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The Impacts of Broadband on Economic Growth in People's Republic of China: Empirical Analysis from Panel Data

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Abstract: **This research study is to analyze the impacts of broadband on economic growth in 30 regions of People's Republic of China during 2006 to 2015 by using panel data. Firstly, adopting Padroni method to examine whether exists the cointegration among economic growth and broadband constructions. Regarding the empirical results, there has a long-run relationship between broadband constructions and economic growth. Secondly, based on the empirical results from panel dynamic ordinary least square (DOLS) and fully modified ordinary least square (FMOLS), there exists a long run elasticity equilibrium co-integration within the variables, and the coefficients of independent variables are positive. Then selecting fixed effect models based on the results of Hausman test and applying panel GLS to measure the impact of broadband constructions on Chinese economy. In conclusion, it can be summarized that broadband constructions are significant aspects which positively impact on Chinese economic development.**

Index Terms— broadband, economic growth, panel data, cointegration, fixed effects, DOLS, FMOLS.

I. INTRODUCTION

Since the 20th century, with the rapid development of scientific and technological innovation, technological progress plays an important role in economic development. Broadband has the characteristics of breaking through the limitation between time and space. On the one hand, broadband use has great connection with daily life, it brought more convenience for users. On the other hand, with broadband infrastructure industry has been developing so fast in recent years, broadband technology as a new factor that promotes GDP growth cannot be ignored, not only due to its major economic activity having large multiplier effects, but also because improvement in broadband constructions usually comes with extensive external social and economic benefits. Moreover, the Chinese economy has developed dramatically in past decades, since 2010, Chinese total GDP value exceeded that of Japan to become the second largest worldwide. Nowadays, Chinese GDP had reached 1,0385.66 billion dollars in 2016. So that China's rapid economic growth has attracted the global attention of many scholars and economists.According to global broadband research institute of United Nations (2013), broadband penetration rate growth by 10 percent could boost GDP growth by 2.5 percent in the People' Republic of China [1]. Also, Chinese internet users have grown to 731 million users and the internet penetration rate reached 53.2 percent in 2016, and Guangdong province has the highest broadband subscribers in comparison to other 29 regions. According to statistical database, GDP value in Guangdong reached about 8 trillion Yuan in 2016, and it is over other provinces of People's Republic of China in recent 28 years, which implies the constructions of broadband and regional economic development has a connection. Improving the constructions of broadband is conducive to economic growth.

Based on the above description, this paper will mainly discuss two problems. Firstly, it will measure whether exist long-run relationship between broadband constructions on Chinese economy. Secondly, as the cointegrated variables are given, then added to examine the long-run elasticity. Thirdly, generalized least square (GLS) method was used to estimate the cointegration regressions. In this paper, Internet users, broadband subscribers port of Internet and investment in computer services and software are represented the broadband constructions respectively.The rest of the paper is organized as follows. Section 2 provides the literature reviews. Section 3 conducts the theoretical model, and section 4 presents the data source and description. The econometric methodology and empirical results are presented in section 5. Lastly, Section 6 reported the conclusions.

II. LITERATURE REVIEW

The dramatic broadband constructions appreciation over recent years, with increasing issues related to internet and economic growth, has been studied. The studies involved are divided mainly into two groups; one to examine the main factors that affecting broadband development, and another to investigate the relationship between infrastructure of broadband and economic growth. However, few studies were conducted by using cointegration relationship between

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broadband constructions and economic growth.The literature with differing empirical evidence regarding the relationship between broadband constructions and economic growth, with some relevant researches finding a one-way or two-way relationship between them. Minges [2] explored the relationship between broadband and economic growth with 120 developing and developed countries. The result showed that the fixed broadband would increase GDP growth by 1.21 percent in developed economies and 1.38 percent in developing ones during 1980 to 2006.

Moreover, Atif et al. [3] found every 10 percent increase in the growth of broadband penetration will raise economic growth per employee by approximately 0.035 percentage points among OECD countries over the period of 1998 – 2010. Gilchrists [4] employed the log-linear approximation model to indicate that the higher the broadband penetration the greater the impact on economic growth in the eastern Caribbean telecommunications authority (ECTEL) member countries from 2002 to 2014. Kindbom [5] utilized a fixed effects model and employed ordinary least square (OLS) to find the effect of broadband on the growth of GDP is positive and significant.

There are several Chinese research papers performed the relation of the multi-variables with Chinese economy and broadband infrastructure. Yong Zhang [6] studies the contributions of internet information services on economic growth by utilizing total factor productivity(TFP) to construct the growth model in research, the result indicated that the contributions of internet information services on an average annual GDP growth rate has reached 1.54 percent. Baoguo Han [7] discussed the impacts of broadband network and information services on economic growth by deriving a model of quantitative relationship between information service and the division of labor based on Yang-Borland's division of labor model, from the results found that 10 percent increase in broadband penetration raised annual per capita growth rate by 0.19 percentage points.

As above description, most of the analyses indicated that broadband has significant and positive effects on economic growth. The different results depend on different methodologies and different endogenous variables.

III. THEORETICAL MODEL

The theoretical model of this study is based on the Cobb-Douglas production function (1928). The traditional production function regards the output as a function of capital and labor, according to Cobb-Douglas, which is the basic form as following:

$$Y = AK^{\alpha} L^{\beta}, \qquad (1)$$

where, A is technology efficient determining all factors of production, Y is output, K is capital stock, L is labor force, α and β represent the output elasticity of the capital investment and labor investment.

Therefore, the model function forms of this study have been derived as follows:

$GDP_{it} = F(K_{it}, L_{it}, Int_{it}, Sub_{it}, Com_{it})$ (2) where,

GDP_{it} is gross domestic product in province i at time t,
K_{it} is capital stock in province i at time t,
L_{it} are employment persons in province i at time t,
Int_{it} is Internet users in province i at time t,
Sub_{it} is broadband subscribers port of internet in province i at time t,
Comit is investment in computer services and software in province i at time t.
τ_{it} is the fixed effect
ε_{it} is a random disturbance item.

Taking the natural logarithm into the equation (2), the derived equation for this study as following:

$$LnGDP_{it} = \beta_0 + \beta_1 LnK_{it} + \beta_2 LnL_{it} + \beta_3 LnInt_{it} + \beta_4 LnSub_{it} + \beta_5 LnCom_{it} + \tau_{it} + \varepsilon_{it} \qquad (3)$$

where, β_0 is a constant intercept, $\beta_1, \beta_2, \beta_3, \beta_4$and β_5 are constant slope coefficients of capital stock, employment persons, internet users, broadband subscribers port of internet, investment in computer services and software respectively. τ_{it} is the fixed effect, ε_{it} is a random disturbance item.

The above regression model is used in this paper that explain the relationship between dependent variable and independent variables.

IV. DATA SOURCE AND DESCRIPTION

This study employed panel data analysis for 30 provinces, municipalities and autonomous regions from 2006 to 2015 in People's Republic of China. In addition, in view of data availability considerations, this paper collected data that except Hong Kong, Macao, Tibet and Taiwan regions.
All data collected from Chinese statistical yearbook in national bureau of statistics in People's Republic of China, and those data including real GDP (measured in constant 2006 Yuan), internet users (measured by 10,000 persons), broadband subscribers port of internet (measured by 10,000 ports), capital stock (constant base on 2000 Yuan), employed persons (measured by 10,000 persons), investment in computer services and software (measured by 100 million Yuan). Table 1. is the data statistics description of all

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variables including LnGDP, LnCOM, LnINT, LnK, LnSUB and LnL in China from 2006 to 2015.

Table 1: Data statistic description

	Obs.	Mean	Median	Maximum	Minimum	Std.Dev.
LnGDP	300	9.30836	9.437245	11.19564	6.474662	0.93389
LnCOM	300	4.189488	4.289318	6.496562	0.465117	0.960681
LnINT	300	4.566816	4.699107	6.655183	1.308333	1.004937
LnK	300	9.884396	9.987592	11.69247	7.443492	0.877852
LnSUB	300	6.187289	6.305727	8.469871	2.734368	1.125874
LnL	300	5.944797	6.034484	7.587452	3.765972	0.758345

Source: China Statistic Bureau, 2006-2015.

Table 1 shows that data statistic in Republic of China from 2006 to 2015, 300 observations of LnGDP, LnCOM, LnINT, LnK, LnSUB and LnL in the study. The mean and median value of LnGDP are 9.30836 and 9.437245, respectively, and the maximum and minimum values of LnGDP are 11.19564 and 6.474662, respectively. The standard deviation of LnGDP is 0.93389. Moreover, the mean and median value of LnCOM are 4.189488 and 4.289318 respectively, and the maximum and minimum values are 6.496562 and 0.465117, respectively, the standard deviation of LnCOM was 0.960681. Furthermore, the mean and median value of LnINT are 4.566816 and 4.699107 respectively, and the maximum and minimum values are 6.655183 and 0.465117, respectively, the standard deviation of LnINT is 1.004937. The mean and median value of LnK is 9.884396 and 9.987592, respectively, and the maximum and minimum values of LnK are 11.69247 and 7.443492, respectively. The standard deviation of LnK is 0.877852. And The mean and median value of LnSUB is 6.187289 and 6.305727, respectively, and the maximum and minimum values of LnSUB are 8.469871 and 2.734368, respectively. The standard deviation of LnSUB is 1.125874. Lastly, the mean and median value of LnL is 5.944797 and 6.034484, respectively, and the maximum and minimum values of LnL are 7.587452 and 3.765972, respectively. The standard deviation of LnL is 0.758345.

V. METHODOLOGY AND EMPIRICAL RESULTS

The unit root test is a common approach to analyze whether the data is stationary or non-stationary at level I (0) or first derivation I (1) before testing for cointegration. [8] Then, panel estimation considers about fixed effects model and random effects model, and Hausman test will be used in model selection and compare the estimators of the tested models.

a. Panel unit root test

The unit root test was conducted to avoid of spurious regression problem. All variables need to be stationary at any point estimated, a non-stationary time series will become stationary after differencing several times. [9]

There are six methods for panel data unit root test, which are: Levin-Lin-Chu (2002), Breitung (2000), Im-Pesara-Shin (2003), Fisher-type test using ADF (Maddala and Wu,1999), Fisher-type test using PP test (Choi,2004) and Hadri (2000) to check for the presence of stationary around a deterministic trend or mean with a shift against a unit root.[10] The properties of panel-based unit root tests under the assumption that the data is independent and identically distributed (i.i.d) across individuals. Two panel unit root tests: LLC and IPS, are preformed to check for the presence of stationary in this study.

The results of the stationary test by adopting LLC and IPS with the existence of intercept and trend are shown in the table 2. The results are present level aeries and first difference series. Both LLC and IPS teat present among LnGDP, LnCOM, LnK are only stationary and significance after being first difference. And for LnSUB and LnL, both LLC test results display that stationary in level series, then both tests result are all stationary in first difference series, as LnINT in both tests are stationary at the 1% level. Hence, the results strongly support the conclusion that the series are not cointegrated at I (0), but the series are stationary at I (1), which mean next step could exam whether exist long-run relationship between variables by applying the cointegration.

Table 2: Panel unit root test results

	Level Series		First Difference Series	
Variables	LLC	IPS	LLC	IPS
LnGDP	1.90286	5.09179	-13.9328***	-1.02594**
	(0.9715)	(1.0000)	(0.0000)	(0.0200)
LnCOM	1.62920	3.49863	-18.0327***	-8.12284***
	(0.9484)	(0.9998)	(0.0000)	(0.0000)
LnINT	-24.8722***	-6.30322***	-21.3789***	-2.59643***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
LnSUB	-10.5160***	-1.06424	-27.5326***	-3.56671***
	(0.0000)	(0.1436)	(0.0000)	（0.0002）
LnK	2.98679	32.2084	-22.3229***	93.7770***
	(0.9986)	(0.9988)	(0.0000)	(0.0035)
LnL	-3.65967***	3.51519	-5.60236***	-1.99107**
	(0.0001)	(0.9998)	(0.0000)	(0.0232)

Note:1. The null hypothesis: series has a unit root.

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2. ∗∗∗, ∗∗, and ∗ indicate rejection of the null hypothesis at the 1%, 5%, and 10% level of statistical significance, respectively.
3. The values in parentheses are p.value.

b. Panel cointegration test

This study will proceed to test whether broadband constructions and economics growths are cointegrated. Pedroni (2000, 2004) method is used to perform the cointegration test.

In case of all variables are stationary at order I (1), so there are probably having long-run relationship among internet users (LnINT), broadband subscribers port of internet (LnSUB), capital stock (LNK), employed persons (LNL), investment in computer services and software(LnCOM) and economic growth (LNGDP). Therefore, panel cointegration test is used to confirm the presence of the cointegration of the six variables.

The equation of cointegration regression models explicate as follows:

$$\mathrm{Ln}(GDP)_{i,t} = \alpha_i + \beta[\mathrm{Ln}(\mathrm{Sub})_{i,t} + \mathrm{Ln}(\mathrm{Int})_{i,t} + \mathrm{Ln}(\mathrm{Com})_{i,t} + \mathrm{Ln}(\mathrm{K})_{i,t} + \mathrm{Ln}(\mathrm{L})_{i,t}] + \mu_{i,t} \quad (4)$$

The Pedroni's results are reported in table 3, which 5 out of 7 Pedroni's statistics significantly reject the null hypothesis of no cointegration. In conclusion, Pedroni's results support that exists cointegration among the six variables. In other word, there have a long-run relationship between broadband constructions and economic growth.

Table 3: Pedroni's cointegration tests results

Within dimension	Between dimension
Panel v-Statistic 1.532387* (0.0627)	Group rho-Statistic 7.390499 (1.0000)
Panel rho-Statistic 5.267985 (1.0000)	Group PP-Statistic -17.02839*** (0.0000)
Panel PP-Statistic -13.75943*** (0.0000)	Group A-Statistic -14.75899*** (0.0000)
Panel ADF-Statistic -11.95195*** (0.0000)	

Note:1. The null hypothesis: no cointegration.
2. ∗∗∗ indicate rejection of the null hypothesis at the 1% level of statistical significance, respectively.
3. The values in parentheses are p.value.

c. Panel long run elasticity test

Additionally, after cointegration test, the study about impact of broadband constructions on economic growth would examine the long-run elasticity. Table 4 summarized the coefficients of LnCOM, LnINT, LnSUB, LnL and LnK by adopting panel dynamic ordinary least square methods (DOLS) by Kao and Chiang (1999) and fully modified ordinary least square methods (FMOLS) by Pedroni (2000). [11] From Table 4, it is enough to reject null hypothesis, in another word, there have a long run equilibrium co-integration within the variables and the coefficients of independent variables in the long run are positively and statistically significant at level.

In DOLS, the results imply long run elasticity of LnCOM, LnINT, LnSUB, LnL and LnK on GDP are 0.050872, 0.052400, 0.189460, 0.227362 and 0.467116, respectively. that one percent increases of investment in computer and software will promote economic growth about 0.050872 percent, and one percent grows in internet users will enhance the economic growth about 0.0524 percent. And one percent rise with broadband subscribers' port of internet, which will advance economic growth about 0.189460 percent. And one percent increase in employment persons, it will boot 0.227362 percent in economic growth When one percent increase in capital stock, there will grow 0.467116 percent in economic.

Similarly, according to the FMOLS, it presents when increasing one percent of investment in computer and software, internet users, broadband subscribers port of internet, capital stock, in employed persons, respectively. That would promote economic growth with 0.049477 percent, 0.03496 percent, 0.210509 percent, 0.413855 percent and 0.266436 percent, respectively. In conclusion, the impact on economic growth are not far different with the FMOLS and DOLS in this study.

Table 4: Results of Panel DOLS and FMOLS

Dependent Variable:LnGDP	DOLS	FMOLS
Independent Variabes	Coef.	Coef.
LnCOM	0.050872***	0.049477***
LnINT	0.152400**	0.034960***
LnSUB	0.189460***	0.210509***
LnL	0.227362***	0.413855***
LnK	0.467116***	0.266436***
Adjusted R-squared	0.995550	0.996001
S.E of Regression	0.062297	0.057354

Notes:
1.The null hypothesis: There is no long run equilibrium co-integration within the variables
2. ∗∗ means rejection of the null hypothesis at the 5% level of significance, respectively.

d. Panel estimation

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Panel estimation classified with fixed effects and random effects. Fixed effects method assumes that every province specific effects are fixed over time and affect the economic growth is correlating with the exogenous variables [12]. The fixed effects model is used to analyze coefficients of estimator the model of regression. The model will be taken in the form of equation (5). Random effects method suppose that the individual specific effect is not correlated with the exogenous variables. The random effect model will be seen in the form as equation (6).

$$\mathrm{Ln(GDP)}_{it} = (a_0 + \emptyset_i d_i) + \beta_p \mathrm{IV}_{it} + \varepsilon_{it} \quad (5)$$

$$\mathrm{Ln(GDP)}_{it} = (a_0 + \gamma_{it}) + \beta_p \mathrm{IV}_{it} + v_{it} \quad (6)$$

Hausman (1978) test which be used in model selection and compare the estimators of the tested models. As table 5 is reporting that the p-value of Hausman test statistic is significant at 1% level, which it rejects the null hypothesis, so it defines that random effects model is more appropriate in this study. Moreover, the panel GLS method can be used to examine the specific relationship and impact of independent variables on economic growth.

Table 5 summarize the results of panel GLS approach with fixed effect model, the coefficients of all independent variables are significant at 1% level, and the effects are positive as well. Among the five independent variables, the impact coefficient of internet users, broadband subscribers port of internet and investment in computer services and software are 0.059779, 0.177596 and 0.157036, respectively those three variables represented the broadband constructions. And impact of employment persons and capital stock on economic growth are been found 0.227199 and 0.503345. Taking broadband subscribers port of internet as an example, it represents that one percent increase in broadband subscribers' port of internet is followed by 0.157036 percent change in economic growth.

By performing panel GLS method, also, LnGDP as dependent variables, the following equation is written as below:

$$+0.177596\mathrm{LnINT}_{it} + 0.157036\mathrm{LnSUB}_{it} + 0.227199\mathrm{LnL}_{it} + 0.503345\mathrm{LK}_{it} + \tau_{it} + \varepsilon_{it} \quad (7)$$

According to empirical results, effects are positive as expected, so not only broadband constructions but also capital stock and labor force are crucial components of economic growth.

Table 5: Panel Estimation with GLS method using fixed effect model

Variables	Coefficient	Std. Error	t-Statistic
LnCOM	0.059779***	0.006963	8.585718
LnINT	0.177596***	0.010441	7.431554
LnSUB	0.157036***	0.018043	8.703439
LnL	0.227199***	0.028534	7.962498
LnK	0.503345***	0.029631	16.98703
C	1.907095***	0.207911	9.172662
Hausman test			
Chi-Sq. Statistic	54.005644		
p-value	0.0000		
Adjusted R-squared	0.997631		
S.E. of regression	0.061242		

Notes:

1.The null hypothesis: There is no long run equilibrium co-integration within the variables.

2. *** means rejection of the null hypothesis at the 1% level of significance, respectively.

CONCLUSION

Comparing with other traditional influencing factors, broadband is a new field in researching economic growth in case of People's Republic of China. The main purpose of this study is to explain and analyze the impact of broadband constructions on economic growth in People's republic of China. Moreover, considering another two traditional factors of macroeconomics which related with economic growth, capital stock and employment persons. The empirical results show those followings concluding remarks.

Firstly, all variable series are cointegrated at I (1), and results of panel cointegration test showed a long-run relationship between broadband constructions and economic growth, capital stock and employment persons have a long-run relationship with economic growth as well.

Secondly, this paper examined panel long run elasticity between dependent variables and independent variables by adopting the DOLS and FMOLS methods. The empirical results indicated that variables have long run elasticity equilibrium co-integration, and impact of broadband constructions, capital stock and employment persons on economic growth are significant and positive.

Thirdly, after comparing the fixed and random effects model, the results show that fixed effects model is better in this research. Furthermore, GLS examination reports a positive relationship between broadband constructions and economic growth. And the effects of two traditional factors, capital stock and employment persons are positive as well. Thus, taking advantage of these results can provide policy suggestions for government to take broadband constructions as a vital part in economic growth.

In conclusion. according to the empirical results stated above mentioned, the government can consider long-run policies to adjust the effects of broadband constructions on economic growth, which roughly cover following two points: (1) To

enhance the broadband constructions and Internet popularization, continually. (2) To implement and accelerate the innovation in broadband constructions industry. Furthermore, the technological progress, capital stock and employment should also be considered as well, these are vital components for economic growth in People's Republic of China.

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