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Abstract:

This paper empirically investigates the role of telecommunication infrastructure on long run regional economic growth in China for a sample of 29 regions for a 17 years' period, from 1986-2002. With a panel dataset, this paper uses a dynamic fixed effects model for estimation, which allows us to test the relationship between regional economic growth with initial economic condition, fixed investment, population growth, as well as telecommunications infrastructure. The results show that telecommunications is both statistically significant and positively correlated to regional economic growth in real GDP per capita in China. The results are robust even after controlling for investment, population growth, past levels of GDP per capita, and lagged growth. The results further indicate that the telecommunications investment is subject to diminishing returns, suggesting thereby that regions at an earlier stage of development are likely to gain the most from investing in telecom infrastructure.

1. Introduction

Studies that focus directly on the effect of telecommunication infrastructures on economic output began in the 1960s. In the late 1970s, the role of telecommunications in economic development was examined and some positive results were discovered (see reviews in Saunders, Warford and Wellenius, 1994). Since lots of empirical studies addressing the returns to public infrastructure investments in the late 1980s, (see review in World Bank, 1994), researchers began to pay attention to investment in telecommunications infrastructure again. There are a large number of recent empirical studies on this topic (Norton, 1992; Canning, Fay, and Perotti, 1994; Canning, 1997, 1999; Cronin, et al, 1991, 1993; Cohen, 1992; Greenstein and Spiller, 1995; Nadiri and Nandi, 1997; Wang, 1999; Yilmaz, Haynes, and Dinc, 2001; Yilmaz, and Dinc, 2002). Most of these studies find a positive and significant causal link between telecommunications infrastructure and aggregate output. There is also evidence that telecommunications infrastructure serves as a primary source of economic growth. For example, Greenstein and Spiller (1995) find a positive and significant effect exists by investigating the impact of telecommunication infrastructure (as measured by the amount of fiber-optic cable employed) on economic growth in the United States. A study of Yilmaz, et al. (2001) indicates that the accumulation of telecommunications infrastructure improves the overall productive capacity at the regional level by examining the impact of telecommunications infrastructure on economic output both at the aggregate and sectoral levels in the United States. A more recent analysis of economic growth in OECD by Datta and Agarwal (2004) indicates that telecommunications infrastructure plays a positive and significant role in economic growth in 22 OECD countries from 1980-1992.

Generally, previous literature on the impact of telecommunications infrastructure on economic output or productivity reports some evidence of a causal relationship between telecommunications infrastructure and economic growth in both directions. However, what has not been answered is whether or not the interdependent relationship between economic growth and telecommunications infrastructure investment in the mature economies also holds in a developing country as China- and if so, how it occurs. Most studies of the mutual relationship between telecommunications and economic development have been primarily based on cross-sectional country data or regional data of developed countries. In fact the comparability between developed and developing countries raises many questions. Telecommunications investment may have various effects for economies at different stages of development. Telephone density also means different things in each of these countries, and can hardly be treated equally (Saunders et. al., 1994; Stone, 1993). As a result, the conclusions drawn from those wealthy countries may not be directly relevant to those less developed regions. The precise linkages between telecommunications infrastructure and economic development in China are still open for further study.

Most empirical studies that look at the determinants of growth employed simple correlation methods or Solow-type production function. However, this typically requires the assumption of an identical production function for all countries or regions. This kind of studies has been criticized as not accounting for fixed effects and appropriate causalities and correlations. The work by Holtz-Eakin (1993) and Garcia-Mila, McGuire and Porter (1996) and many others demonstrates that the introduction of state-level fixed effects reduces the returns dramatically for the U.S. public infrastructure studies (e.g. Aschauer, 1989). Studies relying only on simple regression techniques often fail to specify the causal links, or assume one-way causality and overlook the reciprocal effects of variables under investigation (see review in Roller and Waverman, 2001).

More importantly, the world has experienced an explosive growth in telecommunications due to increased investment in this sector and technological leapfrogs which lowered network costs while increasing communication capabilities in the past decade. The most obvious example is the rapid deployment of mobile communications technologies. There are now more mobiles phones subscribers than fixed lines users around the world (International Telecommunications Union (ITU), 2004). The same is true for China, which has more mobile users (269 million) than fixed line users (263 million) in 2003. Since most of the previous studies use number of main lines as the proxy for telecommunications infrastructure (e.g. Hardy, 1980; Savage et. al, 2003, and etc.), we should include mobile subscribers into this concept of "teledensity[1]" if we still want to use this indicator as a proxy for the level of telecommunications infrastructure in China. Fortunately, as we checked, the number of total telephone users is highly correlated (over 0.99 in correlation) with the capital stock of telecommunications sector[2]. So, using the number of telephones per 100, including both fixed and mobile, as the proxy for the level of telecommunications infrastructure in China is appropriate for this analysis.

Our focus on the impact of telecommunications industry on economic growth in China is not without merits. Due to limited development of telecommunications systems and the prior limited demand, China's telecom service sector has been a major beneficiary of the technological leapfrog changes and reforms in the telecommunications sector. The telecommunications sector has been one of the fastest growing sectors in China in the past 20 years. In 1985, the total number of telephone subscribers was 6.26 million while by the

[1] The International Telecommunication Union (ITU) defines "teledensity" as the number of main telephone lines per 100 inhabitants (1999). It is the most widely used indicator for comparing penetration of telephone service in nations. Considering the rapid development of mobile communications, the teledensity used here is defined as the number of telephones, both fixed lines and mobile phones, per 100 inhabitants.
[2] Based on data of telecommunications investment from MII and an assumption of a depreciation rate of 15% for the telecommunications sector.

end of 2002 this number increased to 421.04 million telephone users[3] (Ministry of Information Industry (MII), 2004). Consequently, China's teledensity[4] increased from 0.59 per 100 inhabitants in 1985 to 32.78 per 100 persons (16.69 mine lines per 100 and 16.09 mobile phones per 100) in 2002. As *Fig. 1* shows, the average growth rate of teledensity from 1988 to 1991 doubled the rate of GDP growth and accelerated above 30 percent after 1992. Throughout the 1990s the growth rate of telephone lines consistently exceeded that of GDP, on average three to four times higher. Only in 2002, the growth of teledensity began to decline because of the large subscriber base. In the 1990s, China installed more than 159 million fixed telephone lines and got more than 84 million mobile subscribers (MII, 2004), more than all the rest of the developing world combined. Switchboard capacity leaped from four million lines prior to 1985 to 179 million by the end of 2000 (Lu and Wong, 2003). China now boasts the world's largest telephone subscriber base. Currently its service revenue alone, equipment sales not included, accounts for approximately 2.52 percent of China's total GDP in 2002. This sector is also believed to offer substantial positive externalities to other industries.

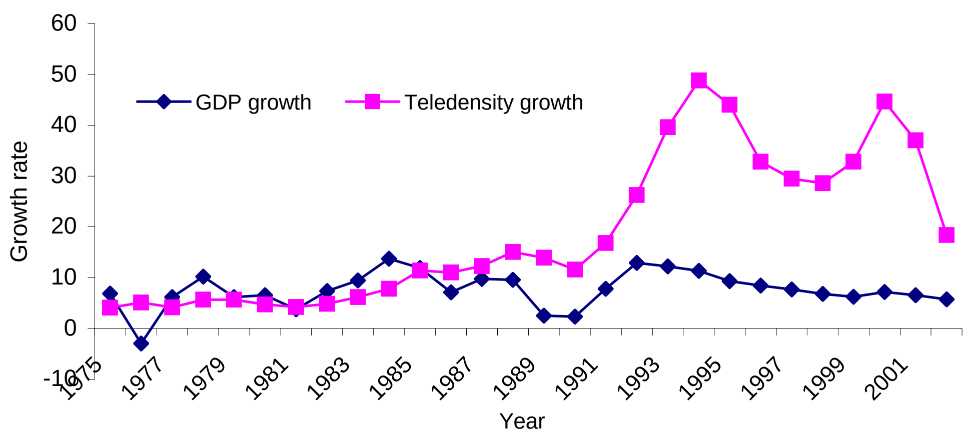
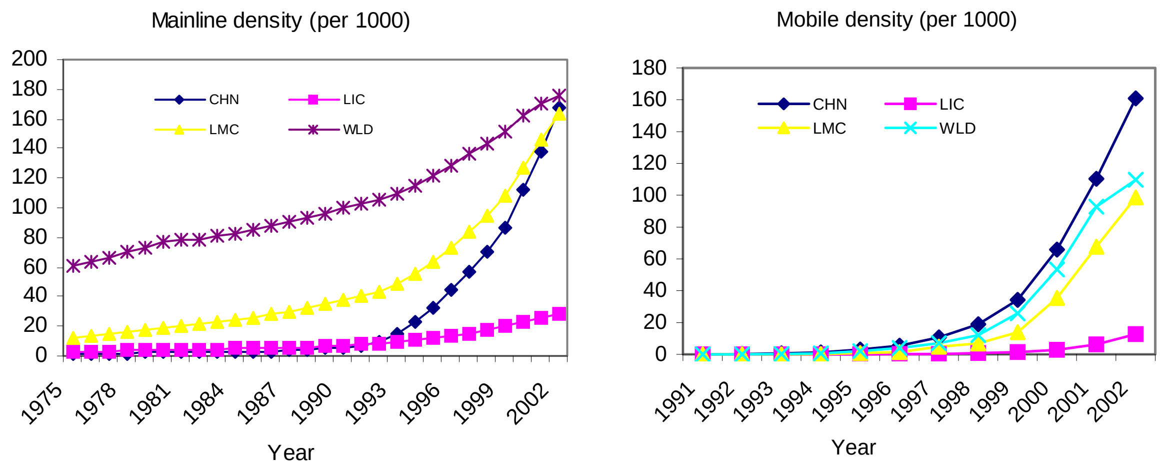


Fig.1 *Growth rate of GDP and teledensity from 1975 to 2002*

[3] Including both fixed line users and mobile users.



Sources: Based on data from World Bank (2004); China Statistical Yearbook (various years).
Notes: *CHN*: China; *LIC*: Low Income Country; *LMC*: Low Middle Income Country; *WLD*: World

Fig. 2 *Development of China's telecommunications infrastructure*

The ITU once established a goal of increasing developing countries' teledensity from 1996 average of 5.07 to 10 in 2010 (ITU, 1998). Since China's teledensity had reached 32.78 (16.8 for fixed line only) telephones per 100 in 2002, as a new low-middle income country[5], China is one of the few developing countries which have successfully turned into a middle income country's level, and even the developed state's in some aspects, in terms of the telecommunications infrastructure. As Fig.2 shows, from a very low level in the early 1990s, China's mainline density had approached world average by the end of 2002. At the same time, China has a rapid-growing mobile communications sector which has a higher speed, as well as the penetration level, than world average (Fig. 2).

Interestingly, concomitant with its rapid telecommunications infrastructure buildup, China had also experienced rapid economic growth with an average growth rate of 7.9 percent per year in terms of GDP per capita in the 1985-2002 period. By speeding up the rate of investment in telecommunications infrastructure, regions in China seemed to gain a considerable boost in its rate of economic growth. However, large disparities occurred in growth performances among provinces from 1985 to 2002. In this period, the gap between the most dynamic province in terms of GDP per capita, Jiangsu, with an annual growth rate

[5] As classified by World Bank, China is a low-income country before 1997 and then in 1998. But in 1997 and the years after 1998, China is classified as a low-middle income country.

of 11.46%, and the least dynamic, Qinghai, at 6.21% has grown. China has also experienced growing interprovince inequality in terms of GDP per capita during its transition process to a market-based economy (Wang and Hu, 1999; Xie and Stough, 2001; Demurger, et al, 2002). At the same time, pronounced regional difference in the availability of telecommunications infrastructure can be found across regions, between core and peripheral regions, as well as between urban and rural areas (Mody and Wang, 1997; Lee, 1997). In 2002, the largest penetration level of telephone can found in Beijing with 106 telephones per 100 while in the lowest penetration level can be found in Guizhou with 13.58 per 100. The rapid economic growth in some regions of China is likely to be stimulated to some extent by the rapid deployment of telecommunication infrastructure. China needs to maintain both its current GDP growth and social stability, so achieving balanced growth so as to reduce regional disparities appears to be one of the major policy challenges China faces. From this perspective, enhancing the growth potential of inland provinces is necessary to reduce regional disparity. This raised an interesting question: did the increase of telecommunications infrastructure contribute to regional economic growth significantly and thus compensate for geographic or resource endowments constraints?

Previous studies also indicate that the impact of telecommunications infrastructure on growth might not be linear because of its network externalities or a diminishing scale of return. For example, some researchers find that investment in telecommunications infrastructure would not significantly affect economic growth of a country until a critical mass of telecommunication infrastructure is achieved (Roller and Waverman, 2001; Savage, et al, 2003). However, Datta, and Agarwal (2004) find some evidence to support a "diminishing return of scale" of telecommunications investment in OECD countries. Some researchers indicate that China is an overachiever in the area of telecommunications infrastructure as compared to its economic development level (Lu, 2000). So it is really interesting to study the nonlinearity relationship between telecommunications investment and economic growth: does the investment in China's telecom sector have diminishing returns or increasing returns of scale, or support the "critical mass" hypothesis?

With a panel dataset, this paper uses a macroeconomic growth framework to study the long run relationship between telecommunications infrastructure and regional economic growth in China. This paper is organized as follows: section 2 outlines the dynamic growth model used in this study. Section 3 discusses the data and variables in detail. Section 4 reports estimation results and the final section concludes. Overall, this study tries to address the following two interesting questions:

- Are prior empirical results of positive and significant impact of telecommunications investment on economic growth robust to such a developing countries as China, and if yes, how?
- What will be the non-linear relationship between telecommunications infrastructure and regional economic growth in China?

2. Methodology framework

We can estimate a growth equation for each province by following the cross-sectional growth framework of Barro (1991), Levie and Renelt (1992)[6] and others to examine the determinants of economic growth. This framework enables us to test conditional convergence hypothesis by adding to a Solow-type equation a set of variables reflecting differences in the steady-state equilibrium. In this case, our focus is to investigate the role of telecommunications infrastructure in explaining the different growth performance across regions in China. So we try to account for differences in initial economic conditions, in population, in fixed investment, as well as in telecommunications infrastructure endowment. The growth equation is thus extended to include the effects of telecommunications infrastructure on growth, which has the following form:

$$GRTH_{it} = \alpha_i + \eta_t + \beta_1 GRTH_{i,t-1} + \beta_2 Ln(GDP)_{i,t-1} + \beta_3 POP_{it} + \beta_4 INV_{it} + \beta_5 TEL_{it} + \mu_{it} \quad (1)$$

$$GRTH_{it} = \alpha_i + \eta_t + \beta_1 GRTH_{i,t-1} + \beta_2 Ln(GDP)_{i,t-1} + \beta_3 POP_{it} + \beta_4 INV_{it} + \beta_5 TEL_{it} + \beta_6 TELSQ_{it} + \mu_{it} \quad (2)$$

[6]Some recent cases of using this framework to investigate the impact of infrastructure on economic growth include Demurger (2002), Datta and Agarwal (2004), and etc.

where i indexes provinces in China; t indexes time; α_i and η_t are province- and time-specific parameters, respectively. *GRTH* represents the annual growth rate of real GDP per capita, $GRTH_{t-1}$ represents the lagged growth rate of real GDP per capita, GDP_{t-1} represents lagged real GDP per capita. The lagged GDP variable is included to test for convergence in a panel data framework. A significant and negative coefficient of lagged GDP per capital is expected to support the convergence hypothesis: the higher level of past GDP, the lower the subsequent growth in GDP per capita. *INV* measures the share of fixed investment in GDP. The correlation between investment and economic growth is expected to be positive as indicated in previous literature. *POP* represents population growth rate and it is introduced to see the effects of population growth. The expected sign is also positive.

TEL contains a measure of telecommunication infrastructure. As discussed before, the variable we are using here is teledensity, the number of telephones per 100 inhabitants, including both fixed line and mobile. It is an output measure and therefore the current value is expected to have the strongest association with that year's growth rate. But previous studies have indicated a two-way causation between telecommunications investment and economic growth. In order to confirm that the results are not simply due to reverse causality this relationship is tested using current and lagged values of *TEL* (TEL, TEL_{t-1}, and TEL_{t-2}) for Equation (1). The expected signs for telecommunications variable and its lagged variables are positive.

Finally, *TELSQ*, the square of the telecom variable, is included in a separate model (Equation (2)) to study the nature of returns to scale to telecommunications investment. The intension of introducing a square term is to check whether the relationship between economic growth and telecommunications is linear or not. If the coefficient of *TELSQ* (β_6) is negative and significant while the coefficient of *TEL* (β_5) is positive and significant then we have support for a "diminishing returns" hypothesis. And positive signs for both coefficients, β_6 and β_5, would indicate increasing returns. If, however, the signs are reversed (i.e. $\beta_6>0$ and $\beta_5<0$), then we have evidence in support of a "critical mass" theory, as investment in telecommunications infrastructure would not significantly affect economic growth until a critical mass of telecommunication infrastructure is achieved (Roller and Waverman, 2001). The impact of telecommunications infrastructure might be insignificant for low penetration rates.

Table 1 summarized the explanations of the variables used in this model and their expected signs. We expect the sign for $GRTH_{t-1}$, *POP, INV, TEL* is positive, while the sign for lagged GDP per capita, GDP_{t-1}, is negative. And the sign for the square term, *TELSQ,* is to be decided.

Table 1 Variables and Their Expected Signs

Variables	Explanation	Expected sign
GRTH	Rate of growth of real GDP (%)	
$GRTH_{t-1}$	Lagged growth of real GDP (%)	+
GDP_{t-1}	Lagged real GDP per capita (in RMB)	-
POP	Rate of growth of population (%)	+
INV	Share of fixed investment in GDP	+
TEL	Number of telephones per 100 inhabitants	+
TEL_{t-1}	One year lag of *TEL*	+
TEL_{t-2}	Two year lag of *TEL*	+
TELSQ	Square of TEL	?

3. Data

Data for 29 regions of China for the period of 1986-2002 are utilized. China has 31 provinces, autonomous regions and cities under direct guidance of the central government. Due to missing values, Tibet has been excluded from the statistical analysis. Moreover, as the Chongqing area was given a municipality status and separated from Sichuan province only from 1997 onward, we manage to distinguish Sichuan province from old Sichuan Province for data before 1997. As a result, the total number of units in this study is 29 since two regions, Tibet and Chongqing, have been excluded from the analysis.

This analysis is confined with the sample period 1986-2002. It is obvious that before 1985 the size of telecommunications infrastructure in China was very small and as a result its impact on China's whole economy should be marginal. At the end of 1985, the national teledensity was only 0.59 telephones per 100 inhabitants. The investment in

Table 2 Summary Statistics

	GDP per capita (1986)	GDP per capita (2002)	Growth rate (%)	Population growth rate (%)	INV (2002)	Telephones per 100 (1986)	Telephones per 100 (2002)
East China							
Beijing	5683	19315	7.95	2.03	0.56	4.63	105.77
Tianjin	5313	19658	8.52	1.33	0.39	2.18	60.05
Hebei	1802	8515	10.19	1.13	0.33	0.64	28.88
Liaoning	3474	12048	8.08	0.76	0.29	1.28	45.61
Shanghai	8596	31705	8.50	1.74	0.41	2.99	97.57
Jiangsu	2571	14593	11.46	1.02	0.32	0.78	42.63
Zhejiang	2816	15874	11.41	0.83	0.45	0.85	61.17
Fujian	2375	13311	11.37	1.46	0.27	0.52	49.89
Shandong	2165	11387	10.93	0.94	0.33	0.53	32.28
Guangdong	2352	13674	11.63	2.79	0.33	0.82	66.31
Hainan	1843	7724	9.37	1.78	0.37	0.39	30.82
Guangxi	1388	5577	9.08	1.26	0.31	0.31	19.69
Central China							
Shanxi	1987	6072	7.23	1.22	0.40	0.29	28.81
Jilin	2091	7999	8.75	0.96	0.37	1.05	34.81
Heilongjiang	3063	9753	7.51	0.75	0.27	0.87	35.27
Anhui	1662	6123	8.49	1.22	0.30	0.34	21.03
Jiangxi	1323	5466	9.27	1.04	0.36	0.43	22.42
Henan	1485	6026	9.15	1.17	0.28	0.32	19.91
Hubei	2013	7939	8.95	1.07	0.32	0.66	22.57
Hunan	1792	6323	8.20	0.95	0.31	0.12	21.72
Inner Mongolia	1949	6890	8.21	0.96	0.41	0.44	27.66
Western China							
Sichuan	2156	7498	8.10	0.90	0.39	0.24	20.16
Guizhou	1049	2957	6.69	1.50	0.53	0.31	13.58
Yunnan	1426	4807	7.89	1.38	0.36	0.36	21.68
Shaanxi	1491	5005	7.86	1.19	0.45	0.75	27.38
Gansu	1186	3974	7.85	1.37	0.45	0.22	20.40
Qinghai	2282	5984	6.21	1.44	0.68	0.94	25.52
Ningxia	2004	5829	6.90	1.88	0.69	0.79	27.62
Xinjiang	2402	7431	7.31	2.02	0.50	0.31	32.27
National average	2337	7853	7.87	1.12	0.42	0.66	32.78

Source: Based on China National Statistical Bureau (NSB) (1999), Comprehensive Statistical Data and Materials on 50 Years of New China 1949–1998, and China Statistics Yearbook from 2000 to 2003 telecommunications sector was only 0.32% of the national total investment in 1985. It was just from the late 1980s that the telecommunications sector began the rapid expansion. As a result, we will use a panel dataset of 29 regions for a 17 years' period.

Macroeconomic data of GDP per capita, population, physical investment, and teledensity of different provinces from 1985-2002 are collected through Comprehensive Statistical Data and Materials on 50 Years of New China (NSB, 1999) and then updated with China Statistics Yearbook from 1999 to 2003. Table 2 summarizes the statistics for all regions in this sample, along with the national averages.

4. Estimation Results

Due to the panel form of the data set, Hausman test has to be performed in order to choose the correct specification. The Hausman test indicates that a fixed-effects model is preferred to a random-effects model for all the three models listed in Table 3 (*p-value<0.001*). Regression results of equation (1) are presented in Table 3. Model A reports the estimation for fixed effects model without the square term. Model B and Model C use lagged teledensity to replace current teledenisty to whether the positive effect is totally caused by reverse causality.

Table 3 Determinants of Regional Economic Growth, 1986-2002

Variables	Model A: R^2=0.68	Model B: R^2=0.67	Model C: R^2=0.69
Intercept	73.6 (5.79) ***	75.7(5.79) ***	91.6(6.59) ***
$GRTH_{t-1}$	0.33 (7.51) ***	0.33(7.50) ***	0.35(7.53) ***
GDP_{t-1}	-7.61(-5.42) ***	-7.61(-5.42) ***	-9.30(-6.25) ***
POP	-0.78(-5.16) ***	-0.78(-5.19) ***	-0.85(-5.61) ***
INV	7.23 (3.05) ***	7.28(3.07) ***	7.46(3.04) ***
TEL	0.038(1.92) **	-	-
TEL_{t-1}	-	0.048(1.89) *	-
TEL_{t-2}	-	-	0.058(1.73) *

Notes: t-statistics in parentheses; *** significant at 1% level; ** significant at 5% level; *significant at 10% level. Number of observations: 17*29; Number of groups: 29;

As shown in Table 3, the coefficients of most of the variables of interest are significant (most at a 1% level). First, the coefficient of lagged dependent variable, *GRTH*, is positive and significant. The coefficient of logarithm of lagged GDP in log value is negative and significant at 1% level. This result supports the conditional convergence hypothesis, which suggests that regions with higher levels of GDP per capita tend to grow at a slower rate. In other words, the results suggest a catch-up phenomenon among Chinese provinces in the 1986-2002 period, controlling for other factors. This confirms Demerger's (2001) findings of a conditional convergence among regions in China in the 1985-1998 period. The results may contribute to the debate on the convergence issues for China since evidence shows conditional convergence is likely.

Second, *INV,* the share of fixed investment in GDP, is positive and significant at the 1% level. However, contrary to our expectation, the coefficient of population growth is negative and significant at the 1% level. The results indicate that fixed investment is a key factor contributing to economic growth while the population growth has a negative effect on growth. This also confirm previous literature's findings that China's economic growth has been primarily driven by accumulation of fixed-assets (Wang and Yao, 2003; Mody and Wang, 1997). The negative effect of population growth on economic growth may be partially explained by the large population in the countryside and insufficient employment in China. However, referring to Lucas' (1988) work on the contribution of human capital to economic growth, further studies are needed to utilize appropriate indexes of human capita to evaluate the effect of human capita, instead of population, on economic growth.

Table 4 Nonlinearity of Telecommunications and Growth

Variables	R^2=0.68
Intercept	78.9(5.99) ***
$GRTH_{t-1}$	0.34(7.61) ***
GDP_{t-1}	-8.12(-5.68) ***
POP	-0.80(-5.29) ***
INV	6.92(2.92) ***
TEL	0.12(2.40) **
TELSQ	-0.0008(-1.76) *

Notes: *t*-statistics in parentheses; *** significant at 1% level; ** significant at 5% level; *significant at 10% level.

Further, the results indicate a strong and positive relationship between telecommunications infrastructure and economic growth. The telecom variable is positive and significant at the 5% level in Model A, suggesting a positive relationship between telecom infrastructure and economic growth. The coefficients of the lagged values of *TEL,* TEL_{t-1} and TEL_{t-2}, are significant at 10% level and have an almost same magnitude when compared to the current value. These results give support to the argument that the positively relationship is not merely due to reverse causality. Telecommunications infrastructure does have positive impact on regional economic in China.

Table 4 reports the results for the model including a square term, which is intended to test the non-linearity between telecommunications and economic growth. The coefficient of *TELSQ* is negative and significant at a 10% level while the coefficient of *TEL* is positive and significant at a 5% level. The results provide some evidence for the argument of diminishing returns of telecommunication investment in China. In other words, in China the size of the effect of telecommunication infrastructure on regional economic growth is inversely related to its prior level. A unit increase of teledensity for regions with higher level of telecommunications infrastructure has an effect with smaller magnitude on economic growth. This implies that the positive effect of telecommunications on GDP growth is largest for regions with the smallest telecom infrastructure in China. The positive incremental effect becomes less significant for those regions with more developed telecommunications infrastructure. This indicates that regions at an earlier stage of development are likely to benefit most by establishing an approximate telecommunications infrastructure. As a result, we do not find evidence to support the critical mass hypothesis.

5. Conclusions

This paper empirically investigates the role of telecommunication infrastructure on long run economic growth based on a sample of 29 regions of China for a period of 17 years, from 1986-2002. Using a panel dataset, a dynamic fixed effects model is used for estimation, which accounts for regional specific differences in aggregate production functions. First, this result supports the conditional convergence hypothesis, which suggests that regions with higher levels of GDP per capita tend to grow at a slower rate. This paper also confirms that fixed investment has a positive effect on economic growth, while population growth has a negative impact on regional economic growth.

More importantly, the results show that telecommunications is both statistically significant and positively correlated to regional economic growth in real GDP per capita growth in China. The results are robust even after controlling for investment, population growth, past levels of GDP per capita, and lagged growth in GDP per capita. The results further indicate that the telecommunications investment is subject to diminishing returns, suggesting thereby that regions or countries at an earlier stage of development are more likely to gain from investing in telecom infrastructure. From the perspective of public policy, the results of this analysis provides strong evidence for the proportion that providing an efficient and appropriate telecommunications infrastructure is significant for fostering economic growth, as well as reducing regional disparity.

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