Computers with Internet Access and Wage Disparities across Regions: Evidence from China

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Introduction

- Do technological developments improve people's living conditions and increase their welfare, or continue to lead to relative inequality and an increased income gap?
- Regarding the classic insights on technological advances, a controversial puzzle involves their economic impacts and labor in societies, and have always included different claims to handle this dilemma.

	Negative Labor Relation	Positive Labor Relation
Technological Pessimistic	Zhuang Zi Jean-Jacques Rousseau	Karl Marx Ernst Friedrich Schumacher
Technological Optimistic	Adam Smith David Ricardo	John Bates Clark Johan Knut Wicksell John Maynard Keynes

FIGURE 1. CLASSIC THOUGHTS ON TECHNOLOGY DEVELOPMENT AND LABOR RELATION

- In modern era, information communication technology (ICT) has created innovative revolution.
- Appropriate investments toward ICT utilization have increased productivity and efficiency (Milgrom & Roberts, 1990; Brynjolfsson & Hitt, 2003; Akerman, Gaarder, & Mogstad, 2015).
- Computerization and digitization forming the change of technology-skill complementarity (Krueger, 1993; Goldin & Katz, 1998; Autor, Levy, & Murnane, 2003; Ben-Ner & Urtasun, 2013; Akerman, Gaarder, & Mogstad, 2015).
- Skill-biased technologies enlarged wage gap in cities with more skilled workers and created a divergence in welfare (Lindley & Machin, 2014; Berger & Frey, 2016).

Introduction

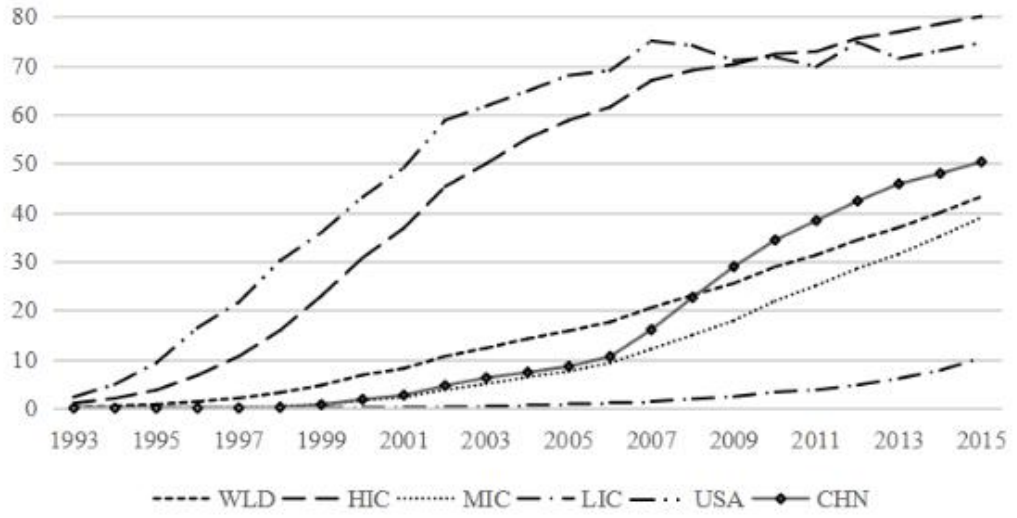

FIGURE 2. INDIVIDUALS USING INTERNET ACROSS DIFFERENT AREAS (% OF POPULATION)

As the internet link to the world, China is the 77th admitted country access the globe in 1994. Compared to individuals using internet in High Income Countries, the gap is still large for China, but rapidly narrowing after its accelerated development.

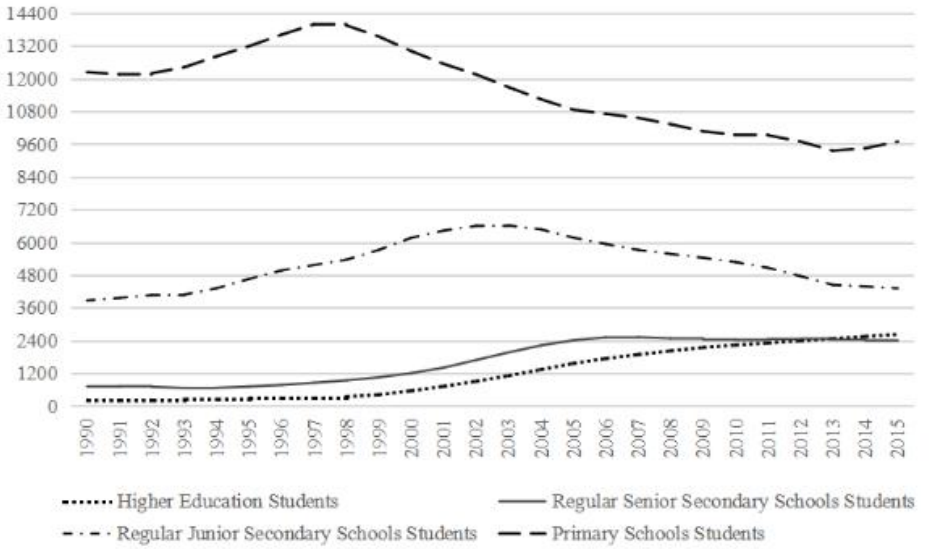

FIGURE 3. NUMBER OF ENROLLMENT STUDENTS IN CHINA (10 THOUSAND PEOPLE)

Educational endowments have increased in China since 1990s. Higher education has grown tenfold between 1990 and 2015. Scale for students of high school and college have expand quickly.

Forman, Goldfarb and Greenstein (2012) depicted a payoff puzzle:

while internet is widely adopted, wage growth is unevenly distributed across U.S. counties.

We resolve a similar puzzle between technological advancement and the competing consequences on:

economic growth and wage inequality.

We analyze the developmental process of utilizing internet across regions in China with its rapid growth over the past decade, and observe the formation of human capital given its educational resources.

Theoretical Background

ICT promotes technical efficiency and information-based human capital increases in skilled regions

- Computer utilization is associated with high levels of human capital (Caselli & Coleman, 2001).
- City with higher education has higher wages (Rauch, 1993; Carlsen, Rattsø & Stokke, 2016).

As ICT improves regional development, the demand for skilled labor also increases

- The arrival of computers for skill-biased technologies in US cities have increased skills, but facilitated wage inequality (Glaeser & Saiz, 2004; Beaudry, Doms, & Lewis, 2010; Lin, 2011; Lindley & Machin, 2014).

Internet has been taken as a skill-biased technology

- With changing welfare, the internet complement skilled workers and act as a substitute for unskilled workers (Akerman, Gaarder, & Mogstad, 2015).
- Internet access increases information demand and lowered the costs of engaging in economic activities (Malecki, 2002; Forman, Goldfarb, & Greenstein, 2005; Bekkerman & Gilpin, 2013).
- Divergence of cities' fortune is explained by complementarity of development among new technologies and skill endowments (Berger & Carl, 2015).

Theoretical Background

ICT Adoption and Wage Inequality

- We consider an economy with one sector that produces consumer goods using three production factors (Autor & Dorn, 2013; Beaudry, Doms, & Lewis, 2010): ICT capital and both low- and highly skilled labor inputs for routine and non-routine tasks. The ICT capital in particular can be substituted for routine tasks and complement those that are non-routine.
- As technology use increases with time, it increases the substitution for labor performing non-routine tasks.
- The wage gap increases with increased technology input, but tends to decrease as an inverted U-shape.

Human Capital and Educational Endowment

- The greater the quantity of human capital, the greater the supply of skilled labor in the local market. This will narrow any wage inequality through a supply of talent to decrease the wage premiums caused by ICT.
- Educational endowments have a similar impact with increased ICT adoption and the increased demand for skilled labor (Caselli & Coleman, 2001; Glaeser & Saiz, 2004). This increase in demand for skilled labor creates further wage premiums and increases the wage gap.
- We test our model and determine whether the supply of or demand for skilled labor dominates the relationship between educational endowment and wage inequality

Hypotheses

Hypothesis 1: The prevalence of internet access enhances regional economic growth. With greater ICT adoption and skilled labor supply, the area's economic wealth can increase.

Hypothesis 2: The prevalence of internet access enlarges the wage inequality between skilled and unskilled labor. The wage of skilled labor is decided by the demand side, and high-level human capital receives a wage premium due to insufficient supply. Therefore, the region with higher level of ICT usage will have more pronounced wage inequality.

Hypothesis 3: An inverted U-shaped relationship exists between internet access and economic growth and wage gap, respectively. The turning point can be observed along the complete developmental process of adopting ICT technology. With the growing of internet access, the marginal rate of technology substitution and marginal output would decrease after reaching the turning point of economic growth and wage inequality, respectively.

Hypothesis 4: Technological endowment enhances a region's productivity and increases its economic growth. Meantime, technological endowment reshapes skill-biased technology on economic growth and wage inequality both in linear relationship and inverted-U shaped relationship.

Hypothesis 5: Education endowment ensures a region's economic growth. Meantime, educational endowment reshapes skill-biased technology on economic growth and wage inequality.

Methods

Data: The study employs the data from mainland Chinese provinces and cities at the prefectural and county levels (county-level administrative division municipalities).
We construct the variables and compose 3 sampled panels from the Annual Statistical Yearbook of China, Educational Statistical Yearbook of China, China Labor Statics Yearbook, provincial statistical yearbooks, local statistical bureau reports, government bulletins, and other formal media documents.

The provincial level panel contains 30 provinces (including the four provincial level municipalities: Beijing, Tianjin, Shanghai and Chongqing) from 2001 to 2015. The prefecture-level cities panel includes a complete sample of 284 prefectural cities and spans 2001 to 2015. The county-level cities panel contains 367 county-level cities and spans 2011 to 2014.

Prior research has indicated that Chinese regional database is appropriate for geographically based economic analyses on issues such as agglomeration, migration, labor market, and city stability (Au & Henderson, 2006).

Methods

Estimation: we construct the statistical model of the impacts of internet access on economic growth and wage inequality across provinces, prefecture-cities, and county-cities.

H1:

$$LnGDP_{i,j,t} = \alpha + \beta_1 Internet_{i,j,t} + wControl_{i,j,t} + u_{i,j,t}$$

H2:

$$LnGap_{i,j,t} = \alpha + \beta_1 Internet_{i,j,t} + wControl_{i,j,t} + u_{i,j,t}$$

H3:

$$LnGDP_{i,j,t} = \alpha + \beta_1 Internet_{i,j,t} + \beta_2 (Internet_{i,j,t})^2 + wControl_{i,j,t} + u_{i,j,t}$$

$$LnGap_{i,j,t} = \alpha + \beta_1 Internet_{i,j,t} + \beta_2 (Internet_{i,j,t})^2 + wControl_{i,j,t} + u_{i,j,t}$$

We interact internet access with computer usage and educational endowment, respectively, to examine how the prior endowment of skill and human capital can further moderate the focused relationship. We assume both computer usage and educational endowment are exogenous in the model, only influenced by such factors as developmental and historical events.

H4:

$$LnGDP_{i,j,t} = \alpha + \beta_1 Internet_{i,j,t} + \beta_2 (Internet_{i,j,t})^2 + \lambda_1 Computer_{i,j,t} + \lambda_2 Internet_{i,j,t} \times Computer_{i,j,t} + \lambda_3 (Internet_{i,j,t})^2 \times Computer_{i,j,t} + wControl_{i,j,t} + u_{i,j,t}$$

$$LnGap_{i,j,t} = \alpha + \beta_1 Internet_{i,j,t} + \beta_2 (Internet_{i,j,t})^2 + \lambda_1 Computer_{i,j,t} + \lambda_2 Internet_{i,j,t} \times Computer_{i,j,t} + \lambda_3 (Internet_{i,j,t})^2 \times Computer_{i,j,t} + wControl_{i,j,t} + u_{i,j,t}$$

H5:

$$LnGDP_{i,j,t} = \alpha + \beta_1 Internet_{i,j,t} + \beta_2 (Internet_{i,j,t})^2 + \gamma_1 College_{i,j,t} + \gamma_2 Internet_{i,j,t} \times College_{i,j,t} + \gamma_3 (Internet_{i,j,t})^2 \times College_{i,j,t} + wControl_{i,j,t} + u_{i,j,t}$$

$$LnGap_{i,j,t} = \alpha + \beta_1 Internet_{i,j,t} + \beta_2 (Internet_{i,j,t})^2 + \gamma_1 College_{i,j,t} + \gamma_2 Internet_{i,j,t} \times College_{i,j,t} + \gamma_3 (Internet_{i,j,t})^2 \times College_{i,j,t} + wControl_{i,j,t} + u_{i,j,t}$$

Results

Table 1 Effect of Internet Access on Regional Economic Growth

	(1)	(2)	(3)	(4)	(5)	(6)
	ln_GDP_prov	*ln_GDP_prov*	*ln_GDP_city*	*ln_GDP_city*	*ln_GDP_coun*	*ln_GDP_coun*
internet_access	0.00101***	0.00368***	0.000352***	0.00115***	0.0705***	0.179***
	(0.000336)	(0.00110)	(0.000112)	(0.000268)	(0.0170)	(0.0296)
internet_access^2		-0.00000391***		-0.00000126***		-0.0207***
		(0.00000108)		(0.000000255)		(0.00405)
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes
Regional Fix Effect	Yes	Yes	Yes	Yes	Yes	Yes
Year Fix Effect	Yes	Yes	Yes	Yes	Yes	Yes
Observations	450	450	4187	4187	1299	1299
R^2	0.9574	0.9614	0.9392	0.9402	0.9743	0.9751

Note: Driscoll-Kraay standard errors in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

H1

H3

Table 2 Effect of Internet Access on Regional Wage Gap

	(1)	(2)	(3)	(4)	(5)	(6)
	ln_gap_prov	*ln_gap_prov*	*ln_gap_city*	*ln_gap_city*	*ln_gap_coun*	*ln_gap_coun*
internet_access	0.0000448	0.000789*	0.000143**	0.000871***	0.0177*	0.0397***
	(0.000157)	(0.000441)	(0.0000690)	(0.000247)	(0.00973)	(0.0140)
internet_access^2		-0.00000109*		-0.00000115***		-0.00421***
		(0.000000545)		(0.000000287)		(0.00118)
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes
Regional Fix Effect	Yes	Yes	Yes	Yes	Yes	Yes
Year Fix Effect	Yes	Yes	Yes	Yes	1299	1299
Observations	450	450	4187	4187	0.5225	0.5231
R^2	0.9840	0.9847	0.9515	0.9522	*ln_gap_coun*	*ln_gap_coun*

Note: Driscoll-Kraay standard errors in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

H2

H3

Results

The horizontal axis measures internet access per worker and re-scales initial axis by the value of turning point.
Vertical axis reports regional GDP over workers by logarithm or worker's wage gap by logarithm at province and city level.
There are two groups divided around the median value of internet access per worker.
The solid red line represents fitted linear relationship and dashed green line represents fitted non-linear relationship.

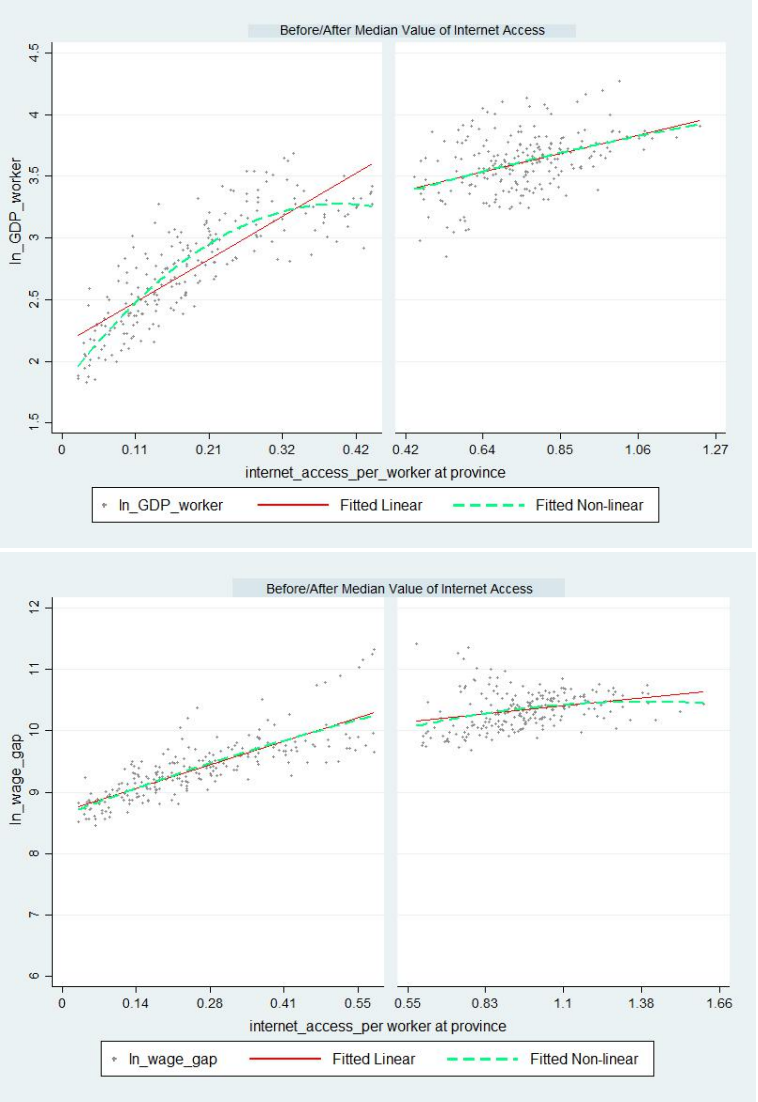

FIGURE 4. LINEAR AND NON-LINEAR RELATIONSHIP AT PROVINCE LEVEL

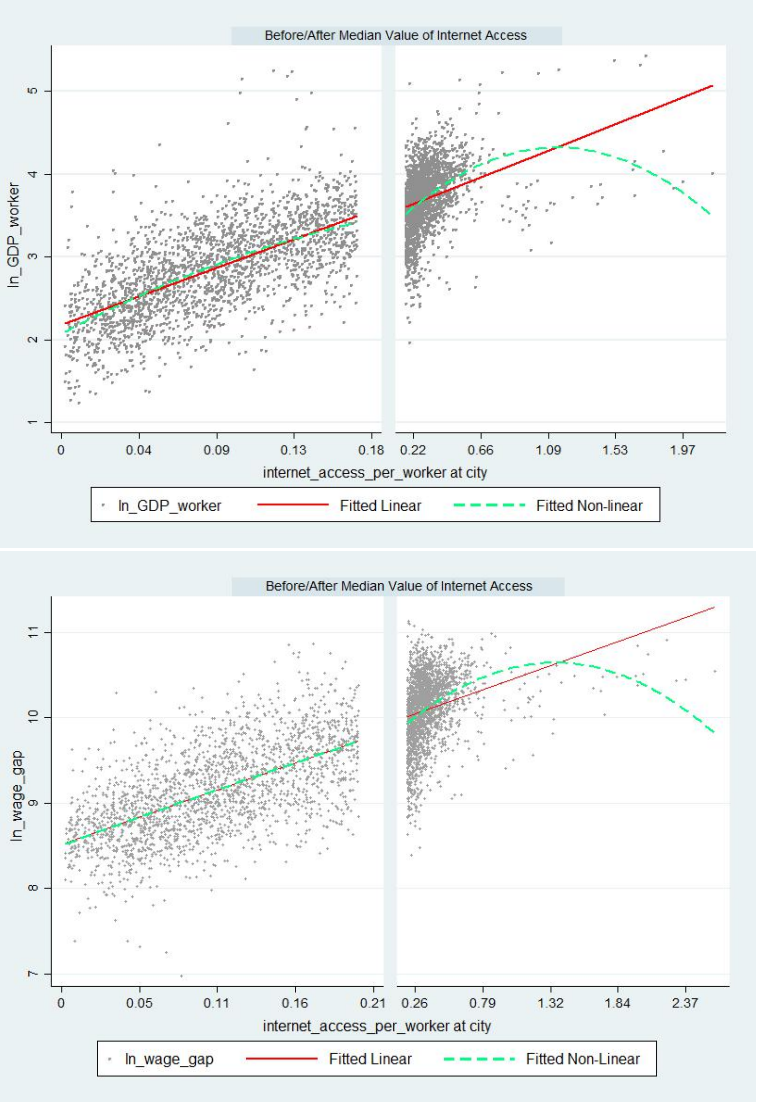

FIGURE 5. LINEAR AND NON-LINEAR RELATIONSHIP AT CITY LEVEL

Results

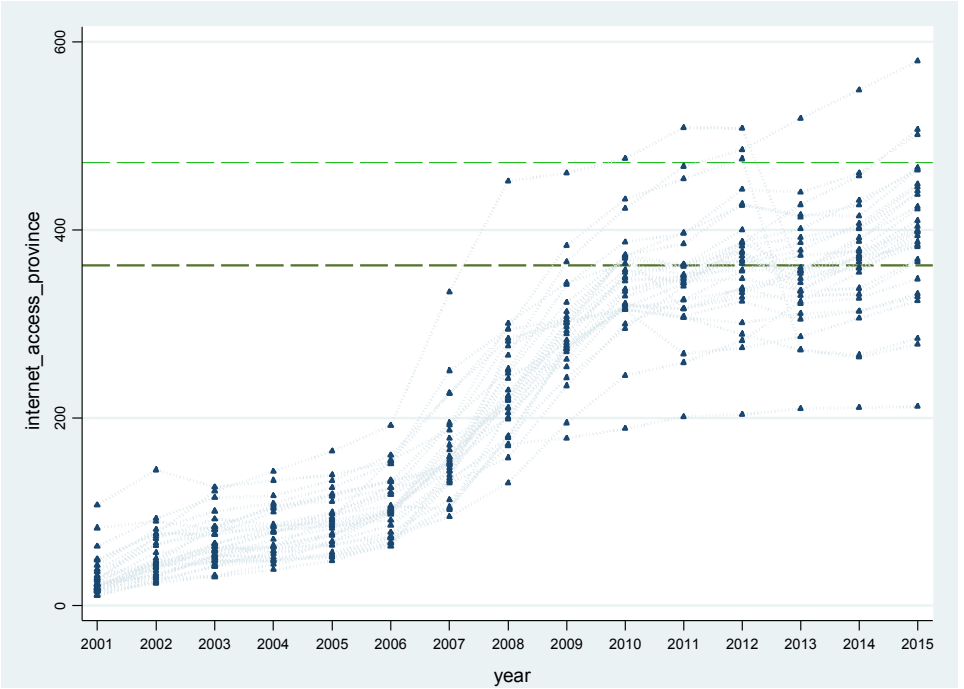

FIGURE 6. INTERNET ACCESS AT PROVINCIAL LEVEL WITH TIME TREND

Note: The dashed light green line indicate the turning point line of economic growth with the internet access per worker. The dashed dark green line indicate the turning point line of wage gap with the internet access per worker.

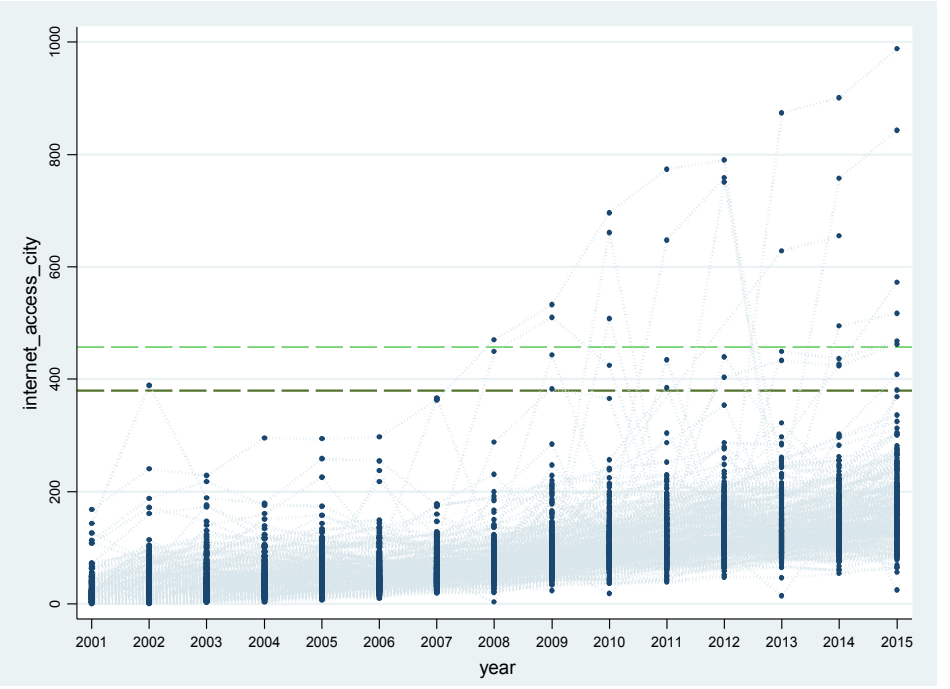

FIGURE 7. INTERNET ACCESS AT CITY LEVEL WITH TIME TREND

Note: The dashed light green line indicate the turning point line of economic growth with the internet access per worker. The dashed dark green line indicate the turning point line of wage gap with the internet access per worker.

Results

Table 3 IV Estimate of Rice and Wheat at Provincial Level

	internet_access_prov	*ln_GDP_prov*	*ln_gap_prov*
rice_wheat_prov	0.0292***		
	(0.00798)		
internet_access_prov		0.0119**	0.0131**
		(0.00559)	(0.00639)
internet_access_prov^2		-0.0000146**	-0.0000170**
		(0.00000723)	(0.00000827)
Control Variables	Yes	Yes	Yes
Province Fixed	Yes	Yes	Yes
Year Fixed	Yes	Yes	Yes
Observations	417	417	417
R^2	0.947	0.9298	0.9336

Note: Standard errors in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 4 IV Estimate of Post Office Registration at City Level

	internet_access_city	*ln_GDP_city*	*ln_gap_city*
post_office	0.280*		
	(0.157)		
internet_access_city		0.0102***	0.00413**
		(0.00265)	(0.00180)
internet_access_city^2		-0.0000126***	-0.00000525**
		(0.00000336)	(0.00000228)
Control Variables	Yes	Yes	Yes
City Fixed	Yes	Yes	Yes
Year Fixed	Yes	Yes	Yes
Observations	4170	4170	4170
R^2	0.554	0.8346	0.9413

Note: Standard errors in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 5 Robustness Check for City Level Effect by Time Periods

	(1)	(2)	(3)	(4)
	ln_GDP_city	*ln_GDP_city*	*ln_gap_city*	*ln_gap_city*
	(2001-2008)	*(2009-20015)*	*(2001-2008)*	*(2009-20015)*
internet_access_city	0.000715**	0.00107***	0.000595*	0.000304***
	(0.000343)	(0.000126)	(0.000359)	(0.0000991)
internet_access_city^2	-0.00000177**	-0.000000869***	-0.00000256***	-0.000000273***
	(0.000000859)	(0.000000107)	(0.000000949)	(9.69e-08)
Control Variables	Yes	Yes	Yes	Yes
City Fix Effect	Yes	Yes	Yes	Yes
Year Fix Effect	Yes	Yes	Yes	Yes
Observations	2217	1970	2217	1970
R^2	0.9213	0.7386	0.8929	0.8432

Note: Driscoll-Kraay standard errors in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Results

H4

Table 6 Interactive Effect of Internet Access and Computer Use

	(1)	(2)	(3)	(4)	(5)	(6)
	ln_GDP_city	*ln_GDP_city*	*ln_GDP_city*	*ln_gap_city*	*ln_gap_city*	*ln_gap_city*
internet_access_city		0.000625***	0.00176***		0.000416***	0.00172***
		(0.0000963)	(0.000301)		(0.000151)	(0.000323)
internet_access_city^2			-0.00000214***			-0.00000259***
			(0.000000443)			(0.000000482)
pc_use	0.00648***	0.00888***	0.0111***	0.000792*	0.00348***	0.00744***
	(0.000465)	(0.00116)	(0.00201)	(0.000456)	(0.00119)	(0.00140)
pc*internet_access_city		-0.0000143**	-0.0000404**		-0.0000182**	-0.0000636***
		(0.00000704)	(0.0000176)		(0.00000901)	(0.0000156)
pc*internet_access_city^2			6.43e-08**			0.000000108***
			(3.02e-08)			(2.66e-08)
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes
City Fix Effect	Yes	Yes	Yes	Yes	Yes	Yes
Year Fix Effect	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4187	4187	4187	4187	4187	4187
R^2	0.9410	0.9424	0.9437	0.9514	0.9518	0.9530

Note: Driscoll-Kraay standard errors in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 7 Interactive Effect of Internet Access and Educational Endowment

	(1)	(2)	(3)	(4)	(5)	(6)
	ln_GDP_city	*ln_GDP_city*	*ln_GDP_city*	*ln_gap_city*	*ln_gap_city*	*ln_gap_city*
internet_access_city		0.000830***	0.00137***		0.00101**	0.00179***
		(0.000212)	(0.000388)		(0.000403)	(0.000494)
internet_access_city^2			-0.00000123			-0.00000204***
			(0.000000878)			(0.000000780)
ln_col_edu_city	0.0179***	0.0201***	0.0185***	-0.00174	0.00213	0.00171
	(0.00433)	(0.00484)	(0.00399)	(0.00432)	(0.00544)	(0.00528)
ln_col*internet_access_city		-0.0000674**	-0.0000326		-0.000122**	-0.000134***
		(0.0000319)	(0.0000459)		(0.0000485)	(0.0000424)
ln_col*internet_access_city^2			-7.01e-10			0.000000134
			(0.000000104)			(9.84e-08)
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes
City Fix Effect	Yes	Yes	Yes	Yes	Yes	Yes
Year Fix Effect	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4187	4187	4187	4187	4187	4187
R^2	0.9384	0.9393	0.9403	0.9514	0.9517	0.9523

Note: Driscoll-Kraay standard errors in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

H5

Results

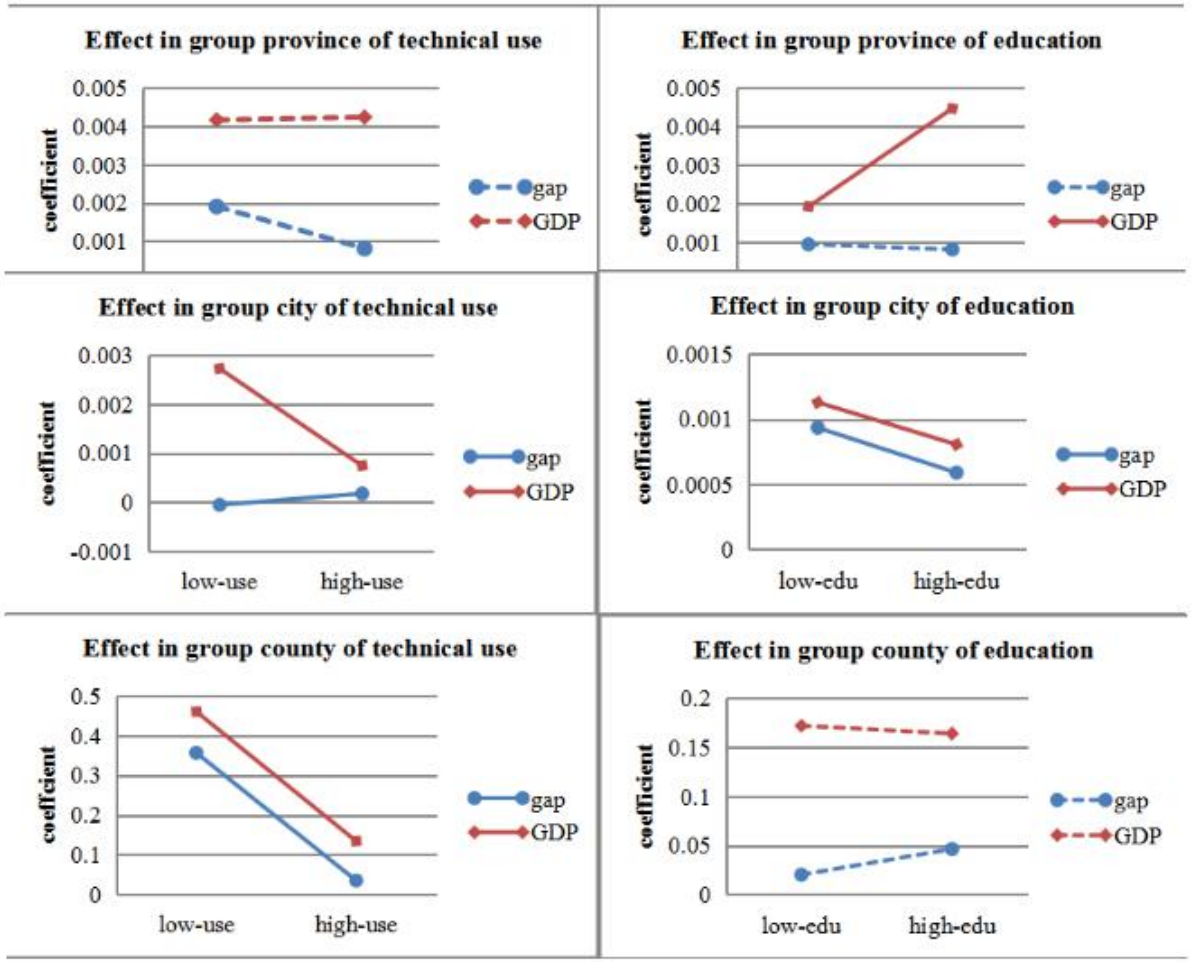

FIGURE 8. EFFECTS ON ECONOMIC GROWTH AND WAGE GAP IN DIFFERENT GROUPS

Note: The dashed line indicate the insignificant effect. The solid line indicate the significant effect.

Conclusion

- China offers a context that has gone through the process of advancing technology during an observable time window for ICT technology adoption.
- Undertaking this examination, we calibrate the puzzle raised by Forman, Goldfarb and Greenstein (2012) that *widely-used advanced internet technology generate unequal distribution of wage growth across regions*, depending on how the region is equipped with proper endowments.
- Consensus hasn't been achieved previously whether the technology shock is positive or negative. We further shed light on the understanding of puzzling impact of skill-biased technology on economic growth and wage inequality.
- As these effects can be observed at economies' different developmental stages, this helps in the search for a solution to the problematic combination of growth and inequality.
- Our findings help resolve the puzzle in the way that *the adverse impact of new technology adoption can be alleviated by increasing supply of skilled labor and accumulating educational endowment*.
- By grouping our results, we attempt to explain the former puzzle of technological optimistic and pessimism in the literature.
- Our study explains why the wage of workers has risen at information-based skilled cities in China. Enhancing the supply of skilled labor and improving the investment in human capital can still help make sustainable development at the present time.