THE ROLE OF TELECOMMUNICATIONS INFRASTRUCTURE IN REGIONAL ECONOMIC GROWTH IN CHINA

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ABSTRACT: Different from traditional infrastructures, telecommunications infrastructure has greater potential to lead “leapfrogging” development in the developing countries. This paper provides empirical evidence on the links between telecommunications infrastructure and regional economic growth in China. With a panel dataset of 29 regions of China for a 17-year period, 1986-2002, this paper uses a dynamic fixed effects model to investigate this relationship while controlling for a set of other variables including initial economic condition, fixed investment, employment, population growth, foreign direct investment. The results show that telecommunications infrastructure endowment is a key factor in explaining regional economic growth in China. The results are robust even when controlling for past levels of GDP per capita, lagged growth, and other factors. The results further indicate that the telecommunications investment is subject to diminishing returns, thus suggesting that regions at an earlier stage of development are likely to gain the most from investment in telecommunications infrastructure.

1. INTRODUCTION

There appears to be sufficient empirical evidence to indicate a positive and statistically significant relationship between infrastructure investment and long-run economic growth under certain circumstances. However the direction of causality, and the extent and nature of the contribution, is still largely unsettled (see review by Poot, 2000). Conclusions drawn from previous infrastructure studies generally apply to telecommunications service since telecommunications networks exhibit all the characteristics of an infrastructure network such as immobility, large initial investment, natural monopoly inclination, and presence of external and network economies (Youngson, 1967; Lakshmanan, 1989). However, telecommunications infrastructure capital stands in some contrast with other types of infrastructure capitals: telecommunications has pervasive economy-wide effects, it has experienced radical technical and productivity change, it has attracted large amounts of investment capital from both the public and private sectors, and its rapid diffusion has been propelled by sharply reduced costs and increased capacity (Nadiri and Nandi, 2003). Some researchers have noted that telecommunications infrastructure has the potential to lead "leapfrogging development"[1] in the developing countries. Bruce (1989) and Singh (1999) indicate the potential role of telecommunications sector in accelerating the pace of development in developing countries. Many policy makers and theoreticians propose that information technologies, especially telecommunications, can help developing countries accelerate their pace of development or telescope the stages of growth. This study provides empirical evidence of the relationship between telecommunications infrastructure and economic growth in one of the world's fast-growing developing economies, China.

Studies that focus directly on the effect of telecommunication infrastructures on economic output began in the 1960s (Jipp, 1963). In the late 1970s, the role of telecommunications in economic development was examined and some positive results were discovered (see review in Saunders, Warford and Wellenius, 1994). When many empirical studies addressing the returns to public infrastructure appeared in the late 1980s, researchers began to pay attention to investment in telecommunications infrastructure again. There are a large number of recent empirical studies on this topic (eg. Chen and Kuo, 1985; Cronin, Paker, Colleran and Gold, 1991; Norton, 1992; Cronin, Colleran, Herbert, and Lewitzky, 1993; Dholakia and Harlam, 1994; Greenstein and Spiller, 1995; Madden and Savage, 1998; Canning, 1999; Wang, 1999; Roller and Waverman, 2001; Dutta, 2001; Demurger, 2001; Yilmaz, Haynes, and Dinc, 2001, 2002; Nadiri and Nandi, 2003; Savage, Schlottman, and Wimmer, 2003; Canning and Pedroni, 2004; and Datta and Agarwal, 2004). Most of these studies find a positive and significant causal link between telecommunications infrastructure and aggregate output. For example, Yilmaz, et al. (2001) show 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. Greenstein and Spiller (1995) find telecommunications infrastructure (as measured by the amount of fiber-optic cable employed) has a positive and significant effect on employment growth in the United States. A more recent analysis of economic growth in OECD countries by Datta and Agarwal (2004) indicates that telecommunications infrastructure plays a positive and significant role in economic growth in 22 OECD nations from 1980 to 1992.

However, there are several deficiencies in previous research. First, the precise causal mechanism between telecom infrastructure and development is usually assumed or asserted rather than explored in previous studies. Causal direction is difficult to determine by correlation or regression studies alone: while infrastructure may affect productivity and output, economic growth can also shape the demand and supply of infrastructure services, which is likely to

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[1] Telecommunications literature uses the word "leapfrogging" in two ways: first, , the term "leapfrogging" is used to imply that telecommunications can help developing countries skip over the stages of development and become members of a post-industrial society. Second, it is used to mean that telecommunications can help developing countries accelerate their pace of development (Singh, 1999).

cause bias in the estimated returns to infrastructure. Second, in most previous studies using telephone per capita or the total number of telephones as the indicator for telecommunications infrastructure, mobile communications facilities are not considered[2]. The only exception is Dutta (2001). Finally, most early studies did not check for the spatial dependence issue in their analysis. The presence of spatial dependence may lead to misspecification while one of the main reasons for spatial dependence in the error terms of regional econometric model is that omitted variables may be related to the connectivity of neighbouring regions (Kelejian and Robinson, 1997; Yilmaz, et al, 2001). This issue is particularly important for regional economic growth studies using panel data.

This study fills the gap in the literature by employing a dynamic growth model to study the effect of telecommunications infrastructure on regional economic development. A focus on China, instead of other countries, is not without merit. In the past two decades of market-oriented reforms, China has been one of the world's fastest-growing economies. In the 1985-2002 period, China's average growth rate in terms of GDP per capita was 7.9 percent per year. However, China has experienced growing inter-province inequality in terms of GDP per capita in this period (Wang and Hu, 1999; Xie and Stough, 2001; Demurger, 2001). More important, large disparities occurred in growth performance among provinces[3] from 1985 to 2002. In this period, the gap between the most dynamic province in terms of real GDP per capita, Jiangsu, with an annual growth rate of 11.46 percent, and the least dynamic, Qinghai, at has grown by 6.21 percent. Although there are many recent studies on China's economic growth, few of them have paid attention to the specific relationship between infrastructure endowments, especially the telecommunications infrastructure, and growth[4]. Finally, it is likely that conclusions drawn in previous studies which were primarily based on aggregate cross-country data or regional data for developed nations may not be directly projected to China.

In fact, after two decades of unprecedented growth, China now boasts the world's largest telecommunications network, both for fixed-line and mobile communications. There are many ways telecommunications may contribute to regional economic growth in such a developing country. First, the telecommunications service sector itself generates revenue and creates jobs. The revenue generated by the telecom sector alone accounted for 2.52 percent of total GDP in 2002 (Ministry of Information Industry (MII), 2004). Second, regional telecommunications infrastructure may serve as an essential ingredient of many local economic activities through lowering transaction costs, improving

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[2] Of course, such problem does not exist for those studies using the indicator of telecommunications investment or capital stock (e.g. Cronin, et al, 1991, 1993; Yilmaz, et al. 2001, 2002).

[3] Throughout this paper, references to China are to the Mainland China and term "provinces" refers to the set of 29 provinces, autonomous regions and municipalities. The term "region" used in this paper usually refers to regions at the province-level in China.

[4] The few studies considering the role of infrastructure include Fleisher and Chen (1997), Mody and Wang (1997), Demurger (2001) and a few others.

marketing information, and accelerating information diffusion. Third, because of China's huge size, great regional differences in geography and in natural resource endowments may have a substantial impact on regional growth performance. The availability of an appropriate telecommunications infrastructure, working with other kinds of infrastructure, may be helpful in improving regional economic growth by compensating for these natural constraints. More important, since telecommunications technologies increase accessibility and support more locational freedom, the search by firms or investors for the least-cost location is likely to reshape regional development patterns. Telecommunications facilities may serve as an important component of regional infrastructure systems in attracting foreign and domestic investment which has been a driving force of China's economic growth.

With a panel dataset covering 29 provinces of China over the period from 1986 to 2002, this paper uses a dynamic growth model to study why the regional growth performance has been so different across regions in the reform period and what is the long run relationship between the distribution of telecommunications infrastructure and regional economic growth in China. This paper is organized as follows: Section 2 gives a description of China's telecommunications infrastructure build-up and a brief overview of economic growth disparity among China's provinces. Section 3 outlines the dynamic growth model and data used in this study. Section 4 reports estimation results and the final section concludes.

2. REGIONAL TELECOM INFRASTRUCTURE PROVISION AND ECONOMIC GROWTH IN CHINA

2.1 Regional telecom infrastructure and economic growth in China

When the People's Republic of China (PRC) was established in 1949, the country with a population of over 500 million had only 263,000 telephones in the cities. The national telephone density was only 0.05 percent and there were no rural telephones (National Statistical Bureau (NSB), 1999). Other than some counties in the coastal provinces, more than 90 percent of counties in China had no telecom facilities at all (Lu and Wong, 2003).

From the 1950s to early 1980s development of the telecommunications in China was very slow because the telecommunications sector was not a top priority during the command economy period (Lu, 2000; Research Center for Regulation and Competition (RCRC), 2002). Telecommunications expenses were classified as "non-productive" and often subject to cuts during hard times. Telecommunications infrastructure was regarded purely as an administrative tool and received low priority in the heavy-industry-oriented development plans. As late as 1980, the number of telephone terminals per 100 residents was only 0.43 and the total number of subscribers was 4.1 million (He, 1997). Most exchanges were manual or semi-manual using crossbar switching equipment with analogue technology. Even by 1985, half of the administrative villages in rural areas still had no access to telephone services. Communications by telephones was generally very difficult because few public telephones were available.

The development of China's telecom industry took place mainly in the last 20 years of the 20th century (see Figure 1 and Figure 3). Due to limited development of telecommunications systems and the prior limited demand, China's telecommunications service sector has been a major beneficiary of the technological leapfrog changes and reforms in the Post and Telecommunications sector. One can actually divide this period into two phases, with the first beginning in 1980 when China lay out the foundation and prepared for the future take-off, and the second beginning in 1990 when the Chinese telecommunications sector started to take off (RCRC, 2002). From the late 1980s, the posts and telecommunications sector saw its share in national total fixed investment assume an upward trend, increasing from 0.73 percent in 1985 to more than 7 percent in 2001 (see Figure 2). In the ten year period from 1990 to 2000, 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 countries combined. The total number of telephone subscribers increased from 6.26 million in 1985 to 421.04 million (including both fixed line and mobile users) by the end of 2002 (MII, 2004). Switchboard capacity leaped from four million lines prior to 1985 to 287 million by the end of 2002 (NSB, 2003).

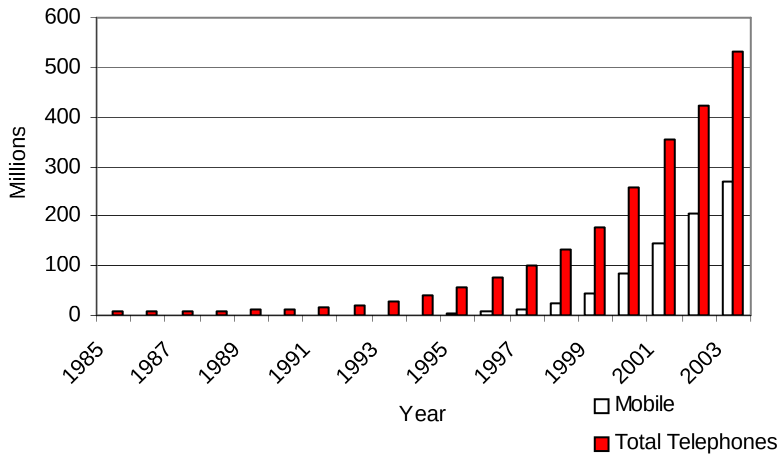


Figure 1. Development of China's Telecommunications Sector, 1985-2003

However, the larger autonomy given to local posts and telecommunications enterprises (PTEs) at every level of the administrative hierarchy has produced large regional disparity in the level of infrastructure provision. The strategic responsibility of telecommunications policymaking is primarily controlled by China's central government. But regional governments also have an increasing ability to manipulate the quality and the level of telecommunication investment in a way that maximizes localized benefits from telecommunications facilities. In the period from the late 1980s to 1998 when the competition had not been fully introduced into the telecommunications service sector, the specially designed incentive system drove local PTEs to raise as much capital as possible to invest in infrastructure expansion[5]. From the mid-1980s, the sources of telecom infrastructure funding in China have been diversified with primary sources incorporating local and central government revenue, bank loans, revenue of telecommunications enterprises, as well as international loans. In this context, a region's capacity to raise funds to finance telecommunications infrastructure investments mainly depends on local government resources, and its ability to negotiate with central government agencies, primarily the Ministry of Posts and Telecommunications (MPT, later MII), as well as local consumers' price tolerance. The different conditions among regions caused great inequality between provinces in telecom infrastructure provision. As Figure 3 shows, there is a pronounced difference across regions in terms of teledensity[6]. Most of those regions with a larger number of telephone sets per 100 are located in or next to coastal provinces. The highest penetration level of telecommunications can found in Beijing with 106 telephones per 100 while in the lowest penetration level can be found in Guizhou with only 13.58 per 100 in 2002. Of all the western regions in China, only Xijiang, has a teledensity a little above the national average of 32 telephones per 100 in 2002. A comparison of maps in Figure 3 showing the distribution of teledenisty across regions in 1986 suggests the pattern did not change much in the 1986-2002 period.

2.2 Regional Economic Growth

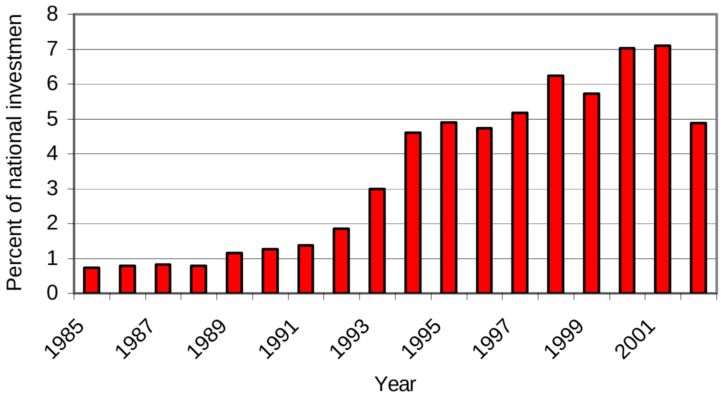
Interestingly, concomitant with its exponential telecommunications infrastructure buildup, China has experienced rapid economic growth from 1980s. As Figure 4 shows, the average growth rate of the number of telephones per 100 accelerated from the late 1980s and reached a rate above 30 percent after 1992. In the same period, gross domestic product kept a high growth rate over 7 percent for most of the period.

At the same time, China experienced growing inter-province inequality and large differences in growth performance among regions in the 1986-2002 period (See Figure 5). There is also a concentration of regions with higher growth rate

[5] From the accounting reform in the mid-1980s, MII began to contract performance responsibilities to all the local PTEs. An important incentive incorporated in these contracts was to link PTEs' wage fund increase to their sales revenue increase. As service prices and tariffs for long-distance communications were set by the MPT and the local rates and installation charges were capped, revenue maximization was equivalent to output maximization. See detailed discussions of the accounting system in Lu and Wong (2003).

[6] "Teledensity" is usually referred to as the number of main telephone lines per 100 inhabitants. However, considering the rapid development of mobile communications, the term "teledensity" here refers to the number of telephones, both fixed lines and mobile phones, per 100 inhabitants.

(over 9 percent a year in terms of real GDP per capita) in the coastal areas. Regions in the western and central China usually have much lower growth rates. Regions with lowest growth rates can be found in western provinces such as Qignhai.



Source: Based on Statistics on Investment in Fixed Assets of China (1950-2000) (NSB, 2002) and China's Statistical Yearbook 2001-2003

Figure 2. Share of Fixed Investment in P & T Sector in National Total

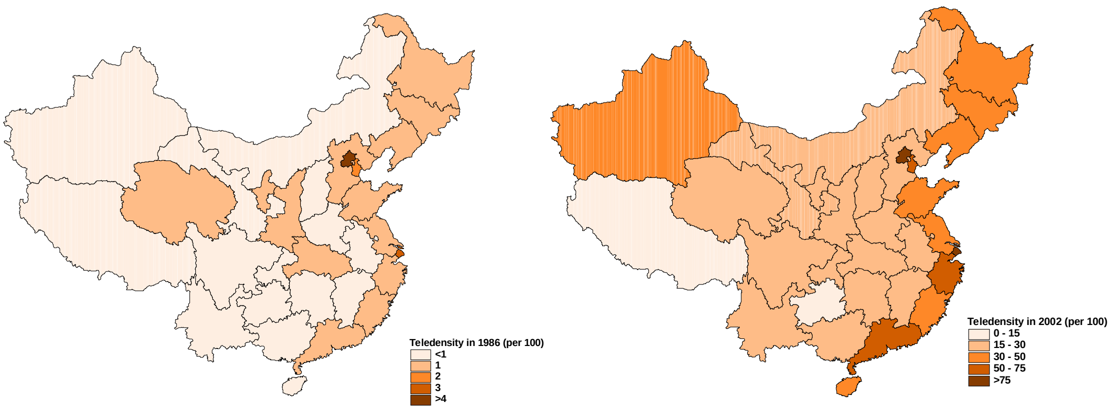


Figure 3. Regional Disparity of Telephones Penetration (Left in 1986; Right in 2002)

Figure 6 suggests that there is no clear relationship between initial GDP per capita (in natural log) and average annual growth rates in the 1986 to 2002 period. At least, there is no obvious evidence in support of an absolute converge hypothesis, althouth this can be investigated in the conditional convergence framework,which suggests economies will converge by controlling for a set of variables reflecting differences in the steady-state equilibrium (Barro, 1991).

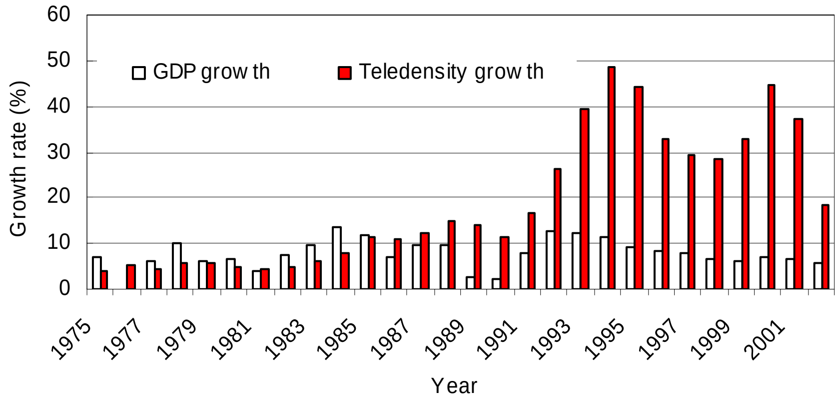


Figure 4. Growth Rate of GDP and Teledensity from 1975 to 2002

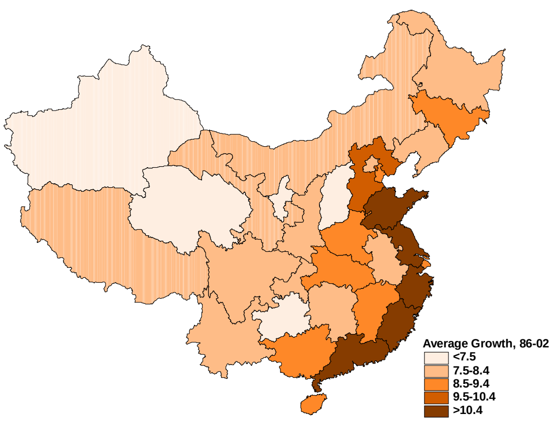


Figure 5. Growth Performance: Average Annual Growth Rate 1986-2002

The question remains, does an appropriate telecommunications infrastructure contribute to regional economic growth significantly in China? In other words, does the different telecommunications infrastructure endowment serve as a significant factor in explaining the different growth performance across regions? In the next section, a dynamic growth model is introduced to investigate the role of telecommunications infrastructure in explaining the regional growth disparity.

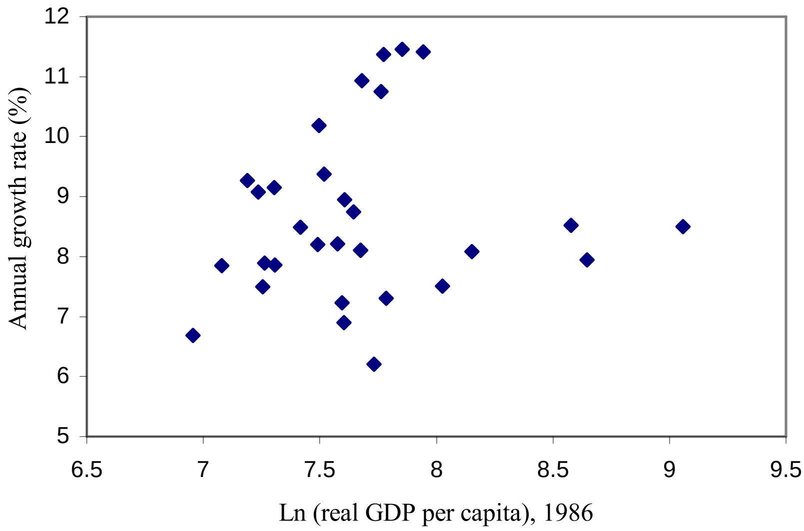


Figure 6. Regional per capita GDP in 1986 and Growth Performance, 1986-2002

3. METHODOLOGY FRAMEWORK

There is a vast literature focusing on investigating the sources of economic growth (see reviews in Barro and Sala-I-Martin, 2004; and in Xie, 2003). In the literature, the most common approach to studying the sources of economic growth is using the now-standard Barro-type framework, which allows testing for conditional convergence by adding to a Solow-type equation a set of variables reflecting differences in the steady-state equilibrium (Barro, 1991). This methodology involves regressing per capita GDP growth during a given time interval on initial per capita income, and a set of conditional variables. More recently, Islam (1995) reformulated the regression equation used in previous convergence studies into a dynamic panel data model with fixed effects and used panel data procedures to estimate it. The main advantage of this dynamic panel data approach lies in its ability to allow for differences in the aggregate production function across economies. This method can also capture short-run autoregressive behaviour by adding a lagged growth rate as an independent variable.One recent application of this framework is Datta and Agarwal (2004), in which they investigate the impact of infrastructure on economic growth in 22 OECD countries.

Since our focus is to investigate the role of telecommunications infrastructure in explaining the different growth performance across regions in China, we can estimate a growth equation for each province by following the Barro-type conditional convergence framework (Barro, 1991; Islam, 1995). In this study, the growth equation is extended to include the effects of telecommunications infrastructure on growth, except for accounting for differences in initial economic conditions, in lagged growth rates, and a set of other variables. The model has the following form:

$$GRTH_{it} = \alpha_0 + \gamma GRTH_{i,t-1} + \delta GDP_{i,t-1} + \sum_j \beta_j X_{j,t} + \alpha_i + \eta_t + \mu_{it} \quad (1)$$

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 the log value of lagged real GDP per capita. *X* contains a set of variables intended to account for production factors and other conditional variables.

The choice of variables follows growth theory and the line of analysis on growth determinants in that literature. Levine and Renelt (1992) find more than 50 variables that, in at least one regression, are significantly related to economic growth. Sala-i-Martin (1997) finds 62 explanatory variables in the cross-country empirical growth literature. The variables considered in growth studies range from traditional economic variables such as physical capital and labour, to a broader range of economic variables including human capital, public capital, R&D investment, and regional inequalities to non-economic variables including social capital, religion, institutions, and political variables. Based on the available data for China, this paper selects the following explanatory variables in the preliminary analysis: fixed investment, foreign direct investment, employment, human capital, population growth, urbanization level, industrial output share from state-owned enterprises, transportation, as well as telecommunications infrastructure, plus for the two level variables, which have been outlined in Equation (1): the lagged growth and lagged GDP per capita.

It is expected that there are positive interrelationships between regional growth and fixed investment, employment, human capital, urbanization rate, foreign direct investment as well as transportation and telecommunications infrastructure. But it is expected that the initial economic conditions as measured by lagged GDP per capita, population growth, and share of state-owned enterprise in total industrial output will have a negative impact on regional growth. The detailed model is given as:

$$\begin{aligned} GRTH_{it} = {} & \alpha_0 + \alpha_i + \eta_t + \beta_1 GRTH_{i,t-1} + \beta_2 Ln(GDP)_{i,t-1} + \beta_3 INV_{it} + \beta_4 FDI + \beta_5 POP_{it} \\ & + \beta_6 EMP_{it} + \beta_7 HC + \beta_8 URBAN_{it} + \beta_9 SOE_{it} + \beta_{10} TRANS_{it} + \beta_{11} TEL_{it} + \mu_{it} \end{aligned} \quad (2)$$

The variables in this equation are measured as follows:

- *GRTH*: annual growth rate of real GDP per capita. $GRTH_{t-1}$ is one year lagged *GRTH.* Here we have an important assumption that the annual growth rate is at least partially dependent on previous year's growth.
- $Ln(GDP)_{t-1}$ represents the log value of the lagged real GDP per capita in 1995 value (RMB). The lagged GDP variable is included to test for conditional convergence in a panel data framework. A significant and negative coefficient of one-year lagged GDP per capital is expected to

provide some evidence in support of the convergence hypothesis[7]: the higher level of past GDP, the lower the subsequent growth in GDP per capita.

- *INV*: the share of fixed investment in GDP. The correlation between investment and economic growth is expected to be positive.
- *FDI*: the share of foreign direct investment divided by total fixed investment. The correlation between investment and regional economic growth is also expected to be positive.
- *POP*: annual population growth rate. *POP* represents the population growth rate and is introduced to assess the effects of population growth on economic growth. The expected sign of *POP* is negative since a lower population growth rate relates to a higher level of GDP per capita.
- *EMP*: the percentage of total employment to total population. The expected sign for *EMP* is positive because a high employment rate relates to a higher level of economic output.
- *HC*: the human capital, which is measured by the average years of schooling for the population aged 6 and above. The expected sign for *HC* is positive.
- *URBAN*: the share of urban population of total population. A reallocation of production factors, in particular labour, from agricultural to industrial and services activities is expected to contribute to economic growth in China. The rate of urbanization can be used to roughly evaluate this relocation and the expected sign for its coefficient is positive.
- *SOE*: the share of state-owned enterprise in total industrial output. Since private sector is usually more efficient and dynamic, it is expected that the share of state-owned enterprise in total industrial output will negatively relate to economic growth. The expected sign for *SOE* is negative.
- *TRANS*: transportation density as measured by the length of rail, highway, and waterway networks per square kilometre. Its expected sign is positive.
- *TEL*: the number of telephones per 100 inhabitants. Its expected sign is also positive.

Data for 29 regions of China for a 17 years' period, from 1986 to 2002, are utilized in this analysis. China has 31 provinces, autonomous regions and cities under direct guidance of the central government. Due to missing data, 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 managed to adjust data for the new Sichuan province from the old one, which included only new Sichuan area. As a result, the total number of

[7] Testing for conditional convergence would require a longer time period, or at least average on more than three years. However the test using one-year lag GDP per capita may provide some evidence of conditional convergence, at least in the short run.

units in this study is 29 since two regions, Tibet and Chongqing, have been excluded from the analysis.

This analysis is confined to 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 0.59 telephones per 100 inhabitants. The investment in telecommunications sector was only 0.73 percent of the national total investment in 1985. It was just from the late 1980s that the telecommunications sector began the rapid expansion (see Figure 1). Also, data at the regional level before 1985 is usually difficult to collect and often incomplete. As a result, we will use a panel dataset of 29 regions for a 17 year period.

Macroeconomic data of real GDP per capita, growth rates, population, fixed investment, employment, urbanization, transport density, foreign direct investment, output of state-owned enterprise, total industrial output and number of telephones for different provinces from 1985-2002 is collected through Comprehensive Statistical Data and Materials on 50 Years of New China (NSB, 1999), Statistics on Investment in Fixed Assets of China (NSB, 2002) and then updated with China Statistics Yearbook from 1999 to 2003. Data of human capital as measured by the average years of schooling before 1998 is available in Yu (2001). After using China Statistics Yearbook from 1999 to 2003, the data on human capital is updated using the Perpetual Inventory method.

4. MODEL SPECIFICATION AND ECONOMETRIC EVIDENCE

4.1 Model Specification

Before turning to a discussion of model specification, it should be pointed out that all the estimations in this study are based on two-way fixed effect models. Due to the panel form of the data set, one common issue for the estimation is whether the individual effects are to be thought of as "fixed" or "random". The assumption in the case of the random model is that the effects are uncorrelated with the exogenous variables. In this analysis, however, estimators that rely on such assumptions are not suitable because it is the fact that correlation exists that forms the basis of the dynamic panel approach that we use. Hence, a fixed effects model is appropriate and preferred.

Since it is important to screen variables in growth studies, as demonstrated by Levine and Renelt (1992), a preliminary analysis of the independent variables helps to determine which variables should be included in further analysis. Here, the lagged growth rate ($GRTH_{t-1}$) and the natural log of lagged real GDP per capita ($Ln(GDP)_{t-1}$) are used as the basic explanatory variables to test which variables have an impact on regional economic growth. A variable is preliminarily considered as a growth factor if it is statistically significant at the 10 percent level when the growth rate (GRTH) is regressed on the lagged growth rate ($GRTH_{t-1}$), the natural log of lagged GDP per capita ($Ln(GDP)_{t-1}$), and the variable being tested in the fixed effect model. Otherwise, the variable is excluded from further consideration in the analysis. Finally, variables that are initially significant are excluded from consideration if they become insignificant or change signs when more variables are added into the model. The variables are kept in the model only when they do not change signs and are significant (at the 10 percent level).

Variables that pass the test include INV, FDI, POP, EMP, and TEL, except for GRTH $_{t-1}$ and ln(GDP) $_{t-1}$. They always have expected signs and are highly significant during the test, even when other variables are included in the model. Table 1 presents one of the tests with the maximum possible variables. Table 2 presents a list of variables used in the final model and their expected signs.

Table 1. Tests of Variables for Modelling

Variables	Coefficient	Standard error	t Statistic	P-value
Dependent variable*: GRTH*				
Intercept	85.7	14.8	5.76	<.0001
$GRTH_{t-1}$	0.296	0.04	6.84	<.0001
$ln(GDP)_{t-1}$	-9.94	1.62	-6.12	<.0001
INV	8.68	2.46	3.53	0.0005
POP	-0.81	0.15	-5.32	<.0001
FDI	0.077	0.03	2.48	0.01
TEL	0.055	0.02	2.21	0.03
EMP	0.076	0.05	1.74	0.07
HC	0.11	1.02	0.11	0.91
URBAN	0.11	0.10	1.11	0.27
SOE	0.02	0.47	0.05	0.96
TRANS	0.51	3.69	0.14	0.89

Table 2. Variables and their Expected Signs

Variables	Explanation	Expected sign
GRTH	Rate of growth of real GDP per capita (%)	
$GRTH_{t-1}$	Lagged growth of real GDP per capita (%)	+
GDP_{t-1}	Lagged real GDP per capita (in RMB)	-
POP	Rate of growth of population (%)	-
EMP	Share of employment in total population (%)	+
INV	Share of fixed investment in GDP (%)	+
FDI	Share of FDI in fixed investment (%)	+
TEL	Number of telephones per 100 inhabitants	+

Several variables are excluded because they are not statistically significant at the 10 percent level when *GRTH* is regressed on $GRTH_{t-1}$, $ln(GDP)_{t-1}$ and the variable being tested. These excluded variables include human capital level (*HC*), urbanization level (*URBAN)*, economic structure measure (*SOE*: share of output of state-owned enterprise in total industrial output), and transportation density (*TRANS).*

As a result, the final model can be written as follows:

$$GRTH_{it} = \alpha_0 + \alpha_i + \eta_t + \beta_1 GRTH_{i,t-1} + \beta_2 Ln(GDP)_{i,t-1} + \beta_3 INV_{it} + \beta_4 FDI + \beta_5 POP_{it} + \beta_6 EMP_{it} + \beta_7 TEL_{it} + \mu_{it} \quad (3)$$

Regression results of Equation (3) are reported in Table 3 (Model A), which is estimated using a fixed effects model. Before turning to interpret the estimation results, we need to assess the spatial dependence issue. As previous studies indicate, the presence of spatial dependence may lead to misspecification because the omitted variables in econometric model may be relate to the connectivity of neighbouring regions. In a properly specified model, it is likely that spatial dependence would be reduced or eliminated.

Table 3. Determinants of Regional Economic Growth, 1986-2002

Variables	Model A: R^2=0.68	Model B: R^2=0.68	Model C: R^2=0.69
Intercept	89.0 (6.37) ***	89.0(6.36) ***	98.69(6.7) ***
$GRTH_{t-1}$	0.29 (6.83) ***	0.29(6.80) ***	0.32(7.0) ***
GDP_{t-1}	-9.57 (-6.24) ***	-9.54(-6.23) ***	-10.57 (-6.54) ***
INV	8.15 (3.42) ***	8.20(3.43) ***	8.13 (3.32) ***
FDI	0.081 (2.67) **	0.08(2.66) **	0.067 (2.14) **
POP	-0.82 (-5.38) ***	-0.82(-5.43) ***	-0.86 (-5.67) ***
EMP	0.071 (1.81) *	0.070(1.88) *	0.07 (1.83) *
TEL	0.053 (2.39) **	-	-
TEL_{t-1}	-	0.066(2.3) **	-
TEL_{t-2}	-	-	0.078 (2.04) **

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

To check for spatial error dependence, a Moran's *I* test is carried out on the residuals for each year. As seen in Table 4, spatial error dependence is not a major concern for our empirical analysis in general. Moran's *I* statistics are insignificant for all the years except for 1987, 1990, 1993, 1994, and 1995. For all these five years, Moran's I values are significant at the 5 percent level. A second effort of running Equation (3) with spatial lagged independent variables indicates that most spatially lagged values of independent variables are not statistically significant. As a modelling choice, the lag of the independent variables except the lagged growth ($GRTH_{t-1}$) are being used. Spatially lagged variables for a region are computed by taking the average value of the contiguous neighbours of a region. Investment (*INV*) is the only significant lagged variable. To summarize, the insignificance of spatially lagged variables confirms the findings in Table 4.

Table 4. Moran's *I* Test for Error Dependency

Year	Moran's *I*	P-value
1986	0.187	0.06
1987	0.238**	0.02
1988	0.038	0.28
1989	0.024	0.32
1990	0.256**	0.01
1991	-0.061	0.42
1992	0.104	0.14
1993	0.236**	0.02
1994	0.220**	0.02
1995	0.368**	0.01
1996	0.063	0.22
1997	-0.025	0.47
1998	-0.290	0.12
1999	-0.049	0.46
2000	0.129	0.11
2001	-0.133	0.23
2002	-0.007	0.41

Notes: ** Significant at 5% level

4.2 Empirical Evidence

As shown in Table 3, almost 68 percent of the variation in the growth rates can be explained by this model. The coefficients of most of the variables of interest are significant (most at a 1 percent level). It confirms that China's regional growth rates are positively related to fixed investment, foreign direct investment, employment, growth rates in previous year, and telecommunications infrastructure and are negatively related to the initial level of per capita GDP and population growth.

TEL contains a measure of telecommunication infrastructure. As discussed before, the variable we are using here is teledensity, the number of telephone sets per 100 inhabitants, including both fixed line and mobile. 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.), but we have considered the addition of mobile communications when we constructed our proxy for the level of telecommunications infrastructure. Because of the rapid deployment of mobile communications technologies in China there are now more mobiles phones subscribers than fixed lines users (269 million mobile users and 263 million fixed line users in 2003). If we had focused our analysis on only fixed lines, a very large proportion of telecommunications infrastructure would be neglected. As we checked, the number of total telephone users is highly correlated (greater than 0.99 in correlation) with the capital stock of posts and telecommunications sector.[8] 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. It is an output measure and therefore the current value is expected to have the strongest association with that year's growth rate. The results indicate a strong and positive relationship between telecommunications infrastructure and economic growth. The telecom variable is positive and significant at the 5 percent level in Model A, suggesting a positive relationship between telecom infrastructure and economic growth.

Previous discussion and some 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 lagged values of *TEL* (TEL_{t-1} and TEL_{t-2}) to replace current value of *TEL* for Equation (3). If the positive effect of telecommunications infrastructure on growth is a result of reverse causality, the coefficient of the lagged values of *TEL* should be insignificant. Model B and Model C in Table 3 report results using lagged teledensity to replace current teledenisty to check whether the positive effect is totally caused by reverse causality. As shown in Table 3, the coefficients of the lagged values of *TEL*, TEL_{t-1} and TEL_{t-2}, are significant at 5 percent 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 the regional economy of China.

Furthermore, previous studies also indicate that the impact of telecommunications infrastructure on growth might not be linear. 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). While others, Datta and Agarwal (2004), find some evidence in support of a "diminishing returns to scale" hypothesis of telecommunications investment in OECD countries. Here a square of teledensity, *TELSQ*, is added to Equation (3) (see Equation (4)) 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.

$$GRTH_{it} = \alpha_0 + \alpha_i + \eta_t + \beta_1 GRTH_{i,t-1} + \beta_2 Ln(GDP)_{i,t-1} + \beta_3 INV_{it} + \beta_4 FDI + \beta_5 POP_{it} + \beta_6 EMP_{it} + \beta_7 TEL_{it} + \beta_8 TELSQ_{it} + \mu_{it} \quad (4)$$

If the coefficient of *TELSQ* (β_8) is negative and significant while the coefficient of *TEL* (β_7) is positive and significant then we have support for a "diminishing returns" hypothesis. That is, a unit increase in teledensity would

[8] Based on data of posts and telecommunications investment from MII and an assumption of a depreciation rate of 15 percent for the telecommunications sector.

have a smaller magnitude of growth for a region with greater level of teledensity. In contrast, positive signs for both coefficients, β_8 and β_7, would indicate "increasing returns". If, however, the coefficient of *TELSQ* (β_8) is positive and significant while the coefficient of *TEL* (β_7) is negative and significant ($\beta_8>0$ and $\beta_7<0$), 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. According to Roller and Waverman (2001), the level of "critical mass" is about 40 mainlines per 100. In other words, the impact of telecommunications infrastructure on growth might be insignificant for regions with penetration rates lower than 40 mainlines per 100.

As Table 5 reports, the coefficient of *TELSQ* is negative and significant at a 10 percent level while the coefficient of *TEL* is positive and significant at a 5 percent level. The results provide some evidence for the argument of diminishing returns of telecommunication investment in China. In other words, the size of the effect of telecommunication infrastructure on the economic growth is inversely related to its prior level. This indicates that the higher the level of telecommunications infrastructure, the smaller the magnitude of the effect of a marginal increase in teledensity on economic growth. This suggests diminishing returns and implies that regions at an earlier stage of development in China are likely to gain the most from further investment in telecom infrastructure. An investment in telecommunications infrastructure in those regions would lead to a higher growth rate than that in already developed regions. The positive incremental effect decreases for those regions with more developed telecommunications infrastructure. Since regions in the central and western China usually have a lower level of telecommunications infrastructure, a strategy for investment in these regions, other things being equal, should have a larger impact on growth.

Table 5. Nonlinearity of Telecommunications and Growth

Variables	$R^2=0.68$
Intercept	89.8 (6.44)***
$GRTH_{t-1}$	0.29 (6.88)***
GDP_{t-1}	-10.0 (-6.44)***
INV	8.09 (3.4)***
FDI	0.07 (2.32)**
POP	-0.83 (-5.48)***
EMP	0.094 (1.82)*
TEL	0.14 (2.45)**
TELSQ	-0.0008 (-1.62)*

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

Estimation results reported in Table 3 and Table 5 provide additional evidence on the determinants of provincial economic growth from 1986 to 2002.

These determinants have already been documented, at least partially, in the existing literature. However, as this analysis employed a dynamic model and may differ from previous studies in specifications, some further comments should be made. First, even after controlling the lagged dependent variable, GDP_{t-1}, the coefficient of the logarithm of lagged GDP per capita is negative and significant at 1 percent level. Although this is not very convincing evidence for the conditional convergence hypothesis, the result suggests that regions with higher levels of GDP per capita tend to grow at a slower rate, at least in the short run, controlling for other conditional variables. In other words, the results suggest a catch-up phenomenon among Chinese provinces in the 1986-2002 period, controlling for other factors. This provides more confirmation for 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 a possibility.

Second, as physical capital is a major production factor, different rates of accumulation of fixed-assets should have a significant impact on growth performance. This hypothesis is confirmed in this study since the coefficient of *INV,* the share of fixed investment in GDP, is positive and significant at the 1 percent level. The results indicate that fixed investment is a key factor contributing to economic growth. This also confirms previous literature's findings that China's economic growth has been driven by accumulation of fixed-assets (see reviews in Wang and Yao, 2003; Mody and Wang, 1997). Together with growth in international trade, *FDI* is usually highlighted as a main engine of China's growth. The inflow of high levels of foreign direct investment is often cited as one of the primary reasons for China's fast growing economy. The level of foreign direct investment is also an indicator of openness of a region to the rest of the world. As expected, the share of FDI in total fixed investment in a region has a positive and significant effect on its economic growth. However, in terms of openness, another commonly used indicator is the ratio of total exports and imports over GDP but this indicator appeared to be insignificant. Hence, openness is only partially measured by FDI.

Another production factor, *EMP*, the share of employment in total population has a positive and significant effect on regional economic growth as suggested by these results. However, we did not find significant evidence in support of a positive effect of human capital on economic growth. Referring to Lucas' (1988) work on the contribution of human capital to economic growth, further studies are needed that utilize alternative indexes of human capital to evaluate human capital's effect on growth which may be more sector specific than our approach. As expected, the coefficient of population growth is negative and significant at the 1 percent level. The results show that the population growth has a negative effect on growth of real per capita GDP. This is understandable since a greater growth rate in population relates to a lower level of per capita GDP.

5. CONCLUSIONS

This paper empirically investigates the role of telecommunication infrastructure on the long run regional economic growth using a sample of 29 regions of China for a 17-year period, 1986-2002. With a panel dataset, this paper uses a dynamic fixed effects model for estimation, which enables testing of the relationship between regional economic growth and initial economic condition, fixed investment, employment, population growth, foreign direct investment as well as telecommunications infrastructure while accounting for regional specific differences in aggregate production functions. Overall, the estimation of a dynamic growth model indicates that differences in telecommunications infrastructure does account for a significant part of the observed variation in the growth performances of China's provinces. Telecommunications infrastructure, as measured by telephones per 100, 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 past levels of GDP per capita, lagged growth in real GDP per capita and other factors. The results of this analysis further indicate that the telecommunications investment is subject to diminishing returns, which implies that the positive effect of telecommunications on GDP growth is largest for regions with the lowest level of telecommunications infrastructure. From the perspective of public policy, the results provide evidence for the proportion that providing an efficient and appropriate telecommunications infrastructure is significant for fostering economic growth in less-developed regions.

This analysis also found some evidence in support of the conditional convergence hypothesis, which suggests that controlling for other factors, regions with higher levels of GDP per capita tend to grow at a slower rate in China. This paper also confirms that fixed investment, foreign direct investment, and employment rate have a positive effect on economic growth, while population growth has a negative effect on regional economic growth.

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