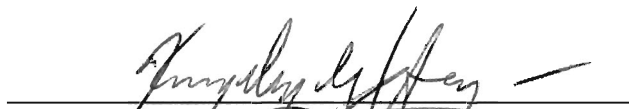
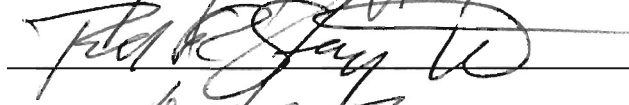



IMPACTS OF TELECOMMUNICATIONS INFRASTRUCTURE AND ITS SPILLOVER
EFFECTS ON REGIONAL ECONOMIC GROWTH IN CHINA

by

Yanchun Liu
A Dissertation
Submitted to the
Graduate Faculty
of
George Mason University
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The Requirements for the Degree
of
Doctor of Philosophy
Public Policy


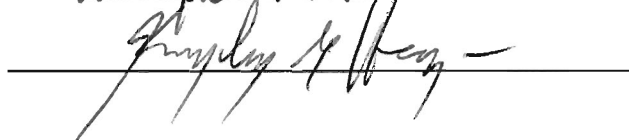
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List of Abbreviations

CPI	Consumer Pricing Index
FDI	Foreign Direct Investment
GDP	Gross Domestic Product
GLS	Generalized Least Squares
NSB	National Statistics Bureau
OECD	Organization of Economic Cooperation and Development
PRC	People's Republic of China
R&D	Research and Development
RMB	RenMinBi (Chinese monetary unit)
Telecom	Telecommunications
Teledensity	The term “teledensity” in this dissertation refers to the number of telephones, both fixed lines and mobile phones, per 100 inhabitants.
U.S.	The United States

Abstract

IMPACTS OF TELECOMMUNICATIONS INFRASTRUCTURE AND ITS SPILLOVER EFFECTS ON REGIONAL ECONOMIC GROWTH IN CHINA

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This dissertation empirically tests the impacts of telecommunications infrastructure as well as its spillover effects on regional economic growth in China. Based on data for 29 regions of China for the period 1986-2006, a panel data approach is used in the context of conditional convergence theory for estimation. A modified shift-share analytical framework is used to decompose regional economic output changes by labor and capital factor inputs. With appropriate controls for heteroscedasticity and spatial autocorrelation, the research findings of this dissertation include: 1) that for total regional economic growth, telecommunications infrastructure has significant negative impacts, implying the possibility of “investment congestion” in the telecommunications sector in China’s regions during the examined period; 2) that for regional economic growth due to capital factors, telecommunications infrastructure has significant and positive impacts, indicating a positive relationship between this key input and regional output growth; 3) that negative and significant spillover effects of

telecommunications infrastructure are identified for total regional economic growth, whereas the spillovers have positive influences on regional growth due to capital factors only; 4) conditional convergence has been occurring among China's regions, providing further evidence to the conditional convergence literature.

Chapter 1 Introduction

This study empirically tests the relationship between regional economic output accounted for by capital factors, with the focus on telecommunications infrastructure and its spillover impacts, in China using a panel dataset comprising of 29 provinces, municipalities, and autonomous cities for the time period of 1986 to 2006. Capital factors, besides availability of telecommunications infrastructure, are examined and determined in the context of regional economic growth in China. The purposes of this study consist of isolation of economic output due to labor factor from those due to capital factors for different regions, impacts of both telecommunications infrastructure and its spillover effects on regional economic output, as well as influences of other capital region-specific factors such as foreign direct investment, urbanization levels, transportation infrastructure, state-owned enterprises, investment in fixed assets, population growth, and human capital stock.

1.1 Background

Specification on the connotation of infrastructure is important before discussion of relationships between economic growth and availabilities of different types of infrastructures. According to the World Bank (1994), infrastructure refers to enormous amounts of tangible capital stock with ownership of either government bodies or private organizations. Another definition of infrastructure is provided by the Association of Local Government Engineers

New Zealand: "...[infrastructure] is the network of assets where the system as a whole is intended to be maintained indefinitely at a specified standard of service by the continuing replacement and refurbishment of its components..." Examples of infrastructures include regulated utilities such as highway systems, railroads, sewer facilities, power generation and distribution, and telecommunications network. Link between infrastructures and economic development of regions is inherent. These long-term and capital-intensive networks facilitate provision of essential public and private services that boost economic growth and increase quality of life. These basic frameworks serve as skeletons of a regions' economic body. Rationale of intensive long-term capital investment on infrastructures manifests itself in that such investment usually generate economy-wide positive externalities (World Bank, 1994). Instead of directly generating economic profits into a region, most infrastructures such as transport and telecommunications networks usually improve productivity of other productive inputs and sustain economic growth in the long run (Jimenez, 1995). It is noteworthy that infrastructures also convey their contributions to economic output as measurable increments in final products. Other contributive influences of infrastructures are also identified in the literature, including lower economic transaction costs in both production and consumption phases of an economic system (Rietveld, 1989; Roller & Waverman, 2001; Bhatta & Drennan, 2003; Crossman, Meyer-Boehm, & Skinner, 2006).

The relationship between regional economic growth and infrastructure has been a hot research topic since 1980s (*e.g.*, Ratner, 1983; Aschauer, 1989a, 1989b, 1989c; Demetriades & Mamuneas, 2000; Miller & Tsoukis, 2001; Charlot et al., 2003). Different from the self-explicit theoretical linkage between economic growth and infrastructure, empirical attempts

in testing effects of infrastructure network capital stock on economic growth and productivity do not reach unanimous conclusion. Controversy exists between two schools of studies in the empirical growth literature. One school affirms the significant influences of infrastructure on economic growth (*e.g.*, Ratner, 1983; Aschauer, 1989a, 1989b, 1989c; Munnell, 1990a, 1990b; Garcia-Mila & McGuire, 1992; Lau & Sin, 1997; Yilmaz, Haynes, & Dinc, 2001; Ding, 2005). Most studies within this school utilize an aggregate production approach based on the neoclassical economic growth framework. This is appropriate because impacts of infrastructure on economic growth mainly lie in economic externalities generated from development of such network. Poot (2000), for example, reviews 39 studies on examination of relationship between infrastructure and economic growth and confirms similarity among findings of these studies with identification of 72% positive conclusions. On the other hand, studies within the school denying positive impacts of infrastructure on economic growth are not few, either (*e.g.*, Hulten & Schwab, 1991; Tatom, 1991; Holtz-Eakin, 1994; Nadiri & Mamuneas, 1996; Canning & Bennathan, 2000; Thangalevu & Owyong, 2000; Ghafoor & Yorucu, 2002; Canning & Pedroni, 2004). The major arguments of this school include skepticism of pseudo-positive effects of infrastructure due to its role of “artifact of an inappropriately restrictive econometric framework” (Holtz-Eakin, 1994, p. 581) and dispute on adoption of the highly aggregate measure of economic output as well as the consequent causality concern. The first school, as contended against by the second school, inappropriately assumes the inherent causal mechanism between infrastructure and economic growth. It remains controversial in current literature to identify a unanimously accepted relationship between economic growth and infrastructure.

Telecommunications networks represent a major type of infrastructure. As illustrated by Lakshmanan (1989), telecommunications infrastructure shows validity of being identified as infrastructure by exhibiting essential features and functions of infrastructure networks, such as huge initial investment of capital, natural monopoly inclination, external economies, and lack in mobility. The effect of telecommunications infrastructure on regional economic development has been the subject of a large body of recent research for the past three decades. Telecommunications infrastructure investment, accompanied by possibility of “diminishing” geographic proximity advantages and consequent “tolerance” of more locational freedom for businesses, emerged as an important factor in regional economic dynamics. Increasing accessibility of farther non-neighbor localities shrinks actual geographic distances between producers, suppliers, and customers. Therefore, search by business entities for least-cost location is significantly affected by availability and quality of telecommunications infrastructure in a region, which will inevitably reshape regional economic development patterns and lead to faster economic growth for better-endowed regions. An ample body of studies has provided sufficient academic evidences on this positive relationship between telecommunications infrastructure and regional economic development (Yilmaz, Haynes & Dinc, 2001, 2002; Yilmaz & Dinc, 2002; Norton, 1992; Wang, 1999; Canning, 1997, 1999; Cohen, 1992; Greenstein & Spiller, 1995; Nadiri & Nandi, 1997; Cronin, et al 1991, 1993).

However, the popular viewpoint on telecommunications infrastructure’s impact on regional economic patterns has been challenged by another group of studies (e.g., Blair & Premus, 1993). In lieu of sole emphasis on the capacity of telecommunication services in reducing the importance of geographical proximity and allowing greater distances in firms’

competition for customers and raw materials, these studies contend that some other factors like a skilled labor reserve, favorable state and local income taxes, booming regional business environment, satisfactory quality of life, and availability of other public basic infrastructure also play an indispensable role in attracting investors into a region for business activities. The existence of more explanatory factors complicates analyses of the contribution of telecommunications infrastructure on regional economic growth, and blurs the feasibility of adopting competition-oriented state policy making in telecommunications sector.

Discrepant levels of productive element endowments such as labor and capital across regions are not necessarily similar and exhibit strong spatial heterogeneous characteristics. The uneven spatial distribution of productive elements on state level orients two research directions: one is to distinguish essential contribution of telecommunications infrastructure, other than factors like labor or other capital inputs, in regional economic growth, and another is to identify effects of telecommunications infrastructure investment in other regions on one regions' output growth. This study advances along both tracks from a spatial perspective. In other words, besides identification of impacts of telecommunications infrastructure on regional economic growth, this analysis also examines the spatial spillover effects of telecommunications infrastructure investment in one region on its surrounding regions in terms of economic growth.

Development of telecommunications infrastructure in China exhibits a dramatically different path from that of developed countries. Nearly stagnant before the 1980s, telecommunications investment in China has increased at an unprecedented speed during the past two decades. As illustrated by Ding (2005, p. 5), teledensity measured by number of

main telephone lines per 100 inhabitants in China increased from 0.2 in 1980 to 41.2 in 2003. According to the statistics released by the Ministry of Industry and Information Technology (MIIT) (2008), about 100 million phone lines (including both fixed lines and mobile lines) have been added each year since 2000, and the total number of telephone lines reaches over 900 million in China in August 2008. The teledensity in August 2008 is 72.6, and 99.5% villages have telephone access during the same period (MIIT, 2008). However, such rapid growth in telecommunications sector does not happen evenly across all regions. Studies have found pronounced regional differences in telecommunications infrastructure availability among regions in China (Lee, 1997; Lu & Wong, 2003; Wu, 2004; Ding, 2005). For example, teledensity in Guizhou province was less than 20 in 2003, whereas over 125 in Beijing (Ding, 2005, p.5). This regional disparity in telecommunications infrastructure mirrors regional economic performance discrepancy among regions in China. It is essential to gain knowledge and understanding of this linkage.

Given research findings on the relationship between telecommunications infrastructure and regional economic growth in literature, it is noteworthy that most of these empirical studies are based upon data from developed countries or regions. Thus, it is not appropriate to apply directly the conclusions derived from developed regions or countries to the context of developing countries like China (Ding, 2005, p. 6). Furthermore, study on regions in China can add to knowledge of the relationship between telecommunications infrastructure and economic growth, which might benefit ultimate settlement of the causality controversy in literature.

This study also incorporates the ideas of economic convergence (e.g., Barro, 1991; Barro & Sala-i-Marin, 1991, 1992, 2004; Wei & Liu, 2003; Ertur et al., 2006; Fischer & Stirbock, 2006) in examining role of both telecommunications infrastructure and its spillover effects in regional economic growth in China. The convergence framework attracts enormous attention in recent years among various economic growth theories and models developed in neoclassical economics. Two mainstream theoretical and empirical branches of the convergence literature dominate current studies. One is the classical Solow aggregate production function approach (e.g., Solow, 1956), and the other resides in the conditional convergence discussion stressing the identification of factors that lead to economic growth (e.g., see reviews in Barro & Sala-I-Marin, 2004). Despite success in examining the relationship between various economic inputs and aggregate economic output, the Solow aggregate production function approach encounters skepticism in justification of the robustness of its conclusions due to its reliance on simple correlation methods. The weaknesses of the Solow framework lie in its failure in explicating the causal links between inputs and output and its reluctance in accounting for fixed effects in cross sectional analysis (Roller & Waverman, 2001). The inconsistency of theoretical reasoning under the Solow framework has led to empirical questioning and calls for a different evolutionary approach which addresses causal links and fixed effects issues. Later the conditional convergence approach, instead of directly compensating for the built-in ineffectiveness of the Solow model, attempts to shift the emphasis to identification of factors leading to economic growth.

Barro & Sala-I-Martin (1991) test the hypothesis that poor countries or regions tend to grow faster than rich ones, and implement the neoclassical growth model as a framework

for testing the convergence of 48 contiguous states in the United States. Their model adds to the Solow equation a set of variables reflecting differences in the steady-state equilibrium following Barro's earlier approach (1991). This seminal work triggered a vast literature around the absolute and conditional convergence discussion. The convergence approach avoids causality and endogeneity issues by identifying the determinative effects of initial per capita income and a series of other conditional variables (e.g., prior infrastructure investment) upon per capita GDP growth. The crucial assumption in the conditional convergence method is the existence of identical aggregate production functions for all the countries or regions being examined. In other words, the unobservable country effects are omitted or considered insignificant under the Barro model.

However, Islam (1995) challenges this aggregate production function unanimity assumption by allowing for such differences in production functions across regions and extending Barro's cross-section approach to a dynamic framework. Specifically, Islam (1995) proposes a panel data approach which includes the unobservable country effects in the equation and estimates them over time and space. This study uses Islam's panel data approach. Thus, despite regional disparities in productive element endowments or technological levels across regions in China, it is reasonable to assume reliability and validity in conducting this analysis within the convergence framework.

This study, instead of using the initial level real GDP per capita as in traditional convergence framework, replaces initial regional economic output with initial levels of productive elements such as public and private capital, labor, and infrastructure. Such treatment is consistent with the traditional convergence model in that convergence of

economic developments between developed and undeveloped regions are negatively related to initial productive element endowments of undeveloped regions. Since literature has confirmed contributive roles of these productive elements, initial levels of these elements should also be negatively related to regional economic growth. Thus, it is possible to examine impacts of telecommunications infrastructure that serves as one type of major productive elements on regional economic growth.

This study is also different from current studies in examining the relationship between telecommunications infrastructure and regional economic growth in that regional economic output growth due to capital factors, not overall regional output growth, is set as the dependent variable. This can be achieved via use of a modified version of shift-share analysis developed by Dinc and Haynes (1997). By decomposing regional output changes, this extended shift-share model can isolate the proportion of output changes due to capital factors only. Therefore, only the portion of growth due to capital, either physical or non-physical, is included in the analysis and volatility of research findings is reduced. The same logic is adopted by Nguyen and Smith in their examination of capital stock's contribution to Australian states' economic growth (2006).

The spatial considerations in this analysis on spillover effects of regional level telecommunications infrastructure investment on economic output rest on the fact that state regulatory and legislative powers are to some extent decisive on this issue, which necessarily embeds this economic growth process with interfering political willingness and purposes (see, e.g., Cohen & Morrison Paul, 2007; Badinger & Egger, 2007; Moreno & Lopez-Bazo, 2007). Considering the dynamic characteristics of telecommunications industry in China (e.g., the

reorganization of the largest telecommunications companies such as China Rail Communications Corporation in May 2008, see Netease news release), provincial policymakers have a major impact on telecommunication infrastructure investment level through regulatory power. Provincial regulatory agencies are responsible to orient investment in the telecommunications infrastructure in each province of China with specific policies. This practice is even applicable to some developed countries like the United States. For example, the bestowed political power from Federal Communications Committee grants state policymakers ample choices of different return rates of telecommunications investment in pursuing relevant policy goals (Yilmaz et al, 2002). The state telecommunications investment policies are designed to either achieve universal access to telecommunications services or adopt telecommunications technology deployment acceleration plans by state governments (see Yilmaz et al., 2002). For both developing countries like China and developed countries like the United States—even in European countries (see Maggioni & Nosvelli, 2006), the legislative power of jurisdictions on telecommunications infrastructure investment and the direct predictable economic benefits from the utilization of favorable policies can jointly ensure reasonability of regional policymakers' unanimous policy preference on attracting productive factors by manipulating political initiatives in the critical telecommunications sector. As a result, some better-endowed or quickly improved regions in terms of telecommunications infrastructure availability may absorb economically productive resources from the neighboring regions by simply encouraging relocation of firms or competing potential investment with their counterparts. Theoretically speaking, this effect of a region's telecommunications infrastructure policy would demonstrate a negative impact on

neighboring regions from a production function point of view. However, as mentioned before, other interferential factors such as business climate, entrepreneurship, and quality of life may weigh more than telecommunications service availability in orienting productive element flow and “offset” this negative effect of province level telecommunications infrastructure competition policy.

1.2 Research Questions and Hypotheses

This dissertation targets the relationship between telecommunications infrastructure as well as its spillover effects and regional economic growth in China based on a panel dataset from a spatial perspective. The research questions in this study include:

- Do capital factors contribute to regional economic growth in China?
- Can regional economic growth due to capital factors be isolated from that due to labor factors?
- What is the relationship between telecommunications infrastructure and regional economic growth after excluding labor?
- Are there spatial spillover effects from telecommunications infrastructure?
- What is the relationship between the spillover effects of telecommunications infrastructure on regional economic growth?

It has been widely recognized that national competitive advantages of China lie in its low labor costs. Thus, findings on the contribution of capital factors to regional economic growth are critical for policy makers in exploration of local competitive advantages other than labor costs. These research questions address key issues related to policy making in telecommunications infrastructure investment in China. This study is beneficial for policy makers to more accurately assess the relationship of telecommunications investment and

regional economic growth after controlling for or excluding the contribution of labor. The set of hypotheses in this dissertation are specified as follows:

Hypothesis 1: *Capital factors such as infrastructure and other forms of physical capital determine a significant proportion of differences in regional economic performance in China.*

The neoclassical economics theories (*i.e.*, Solow, 1956) categorize productive inputs into labor input, capital input, and other inputs such as technology. It is reasonable to separate output growth based on inputs (*i.e.*, from labor input and from capital inputs). Total factor productivity theory provides the theoretical basis for such division of output. With theoretical substantiation, this dissertation hypothesizes that capital investment inputs such as telecommunications infrastructure determines a significant proportion of regional economic growth difference in China.

Hypothesis 2: *Telecommunications infrastructure has significant impacts on regional economic growth after controlling for initial economic conditions and a set of socio-economic variables.*

According to total factor productivity theory, regional economic growth in China is hypothesized as a function of all different productive inputs. Thus, telecommunications infrastructure is seen as one type of economic input and can be included in the model examining the relationship between output growth and inputs. Given the inherent function of telecommunications infrastructure in facilitating business transactions and lowering

transaction costs, regional disparity in telecommunications infrastructure availability can be taken as a factor contributing to regional economic growth differences.

Hypothesis 3: Spillover of telecommunications infrastructure investment by surrounding regions has significant impacts on a region's economic growth after controlling for initial economic conditions and a set of socio-economic variables.

Current literature in examining the relationship between telecommunications infrastructure and regional economic output growth also analyzes spillover effects due to regional investment on telecommunications networks (e.g., Yilmaz, Haynes, & Dinc, 2002). The significance of spillover effects reflects the essential function of telecommunications infrastructure in attracting businesses and other economic resources. Regional competition in terms of productive inputs stimulates regional policy makers to adopt pro-telecommunications investment policy, as is discussed in the context of developed countries and regions. In this dissertation, test of hypothesis on significance of telecommunications infrastructure investment spillover effects on regional economic growth can provide critical policy implications for regional policy makers in China.

1.3 Policy Implications and Contributions

During the past several decades, China has stood out among developing countries in achieving continuous and prominent economic growth. On the one hand, the explosion of economic power in China deserves the attention of the academic community; on the other hand, research findings on the evaluation of different economic inputs' contributing to rapid economic growth pose important policy implications for policy makers and regulators in

China. Despite the popularity of research on the role of telecommunications infrastructure in regional economic growth dynamics, most studies target developed countries and regions. Few studies directly investigate the contribution of telecommunications infrastructure in the rapid development of China's economy. Therefore, research findings of this dissertation have important implications for public policy.

The first policy implication is knowledge on whether capital inputs play a role as significant as labor input. In other words, policy makers can have guidelines on stimulating capital-intensive industries or labor-intensive industries via policy tools. Since economic growth or performance difference on regional level is related to ratio of capital and labor, regional leaders have incentives to adjust public investment to the most efficient uses. Second, as most developing countries and regions, China imports most technological progress and innovations. Development of capital-intensive capital projects such as infrastructure relies most by public investment. Thus, empirical findings on positive impacts of infrastructure on economic growth are extremely important in China. Third, regional policy makers in China can learn whether their local economic environments are appropriate for telecommunications infrastructure to function as an attractive force on economic resources. Political and economic conditions in different regions may ameliorate or prosper depending on the contribution of telecommunications infrastructure and its spillovers. Fourth, regional disparity regarding economic development levels is dramatic across regions in China, and availability of telecommunications infrastructure is equally available. Analysis of telecommunications infrastructure spillovers can provide insights for regional policy makers in their policy making efforts in terms of investment in the telecom sector. The diminishing

return on capital investment exposes investments on telecommunications infrastructure to risk of over-investment, or investment congestion. The over-investment in a sector is an issue in developed countries, and it may also be a problem for some economically powerful regions in China.

This dissertation contributes to the literature in that it is one of the few studies that separately take the spatial distribution of telecommunications infrastructure as an indispensable element in regional economic output growth. Telecommunications infrastructure networks share all characteristics of an infrastructure network such as immobility, large initial investment, and strong economic externalities (Lakshmanan, 1989). Empirical findings of this dissertation can add to current knowledge of infrastructure's role in economic growth. Furthermore, the attempt in this dissertation to conduct analysis at the provincial level, or say sub-national level, may be expected to complement the existing literature on public infrastructure and economic growth, which mainly concentrates on cross-country national level data. Another contribution of this study is the attempt in separating out the proportion of output growth due to capital factors. This increases measurement accuracy of the empirical test of telecommunications infrastructure's impacts on regional economic growth in China. The third contribution is reflected in the inclusion of telecommunications infrastructure spillover effects in the model. The controversy on the existence and sign of the output spillover effects by public infrastructure exists within the contradiction of two groups of studies and a comprehensive summarization will be included in the literature review section. This study will hopefully add to this ongoing debate with evidence of region-level spillover effects of telecommunications infrastructure on regional economic performance.

Fourth, the special role that policymakers play on the highly regulated telecommunications sector determines that the result of this dissertation will provide some relevant policymaking guidance to these stakeholders.

1.4 Organization of Dissertation

The organization of this dissertation is as follows. Chapter 2 reviews history of China's overall and regional economic development; illustration of China's telecommunications infrastructure evolution is also briefed in this chapter. Economic growth among different regions in China exhibits heterogeneous characteristics, a result due to a comprehensive set of economic, political, social, and natural endowment-related factors. Exploratory discussion on these regional differences in economic growth is included in this chapter, as well as that on the availability of telecommunications infrastructure.

Chapter 3 reviews literature on three concentrations. The first concentration contains studies on examination of the relationship between infrastructure (including telecommunications infrastructure) and regional economic growth. Studies on regional economic growth, as categorized into the second concentration of literature, cover analyses using the economic convergence framework. The last concentration of research addresses application of both the traditional and modified shift-share models in analyzing regional economic output and employment trends.

Chapter 4 introduces a dynamic panel data approach developed from the economic convergence framework. Sources of data used for empirical test in this dissertation are also presented in this chapter. The issue of data quality is discussed too.

Chapter 5 presents and discusses the results of empirical analysis in this dissertation. Separation of regional output due to labor factors and capital factors is shown and discussed. Results of identification of roles of both telecommunications infrastructure and its spillover effects in regional economic development dynamics are also presented and interpreted in this chapter.

Chapter 6 concludes this study. This chapter summarizes responses to the research questions and presents results of testing the hypotheses listed in the introduction chapter. Policy implications are developed and illustrated in this chapter, and future research directions are identified.

Chapter 2 Regional Economic Growth and Telecommunications Infrastructure in China

This chapter is divided into two parts. The first part briefly reviews the economic development history of China during the past half century by emphasizing the period from 1978 to 2007. Different from most introductory descriptions of the developmental path of this economic giant, this study tends to trace the economic growth of various regions (or specifically, provinces, municipalities, and autonomous cities) in terms of their regional economic output, population and employment. The second part of this chapter provides an overview of the targeted economic input in this study—telecommunications—within the regions of China. The development of the telecommunications industry as well as the availability of telecommunications infrastructure at the regional level is elaborated.

2.1 Regional Economic Development in China

Dramatic economic changes have been happening in the most populous country in the world since China's establishment in 1949. The substantial economic growth in China has been widely recognized by all other countries as a recent miracle (Wu, 2000). A general estimate of the average annual economic growth rate for China was around 7-8 percent in the first 50 years after 1949, doubling the same rate for the world on average in the same period (Wu, 2000). However, this simple rate cannot reveal the true path of China's economic

development. To better elaborate on the historical perspective, this study refers to the current literature on explaining China's development.

Zhao (1990) enunciates three phases in dividing China's economic history with each with its own speed of economic growth. It is noteworthy that there was no statistical releases on gross domestic product (hereafter referred to as "GDP") by statistics bureaus in China before 1978. Instead, the System of Material Product Balances ("MPS") was adopted to report economic output for both regions and the whole country. Zhao (1990) estimates the ratio between GDP and national income as 1:0.81, which is used to approximate the annual GDP levels for the time period from 1949 to 1978. Although such simple conversion between GDP and national income may incur bias for satisfactory comparability of the data, the economic development history of China can still be systematically presented. Specifically, the three phases are: 1949-1956, 1957-1978, and 1979-presence.

- According to the estimation by Zhao (1990), the average annual economic growth rate for China was 16.8% (with GDP as the indicator) in the first phase (1949-1956). The first five-year plan was completed within this phase.
- In the second phase (1957-1978), economic growth slowed down. The average annual growth rate was 6.36% with GDP in 1957 as the base, and it was 10.44% lower than the same rate from 1949 to 1956.
- The third phase witnessed dramatic economic changes. China opened its door to the outside world and initiated a series of significant economic stimulation policies in 1978. From 1979 to 2006, the annual GDP growth rate was around 7%. In 2002, the ranking of China in terms of annual GDP in the world was No. 6, with the top five countries as the United States, Japan, Germany, Great Britain and France. It took China four years to enhance its ranking from No. 6

to No. 4 in total GDP in 2006, after the United States, Japan, and Germany (see International Monetary Fund database: <http://www.imf.org>).

Telecommunications infrastructure exhibits rapid growth in China only after 1980s. Thus, the discussion centers around the time period from 1979-2006 considering availability of data. This study tests the relationship between regional economic output growth and various regional economic inputs. Regional disparities will be detected with a closer look at regional economic endowments and overall growth. National economic achievements are not necessarily distributed evenly across the various provinces, municipalities, and autonomous cities from 1979 to 2006.

Economic growth in China manifests itself in a continuous upward trend from 1979 to 2006 (see *Table 2-1*). The data in *Table 2-1* lists both the nominal and real GDPs of China as well as their respective growth rates. Differences exist between nominal and real GDPs as well as their growth rates due to high inflation rates. The GDP index doubles in less than ten years from 1978 to 1986. It is noteworthy that the GDP index is not the same as other inflation indicators such as Consumer Price Index (“CPI”). The annual GDP in 2006 (21,087.1 billion RMB) was 52 times more than that in 1979 (406.3 billion RMB). The growth rates (based on nominal GDP) in the last four years within the examined time period (*i.e.*, 2003-2006) are 12.87%, 17.71%, 15.00% and 14.69%, respectively. Taking into account of inflation, the real GDP growth rates (based on 1978 RMB) from 2003 to 2006 are 2.59%, 6.93%, 4.14% and 3.24%, respectively.

Table 2-1 Nominal and Real GDP in China

Unit: Billion RMB

Year	Nominal GDP	Nominal GDP Growth Rate	GDP Index	Real GDP (in 1978 RMB)	Real GDP Growth Rate (in 1978 RMB)	Consumer Price Index	Real GDP Adj. with CPI	Real GDP Growth Rate (CPI Adj.)
1978	3645.2	-	100.0	3645.2	-	100	-	-
1979	4062.6	11.45%	107.6	3775.6	3.58%	-	-	-
1980	4545.6	11.89%	116.0	3918.4	3.78%	109.5	4151.3	-
1981	4891.6	7.61%	122.1	4006.5	2.25%	-	-	-
1982	5323.4	8.83%	133.1	3998.1	-0.21%	-	-	-
1983	5962.7	12.01%	147.6	4039.8	1.04%	-	-	-
1984	7208.1	20.89%	170.0	4240.1	4.96%	-	-	-
1985	9016.0	25.08%	192.9	4674.2	10.24%	131.1	6877.2	-
1986	10275.2	13.97%	210.0	4894.0	4.70%	-	-	-
1987	12058.6	17.36%	234.3	5147.2	5.17%	-	-	-
1988	15042.8	24.75%	260.7	5770.1	12.10%	-	-	-
1989	16992.3	12.96%	271.3	6263.4	8.55%	-	-	-
1990	18667.8	9.86%	281.7	6626.6	5.80%	216.4	8626.5	-
1991	21781.5	16.68%	307.6	7081.9	6.87%	223.8	9732.6	12.82%
1992	26923.5	23.61%	351.4	7662.5	8.20%	238.1	11307.6	16.18%
1993	35333.9	31.24%	400.4	8823.9	15.16%	273.1	12938.1	14.42%
1994	48197.9	36.41%	452.8	10644.1	20.63%	339.0	14217.7	9.89%
1995	60793.7	26.13%	502.3	12103.5	13.71%	396.9	15317.1	7.73%
1996	71176.6	17.08%	552.6	12881.4	6.43%	429.9	16556.5	8.09%
1997	78973.0	10.95%	603.9	13076.6	1.52%	441.9	17871.2	7.94%
1998	84402.3	6.87%	651.2	12960.4	-0.89%	438.4	19252.3	7.73%
1999	89677.1	6.25%	700.9	12795.4	-1.27%	432.2	20749.0	7.77%
2000	99214.6	10.64%	759.9	13055.5	2.03%	434.0	22860.5	10.18%
2001	109655.2	10.52%	823.0	13323.5	2.05%	437.0	25092.7	9.76%
2002	120332.7	9.74%	897.8	13403.5	0.60%	433.5	27758.41	10.62%
2003	135822.8	12.87%	987.8	13750.4	2.59%	438.7	30960.28	11.53%
2004	159878.3	17.71%	1087.4	14702.9	6.93%	455.8	35076.42	13.29%
2005	183867.9	15.00%	1200.8	15311.6	4.14%	464.0	39626.7	12.97%
2006	210871.0	14.69%	1334.0	15807.7	3.24%	471.0	44770.91	12.98%

Source: China Statistics Yearbook series, 1979-2007.

Figure 2-1 shows the overall upward trend of China's real GDP from 1978 to 2006.

Although real GDP of China fell slightly in 1982, 1999 and 2000, but a consistent trend of rising real GDP can best describe the recent economic development history of China since late 1970s.

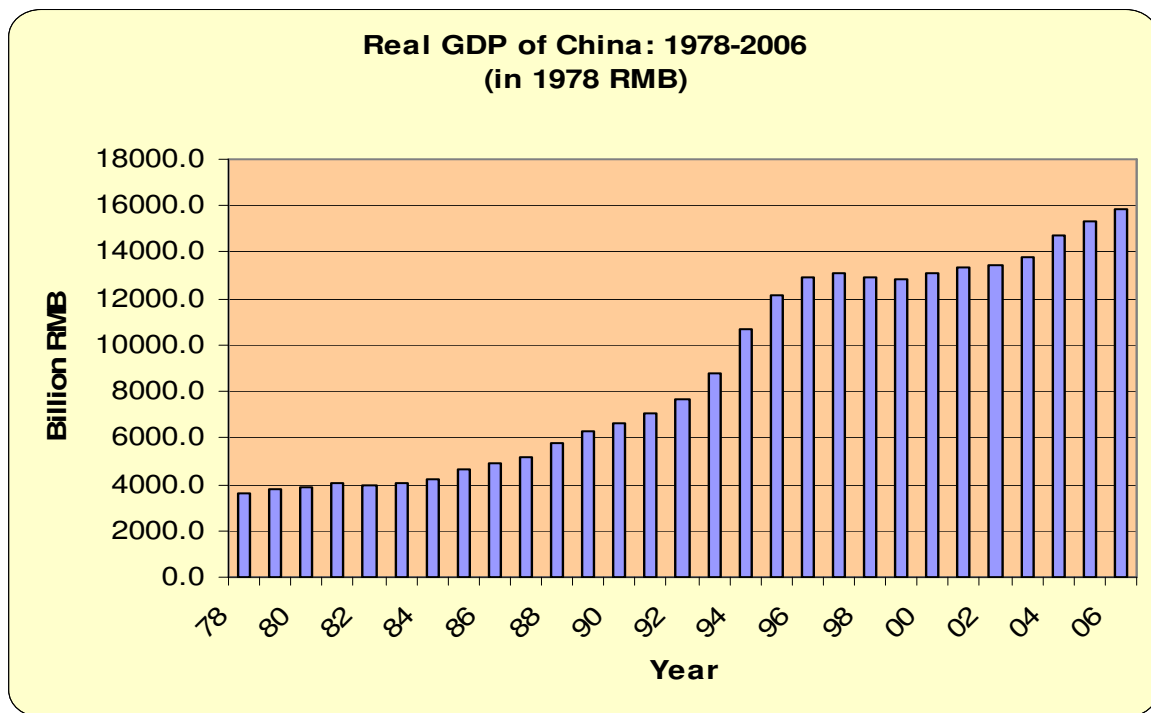


Figure 2-1

Source: China Statistics Yearbook series, 1979-2007.

As shown in *Figure 2-2*, the annual real GDP growth rates from 1978 to 2006 fluctuate with a low of -1.27% in 1999 and a high of 20.63% in 1994. The average real GDP growth rate during the examined 29 years is 5.50%. There are only three years that exhibit negative growth rates—1982, 1998, and 1999. The decade of the 1990s witnessed the fastest ten years in terms of economic output growth, whereas economic growth begins to stabilize around 3-4% in the first several years of the 21st century.



Figure 2-2

Source: China Statistics Yearbook series, 1979-2007

Note: the real GDP growth rates are calculated using 1978 RMB values.

Figure 2-2 seems to provide an “underestimated” real GDP growth rate trend for China due to the deflation of real GDPs into 1978 values, another type of adjustment with CPI may present a better view of the economic growth in China as a whole (see *Figure 3*). Due to the lack of availability of data for 1978-1990, the CPI index only covers the 1991-2006 GDP deflation. A comparison between *Figure 2-2* and *Figure 2-3* indicates that the CPI adjusted real GDP growth rates shows a comparatively flatter trend than those using the real GDPs in 1978 RMB values. In *Figure 2-3*, growth rates center around 10% and there is no dramatic fluctuation within the one and half decades from 1991 to 2006.

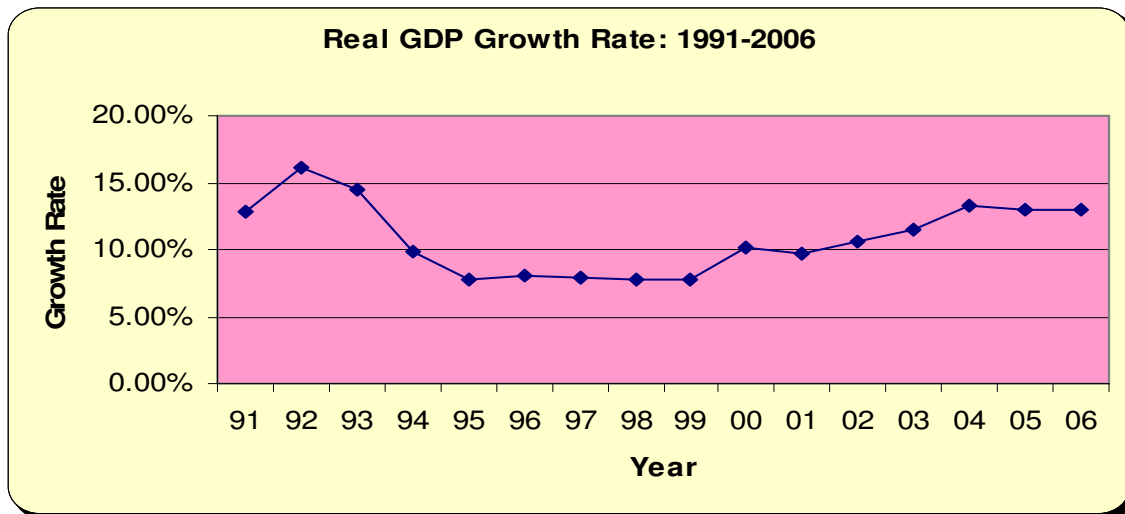


Figure 2-3

Source: China Statistics Yearbook series, 1979-2007

Note: the real GDP growth rates are calculated using GDP values adjusted by CPI.

Another way to examine China's economic development is to see the ranking of China's total annual GDP in the world. The data provided by the International Monetary Fund (IMF) makes it possible to compare national GDPs (see *Table 2-2*). From 2002 to 2006, the total GDP of China increased from 1,454 billion U.S. dollars to 2,645 billion U.S. dollars, witnessing a 81.95% increase within as short a period as four years. The IMF ranking of China also jumped from No. 6 in 2002 to No. 4 in 2006. China's importance in the world can be illustrated by the percentage of China's GDP to the world GDP: China's GDP accounted for 4.43% of the world GDP in 2002, while the percentage increased to 5.49% in 2006. In contrast, the proportion of the top three countries—the United States, Japan, and Germany—in world GDP saw decreases from 2002 to 2006.

Table 2-2 Top 10 Countries with Highest GDP in 2002

Unit: Billion U.S. Dollars

2002				2006		
Ranking	Countries	GDP	% of world GDP	Countries	GDP	% of world GDP
	World GDP	32,813	100%	World GDP	48,145	100%
1	United States	10,470	31.91%	United States	13,245	27.51%
2	Japan	3,925	11.96%	Japan	4,368	9.07%
3	Germany	2,024	6.17%	Germany	2,897	6.02%
4	Great Britain	1,575	4.80%	China	2,645	5.49%
5	France	1,464	4.46%	Great Britain	2,374	4.93%
6	China	1,454	4.43%	France	2,232	4.64%
7	Italy	1,223	3.73%	Italy	1,853	3.85%
8	Canada	735	2.24%	Canada	1,269	2.64%
9	Spain	689	2.10%	Spain	1,226	2.55%
10	Mexico	649	1.98%	Brazil	1,068	2.22%

Source: International Monetary Fund database.

Given the focus of regional economic output in this study, it is necessary to examine China's regional economic growth during the period of 1978 to 2006. Maps are self-explanatory in exhibiting spatial patterns of the regional economic output. *Figures 2-4, 2-5, and 2-6* present, respectively, China's regional output in 1985, 1995 and 2006. As clearly shown in the three maps, regional differences in terms of economic output are significant in all the three selected years. It is noteworthy that such differences do not decline from 1985 to 2006, which demonstrates that the rapid economic growth in China during the past three decades did not mitigate the regional economic growth disparity problem. Generally, coastal regions outperform interior regions in total output, a result of both higher population densities as well as production activities and preferential economic institutions in these coastal regions.

Regional Outputs in China (1985)

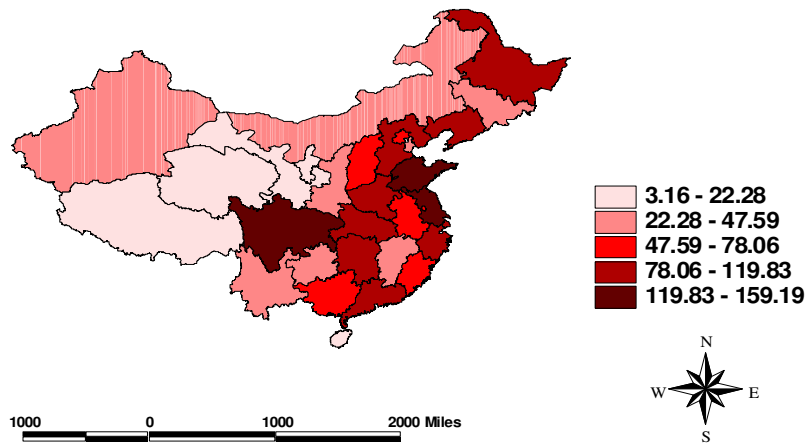


Figure 2-4

Note: Output is measured in billions of RMB (1995 value).

Source: China Statistics Yearbook, 1986.

Regional Outputs in China (1995)

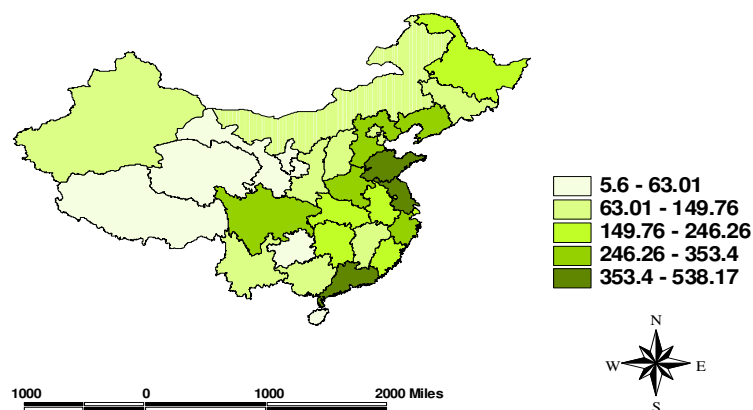


Figure 2-5

Note: Output is measured in billions of RMB (1995 value).

Source: China Statistics Yearbook, 1996.

Regional Output in China (2006)

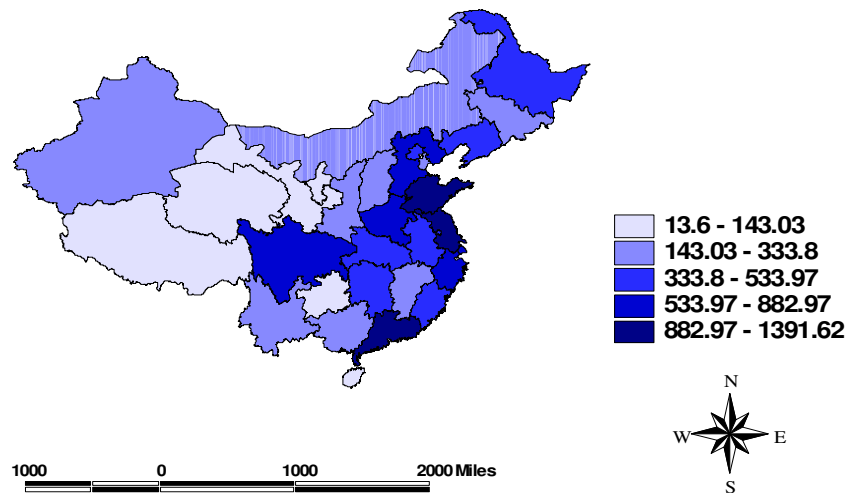


Figure 2-6

Note: Output is measured in billions of RMB (1995 value).

Source: China Statistics Yearbook, 2007.

Another way to examine regional economic output disparity is to compare the regional economic output of the top three provinces against those of the bottom three provinces. *Figure 2-7* indicates that the gap increased dramatically in the time period of 1985 to 2006. The top three provinces—Guangdong, Jiangsu, and Shandong—are located in coastal regions of China, and these coastal regions account for almost all of the fast economic growth. As is shown in *Figure 2-7*, the bottom three provinces—Tibet, Qinghai, and Ningxia—are all located in the northwest regions in China and they did not increase significantly in the past two decades. Their gaps with other developed regions grew.

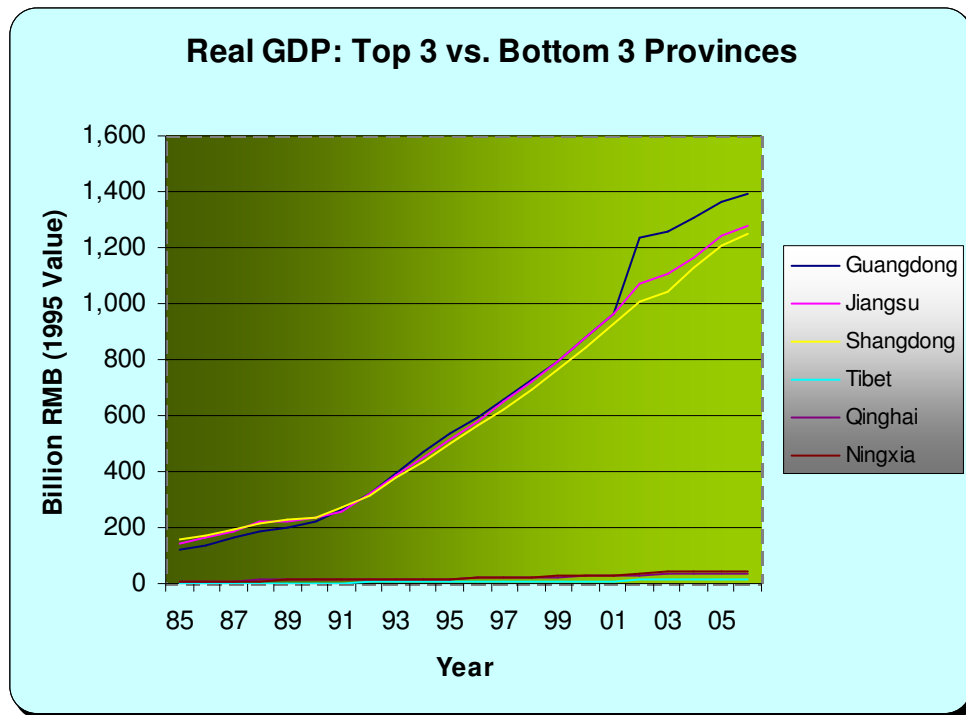


Figure 2-7 Regional Output of Top and Bottom Three Provinces

Note: Output is measured in billions of RMB (1995 value).

Source: China Statistics Yearbook series, 1986-2007.

Total output of the top three provinces accounted for 20%-30% of national GDP while total output of the bottom three provinces remained at around 1% of national output throughout the period. *Figure 2-8* displays these trends in terms of total annual output. The top three provinces' importance increases steadily while the bottom three provinces stagger at a nearly negligible levels.

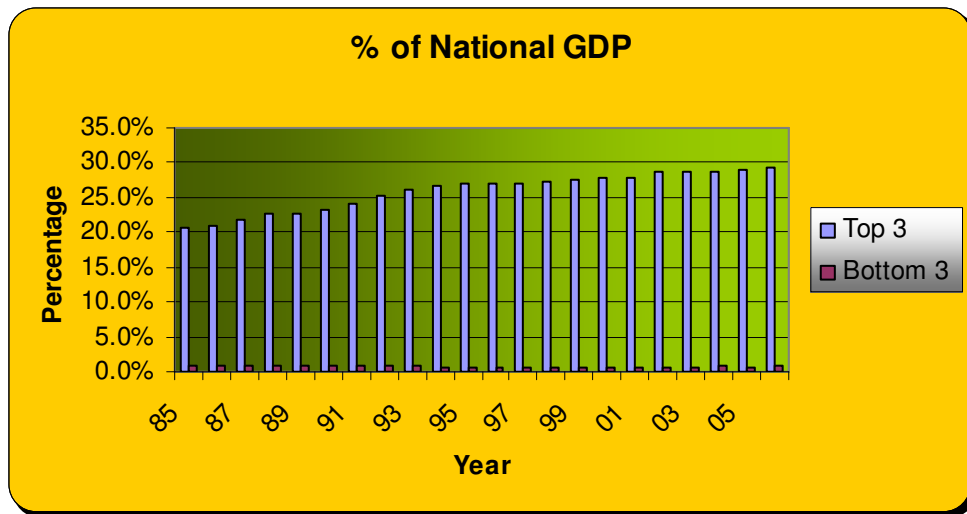


Figure 2-8 Percentages of Regional Output to National Output

Source: China Statistics Yearbook series, 1986-2007.

Different aggregations produce similar growth patterns and gaps. *Figures 2-9, 2-10, and 2-11* show the distribution patterns of top five, bottom ten, and other fifteen provinces, municipalities, and autonomous cities in 1985, 1995, and 2006. The structural changes across the three selected years indicate that regional output disparities are aggravated during the time period of 1985 to 2006. Specifically, the top five provinces—Guangdong, Jiangsu, Shandong, Zhejiang, and Sichuan—increase their proportion of national output from 33% in 1985 to 39% in 1995, and 41% in 2006, whereas the bottom ten provinces, municipalities, and autonomous cities—Yunnan, Tianjin, Inner Mongolia, Xinjiang, Guizhou, Gansu, Hainan, Ningxia, Qinghai, and Tibet—decrease their proportion of national output from 12% in 1985 to 10% in 1995 and 10% in 2006.

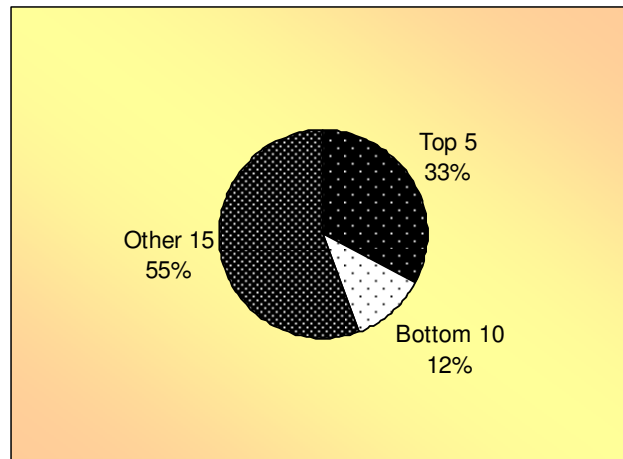


Figure 2-9 Distribution of Regional Output in 1985

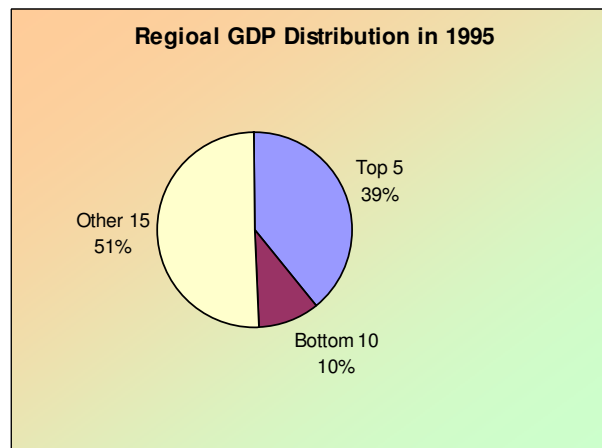


Figure 2-10 Distribution of Regional Output in 1995

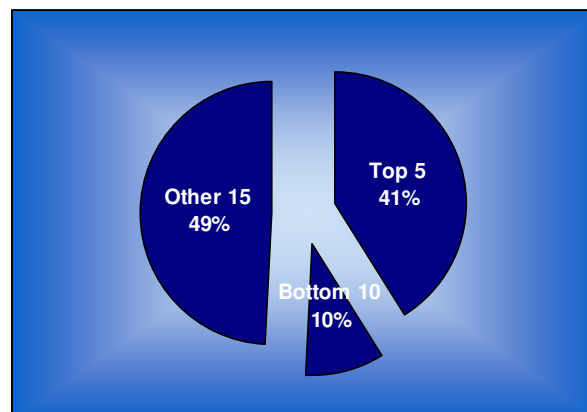


Figure 2-11 Distribution of Regional Output in 2006

In conclusion, China has achieved rapid economic growth during the past three decades. However, such economic growth is not evenly distributed across regions. As shown in the figures and tables, regional economic development disparity is aggravated at times of China's fast growth. It is important to examine the causal factors behind such phenomenon. The next section examines the history and status of telecommunications infrastructure availability across regions.

2.2 Development of China's Telecommunications Infrastructure

The second part of this chapter traces the evolutionary path of the China's telecommunications infrastructure. However, the development of the telecommunications sector in China was so slow before 1990s that the discussion of telecommunications infrastructure construction and availability focuses on the time period from 1985 to 2006. The inclusion of the years from 1985 to 1990 is for consistency purpose with the dataset used in this study. Therefore, factors contributing to the earlier development or buildup of telecommunications infrastructure in China's regions will not be addressed. Instead, emphasis is on depicting the recent evolution of telecommunications infrastructure in China as well as the dramatic regional differences.

Some studies provide descriptive statistics on the extremely low level of telecommunications infrastructure in China in the early years after 1949. For example, Singh (1999) illustrates the status quo of telecommunications infrastructure back in 1949 with a hard number—193,000 telephones for the over 500 million people in 1949. All of the 193,000 telephones were distributed in the “urban” areas of China. Another study by Tang and Lee (2001) join Singh's discussion (1999) by concluding that more than 90 percent of

counties in China did not have telephones, with 10 percent of counties lying in the coastal regions. The next several decades (until 1990s) witness the very slow development of telecommunications sector (see Ding, 2005). Liu (1988) identifies as little as 0.8% of total national investment going to the telecommunications sector in the first five-year period from 1953-1957. The ratio never went beyond 1.5% from the 50's to the 60's (Tang & Lee, 2003). According to the data in He (1997), the teledensity—measured as the number of telephones per 100 habitants—was as low as 0.43 on the national level and the total number of people subscribing to telephone services did not exceed 4.1 million in 1980. The rapid growth of the telecommunication sector in China starts in the mid-1980s, which is also the reason this study selects 1986 as the starting point for its panel dataset.

In 1985, the total number of telephones in China was 6.25 million, and all these phones were fixed line. The annual growth rates of the number of telephones from 1985 to 2006 never fell below 9%, ranging from a low of 9.4% in 2004 and a high of 50.45% in 1994. The mid-1990s was the golden time for the development of telecommunications sector in China, and the best example may be the astonishing growth rate of 50.45% in 1994. *Figure 2-12* presents the annual growth rates for the twenty-one years from 1985 to 2005.

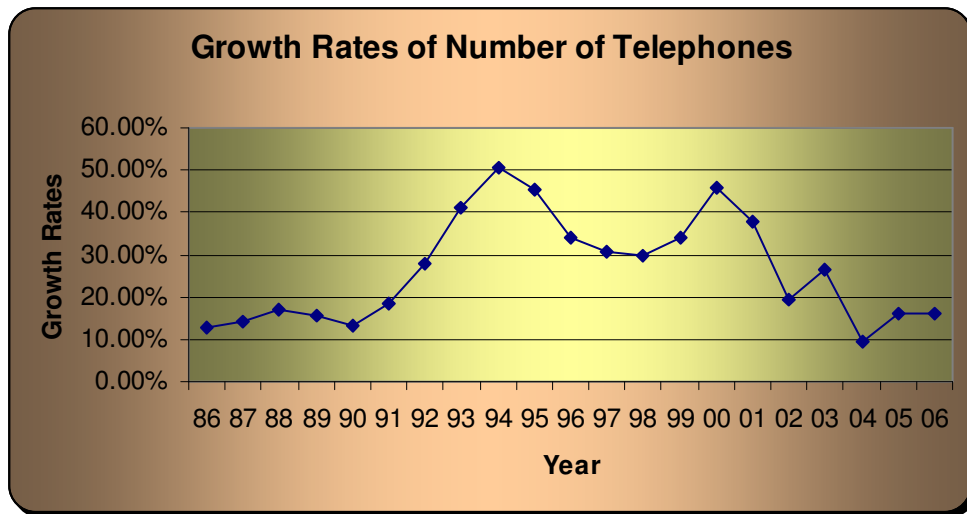


Figure 2-12 Growth Rates of the Number of Telephones

Note: Growth rates of 2004-2006 are estimated using telecommunications industrial capacity provided by China Statistics Yearbook series, 2005-2007.

Source: Comprehensive Statistical Data and Materials on 50 Years of New China, provided by National Statistics Bureau in 1999.

Teledensity is used to demonstrate the availability of telecommunications infrastructure in a region. A brief definition of this concept is the number of telephones (including both fixed and mobile lines) per 100 inhabitants. Although this study does not differentiate fixed from mobile lines in the analysis, it is noteworthy that the mobile telephones increased at an amazingly high rate from the end of 1990s. As argued by Ding (2005), the true story of China's telecommunications sector might be distorted without the inclusion of mobile line phones in the dataset (also see Giovanis & Skiadas, 2005; Ding & Haynes, 2007; Lee & Cho, 2007). The national teledensity in the examined twenty-one years is shown in *Figure 2-13*. The obviously upward trend of teledensity is self-explanatory. The increase in teledensity on the national level accelerates from 1994, and there is no single year that shows a lower teledensity than the prior year. Such rapid and continuous development in

telecommunications infrastructure availability is not enjoyed by China alone. Instead, such a trend tends to be shared by other developing countries such as Brazil and Mexico (see discussion in Ding, 2005). So although this study selects China as its target country for analysis of the role of telecommunications infrastructure, its results may contribute to the existing literature of other nations on the relationship between telecommunications infrastructure availability and regional economic output growth.

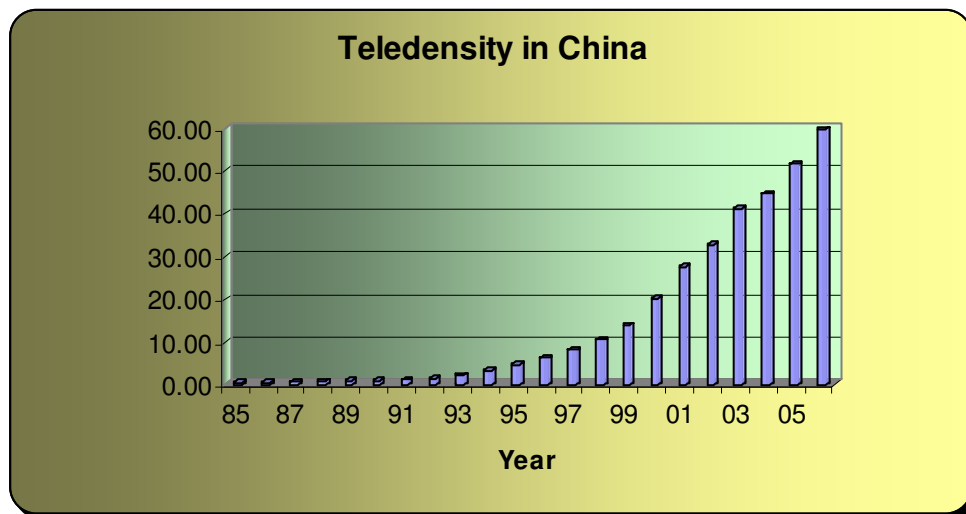


Figure 2-13 Teledensity in China (1985-2006)

Note: Teledensities of 2004-2006 are estimated using telecommunications industrial capacity provided by China Statistics Yearbook series, 2005-2007.

Source: Comprehensive Statistical Data and Materials on 50 Years of New China, provided by National Statistics Bureau in 1999.

From the regions' perspective, regional disparities are as dramatic as those in regional economic output in China. Regional comparison follows the same logic as that made on regional economic output. Three relatively more developed provinces—Guangdong, Jiangsu, and Shandong are picked to compare their teledensities with those of the relatively less developed provinces—Tibet, Qinghai, and Ningxia. *Figure 2-14* demonstrates the regional

disparities in terms of teledensity among the six selected provinces. The comparison result is similar to that of the regional output comparison: the economically more developed provinces show generally higher teledensities than those less developed ones, and the gap increases over time. For example, the teledensity of Guangdong 103.7 is two times more than that of Qinghai 45.95. However, it is reasonable to conclude that all the six provinces—no matter how economically developed—have enjoyed substantial growth in telecommunications infrastructure availability.

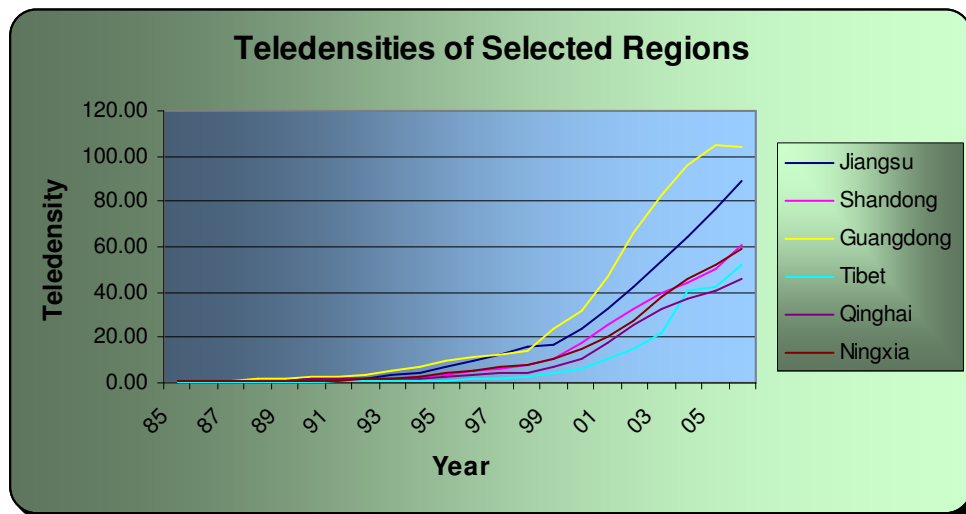


Figure 2-14

Note: Teledensities of 2004-2006 are estimated using telecommunications industrial capacity provided by China Statistics Yearbook series, 2005-2007.

Source: Comprehensive Statistical Data and Materials on 50 Years of New China, provided by National Statistics Bureau in 1999.

Maps are used again to show discrepancies in China's regional endowments in telecommunications infrastructure. *Figures 2-15, 2-16, and 2-17* display the spatial distribution of telephone lines for all regions in China in 1985, 1995, and 2006. The three figures indicate the unequal regional distribution of telephones in all the three selected years.

Another commonality exists in that all three years exhibit a similar spatial pattern of telephone services, *i.e.*, coastal regions tend to have the most telephone service coverage while the northwest regions have the least coverage. Comparison of the three figures reveal that all regions—no matter economically developed or undeveloped—show dramatic increases in total numbers of telephones.

Distribution Pattern of Telephones in China (1985)

1 Dot = 9000 Telephones

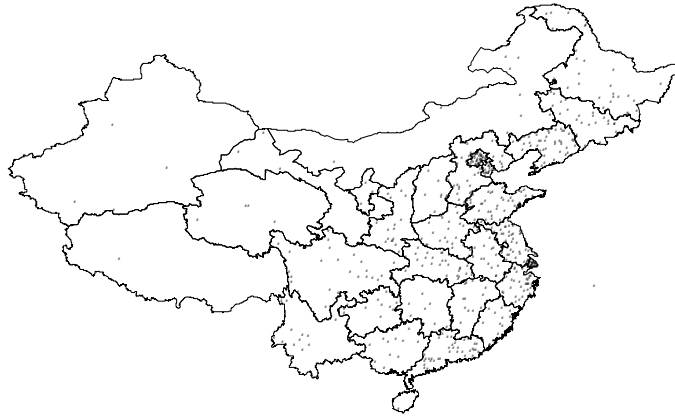


Figure 2-15

Note: The numbers of telephones of 2004-2006 are estimated using telecommunications industrial capacity provided by China Statistics Yearbook series, 2005-2007.

Source: Comprehensive Statistical Data and Materials on 50 Years of New China, provided by National Statistics Bureau in 1999.

Distribution Pattern of Telephones in China's Regions (1995)

1 Dot = 9000 Telephones

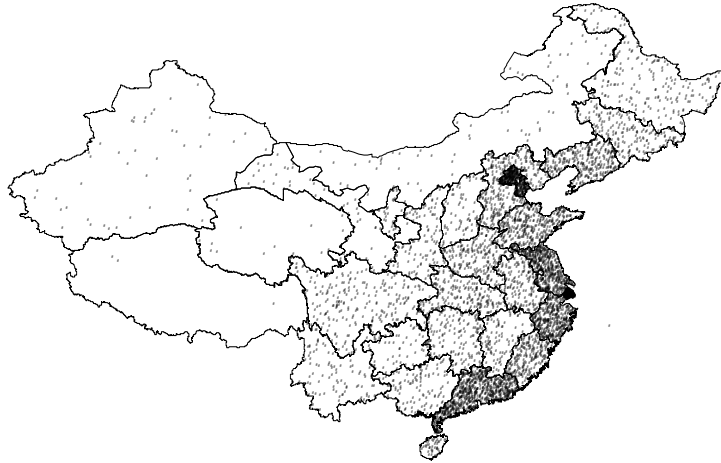


Figure 2-16

Note: The numbers of telephones of 2004-2006 are estimated using telecommunications industrial capacity provided by China Statistics Yearbook series, 2005-2007.

Source: Comprehensive Statistical Data and Materials on 50 Years of New China, provided by National Statistics Bureau in 1999.

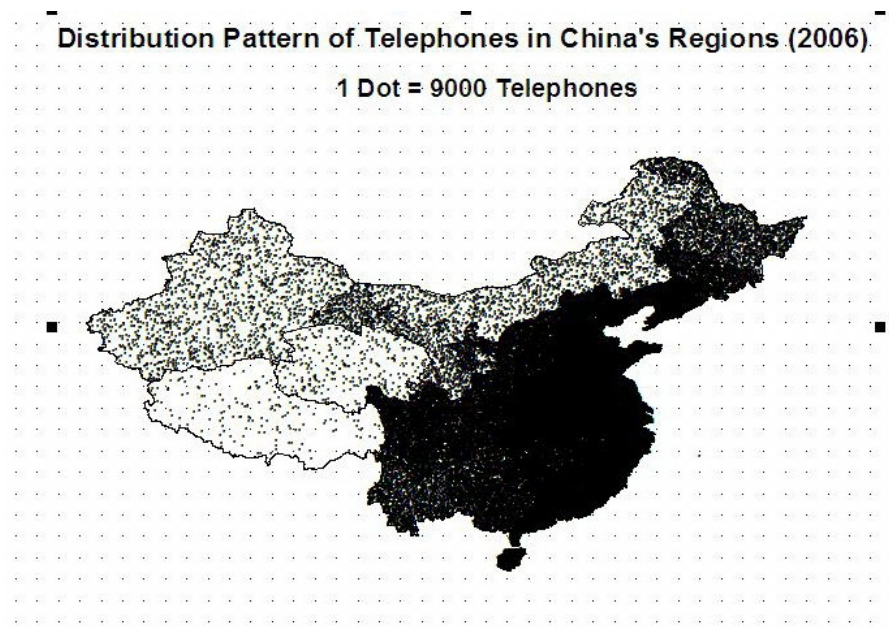


Figure 2-17

Note: The numbers of telephones of 2004-2006 are estimated using telecommunications industrial capacity provided by China Statistics Yearbook series, 2005-2007.

Source: Comprehensive Statistical Data and Materials on 50 Years of New China, provided by National Statistics Bureau in 1999.

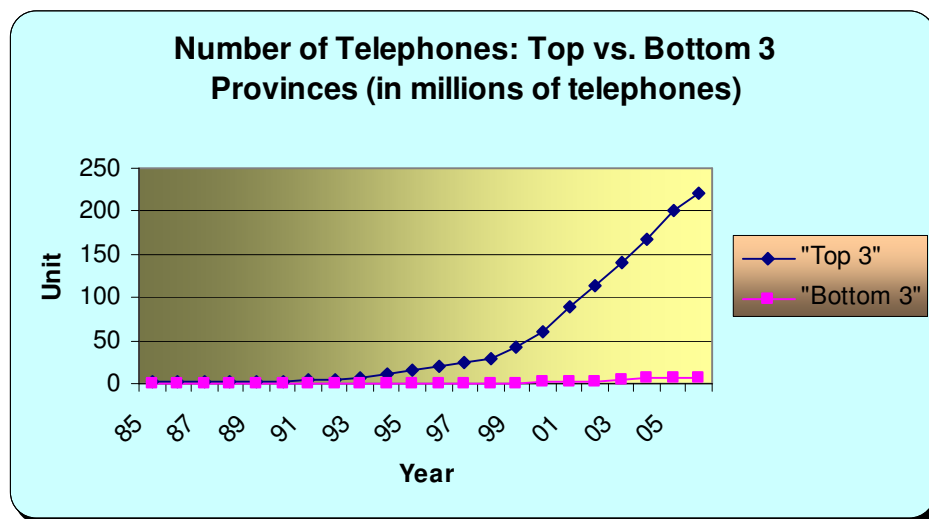


Figure 2-18

Note: the top 3 provinces are Guangdong, Shandong and Jiangsu, while the bottom 3 provinces are Qinghai, Tibet and Ningxia.

Source: Comprehensive Statistical Data and Materials on 50 Years of New China, provided by National Statistics Bureau in 1999.

Maps are also used to present spatial patterns of teledensity (see *Figures 2-19, 2-20, and 2-21*). The insights that can be drawn from the following three figures are similar to those from *Figures 2-15, 2-16, and 2-17*. First, there are significant differences in terms of teledensity among regions in China in all the three selected years. Second, all regions have been increasing their teledensities during the time period from 1985 to 2006. Third, the spatial distribution pattern of teledensity follows the same track as that of telephone lines, with coastal regions outperforming others in telephone services access and availability. Moreover, *Figure 2-18* shows that the gap in terms of telephone lines exhibits an upward trend that is similar to the gap in terms of regional output across regions.

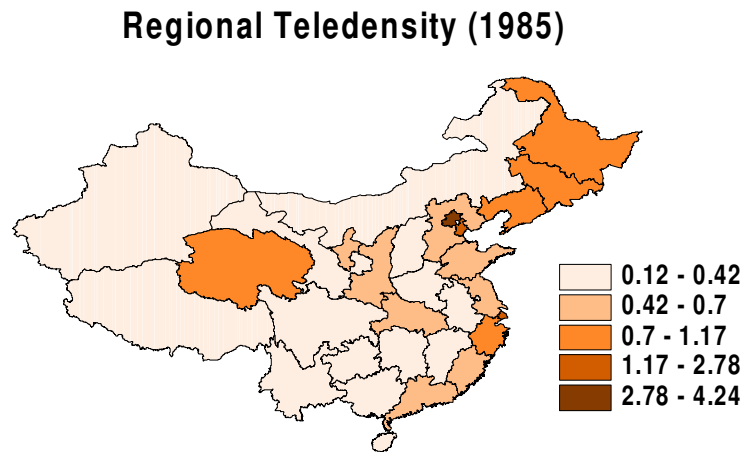


Figure 2-19

Note: Teledensities of 2004-2006 are estimated using telecommunications industrial capacity provided by China Statistics Yearbook series, 2005-2007.

Source: Comprehensive Statistical Data and Materials on 50 Years of New China, provided by National Statistics Bureau in 1999.

Regional Teledensity (1995)

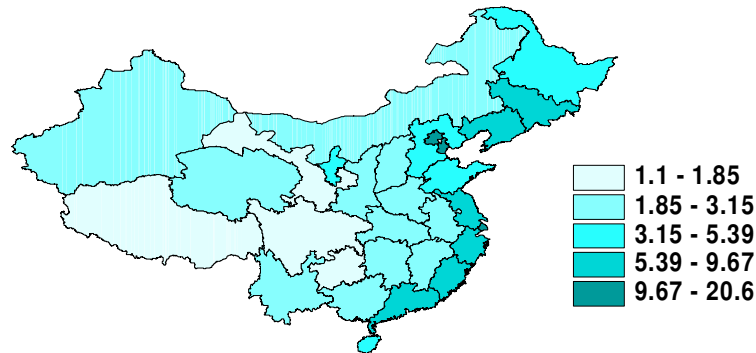


Figure 2-20

Note: Teledensities of 2004-2006 are estimated using telecommunications industrial capacity provided by China Statistics Yearbook series, 2005-2007.

Source: Comprehensive Statistical Data and Materials on 50 Years of New China, provided by National Statistics Bureau in 1999.

Regional Teledensity (2006)

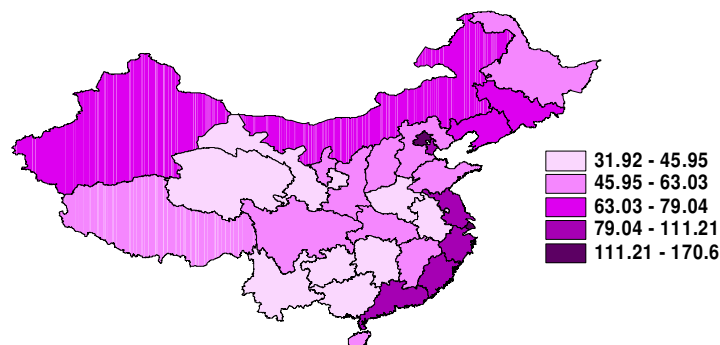


Figure 2-21

Note: Teledensities of 2004-2006 are estimated using telecommunications industrial capacity provided by China Statistics Yearbook series, 2005-2007.

Source: Comprehensive Statistical Data and Materials on 50 Years of New China, provided by National Statistics Bureau in 1999.

2.3 Summary

The growth paths of regional economic output and telecommunications infrastructure during the time period from 1985 to 2006 tend to be similarly rapid. Most of the regions in China—especially those in the coastal region—have achieved astounding growth in economic development. No short-term or long-term economic recessions have happened to this large developing country during the past 3 decades. The issue of regional economic income and output inequality has been a major policy target for policymakers, and the most famous example is the China's Western Development program. This study falls into this broad topic and attempts to analyze such regional economic performance discrepancy with a focus on one of its contributory factors—telecommunications infrastructure. The rationale lies exactly in the similar evolutionary path and spatial pattern between regional output and telecommunications infrastructure availability. Rapid growth in telecommunications sector in nearly all regions in China does not mitigate the dramatic regional disparities in availability of this important productive endowment. Insights from the relationship between these two can be useful for policymaking explorations of lessening China's regional income inequality, which is one of the most important contribution of this study to the existing literature.

Chapter 3 Literature Review

Literature is reviewed in this chapter on examination of the relationship between telecommunications infrastructure and regional economic growth, as well as the economic convergence studies and shift-share model extensions. The first section contains synthesizes studies investigating the relationship between infrastructure (including telecommunications infrastructure) and regional economic growth. Discussion in the context of China is presented in section 2. Section 3 summarizes studies on regional economic growth within the economic convergence framework, as well as application of both the traditional and modified shift-share models in analyzing regional economic output and employment trends.

3.1 Economic Growth and Telecommunications Infrastructure

3.1.1 Economic Growth Theories and Telecommunications Infrastructure

Economic growth can manifest itself through the use of more inputs or higher efficiency to generate more output in a predefined geographical area within a limited time period (Kindleberger, 1965, p. 3). However, conceptual accuracy on this term is blurred by the mixed use of growth and development in the economics context. Higgins and Savoie (1995) defined both terms by drawing a distinction between growth and development: “...economic growth means more output, and economic development implies both more output and changes in the technical and institutional arrangements by which it is produced.”

(p. 3) The discrepancy between growth and development not only results in different terminology, but is also reflected in economic growth and development theories. In this dissertation, interest is laid upon economic growth, instead of economic development. In other words, the contribution of telecommunications infrastructure is measured in terms of pure regional output increases, not improvement of technical or institutional arrangements or in terms of changes in social capital. Therefore, the relationship between economic growth and telecommunications infrastructure can be appropriately evaluated by applications from the school of growth theories.

Neoclassical Growth Theory

The school of neoclassical economic growth theories evolved in late 18th century and 19th century, inspired by the mercantile viewpoints on economic growth (e.g., work of Smith, 1776; Malthus, 1798; Ricardo, 1817). Alfred Marshall represents this school of “neoclassical economists”. Marshall (1890; *e.g.*, Book IV page 5) expounds that supply and demand of products are determined by their respective prices in a market, and that supply and demand curves resemble scissor blades intersecting at market equilibrium. The neoclassical rationale distinguishes the contributions of both population and technology. It assumes that population change and technological improvements are “givens” and determined by non-economic factors, and that the “invisible hand” of price adjusts the allocation of economic resources and directs the decision of economic agents such as capitalists, laborers, investors, savers and consumers. Higher demand and price lead to more investment and savings, which directly increase the capital stock of a nation and consequently raised productivity of its labor force. The neoclassical growth theories are greatly developed by Solow (1956) and Swan (1956)

with an assumption of constant return to scale in the aggregate production function with substitution between capital and labor inputs. Solow (1956) and Swan (1956) argue that technological advancement is the sole source of economic growth.

In the framework of neoclassical economic growth theory, capital and labor inputs explain a major proportion of economic growth, at least in the short run. Thus, regional economic growth differences can be interpreted as availability and mobility of capital and labor inputs. Clark (1940) argues that availability and quality of infrastructure has the determinative force in interregional production factor movements. Telecommunications infrastructure facilitates business transactions and attracts productive elements and economic resources into regions, forming a regional competitive force. Given the direct and indirect channels through which telecommunications infrastructure functions in the production process, these communications networks can be taken as a type of capital input and modeled in Solow's neoclassical economic growth model (see studies of Aschauer, 1989a, 1989b, 1989c; Yilmaz, Haynes, & Dinc, 2001; Ding, 2005). Furthermore, telecommunications infrastructure can ripple its effects to almost all industrial sectors in an economy and can be seen as a "general-purpose technology" (Solow, 1956) in the long run.

Keynesian Growth Theory and Post-Keynesian Models

The neoclassical growth theories, especially employment theory, encounter unprecedented doubt and criticism due to its inability in explaining long-run unemployment. Keynes (1936) stresses the leading role of "demand" rather than "supply" in the economic growth and development process. His perspective was that public spending or expenditures

from government should act as a “visible hand” and readjust the economy to full employment level by increasing aggregate demand.

Domar (1947) and Harrod (1948) question the capital-output ratio indicator of the post-Keynesian model by arguing that a capital-output ratio prediction of overall economic output could only be realized when all other productive factors, such as natural resources, labor force, and technology, maintained a proportional relationship to capital stock. Their conclusions are: the amounts of labor and capital jointly determine the economic growth; insufficient capital stock appears to be the main cause of lagged economic growth or development in the less developed countries; physical capital stock does generate output; net investment induces to capital accumulation and thus promotes higher income or output; higher output level usually allows for more savings (Harrod, 1939; Domar, 1946). One main implication of the Harrod-Domar model is the inability of a free-market economy to maintain a steady-state growth with full employment.

The neo-Keynesianists (Robinson, 1954; Hicks, 1963; Kaldor, 1956, etc.) assimilate Keynesian growth theories as essential ingredients in their theoretical framework, which is established on the basis of competitive equilibrium analysis. Kaldor (1957; 1961; 1962) specifies an investment function and a flexible saving ratio which facilitate attainment of a steady state economic growth.

It is clear that the Keynesian growth theory confirms a positive relationship between investment in physical capital stock and economic growth. Telecommunications infrastructure is a major type of physical capital stock which requires large amounts of capital investment. In a less developed country like China, insufficiency of physical capital

stock seems to be the major cause of its economic lagging status. This means increase in telecommunications infrastructure investment can benefit regions in China by contributing to fast and continuous economic growth.

Endogenous Growth Theory—New Growth Theory

Romer (1986) and Lucas (1988) readdress the issue of economic development and growth by examining determinants of long-term growth from an angle beyond the traditional neoclassical standpoints. They explain economic growth with an endogenous variable such as technical progress. The main argument is that the input of human capital and physical capital by individuals and firms will automatically benefit the productivity of capital held by others through mutual interactions of these economic agents (Arrow, 1962; Romer, 1986; Lucas, 1988). Romer (1986) also stresses the strong spatial spillover effects of investment of physical or human capital. Such spillovers ensure the private marginal product of the capital outlay above the discount rate, which works even with the possible diminishing returns of capital input lacking external boosts to productivity (Romer, 1986). Thus, sustainable economic growth is possible with continuous input accumulation that generates positive economic externalities.

These endogenous growth models suggest changes in the focus of research fields in economic growth by including more aspects of reality such as incomplete appropriability, imperfect competition, and increasing returns to scale (Grossman & Helpman, 1994). However, interpretation of endogenous growth models is impaired by a few barriers. First, empirical efforts based on endogenous growth theories have only been concentrated on testing earlier growth models rather than the theory itself. Second, examination of the

soundness of the endogenous growth model is usually conducted on cross-national data sets and the international production function assumptions are often impractically strict (*e.g.*, utilization of aggregate economic data makes it impossible to differentiate endogenous growth theory from the traditional neoclassical growth theory); economic externalities stressed in the endogenous growth models are essential in growth process and at the same time it is difficult, if not impossible, to test for their presence (Pack, 1994).

The major difference between the endogenous growth model and the Solow aggregate production function approach lies in the endogeneity of technical changes. New knowledge and innovative ideas serve as key elements in stimulating economic growth and should be included in growth models. Since telecommunications infrastructure facilitates transfer or diffusion of knowledge and ideas across regions, this new type of economic input to the knowledge stock is also influenced by telecommunications service availability and quality. The positive economic externalities related to diffusion and accumulation of the knowledge stock can be achieved through investment in telecommunications infrastructure. This corresponds to the capacity of telecommunications networks in acting as a major medium for regions to access knowledge and innovation. Thus, this dissertation emphasizes evaluation of telecommunications infrastructure's impacts on regional economic growth within the framework of endogenous growth theory.

3.1.2 Regional Development Theory and Telecommunications Infrastructure

The literature reviewed in section 3.1.1 is mostly about the economic growth theories and models following the Anglo (American) perspective, which can be appropriately labeled as temporal analytical measures. Corresponding to the Anglo thread line of economics, the

Germanic tradition tones studies on the economic growth process through spatial analysis and examination. The regional development theoretical framework is derived from the comparison between temporal and spatial approaches in the past half-century.

Isard (1960) captures the essence of regional economics by examining target problems addressed by this branch of economics and the four problems included: 1) identification of specific industries that can function profitably in a region; 2) improvement of the welfare of people in a region; 3) avoidance of industrial mixes that are too sensitive to national and worldly business cycles; 4) planning of industrial development in a region (p. 413). The multi-disciplinary characteristics and controversial definition of regional economics do not necessarily hamper the concentration of review on this statement. Regional economic development theories are, similar to the synthesis of economic growth theories in section 3.1.1, chronologically reviewed with a focus on the foundational economics principles (*i.e.*, classical and neoclassical economics theories) and recent development of these theories from an economics geography (spatial) perspective.

Analysis on impacts of telecommunications infrastructure on regional level determines inclusion of spatial economics principles in the methodology design of this study. Spatial heterogeneity is a major issue in studies on a country as huge as China. This section summarizes several major theories in regional development economics and demonstrates the relevancy of regional economic growth analysis to the availability of telecommunications infrastructure.

Location Theory

Several theorists witness the development of a typical regional development branch of theory—location theory. Von Thunen (1826) proposes that market processes determine use of land in different locations. Weber (1800s) stresses that an industry be located where the total transportation cost of raw materials and final products reached the minimum level and where access costs to inputs are minimized. Christaller (1930s) and Losch (1930s) develop the location theory from different research directions. The theory of central places (Christaller, 1930s) can be considered as an inductive analysis of decision making of firms in selecting an optimum location, while Losch (1930s) attempts to bridge the “gaps” between firm-oriented locational theories (e.g., Christaller’s theory of central places) and theories aimed at general spatial equilibrium from a inductive direction. Isard (1959) initiates the concept of industrial complex and sparked concepts of cluster analysis. The aim of industrial complex analysis is to identify favorable development projects by analyzing cost advantages of different combinations of industries for a region often using input-output (I/O) analysis.

Location decisions of businesses are critical to regional economic growth. Factors impacting business owners in location selection include favorable regulations, high quality of life, high quality of infrastructure, competitive human capital, etc. In this context infrastructure cannot only be comprehended as a narrow concept of the capital stock of producers for public services (Ford & Poret, 1991), but also include different types of networks recognized as economic infrastructure (World Bank, 1994). Despite controversy of an accurate definition of infrastructure, the function of these networks in providing general-purpose services to different businesses is an important consideration in locational decision making process of business owners. Telecommunications infrastructure, like transportation

infrastructure, becomes a factor attracting businesses into a region. Analysis on availability of telecommunications infrastructure across regions is important to probe regional economic performance disparity.

Growth Pole Theory

Perroux (1949) develops the growth pole theory in a regional development context by defining a growth pole as one or a group of firms from the same industry, one industry, or a group of industries and further denies the correspondence of his “abstract economic growth” to necessarily a geographical area unit. Per the growth theory, economic growth starts from growth poles and spreads across sectors (Perroux, 1949; Higgins and Savoie 1995; Stimson, et al., 2002). Darwent (1969) confirms Perroux’s emphasis on industry/industries as economic catalysts and moreover introduces the notion of growth centers by designating cities as growth pole. The core-periphery model as developed by Friedmann (1966) corresponds to the growth center theory in that both theories took account for distribution of growth and investment allocation.

Some conclusions are summarized by Higgins and Savoie (1995; p. 106), including that: 1) development involves polarization; 2) growth poles generate spillover effects somewhere, but not necessarily in the peripheral regions; 3) the principal role of growth is to serve as a source and diffuser of innovations; 4) small and middle-sized cities may also serve as growth centers/poles; and 5) enterprises should not be “pulled” or “pushed” into retarded regions at random if generation of spread effects is impossible.

The capital-intensive characteristic of infrastructure determines that better availability and quality of infrastructure are usually enjoyed by economically developed regions and

areas, such as core cities and metropolitan regions. Regional discrepancy in economic developmental levels is dramatic in China, represented by the most developed coastal region and much less developed interior areas. It is predictable that the east coastal region would develop better telecommunications infrastructure than the west region in China. Some leading provinces or regions in the east can be recognized as growth poles and exert spillover effects upon their neighboring regions. However, telecommunications infrastructure in neighboring regions may attract economic resources out of a region, resulting in that negative spillover effects of leading regions' telecommunications services may offset diffusion effects. Thus, evaluation of impacts of telecommunications infrastructure on regional economic growth requires identification and analysis of these spillover effects.

Export Base Theory

Export base theory suggests that in the long run there is a significant relationship between a region's exports and its overall growth (Richardson, 1969; p. 336). Growth of a region's export industries ultimately determines the growth in the region, implying that external demand of a region's output is decisive to economic growth. Richardson (1969) synthesizes two features of export base theory: 1) as an application of Keynesian income theory, export base theory extends its analysis of economic growth into the long run and elevates the role of export industries to such an important level that not only output of the export industries add to aggregate output, but also non-export industries depend on these base industries for existence or prosperity; and 2) national demand is of concern in export base theory in that ultimate growth of a region depends on the overall expansion of national economy.

Limitations of export base theory are obvious. It is an over-simplified form of multiplier in the general theory of short-run regional growth determination. This theory lacks either predictive or explanatory power and is more appropriate to comparative statics than to dynamics. Moreover, the homogeneity of export base is deviated from the reality that export sectors are different in nature and repercussions on local economic activities may vary. Another flaw rests in the neglect of internal growth impulses in regional growth process, which may be comparatively strong. Some other exogenous variables also require recognition and consideration, such as government injections, technological progress within the region, shifts in the investment function or consumption function or the role of human capital. Finally, the export base concept will reflect the case in which markets outside the region are changing from limited areas of national scope or world scope (Richardson, 1969).

Recognition of export industries is of supreme interest to regional policy makers. Development of competitive export industries requires high quality and sufficient availability of infrastructure, including telecommunications infrastructure. The potential of decreasing transaction costs residing in telecommunication networks is attractive to both businesses and regional governments. This also reflects the necessity of evaluating regional economic performance by including telecommunications infrastructure as an independent variable in any growth model.

3.1.3 Regional Economic Dynamics and Telecommunications Infrastructure

It is wise to theoretically identify the mechanisms through which telecommunications infrastructure contributes to regional economic growth. Generally, telecommunications networks benefit regions in support of creation and expansion of markets, reduction of

business transaction costs, flattening of business organizational hierarchies, and facilitation in regional production, distribution, and consumption processes (Ding, 2005, p. 64; Bernstein & Mamuneas, 2007). Studies recognizing such mechanisms are summarized below.

Saunders et al. (1994) calculate the internal rate of return for telecommunications infrastructure as 20%, which is much higher than many other long-term capital investment. High return on investment is critical in buildup of a specific capital, noting that high investment return usually comes from compatibility of an investment project with local economic development needs. It is acceptable to purport that high returns on telecommunications infrastructure investment can promote telecommunications sector as a leading one in regional industrial mix. For example, the International Telecommunications Union (1994) finds that telecommunications sector in many countries has outgrown three times as much as overall economic growth for these economies. It is noteworthy that the causality issue remains in the relationship between telecommunications infrastructure and regional economic growth. This study, as discussed in Section 5.2 of Chapter 5, adopts Granger Causality Test to probe the direction of causality between the two variables of interest in the context of regional economic development in China.

Two studies emphasize the interaction effects between telecommunications sector and other industrial sectors (Greenstein & Spiller, 1995; Yilmaz et al., 2001). These authors filter through all industrial sectors and identify those closely related to telecommunications sector. Yilmaz et al., (2001) generalize that telecommunications sector has more significant influences on service related sectors than on the manufacturing or agricultural sectors. Interaction between telecommunications sector and other industrial sectors is derived from

these sectors' information processing needs. Usually better telecommunications services assure fast and reliable information acquisition and distribution for all types of business organizations. Compared to manufacturing or agricultural sectors, servicing sectors have more intrinsic needs for timely, coordinative, and reliable information transmission. For transitional economies like China, development of telecommunications infrastructure ensures faster transformation of the whole economic system to a more service-oriented one.

More intense interaction between telecommunications sector and service sectors does not preclude the manufacturing sector from enjoying benefits from telecommunications services. Ding (2005, p.65) contends that telecommunications infrastructure may increase production efficiency through provision of better market information. With increased international market competition, manufacturing firms rely more on reliable market prediction and flexible productive capacity in gaining market shares. Globalization of flows of productive elements such as labor, capital, and goods requires telecommunications infrastructure as an indispensable endowment for regional economic environments. Inclusion of telecommunications infrastructure as a production factor makes it possible for manufacturers to reach an optimum capital-labor ratio and increase overall production efficiency.

The endogenous growth theories confirm the critical role of diffusion of technologies and innovations for regional economic growth. This is especially important to developing countries due to the generally low levels of telecommunications infrastructure availability and its quality. Benefits from endogenized technologies and knowledge require existence of telecommunications infrastructure as a reliable medium. On the other hand,

telecommunications infrastructure in developing counties can usually facilitate international technological transfer and natural diffusion, decrease information asymmetry between them and more developed counterparts, and potentially realize leaping-frog strategy in international competitions. Such diffusion related advantages also exist between developed and less developed regions within the same country.

A regional development theory—location theory—depicts processes of decision making for businesses in location selection. Telecommunications infrastructure, due to its capacity in changing directions of productive element flows between regions, becomes a significant locational factor. At the same time, telecommunications infrastructure provides more locational freedom for firms and frees businesses from geographical distance restraints. Reynolds et al. (2004), for example, examines the relationship between telecommunications infrastructure levels and foreign direct investment and confirms the positive impacts of telecommunications services on attraction of foreign investors into regions. This is insightful for regional policy makers in China because the rapid economic growth in China has benefited from foreign direct investment as a contributory force.

Extensive literature on telecommunications infrastructure investment and economic growth identifies telecommunications service availability as a key element in the accumulation of factors boosting economic growth on both regional and sectoral levels (Cronin, et al 1991, 1993; Cohen, 1992; Greenstein & Spiller, 1995; Nadiri & Nandi, 1997; Norton, 1992; Canning, 1997, 1999; Wang, 1999; Yilmaz et al., 2001, 2002; Yilmaz & Dinc, 2002). Empirical studies directly analyzing the effects of telecommunications infrastructure on economic output can be traced back as early as the 1960s. Jipp (1963) uses teledensity as

an indicator for telecommunications infrastructure and finds its positive relationship with national income based on a dataset of different countries. Other early studies join Jipp (1963) in reaching positive conclusions on the relationship (e.g., Bebee & Gilling, 1976; Hardy, 1980). Saunders et al. (1994) analyze the significance of telecommunications infrastructure to regional economic growth and finds that high-quality telecommunications services can boost growth in other sectors through lower transaction costs, larger integrated market, more sufficient marketing information, and faster information diffusion. A simple generalization appears to be appropriate that investment in telecommunications infrastructure can facilitate market transactions and consequently generate positive externalities among productive entities.

Spatial implications are inherent in development of telecommunications infrastructure due to the significant impact of telecommunications service availability on interregional economic activities. New “network neighborhoods” may possibly form with advancements in telecommunications technologies and the relatively diminishing importance of geographic proximity. Theoretically, better availability of traditional telecommunications infrastructure and more advanced telecommunication technologies liberate economic activities from geographical restraints, and allow them to decentralize from the core to the periphery and maintain necessary connections (Abler, 1970; Stough & Paelinck, 1998). The regional disparity on telecommunications infrastructure endowments has been studied extensively. The imbalanced telecommunications technologies penetration among population and regions is examined by studies focusing on the topics of “universal service” and “digital divide” (Capello, 1994; Dinc et al., 1998; Duwadi, 2003; Norris, 2000).

Boarnet (1998) finds negative spillover effects of public streets and highways in California counties from 1969 to 1988. Borrowing from Boarnet (1998), Yilmaz et al. (2002) conducted a research close to this study but in a U.S. context, and therefore provide instructional insights relative to this analysis. They analyzed spatial spillover effects of telecommunications infrastructure on state output growth and found that U.S. states benefit from their own telecommunications infrastructure investment, but investment in the same sector by neighboring states have a small but significant negative effect on their total output. Compared to the analysis by Yilmaz et al. (2002), this research analyzes the same issue from a different point of view—spatial spillover effect of one state on all the other states as a whole. As will be discussed later, the findings in this analysis show that telecommunications investment may lead to increased intrastate output, while significantly increasing economic growth for other states as well. The importance of spatial concerns in this study can also be consolidated from another school of literature on growth and space (e.g., Abreu, De Groot & Florax, 2005; Maggioni & Nosvelli, 2006; Forman et al., 2005; Greenstein & Prince, 2006).

Controversy remains in this research field and a typical study (Holtz-Eakin & Schwartz, 1994) concludes that no significant productivity spillover effects can be quantitatively identified on studying state highways and state productivity benefits beyond state borders. The spatial spillover effect controversy is originated from a group of production function studies of public capital in 1980s and 90s (Eberts, 1986; Deno, 1988; Aschauer, 1989; Jorgenson, 1991; Tatom, 1991; Maggioni & Uberti, 2005). Among these studies, Aschauer (1989) suggests in his study on national time-series data that public capital is not only productive but yields higher returns than private-sector capital investment. On the

contrary, some studies on state-level panel data, after controlling spatial heterogeneity across different states, conclude that there is no significant correlation between public capital stocks and economic output or productivity (Evans & Karras, 1994; Garcia-Mila et al., 1996; Kelejian & Robinson, 1997). Much of these differences appear to relate to the specific type and category of infrastructure, its interdependent substitution and complementary characteristics, and its congestion levels in a given regional or national context. More research work is necessary to resolve the ongoing debate that usually implies important policy implications, at least to state policymakers.

Spatial autocorrelation and spatial heterogeneity issues pose potential problems for the econometrics literature in examining spatial spillover effects of telecommunications infrastructure on regional economic growth. These problems reside in the utilization of cross-sectional or panel data sets in modeling regional output with telecommunications infrastructure as an independent variable. Kelejian & Robinson (1997) point out that one main reason for spatial autocorrelation or dependence in the error terms of regional econometric models resides in the omitted variable problem that may be related to the connectivity of neighboring regions. Yimaz et al. (2002) solved the spatial heterogeneity problem by including spatial dummy variables in their model specifications. Some other studies also stress the importance of controlling both regional disparities and business cycle effects (Garcia-Mila et al., 1996; Lall & Yilmaz, 2001).

In the simplified aggregate neoclassical model, economic growth is seen as independent of the supply of capital and labor, while regional differences in economic growth are explained by the interregional mobility of these production factors. However, the

mobility of productive assets depends on the availability and quality of infrastructure such as transport and telecommunications. The telecommunications infrastructure network facilitates production through an increase of information flows into regions reducing transaction costs and generating market opportunities (Ding, 2005). Economy-wide gains of investment in telecommunications infrastructure also occur through market expansion and improved organizational efficiency of firms (Madden and Savage, 1998). The Solow production function method has been widely used in the literature in examining relationships between regional economic growth and telecommunications infrastructure. This model is sufficiently flexible to admit numerous variations on that theme. In recent years, human capital and public infrastructure has been employed as inputs in the production function (e.g., Aschauer, 1989; Yilmaz et al., 2001).

A vast literature on telecommunications infrastructure investment and economic growth exists and identifies telecommunications service availability as a crucial element in the accumulation of factors boosting economic growth at both the regional and sector specific level (Cronin, et al 1991, 1993; Cohen, 1992; Greenstein & Spiller, 1995; Nadiri & Nandi, 1997; Norton, 1992; Canning, 1997, 1999; Wang, 1999; Yilmaz et al., 2001, 2002). Saunders et al. (1994) review earlier empirical studies and indicate that high-quality telecommunications services are able to boost growth in other sectors through lower transaction costs, larger integrated markets, better market information, and faster information diffusion. A simple generalization appears to be that investment in telecommunications infrastructure can facilitate market transactions and consequently generate positive externalities among productive entities.

Provision of public infrastructure is probably the most common and possibly, under specific circumstances, the most effective means by which governments promote economic growth. The contribution of telecommunications infrastructure to economic growth can be through product inputs and final product output or more importantly, its broader impact on the whole economy. Rietveld (1989) categorizes the roles of telecommunications infrastructure in economic growth into three areas: production, location, and interregional trade. Fox (1990) formulates a regional economic growth model of aggregate supply and aggregate demand to analyze conceptual relationship between infrastructure investment and output.

A quick review of the literature reveals several mechanisms demonstrating how telecommunications infrastructure supports economic growth. First, telecommunications infrastructure can be a direct input in the production process. A number of cross-section studies on infrastructure belong to this group (Aschauer, 1989; Holtz-Eakin, 1994; Yilmaz et al., 2001). Second, telecommunications infrastructure can increase productivity of other productive inputs. More efficient consumption of land, labor, and physical capital by businesses are possible with availability of telecommunications infrastructure (Ding, 2005). Third, telecommunications infrastructure can attract resources from outside regions, serving as a catalyst for regional economic growth. The catalyst role of telecommunications infrastructure has gained substantiation by both empirical and theoretical studies (Mody, 1997; Sun et al., 2002).

In recent years, quantitative assessment of measuring links between infrastructure and regional economic growth have followed Aschauer's (1989) production function approach

(e.g., Cobb-Douglas) and applications of aggregated national time series data to investigate the relationship between public infrastructure capital and aggregated output in the private sector. The other studies using similar methods include Munnell (1990a, 1990b), Garcia-Mila & McGuire (1992), and Lau & Sin (1997). However, recent studies challenge the research findings of infrastructure's positive and significant effects on regional economic growth in terms of the direction of causality (Cadot et al., 2002; Alexander & Estache, 1999; Reinikka & Svensson, 1999; Canning & Bennathan, 2000). The major argument of these more recent studies is that the link between infrastructure investment and economic growth is at best ambiguous, and that physical infrastructure investment may be a form of complementary capital that supports services necessary for the operation of productive private capital. However, the source of funding for public infrastructure must not crowd out private capital borrowing and the public infrastructure created by investment must add new capacity to be an efficient contribution to regional economic activity (Haynes et al., 2006).

3.2 Telecommunications Infrastructure and Regional Economic Dynamics in China

The effect of telecommunications infrastructure on regional economic development has been the subject of a large body of recent research for the past three decades. Telecommunications infrastructure investment creates possibility for regions in enjoying “diminishing” geographic proximity advantages (*i.e.*, the advantages diminish as distance increases) and provides more locational freedom for businesses. Thus, telecommunications infrastructure emerges as an important factor in regional economic dynamics. Numerous

studies have provided sufficient academic evidences on a positive relationship between telecommunications infrastructure and regional economic growth (Yilmaz et al., 2001, 2002; Yilmaz & Dinc, 2002; Norton, 1992; Wang, 1999; Canning, 1997, 1999; Cohen, 1992; Greenstein & Spiller, 1995; Nadiri & Nandi, 1997; Cronin, et al 1991, 1993). These studies are part of a discussion on relationship between economic growth and infrastructure. As indicated in section 3.1.3, controversy remains for a conclusive remark on the essence of infrastructure's role in economic growth. Debates exist on telecommunications infrastructure's impacts on economic growth. Research findings from previous studies are mostly based upon data from developed regions or countries, posing plausibility questions on a universal conclusion in the infrastructure and economic growth discussion.

The current theoretical frameworks cannot be directly adopted to depict the picture of technology's enhancing effects on regional economic performance in China. The difficulty lies in a set of analytical and practical obstacles. First, a considerable group of studies (e.g., Blair & Premus, 1993; Liu & Li, 2006) argues that some other factors like a skilled labor reserve, favorable state and local income taxes, booming regional business environment, satisfactory quality of life, and availability of other public basic infrastructure also play an indispensable role in attracting investors into a region for business activities. Second, the findings of studies that recognize the positive effects of telecommunications infrastructure in economic development rely on strict assumptions such as perfect market and information, and lack of institutional barriers. This explains why most studies are conducted on advanced countries. Third, regression or other statistical measures encounter the thorny causality issue. The assumed causal direction between telecommunications infrastructure and economic

development cripples the reliability of research findings that identify a positive role of telecom technology on economic growth. Fourth, most studies focus solely on fixed communications technology such as fixed-line telephony (Roller & Waverman, 2001; Wang, 1999; Canning & Pedroni, 2004; Datta & Agarwal, 2004). The bias is that hard line regions tend to be older and previously richer regions with comparatively intensive supporting infrastructure ready in place (*i.e.*, transportation). A neglect of recognizing mobile communications on growth will inevitably lead to bias in assessing quantitatively the real effects of the whole telecommunications infrastructure and further undermines test of the original hypothesis.

Literature on telecommunications infrastructure and regional economic growth stresses telecommunications service availability as a key factor in accumulation and coordination of production elements substantiating economic growth on both regional and sectoral levels (Chen & Kuo, 1985; Cronin, et al 1991, 1993; Norton, 1992; Cohen, 1992; Greenstein & Spiller, 1995; Nadiri & Nandi, 1997; Norton, 1992; Canning, 1997, 1999; Wang, 1999; Yilmaz et al., 2001, 2002; Yilmaz & Dinc, 2002). Note that most of these studies conduct empirical analyses on developed countries or regions. A brief discussion on telecommunications infrastructure and regional economic dynamics in the context of China is necessary.

Given the history of under-investment in telecommunications sector and the rapid pace of technological change in recent decades, China has more to gain by investing in telecommunications infrastructure than in other types of infrastructure. China is one of the few developing countries which have successfully and quickly narrowed the gap with much

of the developed world in terms of the telecommunications sector. From the late 1980s, China's telecommunications market has experienced double-digit growth in terms of the telephone penetration rate and continues to expand rapidly as demand surges. Since 2002 China has been boasting the world's largest fixed-line telephone network, as well as the world's largest mobile communications network. As a result, China has improved its teledensity to 41.2 sets per 100 inhabitants in 2003. This typical China's leading sector investment approach is noted by Haynes and Jin (1997) and can be tracked in the telecommunications sector in terms of FDI and joint partnerships in telecommunications equipment production (Ding & Haynes, 2004).

However, different regions in China exhibit a wide array of telephone penetration levels, ranging from less than 20% in Guizhou province to over 125% in Beijing (including both fixed-line and mobile telephony) at the end of 2003. Pronounced regional difference can be found between core and peripheral regions, and between urban and rural areas in China in the availability of telecommunications infrastructure, as well as among the sectors of economic development that might be stimulated by telecommunications (Lee, 1997; Lu and Wong, 2003; Mody, 1997). The trend of unbalanced developments are continuing and to some degree increasing (Hu & Zhou, 2002). Further studies are necessary to investigate the inter-regional distribution of telecommunications endowment in China and the related imbalance in economic sector performance of different regions. More insights into the regional spatial distribution and evolution of telecommunications infrastructure in China, as well as its spatial clustering or dependence, are needed.

Despite rapid economic growth at the aggregate level, China has suffered great inequality in growth performance for different regions during the past two decades (Wang & Hu, 1999; Xie & Stough, 2001; Demurger, 2001; Kanbur & Zhang, 2005; Meng & Qu, 2007; Yang & Lahr, 2008). Was regional economic growth in China stimulated significantly by rapid development of its telecommunications sector, or did China's rapid economic expansion boost the demand for and the ability to supply the consumption of telecommunications services? Although literature has found some evidence of a positive and significant causal relationship between telecommunications infrastructure and economic growth (see review in Roller & Waverman, 2001; Yilmaz et al., 2001; Demurger, 2001), most of the conclusions are based on cross-sectional country data or regional data of developed economies. In fact, telecommunications investment may have various effects for economies at different stages of development.

On the other side, some studies point out that besides its influence on economic growth of regions where it locates, telecommunications infrastructure also has a significant impact on interregional economic patterns (Yilmaz, Haynes, & Dinc, 2002). A popular view is that developments in telecommunications services have reduced the importance of geographic proximity in regional development because telecommunications connects geographically separated locations and all non-neighboring localities become more accessible and in some sense closer to each other. Telecommunications has the potential to serve as a force for convergence of incomes (Kubota, 2000; World Bank, 2000). An alternative view is that disparity in telecommunications endowment across regions may alter the flow of capital, labor, as well as the location decision of firms, and as a result increased

investment in high telecommunications access regions leading to lower economic growth in other regions (Yilmaz et al., 2002). Little attention has been drawn to the causality direction and regional and interregional spatial spillover effects of telecommunications infrastructure in the context of China.

The peculiar economic development history of China for the past half century predetermines its exceptive progress on investment in telecommunications sector. The severe under-investment in telecommunications technological innovation and hardware products production before 1980s is mirrored by the unprecedented development of the telecommunications sector within the time period 1980s to the beginning of the 21st century. Another special characteristics of China is the pronounced regional differences that exist both across provinces of China and between urban and rural areas (Lee, 1997; Lu & Wong, 2003; Wu, 2004). A group of studies test and conclude that there has been great inequality in regional economic growth for different provinces in China for the past two decades (Fleisher & Chen, 1997; Wang & Hu, 1999; Xie & Stough, 2001; Demurger, 2001).

The research on the role of telecommunications infrastructure investment on regional economic development in China is particularly significant at the policymaking level. First, some studies identify telecommunications infrastructure investment as an input to the overall production process (Aschauer, 1989; Holtz-Eakin, 1994; Yilmaz et al., 2001). If this hypothesis stands, Chinese policymakers can set policy agendas by orienting telecommunications infrastructure investment towards foreign direct investment attraction. Second, the function of telecommunications infrastructure on economic growth, according to Ding (2005: p. 57), lies in its capacity of enhancing productivity of other existing inputs.

Thus, provincial policymakers may adopt telecommunications infrastructure investment as a complementary tool for competitive policy against other neighboring provinces, where lack of general macro regulation, may reasonably lead to increased regional differences in economic performance. Third, the agglomeration effect resides in the process that some regions attract inflow of capital, technology, skilled labor, and other productive elements from other regions by improving their own telecommunications infrastructure availability. It is noteworthy that telecommunications has network economies of scale and becomes more valuable when the network expands. Some studies have already identified infrastructure (including telecommunications infrastructure) as an important factor in attracting foreign investment in many developing countries (Mody, 1997; Sun et al., 2002). Therefore, question remains before China's central government whether deregulation policy in telecommunications sector will lead to deterioration of regional economic development polarization and further undermine the stability of economic development at the national level.

3.3 Methodological Overview

This section presents a brief overview of methodologies and measuring techniques in the two related literatures reviewed in section 2 and 3. Accuracy of measurements and appropriateness of methodologies are two indispensable elements in examining or modeling economic growth at either the regional or national level. The importance of methodological discretion can never be underestimated and an independent section in the statement is deserved and necessary.

Numerous measurement tools are available, including: shift-share-analysis – measuring local effects via a comparative analysis of region and nation; location quotient—measuring relative sectoral importance between target region and reference region; data envelopment analysis—measuring relative sectoral productivity in a region relative to the efficiency of relevant sectors in other regions; input-output-analysis –measuring the impact of a region’s output variation on other regions (Stimson et al., 2002). Some models based on different growth theories have been discussed in section 2 and 3, e.g., the neoclassical production function, endogenous growth model. Some related methodologies are discussed below.

3.3.1 Overview of Analytical Techniques Used in Previous Literature

The large amount and wide variety of previous literature on telecommunications infrastructure determines the wide range of analytical techniques used in different studies. This section discusses these techniques by categorizing them into topics of measurement of economic growth and telecommunications infrastructure, analytical methods, development levels and geographical scale.

Economic Growth Measurement

Ding (2005, p.71) groups measures of economic development into economic output measure, economic growth measure, and inequality reduction measure. Studies using economic output measure adopt output as measure of telecommunications infrastructure investment benefits (Jipp, 1963; Bebee & Gilling, 1976; Chen & Kuo, 1985; Dholakia & Harlam, 1994; Yilmaz, Haynes, & Dinc, 2001, 2002; Roller & Waverman, 2001; Savage et al., 2003). Different types of output include private sector output, per capita GDP, GDP per

worker, per capita income, etc. More complicated and comprehensive measures of output are developed by Bebee & Gilling (1976), Cronin et al. (1991), and Greenstein & Spiller (1995). Bebee & Gilling (1976) index regional economic performance with per capita GDP from secondary and tertiary industries, whereas Cronin et al. (1991) add up output from hundreds of industries as representation of the national economy of the United States. Representative industrial output is also selected for the regional economy, as done by Greenstein and Spiller (1995). Greenstein and Spiller (1995) choose manufacturing sector and FIRE (finance, insurance, and real estate industries) sector as representation of regional economic output of the state of Pennsylvania.

The economic growth rate is also frequently used in the previous literature as measure of regional economic growth (e.g., Norton, 1992; Mody & Wang, 1997; Madden & Savage, 1998; Dutta, 2001; Demurger, 2001; Datta & Agarwal, 2004; Canning & Pedroni, 2004; Ding, 2005). Growth rates include real GDP growth rates and per capita income growth rates. Adoption of growth rate as a measure of economic growth is inspired by the seminal work of Barro (1991). Barro (1991) tests convergence of economies among a cross section of countries by examining the relationship between economic growth rates and initial economic conditions. Modification of Barro's model (1991) is provided by Islam (1995). Islam (1995) adds dynamic characteristics to Barro's convergence framework with use of a panel data set. Other studies following Islam's model, for example, include work of Datta & Agarwal (2004), and Ding (2005).

Economic benefits from telecommunications infrastructure can also be measured by reduction of regional economic inequality. The Gini coefficient is used together with growth

by Forestier et al. (2002) in construction of an inequality index for measure of economic benefit. According to findings of Forestier et al. (2002), countries with higher initial levels of teledensity and sectoral growth in telecommunications tend to outrun those inferior counterparts in increasing income inequality. In other words, access to telecommunications services such as telephone communications service generates faster economic growth and increases income inequality among countries or regions. Instead of directly analyzing impacts of telecommunications infrastructure on income inequality, Yilmaz et al. (2002) test spatial spillover effects of telecommunications services in first-order neighboring regions on one region's economic output. Research findings of Yilmaz et al. (2002) imply existence of competition among regions due to telecommunications infrastructure investment, which might be viewed as one source of regional income inequality.

Measurement of Telecommunications Infrastructure

It is not an easy task to find an appropriate measure for telecommunications infrastructure. Measures of capital stock in telecommunications sector are various, including per capita telecommunications investment, per capita telephone access lines, teledensity, length of telecommunications cables, number of internet hosts, etc. Most studies in the literature measure telecommunications infrastructure capital stock with number of telephones or per capita number of telephones (e.g., Jipp, 1963; Hardy, 1980; Dholakia & Harlam, 1994; Wang, 1999; Ding, 2005). Telecommunications investment and telecommunications sectoral capital stock are also used (e.g., Cronin et al., 1991, 1993; Yilmaz, Haynes, & Dinc, 2001, 2002; Beil et al., 2004). For instance, Cronin et al. (1991) summate annual investment in telecommunications structures and non-consumer goods output of telecommunications

equipment manufactures as a measure of telecommunications infrastructure. Greestein & Spiller (1995) rely on the total lengths of fiber-optic cable for measure of capital stock of telecommunications infrastructure in Philadelphia. Yilmaz, Haynes, & Dinc (2001, 2002) calculate capital stock of telecommunications sector by depreciating different years' investment in telecommunications infrastructure for all states in the United States.

Some other studies develop various measures to represent telecommunications infrastructure capital stock. Bebee & Gilling (1976) develop a telephone index based on three indicators for telephone facilities and services availability, including number of telephones per 100 literate inhabitants over 15 years old, number of business-use telephones per 100 nonagricultural inhabitants, and annually average phone calls per inhabitant. A similar index is used by Chen & Guo (1985) to estimate capital stock of telecommunications infrastructure in Singapore. The discussion on measure of telecommunications infrastructure indicates that there is no optimum technique for measurement of this long-term capital investment. However, as long as correlation of the measure adopted and telecommunications infrastructure capital stock is tested to be acceptable, analyses based on regression techniques can still be assured of enough reliability. Research findings among studies using different measures of telecommunications infrastructure capital stock are similar in identifying impacts of telecommunications on economic growth.

Analytical Method

Previous literature on examination of the relationship between economic growth and telecommunications infrastructure present various analytical techniques. Ding (2005, p. 75) summarizes these techniques into four groups: simple regression analysis, Cobb-Douglas

production function approaches, single equation growth models, and structural growth models.

Simple regression analysis is used mostly in earlier studies, together with correlation analysis technique (*e.g.*, Jipp, 1963; Hardy, 1980; Cronin et al., 1991, 1993; Dholakia & Harlam, 1994; Greestein & Spiller, 1995). This technique helps researchers in identifying a stable relationship between telecommunications infrastructure and economic growth for the study area. Furthermore, these studies using simple regression analysis technique also confirm importance of simultaneous investment in other productive elements such as human capital and other physical infrastructure.

Some studies use neoclassical growth models, especially Cobb-Douglas production function approach, in investigation of impacts of telecommunications infrastructure on economic growth (*e.g.*, Norton, 1992; Mody & Wang, 1997; Madden & Savage, 1998; Canning, 1999; Yilmaz et al., 2001, 2002; Datta & Agarwal, 2004; Canning & Pedroni, 2004). This group of studies takes telecommunications infrastructure as one productive input in some type of production function such as Cobb-Douglas production function. Other forms of production functions include translog production function, constant elasticity of substitution production function (CES), and quadratic production function. Instead of discriminating against one or more of the possible forms of production functions, this study uses the most widely used Cobb-Douglas production function, which is also the basis of the conditional convergence framework (*e.g.*, Barro, 1991). According to Daly (1997), the controversial topic on an ideal production function seems to be a technical argument challenging different groups of economics like Solow and Stiglitz.

Significance of telecommunications infrastructure variable in determining regional economic output is tested using either cross sectional or panel datasets. The rationale of this technique lies in the idea that as long as telecommunications infrastructure serves as a productive factor, investment in this factor should be reflected in increase of economic output. Note that most of these studies use only one production equation, meaning that they are also appropriately summarized as single equation models.

Compared to single growth equation models, studies exist using structural econometric models (Bebbe & Gilling, 1976; Chen & Guo, 1985; Roller & Waverman, 2001; Savage et al., 2003). Variations of neoclassical production function resemble a branch of methodological breakthroughs in examining determinants of economic growth. For example, Chen & Guo (1985) adopt a two-stage least square technique and conclude a reciprocal relationship between telecommunications infrastructure and economic development in Singapore. Savage et al. (2003) used a simple two-sector model (telecom sector and non-telecom sector) of production to assess simultaneously the impact of public infrastructure on economic growth by assuming externalities generated by the telecom sector influence output in the non-telecom sector, and vice versa. The authors separate direct and indirect contribution of telecommunications infrastructure and allow for sector economic benefits feedback loops. Yilmaz et al. (2002) transformed the Cobb-Douglas production function by adding a spatial spillover variable in their test of spatial spillover effects of telecommunications infrastructure investment across states in the United States. Roller & Waverman (2001) develop a supply-demand framework by including telecommunications infrastructure investment in their analysis on growth of OECD countries.

Geographical Scale and Development Level

The previous literature on relationship between infrastructure and economic growth exhibits different targeted geographical areas as well as discrepant development levels of examined regions or countries. Cross-country datasets are used in some empirical tests (e.g., Hardy, 1980). There are also studies with analyses on regional data within one single country (e.g., Cronin et al., 1993; Yilmaz, Haynes, & Dinc, 2001, 2002; Ding, 2005). Yilmaz, Haynes, and Dinc (2001) use data on state level for the United States, and Ding (2005) constructs a panel dataset for provinces, municipalities, and autonomous cities in China. Most of these studies analyze data of administrative units such as states or provinces, because data availability is usually better than that of metropolitan regions or other spatial divisions and because, in some cases, the appropriate decision making regulatory unit is the state or province.

Target study areas include developed and developing regions or countries. Early studies are inclined to do empirical tests on developed regions, again, due to better data availability in these areas than less developed regions (e.g., Bebee & Gilling, 1976; Chen & Kuo, 1985; Norton, 1992). More recent studies include developing countries into their analytical scope (e.g., Mody & Wang, 1997; Demurger, 2001). There are also studies that include both developing and developed countries in their analyses (Hardy, 1980; Madden & Savage, 1998; Canning, 1999; Forestier, Grace, & Kenny, 2002). Development levels of study areas matter due to the causality concern in the infrastructure and economic growth literature. In less developed regions, investment in infrastructure is more easily to be construed as a propelling force on economic growth, whereas arguments prevail that

infrastructure investment is usually induced by demand of fast economic growth. For instance, Saunders et al. (1994) argue that developing countries and developed countries cannot be taken in the same dataset due to different connotations of telephone density in different environments. However, Dutta (2001) finds causality in the relationship between economic performance and telecommunications infrastructure on both developed and developing countries. There exist some other studies that, despite recognition of same causality relationship between infrastructure and economic growth, indicate different effects on regional economies. Stone (1993) finds stronger impacts of telecommunications infrastructure on economic growth in upper-middle income countries than those in lower-middle income countries. Thus, it is difficult to directly apply findings from developed regions on developing regions. Furthermore, they may be operating in quite different national or regional regulatory regimes.

3.3.2 Shift-share Analysis

Shift-share analysis was originally designed for studies on regional employment trends, such as manufacturing employment (e.g., Dunn, 1960). Research on manufacturing employment trends is not new. This is partially due to the significant role of manufacturing industry for most developed countries and regions in the latter half of 20th century. Employment dynamics in manufacturing sector attracts academic interests due to its direct relationship to evolution and development of manufacturing industry. Studies addressing manufacturing employment are ample. For example, Dunn (1960) creates the shift-share model to account for regional competitiveness based on employment changes. His traditional shift-share model has been used in analyses of regional employment trends (e.g., Holden et

al., 1987; Barff & Knight, 1988; Plane & Rogerson, 1989; Patterson, 1991). It is noteworthy that shift-share analytical framework can be applied on examination of not only employment variations, but also regional economic output (e.g., Tan, 2004; Yao et al., 2005). This dissertation uses shift-share model to decompose regional economic output in China. Modifications of the traditional shift-share model are applied to isolate the portion of regional economic output due to capital factors from the total output, which is discussed in detail in Methodology chapter.

Despite its popularity in 1980s and early 1990s, the classical shift-share framework receives severe criticism and challenges. The most obvious drawback of the traditional shift-share model lies in its inability to differentiate the offsetting impacts of two driving forces—output and productivity—for employment changes. Rigby and Anderson (1993) contend that information of effects from aggregate output growth and regional productivity increase is buried in general manufacturing employment changes. The authors propose a modified shift-share model by separating employment changes into changes due to productivity increase and changes due to output growth. Recognizing the contribution of Rigby and Anderson's work, Haynes and Dinc (1997) argue that the modified framework blurs effects of productivity and other factors such as investment in infrastructure, development of new technology. They further introduce total factor production into their modification of the Rigby-Anderson model, separating out contribution of other factors on regional employment changes.

The modifications of shift-share model are adopted in numerous studies on empirically examining regional economic dynamics. Hanham and Banasick (1999) use shift-

share analysis to examine the role of spatial structure on changes in regional manufacturing employment in Japan. The authors recognize a progressive underdevelopment of the core regions, which is directly associated with falling output and productivity. On the contrary, peripheral regions in Japan are characterized by prosperity, which can be attributed to rising output and productivity. Paulo et al. (2002) implement the Haynes-Dinc model on analysis of regional employment dynamics of in Brazil from 1985 to 1997. The authors compare impacts of various economic factors, such as output, productivity and capital factors, on regional employment changes.

Given the ever-increasing national competitiveness of China out of its manufacturing base, studies on manufacturing employment in China abound. Tan (2004) empirically tests influences of national industrial structure on local economic development by examining changes of each region's GDP from 1978 to 2001. Banister (2005) discusses multiple aspects of employment and compensation of manufacturing sector in China from 1990 to 2002, including the structure of manufacturing employment, reported trends in manufacturing employment, and reported manufacturing earnings. Yang (2005) also addresses the relationship of industrial structure and regional growth. These studies recognize the link between industrial structure and employment changes based on qualitative analyses. However, impacts of output, productivity and capital factors on regional employment cannot be accurately measured in these studies.

Shift-share framework is also utilized to estimate quantitatively regional manufacturing employment changes. Yang and Leng (2005) applies the shift-share model to test the relationship between regional employment and industrial structure in China.

Structural benefits and competence of servicing sector in Jiangsu province, China, are also examined with shift-share analysis in Yang and Cheng's study (2006). Yao et al. (2005) establish a modified mathematical model based on the traditional shift-share model and investigate the Chinese industrial sectors. Current studies, however, seldom target directly on estimation of contributions of various factors on regional employment changes in China. In other words, development and modification of the classical shift-share model are rarely implemented in existing studies.

The strict assumption of identical steady state economy among regions, or in other words, identical aggregate production functions for all study areas, is plausible and receives skepticism. For example, Islam (1995) argues that such an assumption is not acceptable in real world and difficulty in finding a solution lies in wide use of single cross-country regressions in empirical studies on this issue. The author advocates and proposes a panel data approach to allow for differences in individual countries. Islam (1995) finds that the panel data approach refines findings of empirical tests of conditional convergence by obtaining both higher estimated convergence rates and lower output-capital elasticity which is more consistent with its commonly accepted empirical values. Datta and Agarwal (2004) follow Islam's panel data approach in their analysis on the relationship between telecommunications and economic growth. Ding (2005) also uses Islam panel data set for test of telecommunications infrastructure's impacts on regional economic growth in China.

3.3.3 Economic Convergence Discussion

In the economic growth literature, the most common approach to studying the sources of economic growth is to use the now-standard Barro (1991) framework, which allows

testing for conditional convergence by adding to a Solow-type equation a set of variables reflecting differences in the study-state equilibrium. Islam (1995) reformulated the regression equation used in previous studies into a dynamic panel model with fixed effects and used panel data to estimate it.

The absolute convergence and conditional convergence concepts are discussed and defined in Barro (1991) and Barro and Sala-i-Martin (1992). Addressing the hypothesis that poor countries or regions tend to grow faster than rich ones, Barro (1991) regresses growth rates of a cross section of countries over initial levels of economic conditions (*i.e.*, real per capita GDP and other conditional variables such as school enrollment rates). Sala-i-Martin (1996) summarizes the two main concepts of absolute beta-convergence and conditional beta-convergence: “...there is absolute β -convergence if poor economies tend to grow faster than rich ones...” (p.1020), and “...the growth rate of an economy will be positively related to the distance that separates it from its own steady state...” (p.1027). According to Sala-i-Martin (1996), absolute beta-convergence requires same steady state for both poor and rich economies. The definitions of both absolute and conditional beta-convergence indicate that only an assumption of same steady state for all economies can make the two types of convergence coincide. It is clear to see that the real world does not apply to the strict assumption of absolute convergence.

Two methods are used in analyzing conditional convergence across regions or countries. The first technique is to hold constant the steady state of each economy with a set of proxy variables. Examination of coefficient sign of the lagged GDP variable indicates existence of conditional convergence, *i.e.*, negative sign of the coefficient β confirms

conditional convergence, and positive sign of β indicates non-existence of conditional convergence. Another measure of holding constant the steady state relies on selection of study regions that satisfy the strict similar steady state assumption. Usually regions within the same country or countries similar in technological levels and institutional arrangements can be recognized as groups with similar steady state of economies. For example, Sala-i-Martin (1996) uses the second treatment in an empirical test of conditional convergence on states of the United States, OECD countries, Japanese prefectures, and European regions. This dissertation sets all provinces, municipalities, and autonomous cities as study regions, which assure satisfaction of the similar steady state assumption.

Several studies adopt the convergence framework to analyze China's economic development (e.g., Chen & Fleisher, 1996; Chen, 1999; Wei & Liu, 2003)

3.3.4 Spatial Econometrics

The dataset used in this dissertation is a panel dataset constructed for 30 regions on year-by-year basis, and is used in determining the spatial econometrics analysis.

Observations in the study sample are based on regions neighboring each other, raising spatial autocorrelation concerns. Spatial autocorrelation, also named as spatial dependency, is defined as the relation among values of a variable or variables that is attributable to the geographic arrangement of areal units (Lee & Wong, 2000, p.135).

Some statistical models are targeted towards prediction of values of some variables at a set of locations, and spatial autocorrelation can impair the independence of errors of the estimators, *i.e.*, the difference between the values predicted and the observed values for the variables in a statistical model (Odland, 1988, p.48). To ensure accuracy of estimation results

from a statistical model such as regression, the errors should be small and independent from each other. However, significant spatial autocorrelation causes interdependence among the errors over space, or in another word, existence of significant spatial autocorrelation reveals some systematic spatial organization of the observed values which is not accounted for by the model. Given the popular application of regression models in empirical plan based policy analysis, spatial autocorrelation should always deserve the concern and attention when researchers fit the regression models to spatial data. The basic logic of testing significance of spatial autocorrelation manifests itself in the testing of regression residuals. The testing procedure in the regression model is similar to the treatment in the case of spatial autocorrelation test on original datasets (such as Moran's I and Greary's Ratio tests), but the expected values and variances for regression residuals are discrepant from those for the original datasets (Odland, 1988, p.54).

The spatial autocorrelation measures test and quantify the strength or magnitude of interdependence or correlation in a spatial sense. In most cases a connectivity matrix needs to be established for values of a variable or variables among the examined areal units, and this matrix is designed to capture the spatial relationship. For definition purpose of juxtaposed or adjacent area units, two treatments are utilized among academics: one is the Rook's case, which requires at least one shared boundary between two areal units to be considered as "adjacent" or "juxtaposed"; the second is in Queen's case, which relaxes Rook's restrictive definition by requiring only one shared point between two areal units for them to be considered as adjacent or juxtaposed.

Some studies propose techniques in handling spatial heterogeneity issues (Kelejian & Prucha, 1997; Baltagi, Song & Koh, 2004). Kelejian & Robinson (1997) point out that one main reason for spatial autocorrelation or dependence in the error terms of regional econometric models resides in the omitted variable problem that may be related to the connectivity of neighboring regions. Yimaz et al. (2002) solve spatial heterogeneity (*i.e.*, uneven spatial distribution) problem by including spatial dummy variables in their model specifications. Some other studies also stress the importance of controlling both regional disparities and business cycle effects (Garcia-Mila et al., 1996; Lall & Yilmaz, 2001). Baltagi et al. (2004) developed a spatial panel data regression model with serial correlation on each spatial unit over time as well as spatial dependence between the spatial units at each point in time. In addition, they solved the spatial heterogeneity problem by considering random effects and further derived several Lagrange Multiplier tests for their proposed model.

Spatial dependency is a source of nuisance that deserves special attention in terms of methodological design. The spatial spillover literature will be cited as an example to illustrate the treatment of such nuisance. As mentioned by Rey & Montouri, (1999), examination of spatial spillover effects between states in the context of telecommunications infrastructure investment and regional economic development, is contaminated due to risk of bias out of spatial interactions between neighboring (no matter contiguous or not in this analysis) states. Spatial dependency nuisance might exist in two forms. In the first form, the spatial proximity increases the possibility of mismatch between spatial boundaries of explanatory variables and administrative boundaries used to collect data. This possibility becomes a nuisance dependency in some cases. The second form of spatial dependency resides in the error terms

of the model specifications. Kelejian & Robinson (1997) argue that one reason for spatial correlation or dependence in the error terms of regional econometric models is that some variables related to the connectivity of neighboring regions are omitted or disregarded. Yilmaz et al. (2002) conduct Moran's *I* test for both considerations of spatial autocorrelation. The authors find that in the analysis of spatial spillover effects of state-level telecommunications infrastructure investment on neighboring states, the estimation results are free of bias under both circumstances of possible deterioration due to spatial dependency. Besides Moran's *I* test (Moran, 1950) mentioned above, some other techniques such as Geary's *C* can also be used to test spatial autocorrelation and a distribution is often made between a global Moran's *I* and its local counterpart.

Chapter 4 Methodology and Data

This chapter presents methodologies used in this dissertation and lists data sources for measurement of variables. Three methods—dynamic panel data approach for testing economic conditional convergence, spillover effects identification model, and shift-share analysis—comprise the first three sections in this chapter, as the last section discusses measurement of variables and data sources. The data quality issue is discussed by the end of this chapter.

4.1 Conditional Convergence Model-A Dynamic Panel Data Approach

Identifying the source of economic growth has been a hot topic in the academic literature during the past few decades. Among different approaches to addressing this issue, Barro (1991) earns substantial credits for his now-standard single cross-section approach to testing conditional convergence. This approach is designed on the basis of the neoclassical growth model established by Solow (1956). Barro (1991) includes a set of variables reflecting steady state economic conditions and tests the conditional convergence hypothesis with the diminishing returns assumption in Solow's growth model. Barro's model is discussed in detail below.

The Barro cross-section static approach

Barro (1991) and Barro & Sala-I-Martin's seminal studies (1992) give rise to the conditional convergence concept. Simply put, the conditional convergence happens when partial correlation between growth in income over time and its initial level is negative. This approach allows testing for conditional convergence by adding to a Solow equation a set of variables reflecting differences in the steady-state equilibrium. In general, the convergence hypothesis in the neoclassical growth model (Solow, 1956) manifests itself by reflecting that poor economies tend to grow faster than rich economies in terms of per capital income or product. Such a hypothesis in the neoclassical framework typified by Solow's model leads to absolute convergence, which is usually referred to as sigma convergence. It arises from the assumption of diminishing returns to capital. The diminishing returns to capital in richer regions directs the flow of capital to poorer regions for higher returns, a mechanism boosting growth in the poorer regions and achieving convergence.

However, the fact that saving rates, technology conditions and initial capital stocks can vary widely across different regions necessitates prediction of conditional convergence. This is a situation in which per capita incomes converge, conditional on each economy's steady state. In other words, if economies are similar in preferences, technologies, saving rates and other structural characteristics, the lower the initial levels of output per capita the higher the growth rates. Barro (1991) finds that the convergence holds among groups of countries with certain characteristics in common and among regions within a country that have certain commonalities. Barro's contention indicates that once the determinants of steady-state per capita income are controlled, economies exhibit convergence, which is the conditional beta convergence

According to Barro (1991), the cross-section static approach would have the following specification for this study on regions of China:

$$GRTH_i = \alpha_0 + \delta Ln(GDP)_{i,initial} + \sum_j \beta_j X_{i,j,initial} + \varepsilon_i \quad (4.1)$$

where i indexes the 29 provinces, municipalities, and autonomous cities in China; $GRTH$ represents the annual growth rate of real GDP per capita during the study period; $Ln(GDP)_{i,initial}$ represents the initial level of real GDP per capita in logarithm form for region i ; and X contains a set of variables accounting for production factors and other conditional variables at the beginning of the study period for each region.

Thus, while the set of economic condition variables are held constant, a negative sign of the coefficient of initial real GDP can indicate the existence of conditional convergence. Note that in Barro's single cross-section framework, the total number of regions must exceed some level to avoid the statistically inherent small sample problem. For example, there are 29 regions in this study and apparently the small sample issue is a problem for final results.

The conditional variables are selected along the guidelines in the growth literature. For example, Levine & Renelt (1992) find more than 50 significant variables related to economic growth in one regression. Sala-i-Martin (1997) identifies 62 explanatory variables in the cross-country empirical growth literature. These variables range from traditional economic variables such as physical labor and capital inputs, to a broader scope of economic variables such as human capital, public capital, R&D investment and regional inequalities, even social capital, religion, institutions, and political variables. The variables are based on economic inputs, productivity and environmental considerations as well as the availability of

data. It is noteworthy that some of the variables used in Sala-i-Martin's study (1997) are more appropriately used in an international level analysis, and not all the 62 variables exert significant contributions to the explanatory power of his model. Furthermore, availability of data on the regional level in China causes difficulty in adopting all the possible variables in the literature in the model specifications. Therefore, this study selects fixed investment, foreign direct investment, employment, human capital, population growth, urbanization level, share of state-owned enterprises, transportation, as well as telecommunications infrastructure. Thus, the model is formulated as:

$$GRTH_{it} = \alpha_0 + \beta_1 Ln(GDP)_{i,t-1} + \beta_2 INV_{i,t} + \beta_3 FDI_{i,t} + \beta_4 POP_{i,t} + \beta_5 EMP_{i,t} + \beta_6 HC_{i,t} + \beta_7 URBAN_{i,t} + \beta_8 SOE_{i,t} + \beta_9 TRANS_{i,t} + \beta_{10} TEL_{i,t} + \varepsilon_{i,t} \quad (4.2)$$

The variables in *Equation 4.2* are measured as follows:

- *GRTH*: annual growth rate of real *GDP* per capita. In this analysis, the dependent variable regional economic growth rate is measured by the growth of real *GDP* per capita at provincial level in China. *Ln(GDP)* represents the log value of the real *GDP* per capita in 1995 RMB.
- *INV*: percentage of fixed investment in *GDP*.
- *FDI*: percentage of foreign direct investment divided by total fixed investment.
- *POP*: annual population growth rate.
- *EMP*: percentage of total employment to total population.
- *HC*: human capital which is measured by the average years of schooling for the population aged 6 and above.
- *URBAN*: the share of urban population to total population.
- *SOE*: the share of state-owned enterprises in total industrial output.
- *TRANS*: transportation density as measured by the length of rail, highway, and waterway networks per square kilometer.
- *TEL*: the number of telephones per 100 inhabitants.

The temporal lagged *GDP* variable is included in *Equation 4.2* to test for conditional convergence, *i.e.*, to test convergence after controlling all the conditional variables in the equations. A negative sign of this variable can provide evidence in support of the convergence hypothesis (*i.e.*, the higher the level of past *GDP*, the lower the subsequent growth in *GDP* per capita).

The Islam panel-data dynamic Approach

Islam (1995) questions the assumption of Barro-type analyses that all the countries or regions have identical aggregate production functions. The cross-country or cross-region regressions conducted in the Barro type analyses are weak in justifying the identical production function assumption, as contended by Islam (1995). Corresponding to the inherent weakness in satisfying this strict production function assumption, Islam advocates and implements a panel data approach with fixed rather than random effects in order to allow for the differences of the unobservable individualities, or country effects.

This approach is advantageous in its ability to allow for the differences across countries or regions, as mentioned above. With unobservable bias controlled or corrected, this model also captures the short-run autoregressive behavior by adding the lagged growth rate as an independent variable. This panel data approach receives skepticism itself in that serial autocorrelation and the business cycle are inevitably introduced when more than one observation on each economy are added (Mankiw, 1995). However, Caselliet et al. (1996) asserts that the panel data approach is still better than the cross-section regression approach due to its control over the omitted variable bias and endogeneity problem.

Thus, the Islam-type panel data dynamic approach can be specified as:

$$GRTH_{it} = \alpha_0 + \gamma GRTH_{i,t-1} + \delta \ln(GDP)_{i,t-1} + \sum_j \beta_j X_{j,t} + \beta_{j+1} TEL_{i,t} + \alpha_i + \eta_t + \mu_{it} \quad (4.3)$$

where all the definitions and measurements of the variables are the same as those in the Barro cross-section static approach; α_i , η_t and μ_{it} represent the regional dummy, temporal dummy, and error terms, respectively.

After including all the conditional variables selected in this study, *Equation 4.3* is transformed into:

$$GRTH_{it} = \alpha_0 + \gamma GRTH_{i,t-1} + \beta_1 \ln(GDP)_{i,t-1} + \beta_2 INV_{i,t} + \beta_3 FDI_{it} + \beta_4 POP_{i,t} + \beta_5 EMP_{i,t} + \beta_6 HC_{i,t} + \beta_7 URBAN_{i,t} + \beta_8 SOE_{i,t} + \beta_9 TRANS_{i,t} + \beta_{10} TEL_{i,t} + \alpha_i + \eta_t + \mu_{it} \quad (4.4)$$

Equation 4.4 is used in this analysis to test for the role of telecommunications infrastructure in regional economic growth across 29 provinces from 1986 to 2004 and in our comparison to the previous specified extended Barro model (*i.e.*, *Equation 4.3*). The direction of causality between telecommunications infrastructure and regional economic growth can be tested using the Granger Test technique. Section 5.2 of Chapter 5 discusses this issue in further detail. Generally, a one-way direction of causality exists that telecommunications infrastructure causes regional economic growth, while the reverse relationship does not hold.

4.2 Spillover Effects Identification Model

Telecommunications infrastructure, like many other types of infrastructures, has spillover effects across regional boundaries. Methods in identification of the spillover effects are used in some studies in the literature (e.g., Boarnet, 1998; Yilmaz et al., 2002). This section first presents a conceptual framework for modeling spillover effects of

telecommunications infrastructure, and a model specifying such spillover effects is developed following Yilmaz et al. (2002).

Conceptual Framework

Yilmaz et al. (2002) establish a conceptual framework with telecommunications capital stock and public infrastructure stock as quasi-fixed inputs for gross state production, following Boarnet (1998) in that state output depends upon public infrastructure, telecommunications infrastructure, capital, and labor. Both studies set models based on Cobb-Douglas production function. This study echoes the conceptual framework developed by Yilmaz et al. in most aspects.

According to Yilmza et al. (2002), the state output is achieved through the following function:

$$Q = \alpha(G)\beta(TK)f(K, L) \quad (4.5)$$

where Q is state output; G is public capital stock in a state; TK is telecommunications capital stock in a state; L is labor force and K is private capital stock in a state. TK is separated out from G as an independent input element in the production function.

The following conditions should be met for *Equation 4.5*:

$$\begin{aligned} \alpha'(G) &> 0 \\ \beta'(TK) &> 0 \\ f_K &> 0; f_{KK} < 0 \\ f_L &> 0; f_{LL} < 0 \end{aligned}$$

Assume that markets are competitive and factors of production are mobile as does Cobb-Douglas production function, input price is equal to its marginal revenue product which is determined by G and TK .

$$\frac{\partial Q}{\partial L} = \alpha(G)\beta(TK)f_L(K, L) \quad (4.6)$$

$$\frac{\partial Q}{\partial K} = \alpha(G)\beta(TK)f_K(K, L) \quad (4.7)$$

The factor prices in each state i can be determined as:

$$w_i = p\alpha(G_i)\beta(TK_i)f_L(K_i, L_i) \quad (4.8)$$

$$r_i = p\alpha(G_i)\beta(TK_i)f_K(K_i, L_i) \quad (4.9)$$

where p , w and r are respectively the prices of output, labor and capital.

As indicated by Equation 4.8 & 4.9, increase of telecommunications infrastructure investment in state i will raise the price levels of both labor and capital accordingly. The higher prices of labor and capital, with fully mobile labor force and private capital, will cause labor and capital in other states to flow into state i .

The output in state i will be:

$$Q_i = \alpha(G_i)\beta(TK_i + \Delta TK)f(K_i + \Delta K, L_i + \Delta L) \quad (4.10)$$

The output in all states other than state i will be:

$$Q_{OTH} = \alpha(G_{OTH})\beta(TK_{OTH})f(K_{OTH} - \Delta K, L_{OTH} - \Delta L) \quad (4.11)$$

where subscript OTH indexes aggregation of all states other than state i .

If the original factor input ratio can remain constant with increase in capital and labor, state i will shift to a higher production level while other states suffer a corresponding output loss with the expected long-run equilibrium at factor price level $w_1 = w_2 = \dots = w_i$ and $r_1 = r_2 = \dots = r_i$, and vice versa. Therefore, higher input in telecommunications infrastructure by other states leads to migration of productive resources from state i to the other states, which directly decreases output in this state on the aggregate level. On the other hand, if

increases in labor and capital are not proportional and consequently change the final factor input ratio in a state, the marginal rate of technical substitution can be referred to for a solution. However, this disproportional expansion of labor and capital bases will not change the overall out-migration of productive factors, and the spillover effect analysis in this study is still valid and applicable. A special case requires additional speculation in case the mobility of productive factors is not perfect and the substitution of factors is plausible. A vast literature exists in analyzing both cases and concludes that the sign of spillover effect will hold even if interregional productive factors are fairly immobile and intra-regional productive factor substitution is susceptible to region-specific conditions (Arrow et al., 1961; Borts, 1960; Kendrick & Sato, 1963; Clague, 1969; Blackorby & Russell, 1989).

The aggregation of investment in telecommunications infrastructure by all states other than state i will be analyzed as a whole in the model discussed later in this section. The logic is similar to the study of Savage et al. (2003) in which the authors utilized a two-sector model (telecom sector and non-telecom sector) of production in differentiating contribution of telecom sector to total output from that of other sectors. The model developed below can reasonably test the spatial spillover effects of all states other than state i on its regional output.

Model Specification

Yilmaz et al. (2002) emphasize the competitive advantage of regions with more telecommunications infrastructure investment on altering migration of productive factors. The consequent output gain or loss among regions is in some sense directly influenced by their relative investment in telecommunications infrastructure. It can be justified to expect that increase of telecommunications infrastructure investment in one region can not only

benefit their own output but also damage economic growth of its neighboring region. Thus, the production function after including spatial spillover effect of all states other than state i can be specified as:

$$Q_i = f(L_i, G_i, K_i, TK_i, TK_{OTH}) \quad (4.12)$$

where OTH indexes all the other states except state i ; Q_i is the output of state i ;

L_i, G_i, K_i, TK_i are respectively labor, public sector capital stock, private sector capital stock excluding telecommunications, and telecommunications capital stock in state i ; TK_{OTH} is telecommunications capital stock in all the other states.

The spatial spillover variable in Equation 4.11 is TK_{OTH} . It has been widely recognized that interconnectivity of telecommunications networks diminishes geographical distances among producers, suppliers, and consumers in different regions. Therefore, validity of this model in including all the other states in the spillover variable can be maintained because all states can be deemed to be adjacent to each other in the context of telecommunications infrastructure investment analysis. There are different options to construct the weight matrix for measurement of the spillover variable, such as first order neighbor weight matrix, distance decay weight matrix, and population-distance gravity weight matrix in the literature of spatial econometrics. However, the aim of this study is not to accurately measure the amount of spillover effects of telecommunications infrastructure among regions in China, but to test the existence of significant spillover effects and whether such effects are positive or negative. Besides, the interior regions of China are very different from those in coastal regions in terms of transportation infrastructure, geographical

accessibility, and other productive endowments. Geographical distance is plausible to be a valid option for the spatial weight matrix construction. Therefore, this study adopts the simple form of weight matrix—first order neighbor weight matrix to derive the spillovers variable in the model specifications. This study argues that the first order neighbor weight matrix can catch at least a significant portion of, if not all, the spillover effects in the model used in the analysis.

A regression model is developed out of the log-linear Cobb-Douglas aggregate production function, while the spatial spillover variable TK_{OTH} is included. The model is presented below:

$$\begin{aligned} \log(Q_{i,t}) = & \alpha + \beta_1 \log(L_{i,t}) + \beta_2 \log(G_{i,t}) + \beta_3 \log(K_{i,t}) \\ & + \beta_4 \log(TK_{i,t}) + \beta_5 \log(TK_{OTH,t}) + \varepsilon_{i,t} \end{aligned} \quad (4.13)$$

Business cycle effects and spatial heterogeneity in terms of initial production endowments, business climate, and location in analyzing panel data are included in the constant α of *Equation 4.13*. Some studies suggest controlling heterogeneity with state dummy variables, and eliminating business cycle effects with the use of year-specific intercepts (Yilmaz et al., 2002; Garcia-Mila et al., 1996; Kelanjian & Robinson, 1997; Lall & Yilmaz, 2001). With consideration of controlling both heterogeneity and business cycle effects, *Equation 4.13* is transformed into:

$$\begin{aligned} \log(Q_{i,t}) = & \beta_1 \log(L_{i,t}) + \beta_2 \log(G_{i,t}) + \beta_3 \log(K_{i,t}) \\ & + \beta_4 \log(TK_{i,t}) + \beta_5 \log(TK_{OTH,t}) + f_i + \gamma_t + \varepsilon_{i,t} \end{aligned} \quad (4.14)$$

where f_i is a vector of time-invariant region effects, and γ_t is a vector of year specific intercepts.

Equation 4.14 is the base model in this spatial spillover effect analysis of telecommunications infrastructure on state output. The signs from β_1 to β_4 can be reasonably predicted to be positive and statistically significant, which can be interpreted as the direct input-output association. Due to the anticipated direction of productive factor flow with increase in $TK_{OTH,t}$, a negative sign of β_5 is expected to exist provided statistical significance test is satisfied. In this case, negative spatial spillover effects are identified.

4.3 Shift-share Analysis

This study uses shift-share analysis technique to account for regional output due to both labor and capital factors. Local economic bases are also identified with decomposition of total regional output into national growth share, industrial mix effects, and domestic effects (e.g., Dunn, 1960). Specifically, shift-share analysis decomposes economic change in a region over a given time period into three additive components: National Growth Share, which is the part of change in local output in a region ascribed to growth of output in the national reference area as a whole; Industrial Mix Effect, which measures the industrial composition of a region and reflects the degree to which this region specializes in industries that are developing faster or slower; Regional Share, which is the difference between actual change in output and the expected output change assuming each industrial sector grow at the national rate. This portion measures the extent of changes in a region due to local advantages or disadvantages.

It is noteworthy that shift-share analysis can be applied in analyses of both output and employment. This section reviews evolution of the shift-share models, while most of these models are originally developed for employment trend studies. The classical shift-share model was introduced by Dunn (1960) on the analysis of industrial employment trends, expressed as:

$$NS \equiv E_{ir} g_n \quad (4.15)$$

$$IS \equiv E_{ir} (g_{in} - g_i) \quad (4.16)$$

$$LS \equiv E_{ir} (g_{ir} - g_{in}) \quad (4.17)$$

where NS stands for the National Growth Share; IS is the Industrial Mix Effect Share, and LS represents Local Share. The Total Shift measures actual change in total employment within a region over a time period. The subscript i and r index industrial sectors and regions, respectively. G is regional or national output; g_{ir} is the growth rate in employment in sector i of region r ; g_{in} is the growth rate of employment in industry i for the nation.

$$TS \equiv NS + IS + LS \quad (4.18)$$

$$TS \equiv E_{ir} g_n + E_{ir} (g_{in} - g_n) + E_{ir} (g_{ir} - g_{in}) \quad (4.19)$$

Despite the popularity of this traditional shift-share model, it has been widely criticized (*e.g.*, Rigby & Anderson, 1993; Haynes & Dinc, 1997). Haynes and Dinc (1997), for example, argue that the classic shift-share model and its extensions do not take into account many important background variables such as demographic structure of the region, level of labor force participation, or changes in factor productivity in analysis of a region's employment change. Traditional shift-share models account for regional competitiveness by a single variable (*e.g.*, employment), which is often measured in absolute numbers rather

than quality. Only the change in employment is used to explain the change in the economy and the traditional model may lead to an over-simplified interpretation.

Rigby and Anderson (1993) extend the model by incorporate both output and productivity changes and argue that the traditional shift-share model measures only the combined effects of output growth and productivity change on employment. So, the authors separate the effects of changes in output and productivity on employment, as:

$$TS \equiv TS(a) + TS(b) = \sum E_{ir} [(a_{ir} - a_n) + (b_{ir} - b_n)] \quad (4.20)$$

$$IS \equiv PS(a) + PS(b) = \sum E_{ir} [(a_{in} - a_n) + (b_{in} - b_n)] \quad (4.21)$$

$$LS \equiv DS(a) + DS(b) = \sum E_{ir} [(a_{ir} - a_{in}) + (b_{ir} - b_{in})] \quad (4.22)$$

where a_{ir} represents the rate of employment change in industry i in region r resulting from variations in output over a given time period with productivity constant. b_{ir} represents rate of the employment change in industry i in region r caused by variations in productivity over a given time period with output constant.

$$a_{ir} = A_{ir} / E_{ir} \quad (4.23)$$

$$A_{ir} = (Q_{ir(t+1)} - Q_{irt}) / q_{irt} \quad (4.24)$$

$$b_{ir} = B_{ir} / E_{ir} \quad (4.25)$$

$$B_{ir} = Q_{ir(t+1)} / q_{ir(t+1)} - Q_{irt} / q_{irt} \quad (4.26)$$

$$q_{irt} = Q_{irt} / E_{irt} \quad (4.27)$$

Though the Rigby-Anderson model introduces the idea of productivity, it still neglects influences of other factors, such as capital, technology, infrastructure and quality of material input on regional output. Haynes and Dinc (1997) contend that the Rigby-Anderson model fails in ascribing the contribution of other factors to regional output to productivity. Instead, the authors create a new modification based on Rigby-Anderson extension by

introducing the total factor productivity (TFP) approach. In the TFP approach, productivity is defined as the relationship between output of goods and services and input of resources, usually expressed in ratio form.

$$TFP = Y / [\alpha_1 L + \alpha_2 K + \alpha_3 I + \dots] \quad (4.28)$$

where I is infrastructure and $\alpha_1 + \alpha_2 + \alpha_3 + \dots = 1$. For simplicity, only labor and capital factors are considered.

$$TFP = Y / [\alpha L + (1 - \alpha)K] \quad (4.29)$$

Y represents the total output; L and K are the quantities of labor and capital inputs, respectively. α is the weight of input. It is derived as the estimated shares of factor payments in national income. At the sectoral level, TFP can be calculated:

$$TFP_i = Y_i / [\alpha_i L_i + (1 - \alpha_i)K] \quad (4.30)$$

$$1/TFP \equiv [\alpha L + (1 - \alpha)K] / Y \quad (4.31)$$

$$1/TFP \equiv (\alpha L / Y) + (1 - \alpha)K / Y \quad (4.32)$$

$$1/TFP \equiv 1/TFP_L + 1/TFP_K \quad (4.33)$$

where $TFP_L \equiv \alpha L / Y$ is labor productivity and $TFP_K \equiv (1 - \alpha)K / Y$ is capital productivity.

$$q_{ir} = Q_{ir} / [\alpha_i E_{ir} + (1 - \alpha_i)K_{ir}] \quad (4.34)$$

In this equation, the productivity contains the influence of two parts: labor and capital.

$$1/q_{ir} = \alpha_i E_{ir} / [Q_{ir} + (1 - \alpha_i)K_{ir} / Q_{ir}] \quad (4.35)$$

$$1/q_{ir} = 1/q_{irL} + 1/q_{irK} \quad (4.36)$$

$$1/q_{irL} = \alpha_i E_{ir} / Q_{ir} \quad (4.37)$$

$$1/q_{irK} = (1 - \alpha_i)K_{ir} / Q_{ir} \quad (4.38)$$

A_{ir} and B_{ir} can be obtained by substituting the new value of q_{irL} and q_{irK} .

$$A_{irL} = (Q_{ir(t+1)} - Q_{irt}) / q_{irL} \quad (4.39)$$

$$A_{irK} = (Q_{ir(t+1)} - Q_{irt}) / q_{irK} \quad (4.40)$$

$$B_{irL} = Q_{ir(t+1)} / q_{irL(t+1)} - Q_{irt} / q_{irLt} \quad (4.41)$$

$$B_{irK} = Q_{ir(t+1)} / q_{irK(t+1)} - Q_{irt} / q_{irKt} \quad (4.42)$$

$$a_{irL} = A_{irL} / E_{ir} \quad (4.43)$$

$$a_{irK} = A_{irK} / K_{ir} \quad (4.44)$$

$$b_{irL} = B_{irL} / E_{ir} \quad (4.45)$$

$$b_{irK} = B_{irK} / K_{ir} \quad (4.46)$$

Haynes and Dinc create the model as follow.

$$TS_L = NS_L + IS_L + LS_L \quad (4.47)$$

$$NS_L \equiv NS(a_L) + NS(b_L) = \sum E_{ir} (a_{nL} + b_{nL})] \quad (4.48)$$

$$IS_L \equiv IS(a_L) + IS(b_L) = \sum E_{ir} [(a_{inL} - a_{nL}) + (b_{inL} - b_{nL})] \quad (4.49)$$

$$LS_L \equiv LS(a_L) + LS(b_L) = \sum E_{ir} [(a_{irL} - a_{inL}) + (b_{irL} - b_{inL})] \quad (4.50)$$

The subscript L represents labor. So the Haynes-Dinc model successfully differentiates the effect of productivity from that of output on regional employment. The new modification measures contributions of both output and productivity on regional manufacturing employment. Moreover, contribution of other factors, such as capital, technology, infrastructure, education, human resource, to regional employment ΔEOP can be calculated.

$$\Delta EOP = \Delta E - TSL \quad (4.51)$$

where ΔE is actual employment change over time in a region; TSL is total shift in labor in the region resulting from changes in labor productivity and output. So ΔEOP is the difference between actual change and total shift, *i.e.*, the employment change resulting from other factors' contribution.

It is noteworthy that the residual treatment for all factors other than labor in this method reflects the difficulty of separating capital factors from other productive inputs. This panel dataset does not support accurate measurement of capital stock for each region in

China. Besides, conversion of other inputs such as human capital and technological innovation into monetary units is not attainable. Thus, this analysis follows the Haynes-Dinc (1997) model in isolating labor input from other inputs.

This dissertation adopts the Dinc-Haynes shift-share modification for decomposition of regional economic output. In the shift-share model in this study, employment in manufacturing sector is replaced with regional economic output. Adjustments on ratios of capital and labor to total input are made, correspondingly. The aim of this treatment is to separate out the portion of output due to capital factors, which is the dependent variable in this dissertation.

The attempt to decompose regional economic growth by capital and labor factors requires high quality of labor, wage, and output data. As discussed by the end of this chapter, the analysis results may be impacted by the questionable quality of the employment data reported by China's regions. However, despite the obstacle of data reliability, the efforts in decomposition of regional economic growth can still be justified with the insights from the analysis results.

4.4 Measurement of Variables and Data Sources

This section discusses scope of spatial units, time period, measurement of variables, and sources of data for the analysis in this dissertation.

Spatial Units and Time Period

The dataset in this study is constructed for the 29 regions of China for the 19-year period from 1986 to 2006. The 29 regions are included in the 31 provinces, autonomous

regions and municipalities of China, except for the Province of Tibet and the Chongqing municipality. Tibet is excluded due to missing data, while Chongqing municipality was established in 1997 and hence is incapable of being included for the whole data period. Appropriate adjustments on the Chongqing municipality data are made so that it can be included as part of its original parent province Sichuan.

The initial year of 1986 is selected because a review of the economic development history of China reveals that before 1985 the size of telecommunications infrastructure in China was small and insignificant compared to other physical infrastructure such as transport and electricity. The effects of telecommunications infrastructure on regional economic growth before 1986 are reasonably estimated to be marginal or nonexistent.

Measurement of Variables

Regional economic output, or more exactly the proportion of output due to capital local factors, is the dependent variable in the model used in this dissertation. Many indicators have been used in previous literature for measurement of this variable, including: per capita income indicators from demand perspective and per capita output indicators from perspective of supply. Regional per capita income signifies purchasing power of local community for goods and services and it can be appropriately understood as an economic welfare indicator. On the other hand, per capita output examines the supply side of a region's market, *i.e.*, capacity of supplying goods and services. Despite the interrelation between demand and supply of goods and services in a region, per capita income indicators are seldom used in analyses due to lack of consistent deflators to adjust data over a time period. Instead, per capita output indicators are widely accepted in literature due to availability and quality of

data, as well as reliable and comparable deflators. Thus, this study also uses regional per capita real GDP as a measure of regional economic output in China. Specifically, the growth rates for the portion of regional per capita real GDP due to regional capital factors are calculated after implementation of shift-share analysis technique are used in this study as measurement of regional economic growth in China.

Labor and capital are the most important two types of inputs in neoclassical growth models. This study uses total number of workers as measurement of labor force, regardless of quality variance. China Statistics Yearbook defines the “total number of workers” as total number of people who are 16 years of age or older and participate in certain social production activities for salaries, wages, or operations profits. This indicator of labor force reflects real conditions of total labor resource utilization in a certain time period. Accumulation of physical and nonphysical capital stock is also critical to economic growth. This dissertation uses total amount of fixed assets formation as an indicator or capital inputs for regions in China. According to China Statistics Yearbook, total amount of fixed assets formation means the total amount of residual values after subtracting sale of fixed assets from fixed assets acquisitions by all producers in a region in a certain period.

Human capital addresses quality of labor force. The total number of workers indicator cannot differentiate regions from each other in terms of labor quality, whereas inclusion of human capital variable in regional growth models usually enhances reliability and robustness of results. The rationale is clearly argued in the literature of endogenous growth studies (e.g., Lucas, 1988, 1990). Empirical studies on role of human capital in regional economic growth dynamics also abound (e.g., Barro, 1991; Mankiw et al., 1992; Ding, 2005). Many

approaches exist for measurement of human capital stock, including adjusted labor force by their levels of education, and proxy for human capital stock with educational attainment such as school enrollment ratios or literacy rates. This study follows Yu (2001) and Ding (2005) in approximation of human stock for regions in China with average years of schooling for population aging greater than 6 following the World Bank approach.

Urbanization in developing countries like China usually indicates dramatic regional economic development disparity between rural and urban areas, flow of labor especially young labor force from rural areas to urban areas, and increasing gap of life quality between rural and urban regions. Growing urbanization reflects distinct rural/urban divide and production factor reallocation in China. This study uses a proxy indicator—urbanization rate—as an independent variable for explanation of regional economic performance.

Foreign direct investment is important in regional economic growth analysis in China due to the successful implementation of the Reform and Opening Up policy by China's central government after 1978. Overseas investment in China has been increasing during the study period, as well as export of goods made in China in international market. The Ministry of Commerce in China claims that China is the number one host country of foreign direct investment in 2006 with total amount of \$134.84 billion capital inflow. The total amount of foreign direct investment is used in this study as measurement of foreign direct investment.

Telecommunications infrastructure is measured as total number of telephones including both fixed and mobile lines. This approach has been widely applied in previous literature (e.g., Hardy, 1980; Savage et al., 2003; Ding, 2005). Inclusion of mobile telephones in the proxy of telecommunications infrastructure is important because of the fact that mobile

subscribers in China have outnumbered fixed line subscribers since 2003 (Ding, 2005, p.109). Correlation between number of total telephones and capital stock of telecommunications sector in China has been found as high as 0.99 (Ding, 2005, p.109). Thus, total number of telephones is a reliable indicator for telecommunications infrastructure in this dissertation. As for the spillover variable for telecommunications infrastructure, sum of telephones in all regions other than region i is calculated and taken as a proxy.

Another type of infrastructure included in this study is transportation networks. Literature on discussion of transportation infrastructure abounds. This study uses total lengths of navigable highways as measurement of transportation infrastructure for regions in China. The rationale lies in the fact that most of the investment on transportation infrastructure focuses on construction of highways.

Sources of Data

The aggregate provincial economic data of real GDP per capita, employment, population, fixed investment, urbanization, transportation infrastructure, foreign direct investment, total industrial output and number of telephones for different provinces, municipalities, and autonomous cities from 1986 to 2006 is provided by the Comprehensive Statistical Data and materials from 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 2007. Average years of schooling before 1998 for the human capital variable is referenced to Yu (2001). The data on human capital after 1998 is updated based on data from the China Statistics Yearbook from 1999 to 2007. All variables in money values are standardized into 1995 local currency (RMB) values.

Data quality is a significant issue for any quantitative analyses. As a developing country, the aggregate level of economic data are gathered by different levels of statistical agencies. Reliability and accuracy of data within the panel dataset used in this study may not be as high as those of developed countries such as the United States. However, as listed below, this study applies the most official source of data from the National Statistics Bureau which is assumed to be the agency that provides the most consistent and systematic data on regional level.

Statistical sources of data for this study include:

- National Statistics Bureau (NSB), China Statistics Yearbook (1987 to 2007). Location: China Statistical Yearbook Press, Beijing, People's Republic of China (in Chinese).
- Department of Comprehensive Statistics, NSB. Comprehensive Statistical Data and Materials on 50 Years of New China. Location: China Statistics Press, Beijing, People's Republic of China (in Chinese).
- Ministry of Information Industry (MII). Statistics Yearbook of Telecommunications in China. Location: China Statistical Yearbook Press, Beijing, People's Republic of China (in Chinese).
- China Transportation and Communications Society. Yearbook of Transportation and Communications in China. Location: Yearbook House of Transportation and Communications in China, Beijing, People's Republic of China (in Chinese).
- World Bank. World Development Indicators. Location: Washington D.C., the United States.

In the end, discussion on the issue of data quality in the context of regional economic development analysis in China. The quality of data in quantitative analyses draws more attention of researchers in studies on China than those on developed economies. To the author's best knowledge, the series of statistical yearbooks released by the National Bureau

of Statistics, People of Republic of China are the most authoritative and consistent source of data. Furthermore, this study recognizes the possible bias in data collection and presentation in the statistical yearbooks. For example, the enormous regional migration of labor, especially workers in the manufacturing sector, may challenge statistics on employment data reported by different provinces. The regional GDP may be biased due to the difficulty of accounting for the output of the dynamic private sector. Other issues may exist such as the appropriateness of measuring human capital with the World Bank approach that is used by Yu (2001) and Ding, Haynes, and Liu (2008). However, given the comparability and consistency of the data within the panel dataset, the author argues that the data quality issue may not be that significant to lead to misleading regression results.

Chapter 5 Empirical Analysis of the Relationship between Regional Economic Growth and Telecommunications Infrastructure in China

This study examines the empirical relationship between regional economic growth performance and availability of telecommunications infrastructure across all regions in mainland China. Specifically, regression analysis is conducted on a panel dataset comprising a series of socio-economic variables, including telecommunications infrastructure variable, with data from 29 Chinese provinces, municipalities, and autonomous cities during the time period of 1986 to 2006. This chapter is organized as follows: section 1 presents the calculation results of the regional economic growth rates of per capita GDP (decomposed with the modified shift-share method developed by Haynes & Dinc in their 1997 study) for selected years; section 2 gives model specifications for the regression analyses on the panel dataset; discussion of the regression analyses results follows in section 3, and section 4 concludes this chapter.

5.1 Contribution of Capital Factors to Regional Economic Growth

Prior studies in the existing literature with a focus on examining the contribution of capital factors, such as the key variable in this study telecommunications infrastructure, tend

to probe economic performance of regions with per capita GDP (see studies reviewed in Chapter 3). Introduction of the shift-share framework and its latter development (e.g., Haynes & Dinc, 1997) makes it possible to decompose a region's growth into two parts: growth from labor, and growth from capital factors. The methodological overview discussion in Chapter 4 illustrates the theoretical basis and model specifications of such decomposition. It is reasonable to foresee that the inherent limitation of the shift-share framework (see relevant discussions on shift-share analytical framework in Chapter 4) may result in insufficient accuracy in isolating contribution of all kinds of capital factors of regions from those of labor factor. However, the context of this study is on a large developing country China which is widely recognized as benefiting mostly from its cheap labor. Therefore, such decomposition, although not as satisfactory as some researchers may desire, is an important attempt in reaching a deeper level of understanding of China's regional economic performance in terms of appreciating the roles of labor and capital. Further development of the shift-share framework or innovation of other decomposition methodologies may improve the results for this study.

As presented in Chapter 4, measurement of regional economic growth in this study relies on growth rates of per capita GDP. The target of adopting shift-share analysis in this study is to differentiate regional growth due to labor factor from that due to capital factors. Such manipulation of the original regional economic growth data is expected to be able to provide a better measurement on the role of capital factors such as telecommunications infrastructure in regional economic dynamics. As illustrated in the rest of this chapter, the isolated part of regional economic growth is taken as the dependent variable in the regression

analysis, and the regression result is compared against that from regression with total regional growth as the dependent variable. *Table 5-1* displays the calculation results of the total regional economic growth from capital factors as well as that of the regional share (*i.e.*, the *LS* share) growth from capital factors for three selected years: 1986, 1995, and 2006.

Table 5-1 Regional Growth from Capital Factors (%)

Region	Total Growth from Capital Factors			Regional Share of Growth from Capital Factors		
	1986	1995	2006	1986	1995	2006
<i>Ningxia</i>	8.40	10.76	-6.02	7.15	8.58	-6.20
<i>Anhui</i>	7.02	6.97	-5.95	5.78	4.79	-6.14
<i>Zhejiang</i>	6.87	-1.59	21.08	5.63	-3.78	20.90
<i>Tianjin</i>	6.27	-1.52	-3.17	5.02	-3.71	-3.36
<i>Henan</i>	5.78	5.47	0.79	4.54	3.28	0.60
<i>Xinjiang</i>	5.16	-2.37	-3.34	3.92	-4.55	-3.53
<i>Hubei</i>	4.93	3.11	12.98	3.69	0.93	12.79
<i>Heilongj</i>	3.90	5.89	0.25	2.66	3.71	0.06
<i>Yunnan</i>	3.73	-0.50	4.66	2.49	-2.69	4.47
<i>Shaanxi</i>	2.76	-6.60	1.15	1.51	-8.79	0.97
<i>Sichuan</i>	2.66	-2.27	4.63	1.42	-4.46	4.44
<i>Liaoning</i>	1.92	-1.42	-3.64	0.68	-3.60	-3.83
<i>Guangxi</i>	1.79	-3.17	-2.44	0.55	-5.36	-2.62
<i>Neimenggu</i>	1.23	0.46	-3.05	-0.01	-1.73	-3.24
<i>Qinghai</i>	0.97	3.37	0.65	-0.27	1.18	0.46
<i>Gansu</i>	0.27	-33.04	-4.25	-0.97	-35.23	-4.43
<i>Jiangsu</i>	0.11	0.17	10.70	-1.13	-2.02	10.52
<i>Guizhou</i>	0.05	-4.88	-3.68	-1.20	-7.07	-3.87
<i>Shanghai</i>	-0.06	-9.22	-8.21	-1.30	-11.41	-8.39
<i>Hunan</i>	-0.70	7.13	-1.42	-1.94	4.95	-1.61
<i>Guangdong</i>	-0.86	-5.62	5.33	-2.10	-7.80	5.14
<i>Jilin</i>	-0.99	4.63	-3.99	-2.23	2.45	-4.18
<i>Beijing</i>	-1.01	1.27	-1.30	-2.25	-0.92	-1.48
<i>Shandong</i>	-1.01	10.77	-4.46	-2.25	8.58	-4.65
<i>Jiangxi</i>	-1.18	9.36	0.19	-2.42	7.17	0.00
<i>Fujian</i>	-1.31	0.39	9.02	-2.56	-1.80	8.83
<i>Shanxi</i>	-1.54	0.67	-1.51	-2.78	-1.52	-1.70
<i>Hebei</i>	-2.67	11.53	-2.13	-3.91	9.35	-2.32
<i>Hainan</i>	-4.05	-6.82	-4.87	-5.29	-9.00	-5.05

Note: the date is sorted by Total Growth from Capital Factors in 1986.

Source: Calculation by author based on China Statistics Yearbook 1987, 1996, and 2007.

A brief review of the above table indicates a significantly different growth performance pattern for most regions of China from that of the overall regional economic growth as listed in Chapter 2. Instead of the almost uniform positive signs the overall economic growth rates for all regions, the growth rates from capital factors do not exhibit similar characteristics. The existence of frequent negative signs for all the three selected years 1986, 1995, and 2006 imply that capital factors may not make equivalent contributions to regional economic performance as regional labor input. The simple average growth rates from capital factors for all regions are 1.67% for 1986, 0.1% for 1995, and 0.28% for 2006; on the other hand, after removing the national and regional industrial mix shares, the simple average growth rates are 0.43% for 1986, -2.09% for 1995, and 0.09% for 2006. Moreover, some regions show dramatic increases or fluctuations across the three examined years. For example, the total growth from capital factors of Fujian province saw an increase from -1.31% in 1986 to 0.39% in 1995 and 9.02% in 2006, while the same rate for Zhejiang province decreased from 6.87% in 1986 to -1.59% in 1995, and increased again to 21.08% in 2006. It seems to be plausible to conclude that capital factors have positive contribution to economic growth (except the -2.09% which may be due to the limitation of the methodology). Furthermore, it is simultaneously difficult to detect an obvious pattern of the growth rates from capital factors in *Table 5-1* that can categorize capital factors' contribution for developed and less developed regions.

Figures 5-1 and 5-2 demonstrate the growth paths of six selected regions in China: three developed regions Guangdong, Zhejiang, and Jiangsu, and three less developed regions Gansu, Ningxia, and Qinghai. The two figures look very much alike, revealing a highly

consistent growth pattern between the total growth from capital factors and regional share growth from capital factors, regardless of the development level of regions in China. For developed regions, capital factors do not appear to make significantly more contribution to regional economic performance than they do on less developed regions. This may support the idea that labor factor plays the most important role in China's regional economic dynamics and regional growth differentiation.

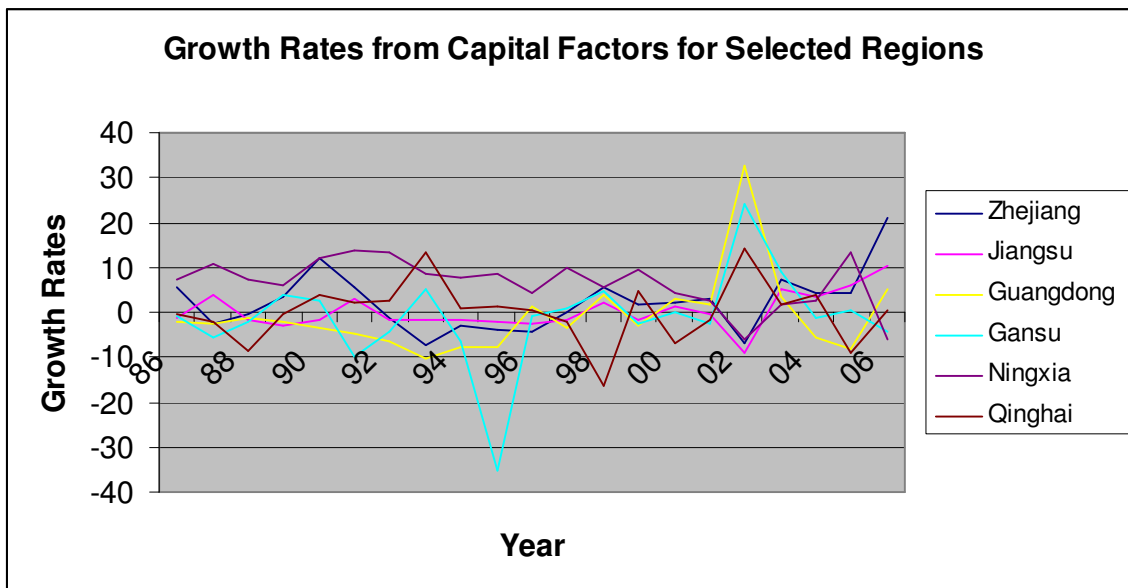


Figure 5-1

Source: Calculation by author based on China Statistics Yearbook 1987, 1996, and 2007.

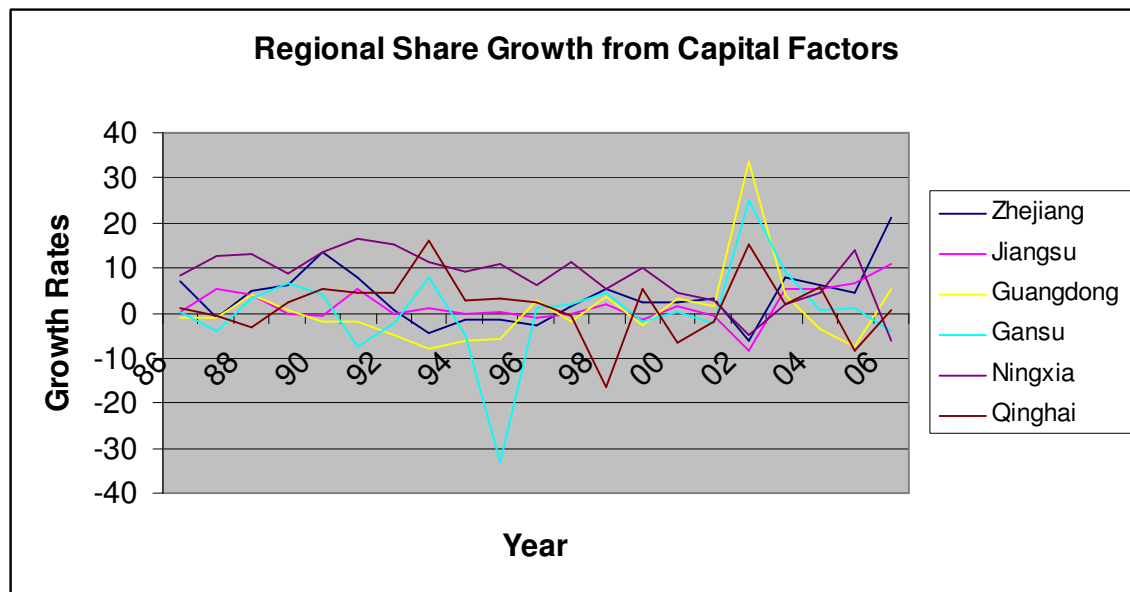


Figure 5-2

Source: Calculation by author based on China Statistics Yearbook 1987, 1996, and 2007.

A closer look at the spatial distribution of the regional growth from capital factors can provide more insights on the above discussion. Controlling contribution of national share and industrial mix share to regional growth, *Figures 5-3, 5-4, and 5-5* show the contribution of capital factors to regional economic growth for Chinese regions from a spatial perspective in three different years 1986, 1995, and 2006. In 1986, interior regions do not exhibit obvious disadvantageous position compared to coastal regions in terms of benefits from capital factors. The 1995 map seems to witness a shift from west to east in enjoying growth from capital factors with a simple comparison against the 1986 map. Coastal regions seem to benefit more in the 2006 map than they do in either the 1986 map or the 1995 map. Generally speaking, the three figures do not present as clear a spatial distribution pattern as they do on regional economic output (see Chapter 2), *i.e.*, the coastal regions do not have obvious advantages in benefiting from capital factors in their regional economic growth.

Regional Growth from Capital Factors (1986)

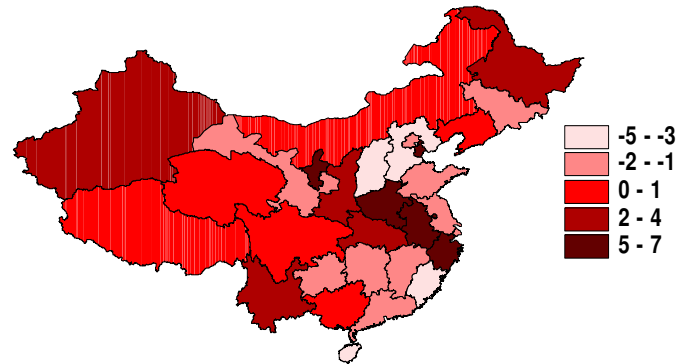


Figure 5-3

Source: Map is constructed based on calculations by author.

Regional Growth from Capital Factors (1995)

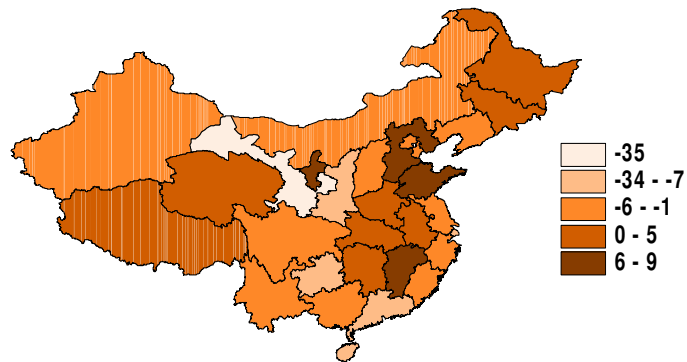


Figure 5-4

Source: Map is constructed based on calculations by author.

Regional Growth from Capital Factors (2006)

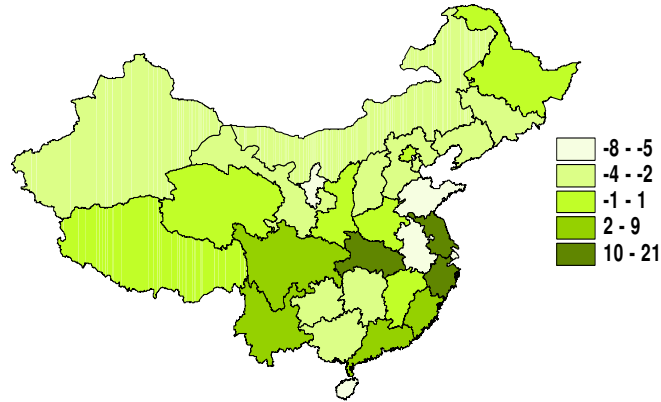


Figure 5-5

Source: Map is constructed based on calculations by author.

It appears reasonable to conclude that capital factors boost Chinese regional economic growth in the examined time period (1986-2006) after removing contributions of labor from the 29 regions' per capita GDP growth. The fluctuation of growth paths of both economically developed and less developed regions is not perfectly consistent with the continuous upward trends of overall regional economic growth rates for the regions in China, indicating the positive effects of capital factors as well as the widely accepted significance of labor input in China's regional economic development process during the past two decades. Therefore, contributions of capital factors to regional economic growth can be isolated from those of labor factor in the context of China with the modified shift-share analytical framework (developed by Haynes & Dinc, 1997). Furthermore, such capital factors seem to have positive impacts on China's regional economic development in the time period from 1986-2006.

The next section addresses the relationship of isolated regional economic growth from capital factors and the socio-economic variables (including telecommunications infrastructure) with a regression analysis on the panel dataset described in Chapter 4. For comparison purpose, regression is performed on the overall regional economic growth (from both capital and labor factors) and the corresponding independent variables.

5.2 Telecommunication Infrastructure and Regional Economic Growth

The decomposed regional economic growth from capital factors is used as the dependent variable in the model specifications presented in the latter discussion. As described in Chapter 4, the selected independent socio-economic variables include fixed asset investment, foreign direct investment, population growth, employment, human capital, urbanization level, output of state-owned enterprises, transportation infrastructure, and the key variable in this study telecommunications infrastructure. To highlight the contribution of this study to the existing growth-and-infrastructure literature, total regional economic growth from both capital and labor factors is taken as the dependent variable in a different model specification in order that a comparison of the results can be conducted. It is noteworthy that to follow the prior studies on the role of telecommunications infrastructure in regional economic dynamics, the spillover effects of telecommunications infrastructure are not included in this section. Instead, the next section 5.3 focuses on this issue in particular.

The Conditional Convergence Framework

The models specified in this study follow the traditional conditional convergence framework (see Chapter 4) that is developed by Barro (1991) and Islam (1995). The rationale

of adopting this methodology lies in its ability to allow investigation of a series of regional economic development determinants. A series of initial conditioning socio-economic variables (including telecommunications infrastructure) are included in the equation developed along the guidelines of the conditional convergence framework. Specifically, the equation takes the form below:

$$GRTH_{it} = \alpha_0 + \beta_0 GRTH_{i,t-1} + \beta_1 Ln(GDP)_{i,t-1} + \beta_2 INV_{i,t} + \beta_3 FDI_{i,t} + \beta_4 POP_{i,t} + \beta_5 EMP_{i,t} + \beta_6 HC_{i,t} + \beta_7 URBAN_{i,t} + \beta_8 SOE_{i,t} + \beta_9 TRANS_{i,t} + \beta_{10} TEL_{i,t} + \gamma_i + \eta_t + \varepsilon_{i,t} \quad (5.1)$$

where i and t represent regions and years in the panel dataset; γ_i and η_t denote region- and year-specific parameters; $GRTH$ may be either the total regional economic growth or the regional economic growth from capital factors only. All the rest independent variables (*i.e.*, $Ln(GDP)$, INV , FDI , POP , EMP , HC , $URBAN$, SOE , $TRANS$, and TEL) have detailed description on their respective measurement in Chapter 4.

Model Specifications

Following the traditional treatments on the socio-economic variables under the conditional convergence framework, this study conducts an initial screening test on the significance levels of all possible independent variables contained in *Equation 5.1* (see other studies such as Ding, 2005). The common treatment on those insignificant variables is to remove them from the final model specification. *Table 5-2* shows the screening test results for the two regression analyses with total regional growth rates and growth rates from capital factors, respectively.

Table 5-2 Screening of Variables for Modeling

Dependent Variable	<i>GRTH</i>		<i>GRTH</i> from Capital Factors		Region Share <i>GRTH</i> from Capital Factors	
VARIABLES	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
<i>INTERCEPT</i>	10.65**	0.014	6.93	0.527	5.46	0.619
<i>GRTH_{t-1}</i>	0.36***	0.000	-0.17**	0.045	-0.17**	0.045
<i>Ln(GDP)_{t-1}</i>	-0.67	0.246	-0.83	0.558	-0.83	0.558
<i>HC</i>	-0.38	0.127	-0.72	0.255	-0.72	0.255
<i>INV</i>	3.13**	0.023	6.97**	0.038	6.97**	0.038
<i>POP</i>	-0.81***	0.000	-1.90***	0.000	-1.90***	0.000
<i>URBAN</i>	0.03	0.129	-0.11**	0.016	-0.11**	0.016
<i>FDI</i>	0.08***	0.000	-0.01**	0.016	-0.01	0.766
<i>TRANS</i>	0.74	0.358	1.24	0.506	1.24	0.506
<i>SOE</i>	-0.09	0.408	0.37	0.175	0.37	0.175
<i>EMPLOY</i>	0.01	0.709	0.15**	0.011	0.15**	0.011
<i>TELE</i>	-0.02*	0.098	0.17***	0.000	0.17***	0.000

Notes: *** significant at 1% level; ** significant at 5% level; * significant at 10% level.

Source: Author's calculation based on data from various sources.

All the three models in *Table 5-2* are derived from *Equation 5.1*, with the only difference being in the specification of the dependent variables (*i.e.*, overall regional economic growth, regional economic growth from capital factors only, and regional share growth from capital factors). As shown in *Table 5-2*, the screening process for the three models reveals both commonality and discrepancy among the results. For total regional growth, lagged GDP per capita, human capital, urbanization, transportation, state-owned enterprise output, and employment variables are not significant. It is noteworthy that the lagged GDP per capita variable is not significant for all the three models while all three models show a negative sign for its coefficient. This may be due to multicollinearity, low data quality or other issues such as heteroscedasticity or spatial autocorrelation for the panel dataset. To follow the guidelines of conditional convergence framework, the lagged GDP per capita is temporarily retained in the model specifications for further analysis until further confirmed by the heteroscedasticity or spatial autocorrelation tests.

As for regional growth from capital factors only and regional share growth from capital factors, no significant difference exists for their results. Besides lagged GDP per capita, human capital, transportation, and state-owned-enterprise output are not significant for both models (except that foreign direct investment is significant for regional growth from capital factors only). Furthermore, the correlation between these two dependent variables is 0.98, indicating the consistent variation pattern for the two decomposed growth rates. Therefore, this study adopts regional growth from capital factors only as the dependent variable for simplicity purpose in further discussion.

The insignificant variables in *Table 5-2* are dropped (except the lagged GDP per capita variable) in the final models. *Equation 5.2* and *Equation 5.3* specify the two models specifically (for *Equation 5.3*, GRTHK represents regional growth from capital factors only).

$$GRTH_{i,t} = \alpha_0 + \beta_0 GRTH_{i,t-1} + \beta_1 Ln(GDP)_{i,t-1} + \beta_2 INV_{i,t} + \beta_3 FDI_{i,t} + \beta_4 POP_{i,t} + \beta_5 TEL_{i,t} + \gamma_i + \eta_t + \varepsilon_{i,t} \quad (5.2)$$

$$GRTHK_{i,t} = \alpha_0 + \beta_0 GRTHK_{i,t-1} + \beta_1 Ln(GDP)_{i,t-1} + \beta_2 INV_{i,t} + \beta_3 FDI_{i,t} + \beta_4 POP_{i,t} + \beta_5 EMP_{i,t} + \beta_6 URBAN_{i,t} + \beta_7 TEL_{i,t} + \gamma_i + \eta_t + \varepsilon_{i,t} \quad (5.3)$$

It is important to begin the model specification discussion with some clarification and enunciation of the model application. Both *Equation 5.2* and *Equation 5.3* are established upon a panel dataset. This dynamic characteristic triggers an issue of fixed or random effects on individual observations. Random effects assume non-correlation between the individual observations and the exogenous variables in the model. It is necessary to test the validity of the random effects assumption in this study due to the built-in correlation between these

individual observations and the exogenous variables in this specification. *Table 5-3* presents the Hausman test results for both models to see if there is significant difference between the coefficients of the fixed and random effects models. As illustrated in the econometrics literature, fixed effects model can remove some of the unmodeled heterogeneity from the error term. As is shown in *Table 5-3*, the Hausman statistic is significant for both models, no matter which dependent variable is used: *GRTH* or *GRTHK*. This indicates that the fixed effects model is preferred over the random effect model. Consequently the estimation based upon these two models should be a fixed effect approach.

Table 5-3 Hausman Test

<i>Dependent Variable</i>		<i>GRTH</i>			<i>GRTHK</i>		
Variables	(b) fixed	(B) random	S.E.	(b) fixed	(B) random	S.E.	
<i>GRTHt-1</i>	0.3602	0.3609	0.0061	-0.1693	-0.0610	0.0504	
<i>Ln(GDP)t-1</i>	-0.5727	-0.6723	0.1460	-0.8264	-1.4007	0.9285	
<i>HC</i>	-0.0578	-0.3781	0.1004	-0.7178	-2.2845	0.4174	
<i>INV</i>	4.0718	3.1317	0.3515	6.9734	-1.3702	1.6434	
<i>POP</i>	-0.8400	-0.8057	0.0001	-1.9009	-1.5184	0.0828	
<i>URBAN</i>	0.0052	0.0270	0.0089	-0.1135	0.0098	0.0331	
<i>FDI</i>	4.0718	3.1317	0.3515	-0.0112	-0.0314	0.0099	
<i>TRANS</i>	0.7444	0.7356	0.0001	1.2360	0.8488	0.4876	
<i>SOE</i>	-0.1385	-0.0911	0.0381	0.3725	0.3045	0.2156	
<i>EMPLOY</i>	0.0164	0.0091	0.0001	0.1469	0.0889	0.0161	
<i>TELE</i>	-0.0074	-0.0177	0.0027	0.1703	0.1201	0.0138	
<i>Prob>chi2</i>		0.0745			0.0166		
Result	Significant at 10% level.			Significant at 5% level.			

Source: Author's calculation based on data from various sources.

Prior to the detailed discussion on the regression results from the two models with either *GRTH* or *GRTHK* as dependent variables, another concern on the inherent characteristics of autocorrelation for a panel dataset, besides the fixed versus random effects issue, should be addressed. The construction of the panel dataset used in this study is based on 29 regions within the same country and 21 consecutive years. It is reasonable to predict

the existence of temporal and spatial autocorrelation. Ding (2005) argues that the temporal autocorrelation issue is negligible due to the continuous upward trend for the economic growth of most Chinese regions. This study adopts Ding's rationale and ignores the business cycle effects in the analysis (see detailed discussion in Chapter 2 on Chinese economic development cycle from 1986 to 2006). Spatial autocorrelation is inevitable in that the neighboring regions (especially the first-order neighboring ones) tend to have closer relationships and economic endowments in terms of the input-output analysis of their economic development. Drukker (2003) proposes a simulation with the statistical software package Stata 9.0 to test for the significance of autocorrelation in panel datasets. This study uses this method and performs a corresponding test of the spatial or temporal autocorrelation issue on the dataset used herein. Besides panel dataset autocorrelation, it is necessary to consider the heteroscedasticity issue in this analysis. A Likelihood-ratio test can be conducted with Stata 10.0 to test the existence of heteroscedasticity. *Table 5-4* lists the results of the Likelihood-ratio test and the Drukker test.

Table 5-4 Likelihood-ratio Test and Drukker Test

<i>Likelihood-ratio Test</i>	<i>Drukker Test (2003)</i>
Cross-sectional time-series FGLS regression	Woodbridge test* for spatial or temporal autocorrelation in panel data
Coefficients: Generalized Least Squares	Null Hypothesis: No first-order autocorrelation
Panels: Heteroskedastic	F(1, 20)=6.452
Assumption: . nested in hetero	Prob>F=0.0195
LR Chi2(20)=335.54	
Prob>Chi2=0.0000	
Test Result: Significant at 1% level.	Test Result: Significant at 5% level.

*Drukker (2003) develops his test on panel data autocorrelation based on the Woodbridge test (see Woodbridge, 2002).

Source: Author's calculation based on data from various sources.

Table 5-4 confirms both heteroscedasticity and autocorrelation issues in the dataset used in this study. The p value of the Likelihood-ratio Test is significant at 1%, whereas Drukker Test shows a p value of 0.0195—significant at 5%. To control for heteroscedasticity, this study cites the method developed by Engle (2001). Engle (2001) solves this problem using the autoregressive conditional heteroscedasticity (ARCH) approach. This approach aims at controlling heteroscedasticity in multi-variate regression models. With the statistical software package STATA 10., it is possible to test the panel dataset used in this study with the ARCH method. *Table 5-5* shows the results from ARCH method.

Table 5-5 Regression Results from ARCH Method

Dependent Variable:	<i>GRTH</i>		<i>GRTH</i> from Capital Factors	
VARIABLES	Coefficient	P-value	Coefficient	P-value
<i>INTERCEPT</i>	13.17***	0.000	21.36***	0.009
<i>GRTH_{t-1}</i>	0.28***	0.000	-0.05	0.505
<i>Ln(GDP)_{t-1}</i>	0.25	0.732	-1.27	0.275
<i>HC</i>	-1.33***	0.000	-2.31	0.000
<i>INV</i>	4.65***	0.006	-1.97	0.523
<i>POP</i>	-0.91***	0.000	-1.90***	0.000
<i>URBAN</i>	0.05**	0.020	-0.01	0.742
<i>FDI</i>	0.12***	0.000	-0.04	0.435
<i>TRANS</i>	0.28	0.816	0.72	0.685
<i>SOE</i>	0.21	0.108	0.31	0.227
<i>EMPLOY</i>	0.02	0.692	0.09	0.134
<i>TELE</i>	-0.04*	0.000	0.12***	0.000

Note: *** significant at 1% level; ** significant at 5% level; * significant at 10% level.
Source: Author's calculation based on data from various sources.

Comparison of *Table 5-5* and *Table 5-2* indicates that for the *GRTH* model, no significant difference exists except for the human capital variable (significant in *Table 5-5* while insignificant in *Table 5-2*). Without further evidence supporting emphasis on the heteroscedasticity, this study ignores this issue and follows the other studies on this topic (e.g., Ding, 2005; Ding et al., 2008).

The spatial econometrics literature proposes various methods to treat the spatial autocorrelation issue in cross-section or panel datasets (e.g., Anselin & Florax, 1995). The major idea in this literature is to approximate observations of a region with the weighted average of its neighboring regions' observations. The weights are usually set as geographic distance between regions or dummy values based on contiguity. This study adopts the contiguity dummy variable method to obtain the average values for all the variables in the *GRTH* and *GRTHK* models. Specifically, for each of the 29 regions in China, the observations for all the modeled variables will be averaged for observations of all its first-order neighboring regions (including the region itself). The author argues that such first-order neighbor average treatment can at least mitigate, if not eradicate, the spatial autocorrelation nuisance in the regression analysis.

Screening regressions are performed again for both the *GRTH* and *GRTHK* models, using the dataset with each variable adjusted by the first-order neighbor averaging treatments. The Hausman test statistic is not significant (Probability>Chi2=0.2945) for the *GRTH* model, whereas it is significant for the *GRTHK* model (Probability>Chi2=0.000). Thus, the screening regressions will be based on the random-effects for the *GRTH* model and fixed-effects for the *GRTHK* model (see *Table 5-6*).

Table 5-6 Screening of Variables for Modeling

Dependent Variable	<i>GRTH</i>		<i>GRTHK</i>	
VARIABLES	Coefficient	P-value	Coefficient	P-value
<i>INTERCEPT</i>	17.12***	0.001	30.01	0.003
<i>GRTH_{t-1}/GRTHK_{t-1}</i>	0.46***	0.000	-0.21***	0.000
<i>Ln(GDP)_{t-1}</i>	-1.40**	0.039	-3.97***	0.005
<i>HC</i>	-0.50**	0.038	0.30	0.503
<i>INV</i>	3.17**	0.017	6.93***	0.009
<i>POP</i>	-0.92***	0.000	-1.94***	0.000
<i>URBAN</i>	0.07***	0.000	-0.09**	0.028
<i>FDI</i>	0.09***	0.000	0.01	0.674
<i>TRANS</i>	1.41*	0.078	6.29***	0.000
<i>SOE</i>	-0.17	0.276	0.52	0.160
<i>EMPLOY</i>	-0.03	0.389	-	-
<i>TELE</i>	-0.03***	0.002	0.12***	0.000

Source: Author's calculation based on data from various sources.

Note: For *GRTHK* model, the dependent variable is regional growth from capital factors only, and the employment variable is removed from the regression. *** significant at 1% level; ** significant at 5% level; * significant at 10% level.

The most significant improvement of the results shown in *Table 5-6* from those shown in *Table 5-1* is in terms of the lagged GDP per capita variable. In *Table 5-6*, the lagged GDP per capita variable is significant at 5% and 1% levels for the *GRTH* and *GRTHK* models while exhibiting negative signs for both models. This finding confirms the validity of conditional convergence framework in the context of China's regional economic development. Moreover, the key variable telecommunications infrastructure is significant at 1% level for both models, while the sign is negative for *GRTH* model and positive for *GRTHK* model. Further discussion on this variable follows in the discussion on empirical results from the final analyses.

With consideration of fixed-effects versus random-effects tests, heteroscedasticity, and spatial autocorrelation, the models used in this study can be finalized as *Equation 5.4* and *Equation 5.5* (see below).

For the *GRTH* model,

$$GRTH_{it} = \alpha_0 + \beta_0 GRTH_{i,t-1} + \beta_1 Ln(GDP)_{i,t-1} + \beta_2 INV_{it} + \beta_3 FDI_{it} + \beta_4 POP_{it} + \beta_5 HC_{it} + \beta_6 URBAN_{it} + \beta_7 TRANS_{it} + \beta_8 TEL_{it} + \gamma_i + \eta_t + \varepsilon_{it} \quad (5.4)$$

For the GRTHK model,

$$GRTHK_{it} = \alpha_0 + \beta_0 GRTHK_{i,t-1} + \beta_1 Ln(GDP)_{i,t-1} + \beta_2 INV_{it} + \beta_4 POP_{it} + \beta_6 URBAN_{it} + \beta_7 TRANS_{it} + \beta_8 TEL_{it} + \gamma_i + \eta_t + \varepsilon_{it} \quad (5.5)$$

Discussion of Regression Results

The regression results for *GRTH* and *GRTHK* models are listed in Table 5-7 and Table 5-8, respectively. Ding (2005) resolves the causality direction problem between regional economic growth and telecommunications infrastructure by including a lagged telecom variable in the regression. This study follows this idea and uses the one-year lagged values in the panel dataset. Similar to the study of Ding (2005), the diminishing returns of telecommunications infrastructure are also examined in this study for both *GRTH* and *GRTHK* models.

**Table 5-7 Determinants of Regional Economic Growth, 1986-2006
(GRTH Model)**

Dependent Variable	Model A		Model B		Model C	
VARIABLES	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
INTERCEPT	15.38***	0.001	15.56***	0.002	17.67***	0.000
GRTH _{t-1}	0.47***	0.000	0.47***	0.000	0.48***	0.000
Ln(GDP) _{t-1}	-1.41**	0.037	-1.51**	0.032	-1.81***	0.008
HC	-0.43**	0.040	-0.32	0.147	-0.32	0.149
INV	2.78**	0.032	2.84**	0.036	3.09**	0.021
POP	-0.91***	0.000	-0.89***	0.000	-0.90***	0.000
URBAN	0.07***	0.000	0.07***	0.001	0.07***	0.001
FDI	0.10***	0.000	0.09***	0.000	0.09***	0.000
TRANS	0.93*	0.08	1.04*	0.052	1.16**	0.033
TELE	-0.03***	0.002	-	-	-	-
TELE _{t-1}	-	-	-0.04***	0.005	-	-
TELE ²	-	-	-	-	-0.0001***	0.018
Adj. R Square	0.5444		0.5462		0.5444	
Hausman Test	Prob>Chi2=0.1229		Prob>Chi2=0.0045		Prob>Chi2=0.0000	
Fixed-/Random-effects	Random-effects		Fixed-effects		Fixed-effects	
Implied λ	1.41 %		-		-	
Half-life Years	50		-		-	
Durbin-Watson stat	1.460724		-		-	

Source: Author's calculation based on data from various sources.

Note: *** significant at 1% level; ** significant at 5% level; * significant at 10% level.

**Table 5-8 Determinants of Regional Economic Growth, 1986-2006
(GRTHK Model)**

Dependent Variable	Model E		Model F		Model G	
VARIABLES	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
INTERCEPT	31.63***	0.002	29.35***	0.003	19.56**	0.044
GRTH _{t-1}	0.21***	0.000	0.21***	0.000	0.22***	0.000
Ln(GDP) _{t-1}	-3.98***	0.004	-3.65***	0.008	-2.27**	0.088
INV	7.21***	0.006	7.26***	0.006	5.87**	0.027
POP	-1.96***	0.000	-1.98***	0.000	-1.89***	0.000
URBAN	-0.08**	0.035	-0.08**	0.032	-0.08**	0.034
TRANS	5.99***	0.000	6.02***	0.000	5.78***	0.000
TELE	0.13***	0.000	-	-	-	-
TELE _{t-1}	-	-	0.13***	0.000	-	-
TELE ²	-	-	-	-	0.0005***	0.000
Adj. R Square	0.2707		0.2650		0.2488	
Hausman Test	Prob>Chi2=0.000		Prob>Chi2=0.0000		Prob>Chi2=0.0075	
Fixed-/Random-effects	Fixed-effects		Fixed-effects		Fixed-effects	
Implied λ	3.98 %		-		-	
Half-life Years	18		-		-	
Durbin-Watson stat	1.893866					

Source: Author's calculation based on data from various sources.

Note: *** significant at 1% level; ** significant at 5% level; * significant at 10% level.

For the GRTH model (see Table 5-7), all model specifications A, B, and C show that the independent variables can explain about 54% of the variation in the dependent variable.

Similarly, all three model specifications show a significant (at 1% level) lagged GDP per capita variable with a negative sign, indicating that conditional economic convergence has been occurring during the 1986 to 2006 period across China's regions. In model A, the key variable telecommunications infrastructure is significant at the 1% level with a negative sign. This seems to be inconsistent with the findings of other studies (*e.g.*, Ding, 2005; Ding et al., 2008). The negative sign may imply that investment congestion exists in the telecommunications sector in China. Fisher and Turnosky (1998) find in their study on the interaction of public capital investment and private capital formation that public good is treated as a durable capital good subject to congestion. In other words, the authors contend that over-investment from the governments may squeeze out private investment, causing congestion of investments in a sector. The lagged telecommunications infrastructure is also significant with a negative sign, confirming that availability of telecommunications infrastructure does have significant impacts on regional economic growth. Furthermore, the foreign direct investment, urbanization, transportation, and fixed asset investment all are significant and positive, which is consistent with findings in the relevant literature. The negative signs for both human capital and population growth may be explained by the large population in China, implying the low productivity from the labor input. Finally, the half-life convergence period is about 50 years, and it may take China's regions 100 years to achieve regional economic growth convergence. Furthermore, the Durbin-Watson statistic for Model A has a value of 1.460724, indicating that there seems not to be positive temporal autocorrelation in this model.

On the other hand, *Table 5-8* displays the regression results of the *GRTHK* model. Similar to *Table 5-7*, conditional convergence is affirmed in all the model specifications E, F, and G by exhibiting a significant (at 1% level) and negative lagged GDP per capita variable. The low explanatory power of the three models (24%-27%) may be due to the limitation of shift-share analytical framework in decomposing regional economic growth—the dependent variable. However, this does not affect the examination of the relationships between the growth from capital factors and various independent socio-economic variables. The most important improvement in model E lies in the positive sign of the telecommunications infrastructure. Significant at 1% level, telecommunications makes positive contribution to regional growth from capital factors only. As a fast-developing and important capital input in regional development, telecommunications infrastructure has been boosting regional economic development during the examined period. The significant positive lagged telecom variable proves the positive contribution made by telecommunications infrastructure (model F). The squared telecom variable has a negligible coefficient 0.0005 in model G (-0.0001 for model C), implying there seems not to be diminishing returns to telecommunications investment yet. This further supports the argument that telecommunications infrastructure has positive impacts on regional economic growth from capital factors only. Therefore, isolation of regional economic growth from capital factors justifies investment in telecommunications infrastructure in the context of China's regional development, *i.e.*, despite the fact that telecom investment seems to have a negative relationship with regional growth, it does contribute to regional economic prosperity among all the capital factors. Furthermore, the other independent variables fixed asset investment and transportation

infrastructure both are significant and positive, establishing that both capital inputs have been contributing to regional economic development. Similar to models A-C, population growth and urbanization are insignificant and negative, re-affirming the negative effects of a large population on regional economic dynamism. At last, the half-life convergence period of 18 years seems to suggest that it only takes 36 years for China's regions to achieve convergence without consideration of the labor endowment. Moreover, Model E shows a Durbin-Watson statistic of 1.893866, removing any further concern of the temporal autocorrelation in this model.

Robustness of the Regression Results

Several issues remain on the robustness of the regression results from a panel dataset, including: causality direction between the dependent variable regional economic growth and the key variable telecommunications infrastructure, multicollinearity among the independent variables, heteroscedasticity, spatial autocorrelation, and temporal autocorrelation.

Besides the significance and sign of the telecommunications infrastructure variable, it is also important to verify the causality direction between this variable and the dependent variable. In other words, further test is required to test the hypothesis that telecommunications infrastructure causes development of regional economies in China. This study uses the Pairwise Granger Causality Test with 3 lags to detect the causality direction. Selection of 3 lags is due to the short sample period of 21 years and the rapid growth of the telecommunications sector. The author argues a lag of 3 years may be appropriate to predict future values between the two variables of interest. *Table 5-9* shows the Pairwise Granger Causality Test results.

Table 5-9 Granger Causality Tests

Pairwise Granger Causality Tests			
Sample: 1986-2006			
Lags: 3			
Null Hypothesis:	Obs	F-statistic	Probability
TELE does not Granger Cause GROWTH	522	2.92468	0.03336
GROWTH does not Granger Cause TELE	522	0.67852	0.56548

Source: Author's calculation based on data from various sources.

From *Table 5-9*, the null hypothesis that *TELE* does not Granger Cause *GROWTH* is rejected by the probability of 0.03336 at 0.05 level, whereas the hypothesis that *GROWTH* does not Granger Cause *TELE* cannot be rejected with a probability of 0.56548. Therefore, telecommunications infrastructure significantly causes development of regional economies in China, while the rapid regional economic growth does not cause development of the telecommunications sector.

Multicollinearity is an inevitable issue in any multivariate regression analysis. The correlation between independent variables can reduce reliability and robustness of the results in terms of values and signs of coefficients as well as significance of some independent variables. As shown in *Table 5-10*, correlation exists between the key variable telecommunications and all other independent variables except population growth. The lagged GDP per capita shows strong correlation with other independent variables such as urbanization and transportation infrastructure. Besides, there exists strong correlation between urbanization and transportation.

Table 5-10 Correlations Between the Independent Variables

	<i>GRTH_{t-1}</i>	<i>TELE</i>	<i>Ln(GDP)_{t-1}</i>	<i>URBAN</i>	<i>TRANS</i>	<i>POP</i>	<i>INV</i>
<i>GRTH_{t-1}</i>	1.0000						
<i>TELE</i>	-0.2633	1.0000					
<i>Ln(GDP)_{t-1}</i>	-0.0581	0.7797	1.0000				
<i>URBAN</i>	-0.0629	0.6097	0.8279	1.0000			
<i>TRANS</i>	-0.0226	0.6425	0.7050	0.7255	1.0000		
<i>POP</i>	-0.0447	-0.0443	-0.0756	0.0823	0.0480	1.0000	
<i>INV</i>	0.0238	0.4500	0.4861	0.3925	0.2342	-0.0360	1.0000

Source: Author's calculation based on data from various sources.

Treatment of multicollinearity in multivariate regression models is either principal component method or stepwise regression method. The special characteristics of conditional convergence framework is the inclusion of lagged GDP and a series of socio-economic variables which tend to be correlated to each other. Furthermore, it is reasonably predictable that a lagged GDP per capita may be easily correlated to the socio-economic variables. A tradeoff is inevitable between combination of some of the independent variables such as urbanization and transportation infrastructure and retaining more variables in the dataset. The author chooses to leave the seven independent variables in the model specifications to follow the rationale of conditional convergence framework. Furthermore, the Variance Inflation Factor Test (VIF test) of this model shows a mean VIF value of 5.05. The econometrics literature normally treats any VIF value that is less than 10 to be a sign that multicollinearity is not a major issue. Thus, it is justifiable to leave all the seven explanatory variables in the model specifications.

The Durbin-Watson statistic in *Table 5-7* and *5-8* seems to drop temporal autocorrelation as a major issue for this study. The spatial autocorrelation concern is also relieved with adoption of the first order neighboring weight matrix in the dataset. However,

existence of heteroscedasticity (*i.e.*, the Log-likelihood and Drukker tests results in *Table 5-4*) requires further estimation of the regression results with other techniques such as the Generalized Method of Moments (GMM). Caselli et al. (1996) propose the first order GMM estimator, and this estimator is further developed by Bluendell and Bond (1998) in terms of addressing the weak instrument problem, heteroscedasticity, autocorrelation within individual observations, and the endogeneity issue. This study adopts the Panel Generalized Method of Moments method to further estimate the regression equation and compares the results with those of Model A and Model E that are listed in *Table 5-7* and *Table 5-8*. The Panel GMM estimation results are listed in *Table 5-11*.

Table 5-11 Panel GMM Estimation Results

Method: Panel Generalized Method of Moments				
Transformation: First Differences				
Sample (adjusted): 1989-2006				
Periods included: 18				
Cross-sections included: 29				
Total panel (balanced) observations: 522				
Difference specification instrument weighting matrix				
White period standard errors & covariance (d.f. corrected)				
	Dependent Variable <i>GRTH</i>		Dependent Variable <i>GRTHK</i>	
	Coefficient	Prob.	Coefficient	Prob.
<i>GRTH (-1)</i>	0.07	0.2250	0.03	0.4166
<i>GRTH (-2)</i>	0.02	0.7534	-0.02	0.7360
<i>Ln(GDP)_{t-1}</i>	-0.28	0.7774	-3.76**	0.0442
<i>HC</i>	-0.37	0.4471	-1.16	0.3686
<i>INV</i>	7.37***	0.0081	8.44	0.2156
<i>POP</i>	-1.21***	0.0000	-1.83***	0.0000
<i>URBAN</i>	0.02	0.5210	-0.01	0.9172
<i>FDI</i>	0.19***	0.0001	-0.01	0.8656
<i>TRANS</i>	1.90*	0.0814	4.87**	0.0193
<i>TELE</i>	-0.05**	0.0195	0.12***	0.0000

Source: Author's calculation based on data from various sources.

Note: *** significant at 1% level; ** significant at 5% level; * significant at 10% level.

Comparison of the results in Table 5-11 against those in Table 5-7 (Model A) and Table 5-8 (Model E) indicates that no significant differences exist for the key variable telecommunications infrastructure. Telecommunications variable is significant with a negative sign with overall regional growth as dependent variable in both the random-effects regression and Panel GMM estimation, whereas it shows a positive sign and 0.01 significance level under both methods. The other independent variables do not show differences in coefficient signs, and less variables are significant under the Panel GMM estimation method. The lagged GDP per capita variable is not significant in the GRTH model and significant in the GRTHK model under Panel GMM estimation, with a negative sign in both models. Therefore, it seems reasonable to conclude that the heteroscedasticity, autocorrelation, and endogeneity issues are not significant enough to impact the regression results in a significant way. The regression results in *Table 5-8* and *Table 5-9* are robust and can be relied on for conclusions and policy recommendations.

5.3 Spillover Effects of Telecommunications Infrastructure

In section 5.2, the positive relationship between telecommunications infrastructure and regional economic growth has been tested, joining other studies in the existing literature on this topic (*e.g.*, Ding, 2005; Ding et al., 2008). However, the spillover effects of telecommunications infrastructure are not well researched in the context of developing countries such as China. This study contributes to the current literature by testing the existence of spillover effects of telecommunications infrastructure across China's regions.

To test the spillover effects, this study adopts the method in Yilmaz et al.'s study (2002) in which the authors included a first-order neighbor telecommunications infrastructure

variable in their Cobb-Douglas Production Function based test of the spillover effects of the telecom services across the 50 states of the United States. Specifically, the “spillover” variable is the average of the telecom observations for a region’s first-order neighboring regions. *Table 5-12* outlines the regression results for both *GRTH* and *GRTHK* models with the additional spillover variable.

Table 5-12 Determinants of Regional Economic Growth, 1986-2006

Dependent Variable	<i>GRTH</i>		<i>GRTHK</i>	
VARIABLES	Coefficient	P-value	Coefficient	P-value
<i>INTERCEPT</i>	7.74***	0.000	3.93	0.122
<i>GRTH_{t-1}/GRTHK_{t-1}</i>	0.46***	0.032	0.21***	0.000
<i>Ln(GDP)_{t-1}</i>	-0.27	0.176	-3.97	0.480
<i>HC</i>	-0.55	0.205	-	-
<i>INV</i>	2.47*	0.057	6.17***	0.018
<i>POP</i>	-0.91***	0.000	-1.90***	0.000
<i>URBAN</i>	0.05***	0.000	-0.14***	0.000
<i>FDI</i>	0.09***	0.000	-	-
<i>TRANS</i>	0.46	0.345	4.70***	0.000
TELE SPILLOVER	-0.04***	0.000	0.10***	0.000
<i>Adj. R Square</i>	0.5399		0.2559	
<i>Hausman Test</i>	Prob>Chi2=0.9999		Prob>Chi2=0.0000	
<i>Fixed-/Random-effects</i>	Random-effects		Fixed-effects	

Source: Author’s calculation based on data from various sources.

Note: *** significant at 1% level; ** significant at 5% level; * significant at 10% level.

As is shown in *Table 5-12*, spillover effects exist for telecommunications infrastructure among the 29 regions in China from 1986 to 2006. Both *GRTH* and *GRTHK* models show significant telecom spillover variables. However, the sign of this spillover variable is negative for the *GRTH* model, whereas a positive sign is achieved in the *GRTHK* model. For regional growth from both labor and capital factors, there seems to be the possibility that competition exists due to the investment in the telecommunications infrastructure from the neighboring regions. In other words, the more the neighboring regions invest in their own telecommunications infrastructure, the more pressure this region will face

in terms of attracting productive endowments in its own development as the source of the growth of neighboring regions.

On the other hand, if the labor's contribution to regional economic growth is removed, the *GRTHK* model suggests that “clustering” effects of the telecommunications infrastructure in neighboring regions tend to exist. This may imply that productive endowments tend to flow to regions whose neighboring regions also have well-established telecommunications infrastructure.

The findings in this research are instructive for regional policy makers in China, especially in the context of telecommunications sector policy setting. Investment in telecommunications sector by a region is closely linked to that by other regions. Policymakers are suggested to carefully examine the productive endowment availability of their regions and set their investment policies in the telecommunications sector. For instance, for regions already equipped with rich capital factors, policymakers should consider competition effects of further investment in the telecommunications sector given the negative impacts of such investment on regional economic development, and vice versa. Furthermore, policy makers need to consider the level of the policy setting, *i.e.*, provincial or national. In other words, a good policy for provinces might be different for the national as a whole.

5.4 Summary

This study relies on a panel dataset containing data for 29 regions of China within the period from 1986 to 2006 for linear regression analyses aiming at examining the relationship between telecommunications infrastructure and regional economic output growth.

Availability of data in the panel dataset permits the author to conduct dynamic panel data approach to test the conditional convergence hypothesis in China's regional development process during the past two decades as well as the impacts of various socio-economic variables including fixed asset investment, foreign direct investment, population growth, employment, human capital, transportation infrastructure, and telecommunications infrastructure on regional economic development in China.

One innovative step taken in this study is to decompose the regional economic output growth by production factors (*i.e.*, labor and capital factors). Besides the total regional output growth used as dependent variable in prior studies such as Ding (2005), this study uses regional economic growth from capital factors as the dependent variable in the final model, given the fact that telecommunications is actually an important type of productive capital factor. The growth patterns for the capital factors only across all the 29 regions are examined in this chapter in the form of maps. The positive values for the decomposed regional economic growth variable sustains the argument that capital factors do make significant contributions to regional economic growth in China whose development is deemed to be derived solely from cheap labor.

The analysis reveals the significant relationship between telecommunications infrastructure and regional economic development. Difference in regional endowment of telecommunications infrastructure does account for a significant portion of the variations of both the total regional economic growth and the growth from capital factors alone. However, the findings indicate that telecommunications infrastructure appears to have a negative impact on overall regional economic growth, whereas its impact is positive for regional

economic growth from capital factors. Such results imply that the fast-paced development and investment in the telecommunications infrastructure in nearly all regions in China may have already caused the so-called “investment congestion” phenomenon. Furthermore, the positive impacts of telecommunications infrastructure on regional economic growth out of capital factors follow the conclusions of prior studies (*e.g.*, Ding, 2005; Ding, Haynes, & Liu, 2008). The lagged telecom variable is also significant, supporting the recognition that telecommunications infrastructure boosts regional economic development.

The spillover effects of telecommunications infrastructure have been identified in this study. The investment on telecommunications infrastructure by a region’s neighbors have negative influences on this region’s overall economic growth. Better availability of telecommunications services in one region’s neighbors tend to compete for its production factors (*i.e.*, competition matters). More investment from other regions increase those regions’ competitive power, which supports the positive role of telecommunications infrastructure in a region’s economic development process from a different perspective. On the other hand, the results for the analysis with the decomposed regional economic growth as dependent variable shows that excluding contribution of labor factors, telecommunications infrastructure seems to have positive spillover effects. In other words, it may be that the labor factor causes the “investment congestion” phenomenon for the overall regional economic growth. The author recognizes that there may be other factors that lead to the congestion results, including poor data quality, multicollinearity, heteroskedasticity, and temporal autocorrelation.

The research findings in this study also provide some evidence supporting the conditional convergence school. Regional economic convergence has been occurring in China for the past two decades, implying that the less developed regions are growing at a faster speed than those developed regions. The convergence period of 100 years is based on the estimate of this analysis, whereas excluding the labor factor contribution, convergence will be achieved in a much nearer future (36 years). In other words, the research findings in this study seem to support the argument that regional labor endowments takes longer time to converge than capital endowments. As for the other socio-economic variables, the large population in China seems not to be helpful given the negative impact from population growth. As expected, fixed asset investment, foreign direct investment, and transportation infrastructure have a positive contribution to regional economic development in China.

Chapter 6 Conclusions

This chapter concludes this dissertation and provides some policy implications for regional policymakers in China. The major research findings from these analyses are summarized. The answers to the research questions as well as the testing results for the hypotheses outlined in Chapter 1 are elaborated. Policy implications are drawn based on these research findings and future research directions are proposed.

This study implemented the Haynes-Dinc's (1997) modified shift-share analysis framework to decompose the annual regional economic output changes in 29 provinces, municipalities, and autonomous cities in China during the period of 1986 to 2006. Regional and industrial differences in labor and capital productivity, as well as the influences of productivity variances on regional output changes, are estimated based on this framework. On the one hand, the corresponding analysis shows that all regions in China experienced expansions of output in the investigation period, though the extent to which such expansions occur varies by region; on the other hand, the contribution from capital factors to regional economic growth can be isolated from that out of labor factor and has been confirmed in the context of China. This is important as it is a country claimed to develop its economy most from the cheap labor factor. The decomposed regional growth rates do not exhibit a clear spatial pattern of the regional economic development boosted by capital factors only, which

is contrast to the fact that total regional output does show an obvious spatial distribution that capital intensive coastal regions significantly outperform interior hand regions. This may be a result from the different substitution rates across China's regions. Such decomposition of the regional economic growth variable in the final model specifications is a major contribution to the literature, which is manifested by the fact that telecommunications infrastructure is actually the most important type of capital factor input. The author believes that such decomposition can substantially facilitate testing on the relationship between the telecommunications infrastructure and regional economic growth.

The dynamic panel data approach used in this study sets the models by including a series of socio-economic variables in the equation that is derived from the conditional convergence theoretical framework. Specifically, the fixed-effects two-way regression analyses estimate the relationship between regional economic growth (as well as the growth from capital factors only) and initial economic conditions. These initial economic conditions are represented by the one-year lagged GDP per capita, fixed investment, employment, population growth, foreign direct investment, and telecommunications infrastructure. Thus, regional specific differences in aggregate production functions can be accounted for. The heteroscedasticity and spatial autocorrelation issues are tested with the Likelihood-ratio test and an autocorrelation test developed by Drukker (2003), respectively, for the panel dataset. Results from the ARCH test does not exhibit significant differences between the fixed-effects model and ARCH model, and heteroscedasticity appears not to be a major obstacle to invalidate the regression results in this study. As for the spatial autocorrelation, average of a region and its first-order neighboring regions for each variable in the models is used for the

regression analyses, enhancing reliability and robustness of the results after controlling for the spatial autocorrelation effects. Finally, the business cycle effects are ignored in the empirical tests due to the continuous upward trend of regional economic growth for most China's regions in the examined period.

The research findings indicate that differences in telecommunications infrastructure across the 29 regions in China during the 21-year period have significant impacts on regional economic performance and growth. However, based on the regression analysis results, telecommunications infrastructure appears to have a negative impact on regional economic growth in China, causing “investment congestion” phenomenon in the telecom sector in China. Given the fact that the telecom sector in China grows at an amazingly high speed since 2001, inclusion of the most recent years (*i.e.*, 2003-2006) may reveal the most recent status quo in this sector. That is, the increase in telecommunications infrastructure investment has outpaced the overall demand on telecom services from regions in China, and such over-investment reduces the overall economic production efficiency of China's regions. On the other hand, after excluding the contribution from labor factors in regional economic growth, telecommunications infrastructure exhibits a significant and positive relationship with each region's economic development. This confirms the important role of telecommunications infrastructure among all the productive capital factors or inputs, echoing the theoretical synthesis on the special characteristics of this sector in its close interactions with other factors (*e.g.*, better availability of telecommunications services in a region may attract more productive elements into that region).

Another major contribution of this study lies in the identification of spillover effects of telecommunications infrastructure in the context of China. Few prior studies probe the spillover effects of this key infrastructure in the context of developing countries like China. The findings confirm existence of such spillover effects. For overall regional economic growth, investment on telecommunications by a region's neighboring regions have negative impacts on this region. This can be explained by the fact that telecommunications infrastructure may serve as a factor in businesses' location decision, and competition of productive factors among adjacent regions leads to such a negative relationship. The rapid accumulation of investment in telecommunications infrastructure in the coastal regions may have attracted more and more economic resources such as human capital and new businesses compared to the interior regions. The direct result of such competition from different levels of telecommunications infrastructure is the negative impacts on neighboring regions' economic growth. In contrast, for the regional economic growth from capital factors only, a region can enjoy the "free-rider" effects from investment of its neighboring regions on telecommunications infrastructure. The more a region's neighbors invest in telecom sector, the better impacts this region can expect on its own development. It seems the competition impacts of such investment is closely related to human capital or labor factor. In other words, after removing the labor factor and human capital factor, investment in telecommunications sector by neighboring regions seems to be able to benefit a region in its own economic growth. Despite the opposite impacts that telecommunications infrastructure spillover in the two analyses, there seem to exist significant spillover effects from telecommunications infrastructure across the 29 regions in China during the past two decades.

The analyses in this study also provide evidence for validation of the conditional convergence discussion with the example of a developing country China. The tests on the regions in China show that controlling for other factors, regions with lower levels of initial real GDP per capita tend to grow with faster rates than those with higher levels of initial real GDP per capita. The overall regional economic growth convergence can be expected to be achieved within 100 years, based upon calculation of the half-life convergence period. However, exclusion of labor factors can accelerate this process into as short as 36 years. Therefore, labor factor seems to be an indispensable endowment that impacts the convergence process among China's regions. Disparity in labor endowment seems not to be able to change in the short run. A major proportion of the huge 1.3 billion population in China keeps crowding into the coastal regions, while migration into the interior land is not happening in the foreseeable future.

An interesting finding is that population growth and urbanization seem to have negative and significant impacts on regional economic growth. This may facilitate explanation on the opposite results of the two models for the key variable telecommunications infrastructure. It seems that regions do not enjoy benefits from the rapid growth of population and migration of population from rural to urban areas. This may reflect the traditional diminishing returns on productive inputs, *i.e.*, the over-supply of labor lowers the overall regional productive efficiency. The other socio-economic variables fixed asset investment, transportation infrastructure, and foreign direct investment all make significant and positive contributions to regional economic development. The only exception is the human capital variable, which has negative influences on regional economic growth. One

explanation may be the fact that China is still in an early development phase, and labor-intensive industries still dominate the industrial structure of this large developing country. It can be expected that with development of the overall economy and industrial structure adjustments towards more high-tech and technology-intensive end, the human capital variable will show a positive impact for regions in China.

The confirmation on the contributive role of telecommunications infrastructure on regional economic growth in China is instructive for policy making in the context of developing countries. First, the findings in this paper generally support the investment induced growth point of view and consequently supports investment policy in the telecommunications and infrastructure sectors in lagging regions of developing countries (*i.e.*, the growth from capital factors model). Although the substitution or interaction between labor and telecommunications infrastructure may cause the “investment congestion” results (*i.e.*, the overall regional economic growth model), the finding of a significant relationship between the telecom service availability and economic growth should be instructive to many regional policymakers in China. Regions with low labor base may consider increasing investment into their telecom sector and enjoy the benefits from the contribution of this sector to their economic growth; on the other hand, regions like coastal regions that already enjoy advantageous telecommunications endowment and their labor base may consider the “investment congestion” effects and it would be helpful to direct their investment into other productive factors. The discretion of regional policymakers is critical in determining the ultimate contribution of the telecommunications infrastructure to their regional economic development. Second, knowledge on the spillover effects of telecommunications

infrastructure is also essential for wise regional policymaking. Sufficient understanding by regional policymakers on the nature of the telecommunications infrastructure itself and the relative strengths of this input among itself and neighboring regions can orient appropriate investment decisions into the telecom sector. Third, regional economic convergence exists in China, and policymakers of the central government can justify their regional income inequality reduction policies such as the grand western development program. Such programs are designed to mitigate regional gaps in economic growth by issuing preferential policies for economically less developed regions. With proper institutional orientation and support, regional economic growth convergence process can be accelerated. Fourth, instead of attracting more labor into their regions, policymakers should establish institutions adjusting industrial structure to the more high-tech and technology-intensive end and increase the quality of the labor force. Furthermore, the negative effects of population on economic development may stimulate policymakers to continue the population control policy.

Future research is necessary in the following areas: first, this study does not specifically address or control the endogeneity problem. The GMM estimator does not benefit this analysis in controlling this problem. Other approaches may be necessary to further resolve the endogeneity issue. Second, the Lotka-Volterra model (*e.g.*, Volterra, 1928) can be used to test the convergence hypothesis of economic development convergence in China. The convergence literature identifies this model as a dynamic multi-causality model without the strict assumptions as required by the Barro approach. Comparison of the results from both the Lotka-Volterra model and the Barro approach can provide more insights to this analysis. Third, other methods in decomposing regional economic growth may be necessary,

and the limitation of the shift-share analytical framework poses constraints on the dependent variable in the panel dataset. Improved results can be expected with better ways of isolating regional economic growth from capital factors from that out of labor factors. Fourth, the negative impacts of telecommunications infrastructure on the overall regional economic growth is not consistent with findings of other prior studies on this topic. More research efforts are necessary to justify the existence of “investment congestion” phenomenon in China’s regions. The monopoly of large telecommunications companies controlled by governments in China may be the direct cause of the investment congestion in the telecom sector. In future research, a dummy variable reflecting the regional political initiatives in telecom investments can be added into the analytical framework. Other approaches to revealing the investment congestion phenomenon in China may rely on adjustments of the panel dataset. For example, the time period with fastest telecom growth can be identified for the regression analysis; selection of regions with most intensive telecommunications investments may test the investment congestion hypothesis; and regressions can be performed on a “moving window” basis—increasing or decreasing the beginning or the ending years by one year each time. Fifth, it will be useful to compare the findings on the telecommunications infrastructure spillover effects with other diffusion models with those in this study.

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