (1)$$

Here *MQ* refers to a multilateral translog index of output,[13] *LQ* to real wage rate as a measure of labor quality, *KQ* to average vintage as a measure of capital quality, *AL* to average sheath km of cable per access line, and *RS* to ratio of residential to total access lines. *MQ* measures scale effects, while *LQ* and *KQ* represent the state of technology. *AL* and *BS* represent firm-specific regional characteristics because their values are expected to be higher in rural and residential areas than in urban and business ones.

The above equation contains three policy dummy variables, *COM*, *IR1* and *IR2*. COM equals 1 when any local service competitor entered into any operating region of a sample ILEC, and otherwise equals 0. *IR1* equals 1 when other forms of incentive regulation, specified in Table 1, were introduced in a specific year, and otherwise equals 0. Finally, *IR2* equals 1 when price-cap regulation and its variants were put into force or any rate regulation was abolished, and otherwise equals 0. Regulatory score and competition score were used instead of these policy dummy variables to check the robustness of the findings. Competition score is defined as the number of local service competitors.[14]

The estimation is carried out by using conventional panel analysis models, *i.e.* random

[13] Refer to Caves *et al.* (1982) for the method of calculating a multilateral translog index.
[14] Because the number of local service competitors is not publicly available after 2000, it is proxied by the number of reporting CLECs for the period 2000-2004, with its value being adjusted by using the ratio of the number of local service competitors to the number of reporting CLECs in 1999.

effects (RE) and fixed effects (FE) models. Alternatively, the panel analysis models are combined with instrumental variable (IV) estimation methods because an output variable may be endogenously determined and hence, may be correlated with error terms.

Estimation Results

Table 5 gives the estimates for the TFP regressions. In Table 5, models 1 and 3 are RE models, while models 2 and 4 are FE models. Models 3 and 4 combine IV estimation method with RE and FE models, respectively. Table 5 indicates that both F tests and Breusch-Pagan Lagrangian multiplier tests confirm the presence of group effects. Also, Hausman tests are always in favor of FE models.

In Table 5, it appears that most of the parameter estimates are consistent with *a priori* theoretical expectations. The parameter estimates of ln*MQ* are positive and statistically significant in all models except for Model 3. That is, an increase in the level of output tended to result in the TFP growth. The coefficients of ln*LQ* and ln*KQ* have a positive sign and are mostly statistically significant, which indicates the possibility that input quality improvements led to productivity growth. Considering that ln*AL* and ln*RS* have mostly negative and statistically significant parameter estimates, it is likely that a higher ratio of rural and residential areas caused a decline in the TFP. This finding, however, is not unambiguous because the parameter estimates are statistically insignificant in some models.

The reported parameter estimates for competition and regulation dummy variables are always positively signed, which means that the introduction of competition and incentive regulation had a positive effect on the TFP of sample ILECs. On the other hand, the parameter estimates of COM are statistically significant in more reliable FE models, while those of *IR1* and *IR2* are mostly statistically insignificant.[15] That is, the results confirm the positive effect of competition on the performance of LECs, and not the positive effect of incentive regulation. This finding may be puzzling, considering the consensus among economists on the positive effect of incentive regulation on efficiency improvement and productivity growth.

< *Table 5 inserted here* >

To attempt in-depth analysis of the seemingly puzzling result, technical change indexes were regressed on the same explanatory variables as in the TFP regressions. When the TFP level index is replaced by the technical change index in Equation 1, the equation becomes just a technical change regression equation. In Table 6, the three test results indicate that FE models are preferable to RE model as well as ordinary pooled models with no group effects. Thus the subsequent discussions focus on the results in FE models.

Models 2 and 4 in Table 6 provide almost the same results as in Table 5. For instance, the higher level of output and better input qualities tended to cause faster industry-wide technical change. Also, it appears that the ratio of residential areas had a negative effect on technical change. However, no causal relationship between the average cable length per access line and technical change is found. On the other hand, all the reported parameter estimates for COM, IR1, and IR2 are now positively signed and statistically significant. If this finding is true, it is likely that competitive pressure and flexible rate regulation contributed to industry-wide technical change. It is worth remembering that there were no systematic changes in the efficiency over time in Table 4, which means that competition

[15] When competition and regulatory scores were used instead of policy dummy variables, their parameter estimates are always statistically insignificant.

incentive regulation might result in no catch-up effects. Combining these two observations, it is concluded that the introduction of incentive regulation led to industry-wide shifts in the production frontier but did not cause carrier-specific improvement in the efficiency. Therefore, it may not be surprising that the effect of incentive regulation on the TFP is not distinguishable, since the TFP change is determined by the combination of technical change and efficiency.

< Table 6 inserted here >

Ⅳ. Inter-modal Competition as a Key Source for the Slowdown in TFP

Driving Forces behind the Slowdown in TFP

The previous section has identified several factors which affect the TFP change in the U.S. local telecommunications markets: the level of output, labor and capital qualities, firm-specific regional characteristics, and regulatory policies. Since it is unlikely that firm-specific regional characteristics experienced any dramatic change over time, they could not be the main reasons behind the recent slowdown in the TFP of sample ILECs. Neither do regulatory policy variables because the previous section showed that competition and incentive regulation tended to lead to industry-wide technical change, and probably, TFP growth. Accordingly, it must be a change in either the level of output or input qualities that caused the sharp decline in the TFP after 2000.

Table 7 shows the average annual change rate of output and input qualities for sample ILECs. One of the most noteworthy findings in Table 7 is a sharp drop in output growth after 2000. Specifically, the average annual change rate in the level of output, measured by a multilateral translog index, dropped from 6.8% for the period 1997-2000 to -2.7% for the period 2001-2004. As explained in the appendix, access lines and telephone calls were aggregated into the multilateral translog index of output. The average number of telephone calls for a sample LEC began to decline after 200, and the average number of access lines increased albeit at a slower rate for the same period.[16] In particular, the average annual change rate of telephone calls was -4.2% for the period 2001-2004.[17] As mobile services have gained considerable consumer acceptance, they are increasingly substituting fixed telephone calls and then, fixed telephone lines. Similarly, broadband services are ready to capture fixed telephone calls and lines as a potential substitute. Without question, inter-modal competition from mobile and broadband services results in a steady decline in the number of fixed telephone calls and also, a slower increase or a decrease in the number of telephone access lines. Stop in growth of output or a decline in the level of output leads to deterioration in the TFP, as long as a company does not immediately adjust itself to a new long-run equilibrium.

In Table 7, it is found that improvement in the capital quality has substantially slowed down after 2001. Specifically, the average annual change rate of the capital quality decreased from 7.2% for the period 1997-2000 to 1.2% for the period 2001-2004. It is understandable that LECs, facing a decline in demand, gradually reduce the quantity of investment. The less quantity of new investment implies a slower increase in the average vintage of capital stock. In sum, inter-modal competition from mobile and broadband

[16] As a matter of fact, the U.S. total number of wireline telephone lines peaked at 192 million in 2000. Thereafter it began to fall, declining 175 million in 2005 (2007b, Table 7.1).

[17] The total number of interstate switched access minutes handled by all long distance carriers grew steadily from mid-1984 to 2000 stemming from a combination of overall economic growth and price reduction. Since 2001, interstate switched access minutes have declined, due to a number of reasons including substitution of other services (FCC, 2007b, p. 10-1). Also, the number of local calls carried by large reporting ILEC peaked at 554 billion in 1999 and has declined steadily, reaching 337 billion in 2005 (FCC, 2007b, Table 10.2)

services may have effects on the TFP change through their impact on the quality of capital. On the other hand, no systematic change of labor quality indexes over time is found. From now on, the study discusses how inter-modal competition from mobile and broadband services affects changes in the level of output and the quality of capital.

< Table 7 inserted here >

Inter-modal Competition and Demand for Telephone Calls

To examine the effects of inter-modal competition on output growth, the study attempts to estimate telephone demand equations. The analysis is carried out by including mobile and broadband penetration ratio into telephone demand equations as one of explanatory variables. On the other hand, it is difficult to empirically estimate the demand equations for total telephone calls and that for total access lines by using firm-level data because of insufficient information on service areas in which a LEC operates.[18] Thus the study focuses on telephone calls per access line.

The econometric specification of the demand equation for telephone calls per access line (CALL) is expressed as follows.

$$\ln CALL = \beta_0 + \beta_1 \ln RPM + \beta_2 \ln INC + \beta_3 \ln MDEN + \beta_4 \ln IDEN + \beta_5 \ln CLEC + \beta_6 \ln RESOL + \beta_7 \ln UNE \quad (2)$$

[18] In many cases, there is no publicly available data on population, telephone calls and lines served by CLECs *etc* for a specific area in which a LEC operates.

Here *RPM* refers to telephone prices measured by revenue per minute, *INC* to gross regional product per capita, *MDEN* to density of mobile telephones per 100 persons, *IDEN* to density of broadband access lines per 100 persons, *CLEC* to CLEC's market share, *RESOL* and *UNE* to ratio of CLEC's resold lines and UNEs to ILEC's total access lines, respectively. *MDEN* and *IDEN* capture the effects of inter-modal competition, while *CLEC*, *RESOL*, and *UNE* represent the effects of intra-modal competition. In particular, *RESOL* and *UNE* measure the extent of service-based competition and hence, examine the effects of access regulation on telephone demands.

As before, the estimation is carried out by using panel analysis models, and alternatively, by combining panel analysis models with IV estimation methods. The latter is conducted to consider the possibility that a price variable may be an endogenous variable. The time span encompassed by this estimation is 2001 to 2004 because data on some variables in equation 2 are available only for this period. Thus the number of observations reduces to 98. Table 8 reports the estimation results. F tests and Breusch-Pagan Lagrangian multiplier tests confirm the presence of group effects and Hausman tests are always in favor of RE models. Thus the following discussion focuses mainly on the results for RE models.

Table 8 indicates that telephone price (RPM) has a negative relationship with telephone calls per access line, which is consistent with *a priori* theoretical expectation. On the other hand, the reported parameter estimates for income variable (INC) are statistically insignificant and negatively signed. This result seems implausible, but may be understood in that fixed telephone services enter a fading stage due to fixed-mobile technological substitution.[19] The level of income may play no decisive role in determining the consumption amount of a fading product. All the parameter estimates of CLEC have a positive sign, while those of RESOL and UNE have a negative sign. That is, the more competitive the market, and the weaker the access regulation, the higher the demand for telephone calls. Careful attention, however, should be paid to these interpretations because their parameter estimates are always statistically insignificant.

In Table 8, a matter of concern is the coefficients of MDEN and IDEN. The reported parameter estimates for MDEN are negatively signed and statistically significant at least in RE models, which means that mobile services are unambiguously substituting fixed telephone calls. On the other hand, the parameter estimates of IDEN are positively signed and statistically insignificant. That is, whether VoIP services are a substitute or a complement for fixed telephone calls is not still unambiguous.[20] In sum, this result confirms a negative effect of mobile services on growth in fixed telephone demand and hence, the TFP of LECs.

< *Table 8 inserted here* >

Inter-modal Competition and the Quality of Capital

Table 9 reports the estimation results from considering the quality of capital in place of the output level as a dependent variable with both price and income variables being deleted.

[19] Or this may occur because income is highly correlated with mobile and broadband subscriptions.
[20] Many state regulators recognize the increasing competitiveness of mobile services with fixed telephone services and the potential substitution of fixed telephone services with broadband services. For example, the Florida Public Service Commission (2006, pp. 69-70) reports “a growing number of Florida households may have substituted wireless service and, to a lesser degree, VoIP services for wireline services.”

In Table 9, the Hausman test statistic is unavailable because it has a negative variance estimate. Thus no information on which model is preferable is given. All the coefficients have the same sign in the two models, but their statistical significance varies across models. For example, the reported parameter estimates for MDEN have a negative sign in the two models, but are statistically significant only in the FE models. It appears that mobile diffusion tended to retard improvements in the capital quality for sample ILECs. The sign of other parameter estimates indicates that both the diffusion of broadband services and the ratio of UNE have a positive effect on the capital quality, while both the CLEC's market share and the ratio of resold lines have a negative effect on the capital quality. These interpretations, however, are not always unambiguous because their parameter estimates are often statistically insignificant.

< Table 9 inserted here >

Ⅴ. Conclusions

The study examined the effects of competition and incentive regulation on change in the TFP of ILECs in the U.S. local telecommunications markets, and also, confirmed the key sources for the recent slowdown in the TFP. The empirical analysis is carried out with panel data of 28 ILECs for the period 1991-2004. The estimation results indicated that competition had clear positive effects on both TFP change and technical change, while incentive regulation led to industry-wide technical change and not to carrier-specific TFP growth. Also, the results showed that fixed-mobile substitution had a detrimental effect on the performance of ILECs through its negative impacts on the demand for fixed telephone services and the quality of capital inputs. On the other hand, broadband services were found to have little relationship with the performance of ILECs so far. With rapid diffusion of VoIP, however, the broadband services will soon be an alternative platform for telephone calls which will have a negative effect on the performance of ILECs.

In sum, active intra-modal competition and the introduction of incentive regulation may no longer be a sufficient means in promoting the productivity growth of LECs. Also, it is worth noticing the negative effects of inter-modal competition from mobile and broadband services on the performance of LECs. This may explain the recent acquisition of mobile subsidiaries by incumbent fixed telephone carriers.[21]

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[21] For example, Telecom Italia and Telefonica acquired their mobile subsidiary, Telecom Italia Mobile and Telefonica Moviles, in 2005 and 2006, respectively.

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Appendix: Data and Variables

This appendix describes the details of data construction, especially the method measuring outputs, inputs, and technology variables. The primary sources of company data were the *Statistics of Communications Common Carriers* and the *Automated Reporting Management Information System* (ARMIS) data in which local companies file financial and operating data with the FCC. Annual data for the local operating companies were collected for the period 1991-2004.

Output: The study uses the physical unit of telephone outputs, *i.e.* telephone calls and telephone access lines. All types of telephone calls (local calls, Intra-LATA toll calls, inter-LATA toll calls, and inter-LATA access minutes) were aggregated into the units of telephone calls, with respective revenue shares being used as weights. Then, access lines and telephone calls were aggregated into an output variable by using a multilateral index.

Labor and material input: The quantity of labor input is proxied by the number of full and part-time employees. A current-dollar wage rate is defined as actual compensation per employee. Materials expenses, which are defined as operating expenses minus total labor compensation and minus depreciation charges, are divided by the materials price index to derive the quantity of material input. The producer price index for intermediate inputs is used as a proxy for the price of materials inputs.

Capital input: The net stock of capital input is constructed by the commonly used perpetual inventory method.[22] The depreciation rates for each type of plant are obtained from Fraumeni (1997). In order to construct net capital stock, the study first classifies telephone plants in service into three categories: telephone structures (land, building, cable and wire facilities *etc*), telephone equipment (central office switching and transmission, operator systems *etc*) and general support equipment (computers, furniture, motor vehicles etc). Next, yearly dollar amounts for each category are deflated by respective National Income and Product Accounts (NIPA) price indexes to derive real investment for a specific year. The aggregate capital stock is the weighted sum of the three types of real capital stock, with capital expense shares being used as weights. Jorgenson's formula is used to compute the user-costs of each type of plant.

Technology variables: No single measure of technology can completely capture technological advance over time or differences in technology among operating companies in the telecommunications industry (Sung and Gort, 2006). Instead of a time variable or industry-specific measures of technology such as the ratio of digital to analog access lines, the study uses a measure of input qualities to represent the state of technology. For capital quality, the study uses the weighted average vintage, with weights based on annual

[22] Refer to Berndt (1991) for a detailed explanation on the perpetual inventory method and Jorgenson's user-costs of capital.

investment expenditure flows. The vintage of base-year capital stocks is assumed to be half their service lives. The current-dollar wage rate is divided by the consumer price index to derive a constant-dollar wage rate which is the index of labor quality. .

< Table 1 > State Retail Rate Regulation for Sample ILECs

	No of sample ILECs operating under			Average Regulatory Score
	ROR	PC/Deregulation	Other forms of IC	
1991	10	6	12	3.23
1992	10	7	11	3.43
1993	8	7	13	3.57
1994	7	10	11	4.04
1995	3	15	10	4.78
1996	3	19	6	5.17
1997	3	21	4	5.28
1998	3	21	4	5.33
1999	13	22	3	5.40
2000	2	22	4	5.49
2001	2	22	4	5.50
2002	2	23	3	5.54
2003	2	23	3	5.53
2004	2	23	3	5.54

Source: National Regulatory Research Institute, *State Retail Rate Regulation of Local Exchange Providers*.

Note: ROR, PC, IC denotes rate of return regulation, price cap regulation and incentive regulation, respectively. Refer to the text for the calculation of average regulatory score.

< Table 2 > Measures of Competition for Sample ILECs

	Average no of LSCs	Average no of reporting CLECs	Average no of reporting LECs	Average CLEC market share	Average ratio of resold lines to ILEC access lines	Average ratio of UNEs to ILEC access lines
1994	0.29	-	-	-	-	-
1995	0.82	-	-	-	-	-
1996	2.49	-	-	-	-	-
1997	6.02	-	-	-	0.9%	-
1998	8.90	-	-	-	1.5%	-
1999	9.47	8.58	14.91	8.3%	-	-
2000	-	10.36	16.54	7.4%	-	-
2001	-	9.99	15.84	10.1%	2.6%	5.1%
2002	-	12.15	18.12	12.9%	2.9%	8.4%
2003	-	14.43	20.63	15.8%	3.1%	11.9%
2004	-	15.62	21.82	17.7%	3.8%	13.0%

Source: FCC, *Local Telephone Competition*

Note: LSC and CLEC denotes local service competitors and competitive local exchange carriers, respectively.

< Table 3 > Inter-modal Competition Indexes for Sample ILECs

	Average mobile subscriptions per 100 persons	Average broadband subscriptions per 100 persons
1999	28.72	-
2000	36.61	2.43
2001	43.69	4.51
2002	48.84	6.80
2003	54.94	9.60
2004	63.08	12.88

Source: FCC, *Local Telephone Competition*

Note: ILEC refers to incumbent LEC and UNE to unbundled network elements.

< Table 4 > Average Annual Change of Productivity Indexes for Sample ILECs

	EFF	TECH	TFP	AC	LP1	LP2
1992	5.22%	1.08%	5.85%	-9.14%	6.84%	12.41%
1993	-2.69%	5.35%	2.30%	-0.69%	9.67%	11.20%
1994	0.14%	2.95%	2.56%	-1.25%	13.92%	13.15%
1995	0.16%	8.40%	7.98%	0.24%	14.36%	20.42%
1996	-6.62%	23.13%	12.91%	-4.08%	10.72%	11.94%
1997	7.17%	-2.03%	3.94%	-6.54%	3.96%	5.26%
1998	-2.26%	5.69%	2.98%	-8.98%	6.92%	8.94%
1999	7.02%	9.43%	15.33%	-11.03%	12.42%	8.56%
2000	-0.08%	5.99%	5.14%	2.38%	5.60%	4.86%
2001	-2.28%	1.72%	-1.16%	9.25%	7.86%	-8.49%
2002	0.87%	-4.21%	-4.17%	-1.65%	11.42%	9.86%
2003	2.66%	6.42%	7.16%	-7.92%	19.44%	22.19%
2004	-4.75%	6.91%	0.70%	7.57%	3.79%	-6.06%
’92-‘96	-0.76%	8.18%	6.32%	-2.98%	11.10%	13.82%
’97-‘00	2.96%	4.77%	6.85%	-6.04%	7.22%	6.91%
’01-‘04	-0.88%	2.71%	0.63%	1.81%	10.63%	4.37%
’92-‘04	0.33%	5.06%	4.73%	-2.45%	9.76%	8.79%

Note: EFF, TECH, TFP denotes efficiency change, technical change and total factor productivity growth rate, respectively. AC implies change in average cost which is computed by dividing total costs by the Malmquist index of output. LP1 and LP2 refers to change in access lines per employee and telephone calls per employee, respectively.

< Table 5 > TFP Index Regressions

	Model 1: RE	Model 2: FE	Model 3: RE-IV	Model 4: FE-IV
constant	-1.907** (0.019)		-1.062 (0.247)	
lnMQ	0.097** (0.027)	0.660*** (0.000)	0.040 (0.428)	1.066*** (0.000)
lnLQ	0.369*** (0.000)	0.416*** (0.000)	0.337*** (0.000)	0.412*** (0.000)
lnKQ	0.716*** (0.000)	0.280* (0.034)	0.749*** (0.000)	0.143 (0.352)
lnAL	0.015 (0.882)	-0.682*** (0.000)	-0.013 (0.903)	-0.567*** 0.001
lnRS	-0.375** (0.007)	-0.042 (0.785)	-0.376** (0.009)	-0.117 (0.471)
COM_DUM	0.170*** (0.001)	0.020 (0.667)	0.178*** (0.000)	-0.033 (0.525)
IR_DUM1	0.044 (0.499)	0.109 (0.068)	0.065 (0.362)	0.138* (0.038)
IR_DUM2	0.009 (0.884)	0.020 (0.732)	0.022 (0.754)	0.025 (0.699)
R^2	0.320	0.712	0.302	0.685
Test statistics	F = 18.98 (0.000) , LM= 292.47 (0.000), HT= 101.11 (0.000)		F = 18.88 (0.000) , HT= 86.35 (0.000)	
No of observations	392		364	

Note: ***,**,* implies statistical significance at 1%, 5%. 10% level. FE, RE refers to fixed-effects and random-effects model, respectively, while IV implies instrumental variable estimation method. P-value is in parenthesis. LM, HT refers to Breusch-Pagan Lagrangian multiplier test statistic and Hausman test statistic, respectively.

< Table 6 > Technical Change Index Regressions

	Model 1: RE	Model 2: FE	Model 3: RE-IV	Model 4: FE-IV
constant	-1.566*** (0.001)	-	-1.432*** (0.006)	-
lnMQ	0.033 (0.179)	0.252*** (0.000)	0.021 (0.455)	0.496*** (0.000)
lnLQ	0.181*** (0.000)	0.168*** (0.001)	0.171*** (0.001)	0.174*** (0.001)
lnKQ	0.612*** (0.000)	0.493*** (0.000)	0.629*** (0.000)	0.403*** (0.000)
lnAL	0.164*** (0.005)	0.034 (0.755)	0.162*** (0.008)	0.098 (0.406)
lnRS	-0.567** (0.000)	-0.549*** (0.000)	-0.570*** (0.000)	-0.588*** (0.000)
COM_DUM	0.195*** (0.000)	0.140*** (0.000)	0.000*** (0.000)	0.108*** (0.002)
IR_DUM1	0.086** (0.034)	0.130*** (0.001)	0.095** (0.036)	0.146*** (0.001)
IR_DUM2	0.061 (0.116)	0.067* (0.085)	0.069 (0.112)	0.076** (0.088)
R^2	0.586	0.806	0.546	0.780
Test statistics	F=16.53 (0.000) , LM=361.70 (0.000), HT= n.a		F = 16.46 (0.000) , HT= 80.45 (0.000)	
No of observations	392		364	

Note: the same as in Table 5.

< Table 7 > Average Annual Change of Output and Input Quality for Sample ILECs

	MQ	Q1	Q2	LQ	KQ
1992	6.81%	2.37%	7.95%	2.81%	8.01%
1993	5.76%	4.66%	6.19%	1.19%	3.11%
1994	5.95%	6.98%	6.21%	0.90%	5.87%
1995	10.28%	5.61%	11.67%	0.13%	-3.96%
1996	6.31%	6.42%	7.64%	10.39%	10.21%
1997	7.34%	7.20%	8.50%	-6.80%	10.65%
1998	6.75%	6.23%	8.25%	3.15%	5.41%
1999	6.83%	10.32%	6.49%	4.00%	9.85%
2000	6.23%	7.47%	6.74%	-4.75%	2.79%
2001	-9.79%	1.91%	-14.45%	-1.64%	4.75%
2002	-5.13%	-3.10%	-4.66%	6.26%	6.70%
2003	7.31%	6.66%	9.40%	24.30%	-1.39%
2004	-3.36%	2.81%	-7.04%	1.43%	-5.13%
’92-‘96	7.02%	5.21%	7.93%	3.08%	4.65%
’97-‘00	6.79%	7.81%	7.49%	-1.10%	7.18%
’01-‘04	-2.74%	2.07%	-4.19%	7.59%	1.23%
’92-‘04	3.94%	5.04%	4.07%	3.18%	4.38%

Note: MQ, Q1, Q2 refers to change in the multilateral translog index of output, access lines and telephone calls, respectively. LQ and KQ imply change in labor and capital quality indexes.

<Table 8> Telephone Calls Per Access Line Regressions

	Model 1: RE	Model 2: FE	Model 3: RE-IV	Model 4: FE-IV
Constant	2.173 (0.114)		3.025 (0.101)	
lnRPM	-1.344*** (0.000)	-1.220*** (0.000)	-0.960*** (0.002)	-0.219 (0.788)
lnGRP	-0.057 (0.728)	-0.680 (0.600)	-0.079 (0.697)	-1.159 (0.480)
lnMDEN	-0.688** (0.012)	-0.503 (0.339)	-0.744** (0.018)	-1.181 (0.158)
lnIDEN	0.157 (0.080)	0.153 (0.249)	0.175 (0.076)	0.263 (0.155)
CLEC	0.821 (0.389)	1.106 (0.570)	1.109 (0.330)	4.210 (0.219)
RESOL	-1.912 (0.436)	-2.414 (0.472)	-3.548 (0.220)	-5.290 (0.261)
UNE	-0.986 (0.190)	-0.980 (0.497)	-0.989 (0.257)	-1.588 (0.388)
R^2	0.665	0.569	0.631	0.340
Test statistics	F = 2.87 (0.000) , LM= 15.56 (0.000) , HT= 3.88 (0.794)		F = 1.84 (0.026) , HT= 1.38 (0.986)	

Note: the same as in Table 5. The number of observations is 98.

<Table 9> Capital Quality Regression Equation

	Model 1: RE	Model 2: FE
Constant	3.018*** (0.000)	
lnMDEN	-0.434 (0.616)	-0.351*** (0.000)
linden	0.018 (0.545)	0.093*** (0.001)
CLEC	-0.069 (0.852)	-0.679 (0.064)
RESOL	-0.366 (0.651)	-0.894 (0.202)
UNE	0.073 (0.795)	0.893*** (0.001)
R^2	0.336	0.357
Test statistics	F = 17.82 (0.000) , LM= 19.85 (0.000) , HT= n.a.	

Note: the same as in Table 5. The number of observations is 98.

<Appendix Table> Sample LECs

LEC		No of Access Lines	No of Employees	Efficiency Change	Technical Change Index	TFP Index
Bell South						
	Bell South	29,656,255	61,379	0.983	1.401	1.362
Qwest Corportation						
	Qwest Corportation	20,095,681	43,609	0.981	1.405	1.277
SBC						
	Southwestern Bell Tele Co.	19,912,564	46,547	0.977	1.405	1.038
	Pacific Bell	23,531,974	45,043	0.984	1.416	1.345
	Nevada Bell	407,001	861	1.003	1.392	1.486
	Southwestern New England	2,420,176	7,540	0.997	1.149	1.061
	Illinois Bell Tele Co.	8,333,826	15,321	0.988	1.398	1.362
	Indiana Bell Tele Co.	2,629,469	4,321	0.992	1.627	1.565
	Michigan Bell Tele Co.	6,155,226	12,111	0.998	1.543	1.549
	Ohio Bell Tele Co.	5,010,337	8,623	0.988	1.633	1.541
	Wisconsin Bell Tele Co.	2,629,218	4,152	0.993	1.592	1.761
Verizon						
	VZ - Washington DC	1,457,155	1,817	1.000	1.343	1.343
	VZ – Maryland	4,311,578	7,571	1.004	1.455	1.532
	VZ –Virginia	4,204,873	6,856	1.005	1.702	1.743
	VZ-West Virginia	906,557	2,029	1.027	1.655	2.086
	VZ-Delaware Bell Tel	655,678	896	1.000	1.611	1.605
	VZ-Pennsylvania	7,.095,204	12,350	1.006	1.465	1.466
	VZ-New Jersey	7,387,033	12,651	1.009	1.430	1.515
	VZ-New England	7,782,472	18,370	1.028	1.529	1.441
	VZ-New York Tele Co.	13,681,529	35,707	1.024	1.378	1.521
	VZ-California	4,995,635	11,339	1.016	1.758	1.927
	VZ-Florida	2,703,447	6,993	0.996	1.285	1.252
	VZ-Hawaiian	862,641	2,662	1.013	1.394	1.540
	VZ-North	4,847,140	14,173	1.019	1.370	1.612
	VZ-Northwest	1,874,500	3,772	1.005	1.566	1.717
	VZ-South	1,907,656	4,681	1.042	1.499	2.091
	VZ-Southwest	2,220,613	6,050	1.000	1.542	1.612
Puerto Rico Tele Co.		1,244,357	6,800	1.013	0.974	0.764