

Ward, Michael R.; Zheng, Shilin

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## Mobile telecommunications infrastructure and economic growth: Evidence from China

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“Mobile Telecommunications Infrastructure and Economic Growth: Evidence from China”

Michael R. Ward, *University of Texas at Arlington*

Shilin Zheng, *Chinese Academy of Social Sciences*

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ABSTRACT

We contribute to the role of telecommunications infrastructure on economic growth in three ways. We separately examine fixed-line and mobile telephone subscription levels. We compare results across periods and regions that differ by the level of development. In addition, we develop a method designed to address endogeneity of telecommunications with respect to growth. We find that mobile services contribute much more to growth but that the effect diminishes as the provincial economy develops more.

Key Words: Growth, Mobile Phone, China

JEL Codes: O4, L96

## **1. Introduction**

Advances in telecommunications have been found to contribute significantly to economic growth. But the effects on growth are thought to depend on the particular telecommunications technologies and on a country's level of development. Historically, growing fixed-line subscribership had been associated with economic growth. However, mobile telephone service is often the preferred mode of access for consumers, especially in developing countries. As a consequence economic growth has recently been more often associated with rapid mobile take-up rates while fixed-line take-up rates remained flat. During these infrastructure build-outs, it is not clear how the two technologies have interacted with each other. Moreover, it is difficult to determine to what extent either access mode is a cause of growth or a consequence of it. While much of the existing literature has tackled one or two of these issues in isolation, none has integrated all of these features into a single analysis.

We take advantage of features of the Chinese experience from 1991 to 2010 to uncover some of these subtleties. This period represents a relatively compressed timespan during which telecommunications subscription grew enormously (see Figure 1). China went from a telephone subscription rate of less than 1% to nearly two-thirds. This rapid diffusion occurred during a period of liberalization of the Chinese telecommunications sector. Similarly, China experienced a fast enough rate of economic growth that it transitioned from a low income to a middle income country. Finally, China warrants study as the world's most populous country and second largest economy. These ingredients provide a setting in which it is possible to investigate the causal effects on economic growth of different telecommunications technologies at different developmental stages.

Our estimation strategy is sensitive to both the dynamic nature of the effects of telecommunications on growth and to possible endogeneity bias. As with others investigators, we adopt a dynamic system GMM panel estimator that allows for past values to affect future values. However, we also treat telecommunications subscriptions as endogenous to growth and develop two sets of plausibly exogenous instrumental variables. The first set of instrumental variables is created from measures of competition in each of the provinces that affect prices, and thus subscription levels, that are largely independent of province growth rates. The second set of instrumental variables are created by from the same competition measures but for the neighboring provinces rather than the own province. We find evidence that endogeneity of the telecommunications measures does lead to biased estimates but that either instrument set leads to consistent estimates.

Our results can be summarized as mobile telephone service having a positive effect on growth that is larger during 1991-2000 than 2001-2010. Fixed line services complement mobile services initially, but have a negative effect later on. Combined, fixed and mobile services are estimated to have contributed about 2% to China's growth rate during the first decade but only 0.5% in the second decade.

The rest of the paper is organized as follows. Section 2 reviews recent findings regarding telecommunications and growth. Section 3 describes some of the institutional changes in Chinese telecommunications. Section 4 develops the estimators we employ. Section 5 describes the data that we use. Section 6 reports our results and section 7 concludes.

## **2. Telecommunications and Growth**

Telecommunications is thought to lead to improved economic wellbeing and economic growth through multiple mechanisms as documented through a number of case-study type of investigations. Leff (1984) argues that expansion of telecommunications networks improves the flow of information and increase arbitrage abilities. Norton (1992) pointed to the role of telecommunications in lowering transactions costs as a mechanism to foment growth in developed countries. He also indicated that telecommunications infrastructure lowers both the fixed cost of acquiring information and the variable costs of participating in markets. Telecommunications makes it possible for firms to employ flexible structures and locations, leading to the evolution of complex and large organizations (Wellenius, 1997). Aker and Mbiti (2010) point to as diverse effects from mobile phone usage in particular as facilitating day labor markets, reminding AIDS patients about aspects of their care, reporting confrontations, and bypassing cumbersome banking practices. The increased ability to communicate appears to have led to more efficient markets for both south Indian fishermen (Jensen, 2007) and Nigerian agriculture (Aker, 2010). Overa (2005) finds that Ghanaian traders reduce food spoilage from more efficient marketing using mobile phones. Muto and Yamano (2009) document that mobile phone coverage expansion increases market participation in Uganda for farmers growing perishable crops in remote areas. Abraham (2007) shows that the use of mobile phones fostered the performance of the fishing industry in India as indicated by through increases market integration, gains in productivity and reductions in price dispersion and price fluctuations. Vu (2013) argues that ICT infrastructure fosters technology diffusion and innovation, enhances the quality of decision-making by firms and households, reduces production costs, and generally increases demand.

With a more macro-economic approach, it has been more difficult to identify the mechanisms for ICT's effect on growth. In one of the first studies, Hardy (1980) used a panel dataset of 60 developed and developing countries to find that telephones per capita significantly affected GDP, while the spread of radios did not. However, when regressions were estimated separately for developed and developing countries the results are not significant. Röllner and Waverman (2001) examined a panel of OECD countries and found a causal effect from telecommunications infrastructure only beyond a relatively high critical mass of deployment. Madden and Savage (1998) uncover that telecommunications infrastructure plays a positive and significant role in the development of transition economies. Vu (2011) finds that the effects on economic growth were highest for Internet penetration, then mobile phones and then fixed-line phones.

Since 1990s, mobile telecommunications usage has become increasingly popular, especially in the developing countries. Much of the literature has identified a different effect of mobile telecommunications infrastructure on the economic growth in developed countries versus developing countries. Sridhar and Sridhar (2007) found positive impacts from both mobile and landline phones on national output. Gruber and Koutroumpis (2011) extended their analyses to nearly 200 countries over the period 1990-2007 and also identified effects from fixed and mobile phone connections with a smaller effect for countries with a low mobile penetration. In spite of the rapid adoption of mobile technology, DeMaagd (2008) did not find any long-term productivity improvements in developing countries. Mobile phones tend to substitute for fixed lines in poor countries, but to complement fixed lines in rich countries, suggesting that they would have a stronger growth impact in poor countries. Moreover, many countries with under-developed fixed-line networks have achieved rapid mobile telephony growth with less

investment than similar coverage by fixed-line networks would have required. Indeed, Waverman et al., (2005) used data on 92 countries from 1980 to 2003, and found that mobile telephony has a positive and significant impact on economic growth, and this impact may have been twice as large in developing countries compared to developed countries. In a study examining the effect of mobile phones on GDP per person for 120 developed and developing countries, Qiang et al. (2009) found that for every ten percentage point increase in the penetration of mobile phones, there was an increase in economic growth of 0.81 percentage points in developing countries, versus 0.60 percentage points in developed countries. Lee et al. (2012) examination of 44 sub-Saharan countries over the years 1975-2006 found that mobile phone expansion is an important determinant of the rate of the rising economic growth in the region, and that the marginal impact of mobile telecommunication services was even greater wherever land-line phones are rare.

While many studies make cross-country comparisons, a growing number examine differences across regions within a country. These analyses benefit from more similar legal, cultural, and economic settings across observations. Moreover, since the data are gathered by a single agency, they are likely to be more comparable across observations. Greenstein and Spiller (1996) investigated the effect of telecommunications infrastructure on economic performance in the US. Empirical results indicate that infrastructure investment was responsible for a substantial fraction of the recent growth in consumer surplus and business revenue in local telecommunication services. Narayana (2011), used data from a small-household sample survey in India to show that telecommunication services and economic growth were indirectly linked while estimating the household determinants of the demand for fixed and mobile telephone services. Vu (2013) provides a comprehensive investigation of the contributions of ICT to

Singapore's economic growth during the 1990–2008 period. He found that ICT investment contributed approximately one percentage point to Singapore's GDP with an increasingly important role over time. Kathuria et al. (2009) showed that Indian states with higher mobile phone penetration have a higher economic growth. Blauw and Franses (2011) examined the impact of mobile telephone use on economic development of individual households in Uganda and find strong support that mobile phone use positively impacts economic development.

Another relevant thread in the literature documents the methodological concern of endogeneity between ICT usage and economic growth. While increased telecommunications infrastructure may increase productivity, consumers with higher incomes also demand more ICT services. In a series of papers investigating the US experience, Cronin and co-authors confirmed a two-way causal relationship between telecommunications infrastructure and economic growth and productivity (Cronin, et al, 1991, 1993a, 1993b). Moreover, Yoo and Kwak (2004), Cleslik and Kaniewsk (2004) and Perkins (2005) also identified a bi-directional causality in Korea, Poland and South Africa. Lam and Shiu (2010) found evidence for a bidirectional relationship between real gross domestic product (GDP) and telecommunications development and that the effect of telecommunications is larger in countries that have liberalized this sector.

Endogeneity of telecommunications usage has implications for developing an strategy to identify causal links. Both Röller and Waverman (2001) and Gruber and Koutroumpis (2011) posit a system of production and demand equations that are identified by exclusion restrictions. Chakraborty and Nandi (2011) identify the effects by estimating Granger causality. Thompason and Garbacz (2007) and Baquero (2013) examine technical efficiency by estimating stochastic-frontier production functions. Indeed, in contrast to Röller and Waverman (2001), Baquero (2013) finds technical efficiency from ICT only in lower income countries with that tend to have

smaller critical masses. Many recent studies employ variants of dynamic panel GMM estimators (Dimelis and Papaioannou, 2011, Data and Argawal, 2004).

### **3. The Chinese Telecommunications Experience**

China presents a particularly appealing opportunity to study the effects of the diffusion of telecommunications technology. Since China became more open to market mechanisms in the late 1970s, real GDP per capita is thought to have quadrupled. In this short span, China went from a mostly rural, agrarian society to an increasingly urban, manufacturing hub. Moreover, since the different regions had a fair degree of autonomy in how they implemented the national policy of reform, a degree of *de facto* “federalism” makes for meaningful cross-sectional comparisons. As discussed above, researchers have successfully exploited provincial differences to uncover a nuanced view of the meteoric economic growth.

Other researchers have also exploited Chinese provincial level data in their analyses. Wei and Hao (2010) find that demographic shifts across the provinces account for some of the disparities in regional growth. Weeks and Yao (2003) find that uneven growth rates are linked to different rates of technology progress mainly along an east/west split. Shiu and Lam (2008) likewise find a link between telecommunications and growth only for the affluent east and suggest that the west lacks complementary assets such as human capital, transport and a congenial business environment. Démurger (2001) and lau (2010) identify a number of factors related to China’s growth, including transport and telecommunications, and they find that telecommunications infrastructure plays an important role in economic growth. Ding et al.

(2008) explicitly model the role of telecommunications in the convergence of the provinces of China over time.

An important aspect of our analysis is our identification strategy that stems from measures of market liberalization. We recount the recent history of this experience to understand the validity of our strategy. Major telecommunications reforms were undertaken at the national level, but were implemented based largely based on local provincial decision making. Before 1994 the telecommunications market was administered by Ministry of Posts and Telecommunications (MPT) as a monopoly. Under pressure from both consumers and other ministries, the government launched a series of liberalizations since the mid-1990s. Figure 2 indicates the major changes during the period from 1994 to 2010.<sup>1</sup> The first stage (1994-1997) was designed to introduce competition to what had been a government monopoly. However, domestic competition was thought to be hampered by interconnection arrangements with the MPT (Wu, 2009) and a new market player, China Unicom, is thought to have been too small to compete with the dominant China Telecom.

In the second stage (1998-2001), the MPT was split into a postal ministry and the Ministry of Information Industry (MII), with jurisdiction over telecommunications. The dominant national carrier, China Telecom, was broken into three entities along lines of business and independent enterprises began to expand. The new China Telecom became a fixed-line operator, while its cellular phone and satellite services were taken over by China Mobile and China Satcom. China Mobile competed directly with China Unicom in the mobile telecommunications market. However, China Telecom continued to have a near monopoly on

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<sup>1</sup>What follows is a synopsis of information found in the Ministry of Industry and Information Technology of the People's Republic of China (1990-2010). Annual Reports

fixed services. Three new market players – China Netcom, China Jitong and China Railway – were established during 1999-2000.

In the third stage (2002–2007), two main competitors in the fixed phone service were introduced to the Chinese telecommunications industry. China Telecom was split along regional lines beginning in 2002 but the new entities could enter each other's territories. The southern business remained with China Telecom, while the northern half merged with China Netcom and Jitong. This round of reform also gave China Unicom licenses to operate a Code Division Multiple Access (CDMA) mobile network in effort to help it compete with China Mobile's wireless services. Despite the great liberalization in telecommunications, China's telecom industry remains concentrated, with one company dominating. China Mobile has gained a larger market share than all other players. In 2007, it posted approximately 360 billion Yuan sales revenue – equal to 49 percent of the entire sector's earnings.

The fourth stage (2008-2010) brought on another round of restructuring that consolidated the industry and brought third generation (3G) mobile services closer to release. Under the plan, China Mobile merged with the smaller, fixed-line operator China Tietong; China Telecom acquired China Unicom's CDMA network (including the assets and its user base); with the rest of China Unicom's assets merged into China Netcom – leaving three major players in place of the previous six. Along with telecommunications reform, the market structure of telecommunications industry changed from monopoly to a form of competition. These liberalization reforms have led to substantial increases in consumer welfare (Zheng and Ward, 2011) and a more dynamic industry (Ward and Zheng, 2012). These telecommunications

liberalization reforms provide exogenous instruments to identify variation in mobile telecommunications infrastructure that is independent of economic growth.

In this paper, we attempt to extend the existing research on the relationship between telecommunications infrastructure and Chinese economic growth in a few directions. First, we depart from the existing research and identify the effects on the economic growth of not only fixed telecommunications infrastructure and mobile telecommunications infrastructure separately, but also the interaction of the two.

*H1: Fixed and Mobile telephone services are complements in generating economic growth.*

Since businesses tend to be in fixed locations, they tend to subscribe to fixed service in greater proportions than residential customers. Telephone subscription by business and residential customers likely reinforce the productivity of the other in a form of network externality.

Second, over our sample period, China went from one of the least telecommunications intensive countries to the largest consumer market in the world. Essentially, it went from a less developed country to a middle income country. We test to see if the role of telecommunications was different in subsamples that differ along developmental lines

*H2: Telecommunications services have a larger impact on economic growth in the earlier stages of economic development*

The associated test is implemented two ways: inter-temporally as China became more developed and in the cross-section as Eastern China tends to be wealthier than Western China.

Third, we make progress in identifying *causal* relationships between telecommunications and growth. It is likely that telecommunications use both causes and is caused by economic growth. A consensus is growing that mere conditional correlations are biased estimates.

*H3: Estimating conditional correlations between telecommunications infrastructure and economic growth will be biased estimates of a causal impact that can be remedied with appropriate instrumental variables techniques.*

Many researchers have sought valid exogenous instrumental variables for telecommunications infrastructure in the context of cross-region growth models. We exploit China's reforms in competition policy and ownership rules in pursuit of liberalization. This experience provides for plausibly exogenous variation in telecommunications use so as to identify a causal link between telecommunications and growth. Moreover, we explore the recent use of network theory to generate instruments based on experiences from neighboring provinces.

#### **4. Growth Model and Identification**

We estimate a standard growth accounting relationship built upon the growth framework for panel data of Barro and Sala-i-Martin (1991) and Islam (1995). We relate province level growth rates in per capita income to the level of income per capita, measures of telecommunications infrastructure, control variables typically associated with growth – investment, government consumption, trade openness, and population growth – as well as two-way fixed effects. Our basic estimating equation is of the form:

$$\%Chg\ Inc\ Capita_{i,t} = \alpha Inc\ Capita_{i,t-1} + \beta Telecom + \gamma X_{i,t} + \mu_i + \delta_t + \varepsilon_{i,t} \quad (1)$$

The change in a province's per capita income is related to its level in the previous year, to measures of telecommunications adoption, various control variables,  $X$ , and fixed effects for province and year. Our hypotheses are that the effect of telecommunications,  $\beta$ , is positive, is larger for mobile adoption than fixed line adoption and is larger when and where China was less developed. An important aspect of our empirical strategy has to do with the assumptions placed on the error term,  $\varepsilon_{it}$ .

We progressively relax assumptions in the error term to confirm that our results are not spurious. We begin by assuming that  $\varepsilon_{it}$  is independently and identically distributed (i.i.d.). This implies estimating (1) with a traditional static panel estimator. Next we allow for the growth rate in per capita income to adjust slowly so that a shock to the growth rate in one year affects the current year as well as subsequent years. This causes correlation in the error term over time as  $\varepsilon_{it} = \mu_{it} + \rho \%Chg\ Inc\ Cap_{i,t-1}$ . To address this, we estimate (1) using a dynamic system GMM panel estimator. Including the lagged dependent variable induces autocorrelation that compromises inference testing. A series of papers show how to overcome this source of bias by using further lagged values of the dependent variable, and first differences, as instrumental variables (Arellano & Bond, 1991, Arellano & Bover, 1995).

There is concern of reverse causality between our telecommunications measures and per capita growth because telecommunications is a normal good. In this case we will not have identified a causal link from telecommunications infrastructure in a province to economic growth in that province. To address this issue, we implement the dynamic system GMM panel estimator treating the telecommunications measures as endogenous dependent (Roodman, 2009). Unlike Röller and Waverman (2001) and Gruber and Koutroumpis (2011) we do not estimate a system of production and consumption equations. Instead, we use Hirshman-Herfindahl Index (HHI)

measures of industry concentration.<sup>2</sup> Industry liberalization has tended to decrease industry concentration and improve market performance. Zheng and Ward (2011) show that higher HHI values are related to higher prices and fewer subscribers. HHI values are calculated for both fixed-line and mobile operators in each province and a year. Since these measures are related to telecommunications subscribership and not directly related to economic growth, they should be valid instruments.

Finally, it is possible that decision makers in provinces experiencing greater productivity gains, and thus economic growth, will seek to liberalize faster. If so, measures of concentration will be the result of greater economic growth. This would tend to make the HHI measures correlated with growth directly and, therefore, no longer valid as instrumental variables. To address this possibility, we present a specification that borrows from the literature on causal identification within networks (Bramoullé et al, 2009). The different provinces form a network based on physical distance or connectedness across which information is more likely to flow. In our application, producers, consumers, and government officials in one province may be affected by market conditions in neighboring provinces in addition to market conditions in their own province. This could be due to multiple sources. Telecommunications operators from nearby provinces may see profit opportunities from entering provinces where operations are less efficient. Consumers may be more aware of new services introduced nearby. Regulators may be more familiar with nearby policy implementations they observe more closely. Identification with “peer effects” within a network requires that observations be members of non-overlapping groups. Accordingly, we identify the five provinces nearest to each province and aggregate HHI

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<sup>2</sup> The HHI is a measure of market concentration commonly used in competition policy settings. It is defined as the sum of squared market shares,  $HHI = \sum_{j=1}^J s_j^2$ . All else equal, firms in more concentrated industries tend to be able to set higher prices.

measure over those identified. Thus they are one step further removed from the endogeneity concerns from using HHI measures from the same province.

## **5. Data Sources**

Equation (1) is estimated using panel data for 31 provinces in China over the period from 1991 to 2010. The macroeconomic data comes from the National Bureau of Statistics of China. The industry data are from Ministry of Information Industry of China (MII). Table 1 reports summary statistics for the variables used here in levels and in their natural logarithms.

The National Bureau of Statistics of China provides a number of province level variables measuring investment, education, income, urbanization and so on. Most of these variables either differ substantially across provinces or differ substantially over time but not both. These effects would likely be captured by fixed province and year dummy variables. Some do represent meaningful shifts across provinces over this time period. However, much of this variation is not likely to substantially affect either growth or the telecommunications sector. Province level variables that do vary over time include measures of the population growth rate, gross fixed investment, the size of government (government consumption as a fraction of income), and international openness (international trade as a fraction of income). All data with currency values were deflated by 'Indices of Gross Domestic Product,' which comes from Chinese Statistical Year Book.

The industry data that we use include revenues, subscribers, and minutes of use for both fixed and mobile service in each of the 31 provinces. We use these to construct the subscribership shares for both mobile and fixed line telecommunications. As seen in Figure 1, there has been substantial growth in both subscribers and calling volumes with mobile service

overtaking fixed service sometime around 2003. Telecommunications firms' annual reports provide information by province on sales. We use this information to construct our instrumental variables, Herfindahl Indices for both the mobile and fixed markets. Zheng and Ward (2011) show that these are effective measures for the degree of competition in these markets. Finally, we use the geographic locations of China's provinces to identify the five nearest geographic neighboring provinces for each province (see Figure 3). Specifically, we measure the distances from the geographic centers of each province to every other province. The nearest five provinces are almost always bordering provinces but can include non-bordering provinces when a province borders fewer than five others. In some cases, more than five provinces border the focal province, in which case we exclude all but the nearest five. This information is used to construct the average Herfindahl Index for both fixed and mobile service over these five provinces in that year.

Two market innovations over the period under investigation complicate the empirical analysis below. First, Voice Over Internet Protocol (VOIP) became increasingly popular especially for international toll calls. By 2006, IP calls could account for half of all international toll calls but a much smaller fraction of intra-city calls (Wu, 2009, p. 124). Since these calls are largely unmonitored, most are not measured in our data. Second, fixed line operators without mobile licenses introduced a wireless local loop option, called "the Little Smart," that allowed for limited mobility within a city. These are counted as fixed lines in the data but are perhaps more similar to mobile phones. This option made up about 10% of all subscriptions by 2006 (Wu, 2009, p130).

## **6. Results**

We present results sequentially from estimators that place the most restrictions on the data to estimators that are increasingly more general. As will be seen simple static, and even dynamic, panel estimators appear to generate biased results. However, when we treat telecommunications subscriptions as endogenous, the results are consistently estimated and appear to generate more plausible results. With these specifications, we attempt to uncover more nuanced effects of telecommunications on growth.

As a starting point, we report the results from a static panel estimator from a simple Ordinary Least Squares (OLS) regression with two way fixed effects in Table 2. Coefficients for the groups of 31 province and 20 year dummy variables are always jointly significant suggesting important idiosyncratic effects for both regions and time periods. Thus, coefficients for our other measures are identified only to the extent that within-province variation differs across provinces and over time. Turning to our control variables, the negative coefficient on the level of GDP per capita indicates that growth slows with past growth. This is consistent with a general trend toward relative convergence across provinces. Growth is higher when a province has a with more international trade focus and with more gross fixed investment. Changes in government consumption do not appear to affect growth. Finally, as the population grows, per capita growth tends to fall.

In general, these estimates would suggest that telecommunications is associated with increased growth, although the interpretation is somewhat nuanced. The different specifications introduce various combinations of our mobile and fixed telephone subscription variables. Mobile telephone subscription is always associated with growth but not fixed telephone subscription. Fixed telephone subscription only has a positive effect in the last column that includes a mobile-fixed subscription interaction term. This can be interpreted as fixed service fostering economic

growth only through its complementary effect with mobile service. As discussed above, growth is likely to adjust slowly to changes in the variables we have identified. In Table 3, we report results of a dynamic system GMM panel estimator that introduces the lag of the dependent variable. We instrument lagged growth with up to four lags and differences for a total of 29 instruments. As expected, with a single lag of the dependent variable we observe first-order autocorrelation but not second-order autocorrelation. The Sargan test suggests that our instruments are not endogenous to the growth equation. The coefficient on lagged growth suggests substantial auto-regression in growth rates. Except for the level of GDP per capita, our controls variable coefficients are nearly unchanged from the static panel estimator. While the coefficient of the level of GDP per capita is negative, it is much smaller and is significant only in column one. Of our variables of interest, now only mobile telephone service is ever significantly different from zero, even in column four, the analog to column four in table 2. This specification does not reveal a significant interactive effect between mobile and fixed telephone subscription.

Because of the fast pace telecommunications adoption in China, it is possible that it had a differential impact during the early expansion period than in the later, more-established period. We test for this by separating the sample into early and later decades. The estimates are reported in table 4 and suggest that the periods did indeed differ. They indicate that both fixed and mobile telephone subscriptions were associated with positive growth in the earlier period but that fixed subscriptions became a drag on growth in the latter period. However, these specifications also lead to large differences in the autoregressive effects of growth. This result also raises concern that our telecommunications measures are co-determined with growth and so are not exogenous as assumed in this specification. Thus, these estimates would not represent a causal effect of telecommunications on growth.

Table 5 reports the replication of the specifications of table 4 with the dynamic system GMM panel estimator under the assumption that telecommunications subscription is endogenous. As mentioned above, our instrument set includes same province HHI measures for both mobile and fixed line service. For the specifications that include interactions, columns (2) and (4), we include interactions of the HHI measures to the instrument set. Now the consistent autoregressive nature of our growth measure reemerges. The differences in these estimates from those in table 4 are consistent with the telecommunications measures being endogenous and the results from table 4 being biased. Moreover, these estimates of the telecommunications measures appear to be more plausible. In the early period, both mobile and fixed subscriptions have positive effects on growth with the effect from fixed service coming only through the interaction term. In column 2, the interaction term is significantly positively associated with economic growth. This result is consistent with the literature indicating that there is evidence of complementarities between mobile telephones and fixed telephones (Gruber, 2001; Hamilton, 2003; Madden and Savage, 2004). In the later period, mobile subscriptions continue to have a positive effect but now fixed subscriptions enter negatively.

As a robustness check, we re-estimate this specification with our alternative set of instrumental variables in table 6. Rather than using the HHI measures for a given province, we use the average values of these HHI measures for a province's nearest neighbors. As discussed above, it is possible that liberalization and growth are correlated independent of telecommunications development. Measures of neighbors' liberalization provide one more degree of exogeneity. The coefficient estimates this specification generates are remarkably similar to those that use own-province HHI measures as instruments. In particular, mobile telephone service is related to growth, in the earlier period fixed service has no direct effect but a

complementary effect, and, in the later period, fixed service has a negative direct effect on growth and no complementary effect.

Finally, in table 7, we explore whether the effects differ between the more developed eastern region of China and the less developed western region. Recall that consumers in less developed regions are more likely to bypass fixed telephone service and opt for mobile service. If so, in the more developed east, mobile service should have a relatively smaller effect on growth, and fixed service a larger effect, than in the west. We implement tests for these hypotheses by interacting the telecommunications measures with a dummy for provinces in the east.<sup>3</sup> The coefficients on the interacted terms indicate that this was the case for the 1991-2000 period but that these differences disappeared in 2001-2010 period.

Overall, we can confirm all of our hypotheses except for the anomalous finding that fixed line service hinder growth in the later period. Consistent with the previous literature, we find a larger role for mobile telephone service than fixed line service. However, the differential we estimate is larger than in most other applications. Consistent with the cross-country analyses by Waverman et al., (2005) and Qiang et al. (2009), we find that mobile phones have a larger effect when and where provinces are less developed. Finally, consistent with a growing literature, we find that the endogeneity of telecommunications subscriptions to growth requires an instrument variables approach. Moreover, similar results from the two sets of instrumental variables we develop suggest that instruments are valid and that our estimates are consistently estimated.

There are a few possible explanations for this result. On the one hand, consumer abandonment of “the Little Smart” in favor of true mobile service implies excess telecommunications infrastructure. “The Little Smart” subscriptions, using fixed-line

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<sup>3</sup> Specifically, the eastern provinces are defined as Beijing, Tianjin, Hebei, Liaoning, Shandong, Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong and Hainan.

infrastructure, peaked in 2006 with 90.63 million. In 2009, the Ministry of Industry and Information Technology (MIIT) proposed a plan to take “the Little Smart” away from 1900-1920MHz wireless access system by the end of 2011, which means that “the Little Smart” will withdraw from telecom market. By 2010, “the Little Smart” had only 3.04 million users. China had invested about 100 billion Yuan for “the Little Smart” infrastructure, most of which became stranded.

In addition, splitting the fixed service entities along regional lines and allowing them to enter each other’s territories led to some duplication of infrastructure. Recall that China Telecom was split along regional lines in 2002 with China Netcom operating in 10 Northern provinces while China Telecom continued in the twenty-one Southern provinces. These two could and did enter each other’s provinces with fixed telephone infrastructure investment to compete for fixed services. However, the duplicative investment occurred at a time when demand for mobile services began to dominate fixed services. In the column 4, the estimated coefficient of the interaction term is negative as expected but statistically insignificant. This result indicates that only the increasing mobile subscriptions have positive effects on economic growth during the period when mobile telephones were thought to have largely replaced fixed telephones.

The results of our preferred specifications, where telecommunications is treated as endogenous, indicate a statistically significant effect from mobile telecommunications subscription on growth. Fixed service has a positive complementary effect initially, but appears to be a drag on growth in the latter half of our sample. These effects are economically significant as well. It is possible to get an idea of the magnitude of these effects with a ‘back of the envelope’ calculation. The long-run effect of the telecommunications measures can be obtained by multiplying the average change over the sample with  $\hat{\beta}/(1 - \hat{\rho})$ . By this calculation, the change

in mobile subscriptions by themselves contributed 2.12% to the average 10.1% annual growth rate in the earlier decade. The complementary effect with fixed service contributed only an additional 0.03%. During the latter decade, mobile subscriptions are calculated to have contributed 0.82% to the average 11.0% overall growth rate while fixed service decreased growth by 0.29%.

## **7. Conclusion**

Our analysis leads us to a few general conclusions about the effect of telecommunications on growth. First, telecommunications appears to have been an important contributor to economic growth in China. Second, mobile service contributed more to growth than fixed service. Third, the complementary effects between fixed and mobile service appear to have been small and to not have been present after 2001 when China was less developed. Fifth, the effect of mobile service was relatively smaller, and fixed service relatively larger, in the less developed western China but only before 2001. Sixth, of a purely methodological importance, generating consistent estimates required that we treat the telecommunications data as endogenous and for us to seek an instrumental variables identification strategy.

It is problematic to speculate about how these effects might affect growth going forward. On the one hand, our estimates the contributions of mobile and fixed subscription suggest some diminishing marginal returns. Moreover, as these networks are already largely built out, there appears to be little room for additional contributions to growth. On the other hand, newer telecommunications services are becoming available over time. In particular, Internet usage is increasingly facilitating both in business-to-business commerce and business-to-consumer commerce. Internet services is increasing both along the extensive margin as more people have

access and along the intensive margin as their access is at ever increasing speeds. Just as mobile appears to have become more important than fixed-line services, Internet usage may eventually prove more important than mobile.

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Figure 1. Fixed and Mobile Telephone Subscriptions in China

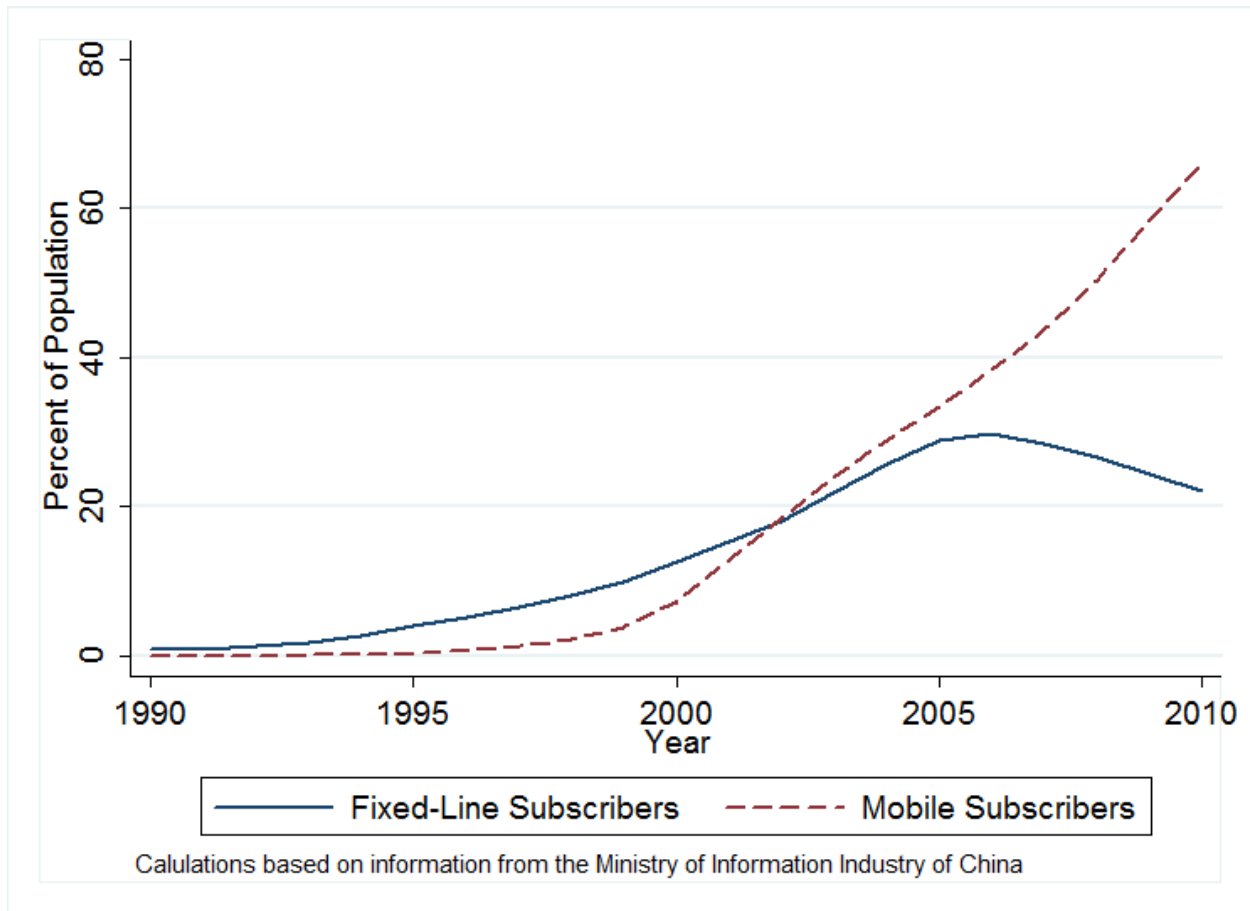


Figure 2. 1991 – 2010 liberalization of the Telecommunications Sector in China.

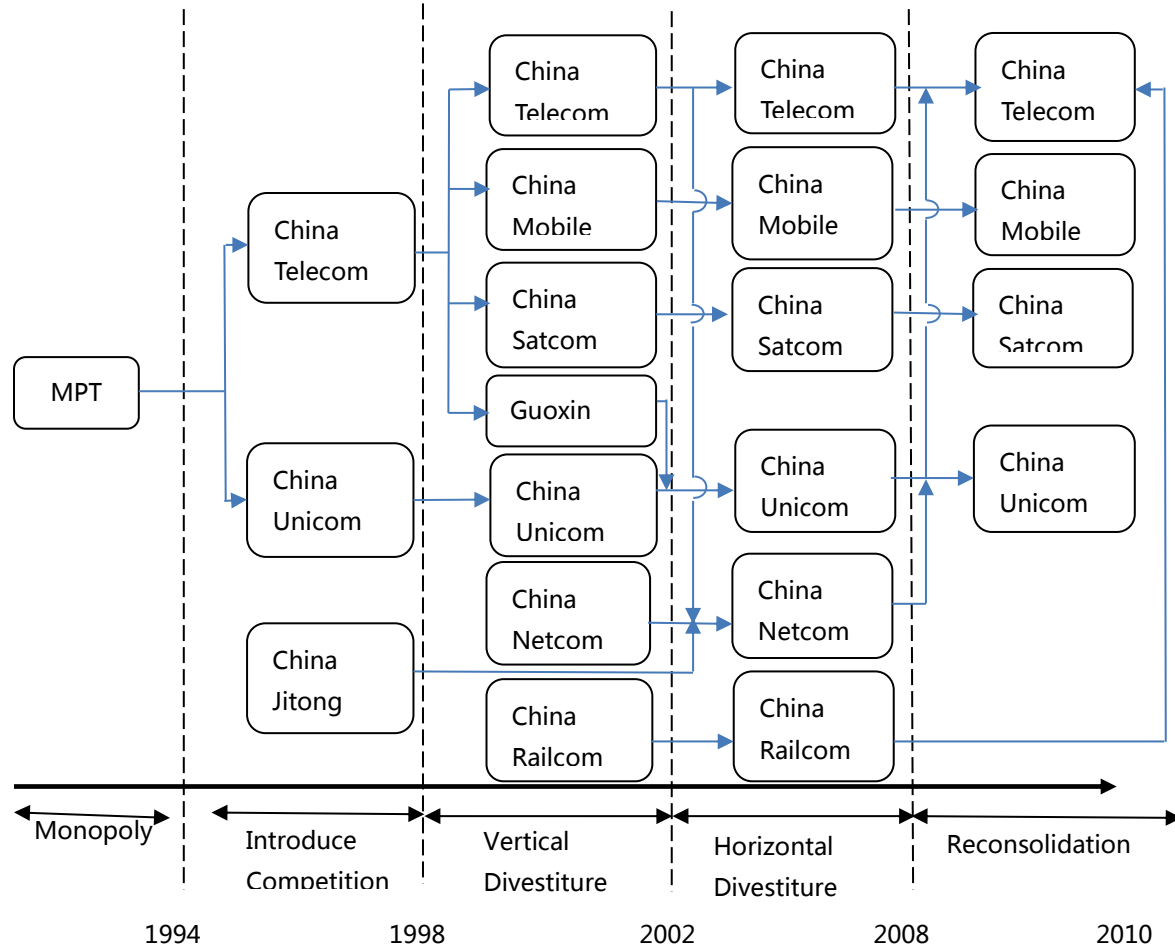


Figure 3 Provinces of China with the number of total and (fixed) telecommunications operators



Table 1. Summary Statistics

Variable	Mean	Std. Dev.	Minimum	Maximum
Percent growth of GDP per capita	0.103	0.044	-0.158	0.390
Mobile subscriptions per capita	19.095	25.114	0.000	117.654
Fixed-line subscriptions per capita	14.403	13.366	0.227	81.308
Fraction International Trade / GDP	0.300	0.409	0.032	2.257
Fraction Gross Fixed Investment / GDP	0.408	0.143	0.072	1.106
Fraction Govt. Consumption / GDP	0.156	0.110	0.049	1.086
Population Growth Rate	0.011	0.026	-0.139	0.358
GDP per capita (Yuan)	3,508	3,885	408	29,605
Mobile Hirschman-Herfindahl Index (HHI)	0.766	0.213	0.421	1.000
Fixed Hirschman-Herfindahl Index (HHI)	0.932	0.092	0.574	1.000
Nearest Five Provinces' Average Mobile HHI	0.765	0.209	0.455	1.000
Nearest Five Provinces' Average Fixed HHI	0.930	0.088	0.711	1.000

Table 2. OLS Estimates with Two-Way Fixed Effects

	(1)	(2)	(3)	(4)
Log Mobile Subscribers per capita	0.005** (0.002)		0.006*** (0.002)	0.004** (0.002)
Log Fixed Subscribers per capita		0.001 (0.005)	-0.006 (0.006)	0.010** (0.005)
Mobile-Fixed Interaction				0.002*** (0.000)
Lag log GDP per capita	-0.079*** (0.013)	-0.067*** (0.012)	-0.079*** (0.013)	-0.032*** (0.007)
Share International Trade	0.013* (0.007)	0.011 (0.007)	0.012* (0.007)	0.010 (0.007)
Gross Fixed Investment / GDP	0.096*** (0.014)	0.101*** (0.014)	0.098*** (0.014)	0.108*** (0.014)
Govt. share of Consumption	-0.023 (0.033)	-0.007 (0.034)	-0.018 (0.034)	0.010 (0.030)
Population Growth Rate	-0.998*** (0.039)	-1.006*** (0.042)	-1.008*** (0.040)	-0.973*** (0.042)
Year Dummies	X	X	X	X
Province Dummies	X	X	X	X
Observations	600	634	600	600
R-squared	0.712	0.715	0.713	0.670
Standard errors in parentheses				
*** p<0.01, ** p<0.05, * p<0.1				

Table 3. SYS-GMM Estimates for 1991-2010 Assuming Telecommunications Exogenous

	(1)	(2)	(3)	(4)
Lag Growth Rate in GDP per capita	0.482*** (0.144)	0.404*** (0.131)	0.491*** (0.147)	0.491*** (0.147)
Log Mobile Subscribers per capita	0.004* (0.002)		0.004** (0.002)	0.005** (0.002)
Log Fixed Subscribers per capita		0.002 (0.004)	-0.006 (0.004)	-0.004 (0.004)
Mobile-Fixed Interaction				0.000 (0.001)
Lag log GDP per capita	-0.005** (0.003)	-0.004 (0.003)	-0.002 (0.003)	-0.004 (0.004)
Share International Trade	0.014*** (0.005)	0.015*** (0.004)	0.015*** (0.005)	0.014*** (0.005)
Gross Fixed Investment / GDP	0.019* (0.011)	0.022** (0.010)	0.021* (0.011)	0.022** (0.011)
Govt. share of Consumption	-0.012 (0.012)	-0.019 (0.012)	-0.013 (0.012)	-0.012 (0.012)
Population Growth Rate	-1.162*** (0.062)	-1.137*** (0.058)	-1.171*** (0.065)	-1.169*** (0.064)
Year Dummies	X	X	X	X
AR (1) P-value	0.000	0.000	0.000	0.000
AR (2) P-value	0.777	0.848	0.803	0.783
Sargan test P-value	0.771	0.552	0.802	0.835
Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1				

Table 4. SYS-GMM Estimates Assuming Telecommunications Exogenous by Period

	1991-2000		2001-2010	
Lag Growth Rate in GDP per capita	0.509*** (0.065)	0.227 (0.193)	-0.102 (0.251)	0.442*** (0.119)
Log Mobile Subscribers per capita	0.005* (0.003)	0.005** (0.002)	0.010** (0.004)	0.013** (0.006)
Log Fixed Subscribers per capita	0.012 (0.007)	0.021*** (0.008)	-0.017** (0.007)	0.006 (0.008)
Mobile-Fixed Interaction		0.001** (0.001)		-0.005** (0.002)
Lag log GDP per capita	-0.029*** (0.008)	-0.036*** (0.008)	0.021** (0.008)	0.007 (0.006)
Share International Trade	0.005 (0.006)	0.006 (0.006)	-0.019 (0.015)	0.022** (0.009)
Gross Fixed Investment / GDP	0.050** (0.022)	0.053*** (0.020)	0.045*** (0.009)	0.032*** (0.011)
Govt. share of Consumption	-0.220*** (0.056)	-0.321*** (0.077)	-0.025** (0.012)	-0.004 (0.010)
Population Growth Rate	-1.213*** (0.062)	-1.114*** (0.058)	-0.951*** (0.065)	-1.170*** (0.064)
Year Dummies	X	X	X	X
AR (1) P-value	0.000	0.093	0.052	0.000
AR (2) P-value	0.916	0.559	0.068	0.150
Sargan test P-value	0.284	0.240	0.574	0.135
Standard errors in parentheses				
*** p<0.01, ** p<0.05, * p<0.1				

Table 5. SYS-GMM Estimates Assuming Telecommunications Endogenous by Period

Own Province HHIs Used as Instruments

	1991-2000		2001-2010	
Lag Growth Rate in GDP per capita	0.548*** (0.069)	0.344*** (0.130)	0.431*** (0.114)	0.214** (0.094)
Log Mobile Subscribers per capita	0.010* (0.006)	0.021** (0.010)	0.017* (0.009)	0.024** (0.010)
Log Fixed Subscribers per capita	-0.021 (0.023)	0.005 (0.022)	-0.032* (0.019)	-0.028** (0.012)
Mobile-Fixed Interaction		0.002** (0.001)		-0.004 (0.003)
Lag log GDP per capita	-0.001 (0.021)	-0.035** (0.017)	0.011 (0.009)	0.023*** (0.008)
Share International Trade	0.009 (0.009)	-0.009 (0.009)	0.013 (0.008)	0.007 (0.008)
Gross Fixed Investment / GDP	0.052** (0.023)	0.071*** (0.022)	0.025** (0.012)	0.032*** (0.009)
Govt. share of Consumption	-0.183*** (0.062)	-0.264*** (0.070)	-0.007 (0.011)	-0.017** (0.008)
Population Growth Rate	-1.195*** (0.197)	-1.109*** (0.184)	-1.166*** (0.051)	-1.097*** (0.039)
Year Dummies	X	X	X	X
AR (1) P-value	0.000	0.003	0.000	0.000
AR (2) P-value	0.723	0.944	0.177	0.101
Sargan test P-value	0.603	0.520	0.304	0.105
Standard errors in parentheses				
*** p<0.01, ** p<0.05, * p<0.1				

Table 6. SYS-GMM Estimates Assuming Telecommunications Endogenous by Period  
Nearest Five Province HHIs Used as Instruments

	1991-2000		2001-2010	
Lag Growth Rate in GDP per capita	0.559*** (0.071)	0.315** (0.133)	0.413*** (0.114)	0.213** (0.098)
Log Mobile Subscribers per capita	0.010* (0.006)	0.018** (0.009)	0.018** (0.008)	0.027*** (0.010)
Log Fixed Subscribers per capita	-0.027 (0.024)	0.008 (0.021)	-0.032* (0.017)	-0.034*** (0.012)
Mobile-Fixed Interaction		0.002** (0.001)		-0.003 (0.003)
Lag log GDP per capita	0.006 (0.022)	-0.035** (0.017)	0.011 (0.008)	0.022*** (0.007)
Share International Trade	0.011 (0.010)	-0.006 (0.009)	0.011 (0.008)	0.005 (0.008)
Gross Fixed Investment / GDP	0.050** (0.023)	0.066*** (0.021)	0.023** (0.011)	0.028*** (0.009)
Govt. share of Consumption	-0.174*** (0.064)	-0.275*** (0.069)	-0.007 (0.010)	-0.016* (0.008)
Population Growth Rate	-1.196*** (0.201)	-1.083*** (0.181)	-1.158*** (0.051)	-1.093*** (0.041)
Year Dummies	X	X	X	X
AR (1) P-value	0.000	0.004	0.000	0.000
AR (2) P-value	0.789	0.788	0.163	0.101
Sargan test P-value	0.629	0.435	0.417	0.307
Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1				

Table 7. SYS-GMM Estimates  
Differences between eastern versus western China

	1991-2000		2001-2010	
Lag Growth Rate in GDP per capita	0.358*** (0.083)	0.374*** (0.083)	0.372*** (0.098)	0.338*** (0.093)
Log Mobile Subscribers per capita	0.012** (0.006)	0.012** (0.006)	0.017** (0.008)	0.019** (0.007)
Log Fixed Subscribers per capita	0.018 (0.019)	0.009 (0.019)	-0.031* (0.016)	-0.033** (0.014)
Log Mobile Subscribers per capita $\times$ East Region Dummy	-0.007*** (0.001)	-0.007*** (0.001)	0.004 (0.005)	0.003 (0.005)
Log Fixed Subscribers per capita $\times$ East Region Dummy	0.013*** (0.004)	0.012*** (0.004)	-0.004 (0.005)	-0.002 (0.005)
Lag log GDP per capita	-0.054*** (0.020)	-0.045** (0.020)	0.011 (0.007)	0.012* (0.007)
Share International Trade	-0.007 (0.009)	-0.005 (0.009)	0.007 (0.007)	0.005 (0.007)
Gross Fixed Investment / GDP	0.046** (0.021)	0.045** (0.021)	0.029*** (0.010)	0.027*** (0.010)
Govt. share of Consumption	-0.162*** (0.058)	-0.152** (0.059)	-0.008 (0.010)	-0.009 (0.009)
Population Growth Rate	-1.081*** (0.178)	-1.075*** (0.181)	-1.143*** (0.045)	-1.129*** (0.044)
Year Dummies	X	X	X	X
Instruments	Own Province HHIs	Nearest Five Provinces HHIs	Own Province HHIs	Nearest Five Provinces HHIs
AR (1) P-value	0.000	0.004	0.000	0.000
AR (2) P-value	0.861	0.841	0.139	0.128
Sargan test P-value	0.116	0.155	0.390	0.433
Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1				