Does National Broadband Plan Narrow Digital Divide?  
Evidence from China

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Abstract

While more and more countries are jumping on the broadband plan bandwagon, there is a dearth of research on whether if a national broad plan could narrow a nation’s regional digital divide. In this paper, we use recent national statistical data sets to quantify the impact of China’s national broadband strategy on the digital divide. Our analysis has shown, while such a strategy could narrow the regional divide in terms of coverage of broadband infrastructure, it has a limited impact on closing the penetration divide, not to mention the quality divide. Particularly for countries that have entered the saturation stage of broadband development, the emphasis on broadband policy must be changed from continuing to invest in infrastructure to targeting users directly.

Keywords: Digital Divide, Broadband, China, Information Development
Introduction

Recently, numerous national plans have been initiated to boost the development of broadband. Some statistics have shown that there appears to be a positive relationship between the presence of a national broadband plan and a country’s broadband penetration (The Broadband Commission for Digital Development, 2013). However, while more and more countries are jumping on the broadband-rush bandwagon, previous research has been inconclusive on the effectiveness of government policy in broadband development (Belloc, Nicita, & Rossi, 2012; Cava-Ferreruela & Alabau-Muñoz, 2006; Falch, 2007; Picot & Wernick, 2007). In particular, there is a dearth of research on whether a national broadband plan could narrow a nation’s regional digital divide.

As the world’s largest developing economy, China in the last decade has taken an incremental approach to address digital divide, maintaining a constantly updated program to connect its vast rural areas (Liu & Jayakar, 2012; Shi, 2008; Jun Xia, 2016a, 2016b). So far, China appears to have a proven record to accomplish its universal service objectives. Since 2013, China has started its ambitious national broadband plan, in which balanced development across different regions is listed as one of the key tasks and specific goals regarding rural/urban broadband development. In this paper, we use three national statistical data sets to quantify the impact of China’s national broadband strategy on the digital divide. To the best of our knowledge, this paper is not only the first attempt in the literature to study the regional digital divide in China quantitatively but also one of the few pieces internationally to evaluate the effectiveness of national broadband in narrowing the digital divide. Since China’s broadband has entered the seemingly saturated stage, lessons drawn from China could be potentially useful to both developing and developed countries.

Literature Review

The digital divide can be defined to exist between countries, regions, communities, organizations, or individuals (Hilbert, 2011; Katz & Gonzalez, 2016; Riggins & Dewan, 2005). From the policymaker’s perspective, it is a ‘relative’ concept because it only assumes significance if it is examined within the specific context of countries or geographical areas, and the choice of the level of analysis influences policy responsibility (Corrocher & Ordanini, 2002; Hilbert, 2011). However, most of the existing studies have generally been conducted at the international/national and individual levels (Barzilai-Nahon, 2006; Katz & Gonzalez, 2016; Vicente & López, 2011). In many cases, the discrepancies at regional/local levels shall not be disregarded, and this level of policy resolution might actually be more meaningful than the national and international levels (Barzilai-Nahon, 2006). In particular, rural-urban disparities have been found in many countries to constitute an important dimension of the regional digital divide (Hindman, 2000; Rao, 2005).

Among the few studies with a regional focus, most, if not all, refer to developed countries, such as the United States and the European Union (EU) (Chakraborty & Bosman, 2002, 2005; Grubesic, 2006; Hindman, 2000; National Telecommunications and Information Administration., 1999, 2004, 2010; Schleife, 2010; Vicente & López, 2011). A study on the digital divide across the regions of the 27 member states of the European Union (EU-27) shows that regional policy seems to be having some positive implications for technology adoption, and the rural-versus-urban
dimension of the digital gap appears to be less important than usually claimed (Vicente & López, 2011). In addition, a German-based study indicates that the different composition of individual characteristics between rural and urban populations, not population density, accounts for the regional digital divide (Schleife, 2010).

In recent years, numerous countries have initiated various national "plans" to drive broadband network development. To various degrees, governments across the globe have returned to playing a proactive role to help speed up broadband development (Calandro & Moyoo, 2012; Galperin, Mariscal, & Vicencs, 2013; Jain, 2014; Jayakar & Liu, 2014a; Shin & Jung, 2012). So far, the evidence from empirical findings exhibits a certain disunity regarding the effectiveness of government policy in broadband development (Belloe et al., 2012; Cava-Ferreruela & Alabau-Muñoz, 2006; Falch, 2007; Picot & Wernick, 2007). Generally, broadband forerunners such as Sweden, Finland, Japan, and Korea took a proactive interventionist approach when they began their broadband rollouts; these approaches featured specific missions, achievable goals and policies designed to achieve success (Eskelinen, Frank, & Hirvonen, 2008; Frieden, 2005; Lau, Kim, & Atkin, 2005). However, it was argued that the effectiveness of the direct government involvement varies across countries and different stages of broadband development (Briglauer, Frubing, & Vogelsang, 2015). Particularly, although technology-centered policy frameworks and broadband strategies seem to generate higher take-up rates and penetration of new technologies, only demand-side policies appear to generate a positive and increasing effect after broadband penetration reaches a certain degree (Belloe et al., 2012; Dias, 2012; Preston & Cawley, 2008; Shin & Jung, 2012; Shin & Kweon, 2011). Nonetheless, while the presence of a national broadband plan could promote broadband development in general (The Broadband Commission for Digital Development, 2013), there seems to be a lack of research on the impact of a national broadband plan on the digital divide.

The Chinese Context

As the world’s largest developing economy, the urban-rural divide is considered one of the outstanding characteristics of Chinese inequality (Knight & Song, 1999). Particularly, the urban-rural dual structure remains the primary and most important analytical framework for the study of China’s digital divide and universal service policy (Guo & Chen, 2011).

China’s Universal Service in Retrospect

China has chosen to follow an incremental approach to address digital inequality (Liu & Jayakar, 2012; Shi, 2008; Jun Xia, 2016a, 2016b). Despite the absence of a universal-service funding mechanism, the “Telephone in Every Village” program succeeded in connecting 99.7% of administrative villages by the end of 2007 and was later extended to natural villages1 (Jayakar & Liu, 2014b). The Chinese government’s proactive measures to encourage competition and to support telecommunication development in the interior regions, combined with technological

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1 An administrative village is the lowest level of government administration in China. The natural village is defined as a rural community consisting of over 20 households, which is usually spontaneously and naturally exists within rural area. An administrative village might comprise of one or more natural villages.
Advances in mobile communications, has helped China since 2005 reverse the well-known association between economic growth and widening digital divide, a difficult dilemma faced by governments of most developing countries (Loo & Ngan, 2012). Since 2007, the Chinese government has gradually added extra layers of services to its universal service program, including broadband. The original Telephone in Every Village was upgraded to “Information to the Countryside” program in 2009, which required state-owned telecommunications carriers to integrate traditional “access” and value-added “applications” into a single package in rural areas. In 2011, China began to implement its 12th Five-Year Plan, in which the government plans to increase the administrative village broadband penetration to 95% and to connect all natural villages with basic telephone service. In terms of implementation, the Chinese government simply distributed the task of providing universal service in the various regions to the country’s state-owned carriers. Overall, while certain noticeable achievements have been made in terms of the increased numbers of rural telephone/broadband penetration rates, rural government websites, rural information stations, and agriculture-related websites, China’s universal service policy has also been found to be uncertain and inconsistent due to the ambiguous roles of government and business and government-business relations, in terms of both regulatory incentives and regulatory governance, and often fragmented under a powerful ideological influence that has led to unclear institutional arrangements and regulatory confusion (Hanna, Qiang, Bhavnani, Kimura, & Sudan, 2009; Harwit, 2004; Jayakar & Liu, 2014b; Jun Xia, 2010; J. Xia & Lu, 2008). Two separate case studies conducted at the provincial level also revealed similar problematic issues, such as a lack of vision, coherent strategy, accountability, and a sustainable business model (Liu, 2012, 2016b; Ting & Yi, 2012).

Most of the above-mentioned studies emphasize the institutional factors that influence the way the universal service programs operate in China. Those studies aptly describe the status quo, reveal the dynamic relationships among the institutions involved in the universal service program, and identify problems and successes. Few studies, if any, have evaluated the impact of China’s national broadband campaign, in which universal broadband service is listed as one of the major strategic goals on the digital divide.

China’s National Broadband Plan

Since 2013, China has consecutively issued three major national policies regarding broadband development, setting specific goals for infrastructure development, initiating projects to boost information consumption and intervening in pricing (Liu, 2016a).

- Notice of the State Council on Printing and Distributing the “Broadband China” Strategy and its Implementation Plan (Guo Fa [2013] No. 31) (hereinafter referred to as the Strategy Plan) issued by the State Council in 2013;
- Several Opinions of the State Council on Promoting Information Consumption to Expand Domestic Demand” (Guo Fa [2013]. No 32) (hereinafter referred to as the Consumption Plan) issued by the State Council in 2013; and
- Guiding Opinions on Accelerating the Construction of High-speed Broadband Network to Increase Internet Speed and Cut Service Charges (Guo Ban Fa [2015]. No 41) (hereinafter referred to as the Service Plan) issued by the General Office of the State Council in 2015.
The Strategy Plan sets quantified goals, a technology roadmap, development timetable, key tasks and specific projects and articulates that China aims to build a ubiquitous, fast and advanced national broadband network before 2020 (State Council, 2013a). The Consumption Plan focuses on boosting domestic information consumption, aiming to boost China’s public and household spending on the information products and services to 3.2 trillion RMB, and the transaction volume on China’s e-commerce platforms was targeted to be 18 trillion RMB in 2015, a greater than 20 percent annual increase from now (State Council, 2013b). The Service Plan requires state-owned telecommunications carriers to lower charges on broadband access with specific instructions. For example, it encourages carriers to offer free data packages during non-peak periods, prohibits the compulsory clearing of unused data, allows the subscriber to transfer unused data to others as a gift, etc. (General Office of the State Council, 2015). Since broadband is formally recognized as a type of strategic public infrastructure and is thus granted the same legal status as conventional utilities, such as running water, electricity, and road work, it marks a major paradigm shift in China’s information policy from considering broadband as an optional value-added telecommunications service to a necessity (Liu, 2013, 2016a). From a broadband ecosystem’s perspective, the three Plans concentrate on components of infrastructure, application and user components and appear to be complementary (Liu, 2017).

Balanced development across different regions is listed as one of the key tasks in the Strategy Plan. Particularly, broadband would be included in the universal service (see Table 1 for the specific goals regarding rural/urban broadband development), focusing on extending broadband network to rural villages through the “broadband countryside project” (State Council, 2013a). Fiscal support, special universal service funding and tax deductions would be available. The Ministry of Industry and Information Technology (MIIT), the National Development and Reform Commission (NDRC), the Ministry of Finance (MOF) and other departments concerned are required to accelerate the improvement of the universal service compensation mechanism whose focus is broadband and to accelerate the construction of rural broadband infrastructure (General Office of the State Council, 2015; State Council, 2013b). In 2014, the three Ministries issued a joint call for applications, in which the successful applicant will be subsidized by the central government to build a broadband network in 100 selected counties in 5 western provinces (General Office of the NDRC, General Office of the MOF, & General Office of the MIIT, 2014).

Table 1. Major Objectives of the Rural Broadband Development

<table>
<thead>
<tr>
<th>Indicators</th>
<th>2013</th>
<th>2015</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of broadband users</td>
<td>Number of households with wireline broadband service (urban/rural) Million</td>
<td>210(160/50)</td>
<td>270(200/100)</td>
</tr>
<tr>
<td>Penetration rate</td>
<td>Household wireline broadband penetration (urban/rural) %</td>
<td>40(55/20)</td>
<td>50(65/30)</td>
</tr>
<tr>
<td>Network capacity</td>
<td>Broadband connection speed in urban areas (in selected developed regions) Mbps</td>
<td>20</td>
<td>20 (100)</td>
</tr>
<tr>
<td></td>
<td>Broadband connection speed in rural areas Mbps</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Broadband penetration for administrative village %</td>
<td>90</td>
<td>95</td>
</tr>
<tr>
<td>Information use</td>
<td>Number of Internet users (rural users) Million</td>
<td>700(180)</td>
<td>850(200)</td>
</tr>
</tbody>
</table>
While it is repetitively mentioned in the three Plans that a universal service mechanism shall be established, no specific details are proposed (Liu, 2016a). So far, China's existing universal service programs have been primarily funded by the state-owned carriers. The issue is unlikely to be settled in the near future after several failed attempts to establish this type of funding mechanism after universal service was written into the Telecommunications Law in 1996 (Jayakar & Liu, 2014a). It appears that China will continue to rely on the state carriers to roll out the broadband network in rural areas. As the nation’s *de facto* monopolist providers of broadband services, China’s state-owned carriers have a proven record of fulfilling the government’s universal service mandates. However, since extending broadband to unprofitable areas requires a significantly higher investment than extending traditional phone service, it remains to be tested whether China’s regional broadband digital divide has been narrowed since the national plan took effect.

**Measuring the Broadband Development**

Digital divide is a multifaceted phenomenon. Generally, there are two types of divides: inequalities in access to (first-level) and use of (second-level) digital technologies. In high-penetration countries where most people already use the Internet in some form, the research agenda has somehow shifted to the second order “digital inequality” because, while physical access gaps among different categories of income, employment, education, age, and ethnicity were more or less being narrowed, skills and usage gaps had emerged (DiMaggio, Hargittai, Celeste, & Shafer, 2004; Riggins & Dewan, 2005; van Dijk & Hacker, 2003; Warschauer, 2003). However, apart from a few cases, the disparity in the ICT adoption between developed and developing countries remained and possibly widened (Ayanso, Cho, & Lertwachara, 2010, 2014; Skaletsky, Soremekun, & Galliers, 2014). Thus, the study of the first-order digital divide form the developing countries’ perspective remains relevant. In this paper, we focus on the first-order digital divide and the access-oriented measurement points such as availability and penetration of infrastructure.

In their study of regional digital divide in EU-27 member countries, Vicente & López (2011) suggested the wireless digital gap and the quality of connections at the regional level should be included. Indeed, mobile Internet diffusion is far outperforming fixed, PC-based Internet access. In terms of physical access, the mobile phone helps bridge the digital divide. For example, Wareham, Levy and Shi (2004) found that certain subgroups of the population in the U.S.—including Afro-Americans, Hispanics, and certain professions that are traditionally unrepresented in terms of fixed Internet use—have adopted 2G mobile communication devices at rates equal or faster than the base population. Japan’s experiences also show that mobile Internet access, compared to computer access, is determined less by demographics, socioeconomic status, and technological readiness, suggesting that barriers to Internet access are lower for mobile phones than is the case for computers (Akiyoshi & Ono, 2008). Thailand’s mobile development also indicates that the price of mobile service is inelastic and mobile Internet could be a potential means to bridge the digital divide in areas that lack fixed line facilities (Srinuan, Srinuan, & Bohlin, 2012). In China, 75% of all Internet users access the Internet via a mobile device, exceeding the proportion of users accessing the Internet via a fixed connection (at 71%) in 2012 (The Broadband Commission, 2013). Therefore, data on mobile broadband, where it is available, are included in our analysis.
In addition, as Internet use becomes increasingly ubiquitous in our everyday lives, and average speeds have improved over time, inequity in terms of the quality of connection has emerged between different societal groups and locations. A study in UK found that higher speeds are generally clustered around major metropolitan areas, and average speeds are significantly slower in rural areas (Riddlesden & Singleton, 2014). Internationally, Hilbert (2016) measured the nationally installed bandwidth potential of 172 countries from 1986 to 2014 and found that the divide in terms of bandwidth does not show any clear monotonic pattern and that the bandwidth divide between high-and-low income countries first increased and only decreased below historic levels recently during 2012–2014. Thus, connection quality has become an important dimension of digital divide and is included in our analysis.

In summary, we use three measurements to capture the dimensions of broadband development: availability, penetration and quality. The data used in this paper are compiled from the China Statistical Yearbooks by the National Bureau of Statistics of China and the China Broadband Speed Reports by Broadband Development Alliance (BDA)\(^2\). The definitions of indicators are explained in Table 2. An important feature of the dataset is that it is a balanced panel dataset, i.e., there are nine sets of yearly records for each of the 31 administrative provinces, autonomous regions and municipalities, covering the period from 2007 to 2015\(^3\). This time period enables a dynamic gap analysis that tracks whether the broadband development gap between two regions is narrowed or widened rather than a static comparison at a specific time.

### Table 2 Dimensions and Definitions of Broadband Development

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Variable</th>
<th>Description</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broadband availability</td>
<td>Coverage</td>
<td>Number of installed broadband access points, including xDSL, LAN, etc., per 100 inhabitants(^*)</td>
<td>China Statistical Yearbook</td>
</tr>
<tr>
<td>Broadband penetration</td>
<td>Penetration</td>
<td>Number of registered in-service broadband access points, including xDSL, FTTX+Lan, LAN, and Mobile (3G, 4G), per 100 inhabitants</td>
<td>China Statistical Yearbook</td>
</tr>
<tr>
<td>Broadband quality</td>
<td>Speed</td>
<td>Average download speed (MB/s)</td>
<td>China Broadband Speed Reports</td>
</tr>
</tbody>
</table>

\(^*\)It is unclear whether the installed broadband access points include mobile networks

The data set includes statistics from 31 administrative provinces, autonomous regions and municipalities (Hong Kong Special Administrative Region, Macao Special Administrative Region and Taiwan are not included because data are not available for these regions). For comparative purpose, the 31 administrative provinces, autonomous regions and municipalities are classified into three economic regions: east, central and west zones, following the standard from the National Bureau of Statistics of China\(^4\).

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\(^2\) BDA is an industry association comprised of China’s major broadband service providers. BDA conducts research on broadband development, policy and standards.

\(^3\) Due to data availability, the measure of speed covers only the year of 2012 and 2015.

\(^4\) East: Beijing, Fujian, Guangdong, Hainan, Hebei, Jiangsu, Liaoning, Shandong, Shanghai, Tianjin, Zhejiang. Middle: Anhui, Henan, Heilongjiang, Hubei, Hunan, Jilin, Jiangxi, Shanxi. West: Gansu, Guizhou, Neimenggu, Ningxia, Qinghai, Shaanxi, Sichuan, Xizang, Xinjiang, Yunnan, Chongqing.

\(^5\) Following their geographic locations and developmental strategies (Western Development Strategy launched in 2000, Rise of Central China Plan launched in 2004), the 31 provincial-level administration regions in mainland
The Impact of the National Broadband Plan

As mentioned in the previous section, China has consecutively issued three major national policies regarding broadband development, starting from the second half of year 2013 to 2015. As shown in Table 3, in terms of the three measurements, all of the three regions have made certain progress. In this section, several statistical techniques are utilized to evaluate the impact of the national broadband plan on the regional digital divide.

<table>
<thead>
<tr>
<th></th>
<th>Coverage</th>
<th>Penetration</th>
<th>Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2013</td>
<td>2015</td>
<td>2013</td>
</tr>
<tr>
<td>East</td>
<td>35.22</td>
<td>54.51</td>
<td>17.28</td>
</tr>
<tr>
<td>Central</td>
<td>18.31</td>
<td>34.74</td>
<td>10.82</td>
</tr>
<tr>
<td>West</td>
<td>18.28</td>
<td>33.08</td>
<td>9.45</td>
</tr>
</tbody>
</table>

First, we adopted a prediction-comparison method. We fit a simple linear model using the dataset before 2013 and apply extrapolation to the year of 2014 and 2015 as predictions for the two variables coverage and penetration, respectively; then we compare the actual numbers with the predictions. Because the introduction of the national plans is viewed as an exogenous structural shock to the linear development of ICTs, if the actual level is higher than the prediction, the national plans are considered to have a positive impact on the development of ICTs. Table 4 summarizes the comparison between the actual and linear extrapolation.

As is shown in Table 4, for the year of 2014, the actual level of broadband coverage and broadband penetration is close to the linear prediction for all the east, central and west regions. However, the actual levels of broadband coverage and broadband penetration are consistently higher than the linear prediction for all three regions in 2015. In particular, the actual broadband coverage and penetration are significantly higher than the linear prediction in 2015.

China can be divided into three regions. Previous study has found that the uneven development of telecommunication services existed among the three regions (Loo & Ngan, 2012).

Due to data availability issue, the variable of speed is not included in this analysis.
coverage levels have great increases from the predictions: 20.41% for the east region, 33.41% for the central region and 27.23% for the west region. The findings suggest that the impact of major national policies starts to kick in the second year after they are issued, leading to a positive boost in the east, central and west regions.

Table 4 Comparison between actual and linear extrapolation

<table>
<thead>
<tr>
<th>Regions</th>
<th>Year</th>
<th>Actual coverage penetration</th>
<th>Prediction coverage penetration</th>
<th>(Actual-Prediction)/Prediction</th>
</tr>
</thead>
<tbody>
<tr>
<td>East</td>
<td>2014</td>
<td>39.83 18.73</td>
<td>40.77 20.11</td>
<td>-2.31% -6.86%</td>
</tr>
<tr>
<td></td>
<td>2015</td>
<td>54.51 22.91</td>
<td>45.27 21.66</td>
<td>20.41% 5.77%</td>
</tr>
<tr>
<td>Central</td>
<td>2014</td>
<td>23.75 12.47</td>
<td>23.20 13.20</td>
<td>2.37% -5.53%</td>
</tr>
<tr>
<td></td>
<td>2015</td>
<td>34.74 15.73</td>
<td>26.04 14.58</td>
<td>33.41% 7.89%</td>
</tr>
<tr>
<td>West</td>
<td>2014</td>
<td>24.06 11.27</td>
<td>23.02 11.76</td>
<td>4.52% -4.17%</td>
</tr>
<tr>
<td></td>
<td>2015</td>
<td>33.08 14.44</td>
<td>26.00 13.06</td>
<td>27.23% 10.57%</td>
</tr>
</tbody>
</table>

Since the actual-prediction difference in terms of penetration seems to not be prominent, a regression analysis is performed to further test the impact of the national broadband plan on this important indicator. A number of economic and demographic factors are selected for this analysis, based upon the research that has been conducted to date, data availability and an estimate of the econometric model of the general form:

\[ PEN_{it} = \alpha + X_{it}\beta + POLICY_{i} + \nu_i + \epsilon_{it} \]

where \( PEN_{it} \) is broadband subscriptions rate in province i in year t; POLICY is a dummy variable that equals 1 after the issuance of the policies (0 otherwise); and \( X_{it} \) is a vector of controlling factors in province i in year t, including AGE (percent of the labor force age 65 or older), HHS (persons per household), GDP (gross domestic product per capita) and EDU (percent of illiteracy in population over age 15).

The model is fitted with both the fixed-effects estimator and the random-effects estimator, and the estimates are reported in Table 5. The models fit the data well, with an overall \( R^2 \) of 75% for the random-effect estimator and an overall \( R^2 \) of 72% for the fixed-effect estimator. It is shown that POLICY has a significant positive effect on the broadband penetration rate, even after accounting for other factors. This means that the broadband policies themselves promote broadband development in China. As far as other variables are concerned, GDP has a significant positive effect and EDU has a significant negative effect on broadband penetration rate. However, HHS has no significant effect on broadband penetration rate, and the effect of AGE is yet to be determined as the two estimators yield conflicting results.

Table 5 Regression results

<table>
<thead>
<tr>
<th></th>
<th>Random-effects</th>
<th>Fixed-effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGE</td>
<td>Coef. 19.76</td>
<td>SE 15.95</td>
</tr>
<tr>
<td>HHS</td>
<td>1.27 1.08</td>
<td>0.24 0.65</td>
</tr>
<tr>
<td>GDP</td>
<td>2.38* 0.16</td>
<td>2.42* 0.20</td>
</tr>
<tr>
<td>EDU</td>
<td>-19.90* 6.37</td>
<td>-34.08* 9.78</td>
</tr>
</tbody>
</table>

The model is adapted from Ford, Koutsky and Spiwak (2007). Factors, which are not relevant for regional level analysis, are excluded.
Although it is shown that the policies have a positive effect in promoting broadband development, whether the gaps between regions are widened or narrowed after the national broadband policies are issued is yet to be discussed. The first step is to look into the statistical summaries of the sample in the years 2012 and 2015. A useful measure for this purpose is the coefficient of variation (CV), which shows the extent of variability in relation to the mean of the sample. The measure of CV is selected over standard deviation (SD) because it can be understood and compared without the context of the data mean. Table 6 shows both the means and CVs of the three variables in 2012 and 2015. As is evident in Table 6, comparing to year 2012, while the means of coverage, penetration and speed for year 2015 show great increase, the CVs of coverage and penetration are decreased, by regions and by administrative provinces, autonomous regions and municipalities. However, the measure of speed shows a different pattern: while the means multiply several times, the CVs remain the same. The results suggest that not only broadband development made progress as time went by but also the gaps between regions were narrowed down in terms of coverage and penetration. In terms of broadband speed, the gap between regions remained at the same level.

Table 6 Statistical Comparison of the year 2012 vs. 2015

<table>
<thead>
<tr>
<th>Year</th>
<th>Statistics</th>
<th>By regions</th>
<th>By provinces</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>coverage</td>
<td>penetration</td>
</tr>
<tr>
<td></td>
<td></td>
<td>mean</td>
<td>23.94</td>
</tr>
<tr>
<td></td>
<td>CV</td>
<td>0.41</td>
<td>0.33</td>
</tr>
<tr>
<td>2015</td>
<td>mean</td>
<td>40.77</td>
<td>17.69</td>
</tr>
<tr>
<td></td>
<td>CV</td>
<td>0.29</td>
<td>0.26</td>
</tr>
</tbody>
</table>

Figures 2–4 show the discrepancies in coverage, penetration and speed among west, central and east regions in 2012 and 2015. The discrepancy is defined as the surplus (or shortage) of the measure for the region over the average of the measure for the entire country divided by the average of the measure for the entire country. A positive discrepancy means the measure for the region is higher than the average for the country, and vice versa. For the measures of coverage and penetration, while the east region scores higher than the average level and the central and the west region score lower than the average level in both 2012 and 2015, the discrepancies seem to narrow across the years. Regarding the measure of speed, while the central region narrows the disadvantage compared to the east region, the west region seems to be further left behind.
Figure 2 Discrepancies in coverage among west, central and east regions, 2012 vs. 2015

Figure 3 Discrepancies in penetration among west, central and east regions, 2012 vs. 2015

Figure 4 Discrepancies in speed among west, central and east regions, 2012 vs. 2015

In addition to examining the broadband development gap between the three geographical regions as defined by administrative bureau, we are also interested in exploring the gap between intrinsic leaders and followers. In the following section, we aim to identify meaningful profiles through cluster analysis. We use a cluster-based methodology and build upon the three main component scores (i.e., coverage, penetration, and speed) to analyze the regional digital divide.
rather than developing a new normalization and weighting method. Our primary focus will be on capturing the natural grouping of the provincial regions as well as the movement of the provinces from one group to another based on the underlying structure of the data.

As a data-mining technique, cluster analysis has been applied to a wide variety of problems. Digital divide literature has also seen this technique, for example, profiling the level of access and use of ICT infrastructures (Ayanso et al., 2010), assessing the digital divide both at the global and regional level (Ayanso et al., 2014) and examining the levels of the ICT infrastructure development among the EU countries (Cuervo & Menéndez, 2006). Consistent with these studies, we use the two-step clustering algorithm to examine the digital divide at the provincial level. The two-step clustering algorithm has two steps: 1) pre-cluster the cases into small sub-clusters and 2) cluster the sub-clusters resulting from the pre-cluster step into the desired number of clusters. One benefit is that it can also automatically select the number of clusters based on objective statistical criteria such as the Bayesian Information Criterion (BIC).

The two-step clustering was applied to the 31 administrative provinces, autonomous regions and municipalities with no pre-specified number of clusters, for the years 2012 and 2015. The algorithm recommended two clusters based on a criterion of BIC changes, which we label as “leaders” and “followers”. There are 6 provinces and municipalities identified as leaders and 25 provinces, autonomous regions and municipalities as followers, for 2012 and 2015. One province, Liaoning, transitioned to the leader group from 2012 to 2015. The other five provinces and municipalities that remained in the leader group are Beijing, Fujian, Jiangsu, Shanghai and Zhejiang. Figure 5 shows the comparison of leaders and followers between 2012 and 2015.

Table 7 presents the summary statistics for the clusters obtained for 2012 and 2015. For both the leader and the follower groups, considerable progress was made for broadband development in terms of coverage, penetration and speed. The progress is particularly significant for the speed component. Additionally, the follower group seems to make greater progress than the leader group, which should lead to a narrowed gap between the two groups. This finding is confirmed by computing the gap between the leader group and the follower group and then comparing 2012 and 2015. The gaps in terms of coverage, penetration and speed are narrowed by approximately 1/3.

Table 7 Cluster profiles for 2012 and 2015
To validate the clusters derived from the cluster analyses, we conducted cluster evaluation using post hoc multivariate analysis of variance and covariance (MANOVA). We test to see if the three-dimensional mean vectors (coverage, penetration and speed) of the leader group and the follower group are different. Table 8 presents the MANOVA results for the clusters for 2012 and 2015. The results reject the null hypothesis that the mean vectors are the same, indicating that the clusters are statistically distinctive from each other.

### Table 8 MANOVA results for cluster validation

<table>
<thead>
<tr>
<th>Source</th>
<th>Statistic</th>
<th>F(df1, df2)</th>
<th>F</th>
<th>Proba&gt;F</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>W</td>
<td>0.26</td>
<td>3</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>P</td>
<td>0.74</td>
<td>3</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>L</td>
<td>2.90</td>
<td>3</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>R</td>
<td>2.90</td>
<td>3</td>
<td>27</td>
</tr>
<tr>
<td>2015</td>
<td>W</td>
<td>0.24</td>
<td>3</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>P</td>
<td>0.76</td>
<td>3</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>L</td>
<td>3.22</td>
<td>3</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>R</td>
<td>3.22</td>
<td>3</td>
<td>27</td>
</tr>
</tbody>
</table>

W = Wilks’ lambda, L = Lawley-Hotelling trace, P = Pillai’s trace, R = Roy’s largest root

### Discussion

Overall, as revealed in the previous section, China’s national broadband strategy has considerably increased the broadband coverage for all regions across China. However, while such policies have statistically significant positive impact on the penetration rate, the progress made so
far seems to be limited. In terms of regional inequality, the results suggest the gaps between regions were narrowed in terms of coverage and penetration. However, divide in broadband speed has remained at the same level. As a matter of fact, while the central region narrows the gap with the east region, the west region seems to be further left behind in terms of broadband speed. Not surprisingly, the traditional coastal-inland divide still remains. The leader group consists of provinces that are all located in eastern coastal regions. However, the gap between the leader and follower groups is expected to narrow because the latter seems to make greater progress.

Sawhney and Jayakar (1999) have articulated a three-fold typology of universal service expansion: territorial, demographic and layered expansions. According to their model, territorial expansion aims to extend networks across geographical space; whereas demographic expansion focuses on connecting more people to the network. The objective of layered expansion is adding new services to the menu of universal service offering or continuously enhancing the quality of the networks (for example, download speeds in broadband networks). In light of this conceptual framework, China’s national broadband campaign has been successful in achieving territorial expansion and narrowing the infrastructure divide. However, little headway has been made in demographic expansion, and the divide in the quality of service, one of the important objectives of the layered expansion, is instead widened. To some extent, the current national broadband plan in regard to digital divide is of no difference to the prior universal telephone service program, which emphasized territorial expansion but was deficient in terms of its demographic dimension (Jayakar & Liu, 2014b).

Previous research has found that China’s national broadband plan is largely a conventional supply-side industrial policy (Liu, 2016a, 2017). The plan emphasizes supply-side policies that seek to enhance broadband availability and largely neglects demand-side policies that aim to stimulate consumer needs (Liu, 2016a). Interestingly, while the goals are outlined, the funding mechanism for China’s broadband plan itself has not been systematically and explicitly addressed, much less universal service. The major strategy of the Chinese government appears to create a competitive market structure and primarily rely on state-owned carriers to fulfill the universal service objectives (Liu, 2017). Since affordable access for all Chinese people to telecommunication services is of extreme significance to the stability of the Party-state and the improvement of rural communications was considered one of the indicators of the Party’s “socialist new countryside” campaign, the universal service program has historically been endowed with political significance, and China’s state-owned carriers have a proven record of accomplishing the territorial expansion (Jayakar & Liu, 2014b; Liu, 2016b; Shi, 2008; Jun Xia, 2016a, 2016b; Jun Xia & Lv, 2008).

Previous research has generally agreed that, although technology-centered broadband strategies seem to generate a higher take-up rate and penetration of new technologies, only demand-side policies appear to generate a positive and increasing effect after broadband penetration reaches a certain degree (Belloc et al., 2012; Dias, 2012; Preston & Cawley, 2008; Shin & Jung, 2012; Shin & Kweon, 2011). China's broadband market entered the saturation stage in approximately 2013 (Liu, 2017). Against this backdrop, the fact that China’s national broadband campaign has a limited impact on increasing broadband penetration in general, narrowing the penetration divide in particular seems to fit well with theoretical proposition.

Indeed, infrastructure is just one of the many dimensions of digital divide. Network availability does not necessarily boost subscription. Economic, political, and social endowments
all have impacts on the degree of broadband adoption (Ford et al., 2007). Continued investment in infrastructure has a diminishing effect on broadband development once a country enters the saturation stage. Consequently, a more comprehensive policy approach is needed than simply laying down broadband cables. In particular, for developing countries, which usually have very limited resources, it is vital to avoid inefficient investment. While China’s broadband policy emphasis seems to be shifting from infrastructure and service to application and user, user-centric demand-side policies such as subsidy to low-income and other disadvantaged sections of the population, digital literacy training and other programs, which are essential to the narrow digital divide, are still missing (Liu, 2017). To further narrow the penetration and quality divides, Chinese government must reallocate resources to user-centric policy instruments.

Conclusions

National governments have initiated various plans to boost broadband development. The United Nation’s Broadband Commission for Digital Development (2013) has estimated that the introduction or adoption of a broadband plan was associated with a 2.5% higher fixed broadband penetration and a 7.4% higher mobile broadband penetration on average. However, evidence from China has shown, while such a strategy could narrow the regional divide in terms of coverage of broadband infrastructure, it has a limited impact on closing the penetration divide, not to mention the quality divide. Since the digital divide is a multifaceted phenomenon, the availability of infrastructure is an essential, but not the only, prerequisite for solving the issue of the digital divide. Particularly for countries that have entered the saturation stage of broadband development, the emphasis on broadband policy must be changed from continuing to invest in infrastructure to targeting users directly. In China’s context, a paradigm shift is recommended in digital divide policy; stepping out of the comfort zone of the investment-driven top-down approach and transitioning to a comprehensive one is much needed.

Some limitations must also be considered in this study. First, to present a parsimonious model constrained by the availability of data resources, we did not include a large number of variables in the analysis. Other factors, such as social and cultural factors, might also contribute to explain the regional divide, which requires more detailed data and variables. Second, our analysis is conducted at the regional level. While the regional divide has been the focus of China’s digital divide in the previous research, it neglects subtle differences. For example, it needs a closer investigation into why the Liao Ning province transitions into the leader group. A multiple case study is warranted to look at how provincial-level policies interact with the national strategy. Third, since the regional digital divide is assessed at a given point in time, future studies should look at how the regional divide evolves over time, since the impact of the national policy might have a delayed effect.

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