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Impact of fast internet access on employment: Evidence from a broadband expansion in China

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ABSTRACT

This paper investigates whether and how broadband internet development affects employment in China. The temporal and spatial variations in Broadband China Strategy implementation allow for applying a staggered difference-in-differences (DID) to identify the intention-to-treat effects of the increased availability of broadband on labor market outcomes. Robust results show that broadband internet development will not affect the employment rate for low- and high-skilled workers. Furthermore, broadband internet development improves low-skilled workers' contract signing, pension, and medical insurance participation by 11.5%, 17%, and 19.8%, respectively but has no significant impact on high-skilled workers. Potential mechanisms can be divided into two aspects. At the micro level, broadband internet development mitigates information friction and increases the probability of online learning for low-skilled workers. Meanwhile, at the macro aspect, adopting broadband Internet enhances firms' productivity where low-skilled workers are most concentrated (manufacturing industry). The heterogeneous results suggest younger and rural workers benefit more. Our findings have great significance in eliminating concerns about broadband investment in developing countries.

1. Introduction

The relationship between technological changes and employment has been a central economic issue for decades. A significant body of theoretical and empirical research has given rise to widespread agreement that new technologies affect the labor market through mechanisms such as complementary, erosion, substitution, and scale effects (Acemoglu & Autor, 2011; Acemoglu & Restrepo, 2019; Ahituv & Zeira, 2011; Autor, Katz, & Krueger, 1998; Autor, Katz, & Kearney, 2006; Kumar, Malathy, & Ganesh, 2011; Mandelman & Zlate, 2022; Vivarelli, 2013). However, these effects play different roles, and no consensus has been reached regarding the most dominant effect (Mondolo, 2022).

Broadband Internet, one of the most important information and communication technologies, is developing rapidly around the world and is considered to be an important driver of economic growth and innovation (Czernich, Falck, Kretschmer, & Woessmann, 2011; Niebel, 2018; Stiroh, 2002; Yang, Zheng, & Zhou, 2022). However, studies on the impact of broadband internet development on the labor market remain relatively scarce. Existing research concludes that Internet development and adoption may raise employment rates and wages (Gürtzgen, Diegmann, Pohlan, & van den Berg, 2021; Hjort & Poulsen, 2019), and the high-skilled workforce are the ones that benefit. The low-skilled workforce may be substituted, leading to employment polarization and increasing income inequality

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(Akerman, Gaarder, & Mogstad, 2015; Atasoy, 2013; Forman, Goldfarb, & Greenstein, 2012).

Furthermore, although broadband internet is often considered digital technology, it differs from computer, automation, and artificial intelligence in that it may affect the labor market through information effects in addition to the complementary and substitution effects. Broadband internet could reduce information asymmetry and searching costs, resulting in increased job applications (Kuhn & Skuterud, 2004). Moreover, adopting the Internet could help enterprises improve internal communication efficiency and productivity, increasing business output and labor demand (Fernandes, Mattoo, Nguyen, & Schiffbauer, 2019; Goldin & Katz, 1998). Taken together, these results suggest the topic is worth further investigation. Additionally, most of these studies occur in developed countries, with empirical evidence from developing countries being scarce due to data limitations (Iacovone & Pereira Lopez, 2018).

In this study, we aim to contribute to the literature by empirically identifying the causal effect of broadband internet development on employment in China. The reason why we take China as an example is because, similar to other developing countries, China has experienced rapid economic growth in the past decades, but the human capital of the workforce remains lower compared to developed countries. For example, China's working-age population only has an average of 10.8 years of education,[1] and only approximately 17.6% of laborers have a college degree or above.[2] The Internet is gaining momentum in China, with a penetration rate of 73% by 2021 (CNNIC, 2022). In the context of another 3.7 trillion yuan Internet infrastructure by the Chinese government over the next five years, further evaluation of the effect of broadband internet development on the labor market is necessary.

To address the potential endogeneity of broadband internet, we employ a staggered difference-in-differences (DID) approach and use the Broadband China Strategy as an exogenous shock to estimate the intention-to-treatment effects of broadband internet development on employment in China. We analyze a national five-wave panel dataset, investigate the effects on employment rates, and examine employment quality overlooked in previous research, such as contract signing, income, pension, medical insurance, and working hours.

The main results of our study are summarized as follows. First, unlike the situation in developed countries (e.g., see Akerman et al., 2015; Mandelman & Zlate, 2022), the impact of broadband internet development on the Chinese labor market has been generally positive. The employment rate shows no significant change, but the broadband internet development improved employment quality (i.e., contract signing rates, pension and medical insurance participation rates) significantly with economic and statistical significance, especially for low-skilled workers. The results remain robust when we alter the estimation method to the approach proposed by Callaway and Sant'Anna (2021). Second, we find that broadband internet development has reduced information friction and increased the probability of online learning for low-skilled workers. The expansion has also promoted business revenue and labor demands in the most concentrated industry for low-skilled workers, namely the manufacturing industry. These micro and macro aspects have jointly contributed to improving the employment quality of low-skilled workers. Finally, the young and rural workers benefit more from the program. Our findings have important implications for developing countries' investment and economic development in broadband internet infrastructure.

The rest of the article is organized as follows. Section 2 introduces the Broadband China Strategy. Section 3 introduces the identification strategy and data sets used for analysis. Section 4 reports the estimation results. Section 5 concludes and draws policy implications.

2. Background

Considering the important role of broadband infrastructure development in economic development, the State Council of China issued *China's Broadband Strategic Program and its Implementation Plan* in 2013. Then, on August 17, 2013, China's State Council officially released the Broadband China Strategy to deploy China's future broadband internet development goals, marking China's broadband deployment promotion to the national strategy.

Broadband China was conducted in three batches, with 39 cities (clusters) selected as demonstration cities in 2014, 2015 and 2016 (see Appendix Fig. A1). The government will support the selected cities in finance and technology. These cities must develop broadband internet rapidly and improve intra-regional Internet transmission speeds, broadband subscribers, broadband penetration, etc. The Broadband China Strategy puts forward two-phased development goals: (1) By 2015, the basic realization of fiber for urban families and broadband for rural families, fixed broadband penetration rate reaching 50%, third-generation mobile communications and its long-term evolution technology (3G/LTE) user penetration rate reaching 32.5%. The broadband internet access capacity of urban and rural households should reach 20 Mbps and 4 Mbps, respectively. (2) By 2020, the broadband internet will fully cover urban and rural areas, the penetration rate of fixed broadband households will reach 70%, the penetration rate of 3G/LTE users will reach 85%, the broadband access capacity of urban and rural households will reach 50Mbps and 12Mbps, respectively. Reducing the cost of broadband internet is also one of the policy objectives of the Broadband China Strategy. The broadband cost in 2020 is expected to decrease by 1/3 compared to 2014.

An accompanying question is whether Broadband China has achieved the desired goals. To answer this query, we plot the trend of broadband penetration between 2012 and 2018 for all demonstration cities and other regular cities in Fig. 1. The results show the two groups of cities have similar trends in broadband internet penetration until 2014 and that the difference between the two is small (around 10%). In 2014 and after, we saw a very significant increase in the growth rate of broadband penetration in demonstration cities compared to regular cities. By 2018, broadband internet penetration rates in demonstration cities were nearly 20% higher than in

[1] Link: http://www.stats.gov.cn/wzgl/ywsd/202108/t20210828_1821223.html (Access on May 6, 2022)

[2] Based on data from China Human Capital Report 2019, link: http://humancapital.cufe.edu.cn/Report_Fulu_19.pdf (Access on May 6, 2022)

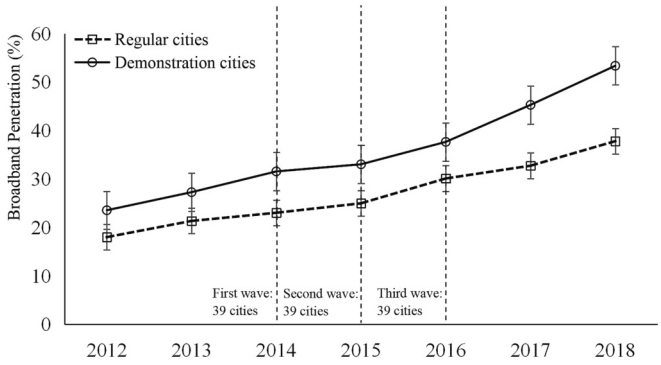

Fig. 1. Broadband China Strategy and cities' broadband penetration.
Source: China City Statistical Yearbook (2012–2018)

regular cities, suggesting that the Broadband China Strategy achieved the expected effect.

3. Method and data

3.1. Empirical approach

Based on the Broadband China Strategy rollout, we use a staggered DID method to explore the impact of broadband internet development on employment quality. The treatment group comprises cities selected as Broadband China demonstration cites, and the control group comprises regular cities. The mathematical formula of the staggered DID model is as follows:

$$Y_{ict} = \beta_0 + Broadband\ China_{ct}\beta_1 + P_{ict}'\alpha + C_{ct}'\omega + \delta_i + \gamma_t + \varepsilon_{ict} \quad (1)$$

where i denotes an individual, c denotes a city, and t denotes a year. $Broadband\ China_{ct}$ is the binary variable of interest that indicates whether city c is selected as Broadband China demonstration cites in year t. β_1 is the coefficient of interest, which reflects the effect of broadband internet development on employment. P_{ict} is the matrix of individual-level control variables, including age and its square term, health condition, and a college degree. C_{ct}' is the matrix of city-level control variables, including per capita GDP (log-form), average annual population (log-form), and proportion of secondary and tertiary industries. Individual- and year-fixed effects are also added, denoted as δ_i and γ_t, respectively. β_0 denotes the constant term and ε_{ict} denotes the random error term. Y_{ict} is the dependent variable. In our benchmark, Y_{ict} denotes whether in employed (employment) or employment outcomes. We choose workers' contract signing, income, pension, medical insurance, and weekly work hours to reflect their employment quality.

3.2. Data

This paper mainly relies on the following databases.

Individual-level data used for the study are from the China Family Panel Studies (CFPS) national research project in 2010, 2012, 2014, 2016, and 2018. This project is organized by the China Social Science Survey Center of Peking University and covers 25 provinces, autonomous regions, and municipalities directly under the central government in China. The samples are selected using a stratified random sampling method, which can represent 95% of the Chinese population (Xie & Hu, 2014). The questionnaire of CFPS is designed to include basic socioeconomic information about individuals and households.[3]

The second database is the China City Statistical Yearbook for 2010, 2012, 2014, 2016, and 2018. This database provides the basic socioeconomic information of a city, such as total population, GDP, industrial structure, etc. The third database is the National Economic Census data for 2013 and 2018, used for our mechanism test.

In terms of sample selection, the sample of this paper is limited to laborers aged between 18 and 65 years old. Samples that had migrated between cities during the observation period and samples that had only occurred once were also deleted.[4]

We summarize the dependent variables of workers in regular and demonstration cities in Panel A of Table 1. The employment rate of workers in regular cities and demonstration cities is 98.7% and 99%, respectively.[5] The employment rates in demonstration cities are significantly higher. We also find workers in demonstration cities have better employment quality because their contract signing

[3] The data supporting the findings of this study are available from [CFPS Conducted by Peking University]. Restrictions apply to the availability of city codes, which were used under license for this study. Since some variables are only provided in certain years of CFPS, the actual observation period depends on the variables.

[4] About only 1% of the samples are removed as a result.

[5] Although the employment rates seem to be relatively high, this value is reasonably after comparing with the sixth census data and the China Labor-force Dynamic Survey (CLDS) database.

Table 1
Descriptive statistics.

	N	Mean	S.D.	N	Mean	S.D.	Mean diff
	Control Group (Regular cities)			Treatment Group (Demonstration cities)			
Panel A: Dependent Variables							
Employment (employed =1, unemployed = 0)	15,519	0.987	0.114	16,383	0.990	0.098	0.003***
Contract (Yes = 1, No = 0)	10,372	0.395	0.489	9986	0.602	0.489	0.207***
Income (unit: yuan)	13,085	31,294.770	93,376.760	14,623	38,417.520	37,889.272	7122.75***
Medical insurance (Yes = 1, No = 0)	15,316	0.200	0.400	14,156	0.359	0.480	0.159***
Pension insurance (Yes = 1, No = 0)	15,316	0.250	0.433	14,504	0.461	0.498	0.211***
Workhours (unit: hours/weekly)	13,070	49.311	19.742	13,814	47.757	17.273	−1.554***
Panel B: Control Variables (Individual Level)							
Age	15,519	40.107	12.442	16,383	39.962	12.004	−0.145
Health (ordered 1–5)	15,519	3.445	1.179	16,383	3.477	1.142	0.032**
College (Yes = 1, No = 0)	15,519	0.167	0.373	16,383	0.249	0.432	0.082***
Panel C: Control Variables (City Level)							
Per capital GDP (unit: yuan)	332	37,995.304	21,096.488	226	61,125.964	35,239.012	23,130.66***
Population (unit: million)	332	440.389	248.985	226	684.166	497.93	243.777***
Secondary industry (unit: %)	332	46.195	9.943	226	48.048	9.745	1.853**
Tertiary industry (unit: %)	332	39.41	8.763	226	43.187	11.478	3.777***

Notes: ***, **, and * denotes *t*-test significant at 1%, 5%, and 10% level, respectively.

rates, income, medical insurance participation rates, and pension insurance participation rates are significantly higher than in regular cities. Workers in demonstration cities only work approximately 47.8 h weekly, 1.6 h less than in regular cities. As for control variables, we find systematic differences between regular and demonstration cities, as reported in Panel B and Panel C of Table 1. It shows that workers in demonstration cities tend to have better health conditions and are more likely to have a college degree. City traits also show that demonstration cities have a higher per capita GDP and population. Their proportion of secondary and tertiary industries is significantly higher than in regular cities.

4. Results

4.1. Baseline

First, we verify whether broadband internet development affects the employment rate (Table 2). The sample in Table 2 includes employed and non-employed groups. In columns (1)–(3), the regression without weights shows that broadband internet development does not significantly affect the employment rate. To make our sample more representative at the national level, we further use the weighted least squares estimation. The CFPS dataset provides the weights for individuals. The weighted least squares estimation is similar to the above (reported in columns (3)–(6)). In the following regression at the individual-year level, the responders' weights are all considered to make our results more representative at the national level.

Table 3 reports the effects of broadband internet development on employment quality among the employed. The results show that broadband internet development significantly positively affects employment, and low-skilled workers benefit more. Specifically, column (1) shows that broadband internet development promotes the contract signing rate, and the subsample regression in columns (2) and (3) indicates broadband internet development affects the low-skilled workers, whose contract signing rates increased 11.5% (significant at 1% level). In columns (4)–(6), we find that broadband internet development has no significant effect on workers' annual income in total groups, and the coefficients of subsample regression are also insignificant. Columns (7)–(9) indicate that the broadband internet development causes an increase of approximately 8% (significant at 1% level) in pension insurance participation rate (full sample) and that this effect exists mainly among low-skilled workers, whose pension insurance participation rates increase dramatically by about 17% (significant at 1% level). Results in columns (10)–(12) are similar, demonstrating that the broadband internet development significantly promotes workers' medical insurance participation rates by 10.4% (significant at 1% level). Low-skilled workers are the main beneficiary group, as their medical insurance participation rates show an approximately 20% increase (significant at a 1% level). The last three columns indicate the negative effect of broadband internet development on employment during weekly working hours, but the coefficients are insignificant at the 10% level.

The above results are consistent with Hjort and Poulsen (2019) that broadband access reduces employment inequality due to the increasing productivity in manufacturing. Additionally, some other logical explanations behind why Broadband China Strategy positively affects low-skilled workers more are as follows: (1) High-skilled workers already had high internet usage before broadband policy implementation (As indicated in Fig. 2, the internet usage rates in high-skilled workers in 2010 already achieved approximately 80%). (2) Low-skilled workers tend to have more budget constraints than high-skilled labor because the former earns significantly less (Appendix Table A2). (3) Low-skilled workers' employment quality is significantly poorer than high-skilled workers (Appendix Table A2). Taken together, these factors lead to a larger marginal effect of the Broadband China Strategy on low-skilled workers, resulting in greater benefits for this group.

Table 2
Impact of broadband internet expansion on the employment rate.

Dependent Var.	Employment (Yes = 1, No =0)					
	Full Sample	High-skill	Low-skill	Full Sample	High-skill	Low-skill
[Mean]	[0.9885]					
	(1)	(2)	(3)	(4)	(5)	(6)
Broadband China	−0.0024	0.0064	−0.0055	−0.0040	0.0068	−0.0070
	(0.0034)	(0.0068)	(0.0039)	(0.0042)	(0.0071)	(0.0053)
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes
Individual FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Sample Weights	No	No	No	Yes	Yes	Yes
Obs	25,671	5062	20,609	25,671	5062	20,609

Notes: * $p < .10$, ** $p < .05$, *** $p < .01$. Estimates are based on the model in eq. (1), using worker-year observations over the period 2010–2018. High-skilled denotes workers who have at least college degree (15 years or more of Education). Low-skilled denotes workers whose highest education background is high school (12 years or less of Education). Individual whose education is between 12 and 15 are assign as high-skilled or low-skilled workers according to proximity principle. Column (1) to column (3) consider the samples of workers aged 18–65 years who are recorded in CFPS survey. Column (4) to column (6) also consider the samples of workers aged 18–65 years who are recorded in CFPS survey, but the weighted least squares estimation is used. Individual weights are according to the CFPS dataset. The dependent variables of all regressions here are work status, which denotes to 1 if the worker is in employment and 0 for unemployment. All regressions include fixed effects for individual and year. The robust standard errors are in parentheses. We also report the unweighted estimation in Table A1, and the results are robust.

4.2. Modify the staggered DID

The literature on staggered DID has been growing rapidly in recent years. Many concerns about the potentially biased estimation in staggered DID have been raised. Therefore, we added a set of robustness checks to overcome the inherent shortcomings of the staggered DID method.

Heterogeneous treatment effects may lead to potential bias in estimating two-way fixed effects (TWFE) models (De Chaisemartin & d'Haultfoeuille, 2020; Goodman-Bacon, 2021). Heterogeneous treatment effects refer to the difference in the effect of the same treatment on different individuals, which may be in terms of the length of time after treatment or the group receiving the treatment at different points. The staggered DID ignores this heterogeneity and may yield the opposite answer because of the negative weighting problem caused by the heterogeneity treatment effect.

First, for the negative weighting problem, we diagnose the severity of the negative weighting problem in the TWFE model. The results are shown in Appendix Table A3. The proportion of positive weights is almost always above 90%, and most of the negative weights are <10%. Hence, the problem of negative weights is not prominent.

We also use an alternative method to estimate the results of staggered DID. Various methods for estimating the Heterogeneity-Robust-Estimator have been proposed to correct the potential bias of TWFE estimates in the staggered DID model. Among them, the method proposed by Callaway and Sant'Anna (2021) to calculate the Cohort-Specific-Average-Treatment Effects on the Treated has been applied in many refereed journals (De Chaisemartin & d'Haultfoeuille, 2020). Therefore, following the approach of Callaway and Sant'Anna (2021) (i.e., CSDID), we use the "never treated" cities as the control group and divide the experimental cities into different groups according to when they were first treated. The average treatment effect of broadband construction on the outcome variables is calculated using a weighted average method after estimating the treatment effect of each group at a specific time.

It should be noted that CSDID can only be performed when the data are a balanced panel; thus, some sample size loss occurs when using this method. CSDID results are reported in Appendix Table A4 and Table A5. Regarding the magnitude and direction of the coefficients, the estimated results are generally consistent with our benchmark regression. In Table A5, we find a slight difference in that the wage of low-skilled workers also shows a significant increase with broadband internet development, implying that we may have underestimated the positive effect of broadband internet development on the quality of employment of the low-skilled laborers in our benchmark regressions.

We further calculate the heterogeneity of the impact of policies on the quality of employment of low-skilled labor in 2014 and 2016 by grouping cities according to the first time they were treated. The results are shown in Table A6. As shown in Table A6, when cities were selected as the first batch of "Broadband China" demonstration cities in 2014, the development of broadband internet could have a more positive and significant impact on the employment quality of low-skilled labor in cities at that stage. Conversely, when cities were selected as "Broadband China" demonstration cities in 2016, the marginal impact of broadband internet development on employment quality was minimal, implying a possible marginal reduction in policy influence and the promotion effects of broadband internet development on employment quality. Our findings provide policy insight that the government should consider the first list of policy pilot cities when developing broadband and internet infrastructure because it may either alleviate or exacerbate regional development imbalances.

Table 3
Effect of broadband internet development on employment quality outcomes.

Dependent Var.	Contract			Ln(income)			Pension insurance			Medical insurance			Weekly workhours		
	Full Sample	High-skilled	Low-skilled	Full Sample	High-skilled	Low-skilled	Full Sample	High-skilled	Low-skilled	Full Sample	High-skilled	Low-skilled	Full Sample	High-skilled	Low-skilled
[Mean]	[0.4970]	[0.7472]	[0.4173]	[10.1989]	[10.5699]	[10.0894]	[0.3917]	[0.6644]	[0.2642]	[0.3133]	[0.5679]	[0.1920]	[48.4575]	[43.7180]	[49.7831]
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Broadband China	0.0645***	−0.0012	0.1150***	0.0031	−0.0325	0.0179	0.0795***	−0.0730	0.1697***	0.1042***	−0.0601	0.1982***	−0.7019	−0.9169	−0.4319
	(0.0159)	(0.0303)	(0.0183)	(0.0175)	(0.0331)	(0.0154)	(0.0168)	(0.0457)	(0.0174)	(0.0175)	(0.0371)	(0.0177)	(0.5581)	(0.9967)	(0.6486)
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sample Weights	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Obs	20,262	4892	15,370	27,155	6249	20,906	29,703	6585	23,118	29,356	6585	22,771	22,227	4858	17,369

Notes: * $p < .10$, ** $p < .05$, *** $p < .01$. Estimates are based on the model in eq. (1), using worker-year observations over the period 2010–2018. Only employed workers are included. High-skilled denotes workers who have at least college degree (15 years or more of Education). Low-skilled denotes workers whose highest education background is high school (12 years or less of Education). Individual whose education is between 12 and 15 are assign as high-skilled or low-skilled workers according to proximity principle. Column (1) to column (15) consider the samples of workers aged 18–65 years who are recorded in CFPS survey. The dependent variables in column (1)–(3) are binary variables that indicate whether the worker sign a contract, only 2014, 2016 and 2018 wave of CFPS asked responders whether they sign a contract, therefore worker-year observations here are from 2014 to 2018. The dependent variables in column (4)–(6) are workers' annual income (log-form). The dependent variables in column (7)–(9) are binary variables that indicate whether the worker has pension insurance. The dependent variables in column (10)–(12) are binary variables that indicate whether the worker has medical insurance. The dependent variables in column (13)–(15) are workers' weekly working hours. All regressions include fixed effects for individual and year, as well as the individual sample weights. The robust standard errors are in parentheses. We also report the unweighted estimation in Table A1, and the results are robust.

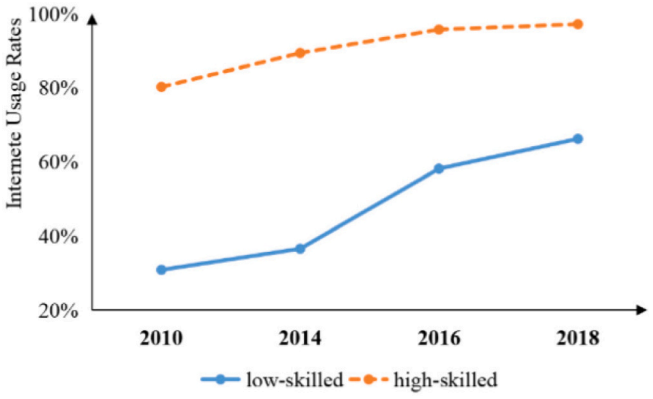

Fig. 2. Internet usage rates of low-skilled and high-skilled workers.

4.3. Parallel trend test

The validity of the staggered DID findings is predicated on the pre-trend assumption. We use the event-study approach to verify this assumption. In addition, the average dynamic effects and non-transient treatment can also be measured by the event-study approach. We modify eq. (1) to explore the parallel trend before the treatment, and the new model can be expressed as follows:

$$Y_{ict} = \beta_0 + \sum_{j=-n}^{k} \beta_j treat_{ct}^{j} + P_{ict}'\alpha + C_{ct}'\omega + \delta_i + \gamma_t + \varepsilon_{ict} \tag{2}$$

where $treat_{ct}^{j}$ is a binary variable that reflects an observation selected j years prior or post to demonstration status. For example, $treat_{ct}^{-4}$ indicates that observation is selected four years before demonstration status, and $treat_{ct}^{4}$ indicates that observation is selected four years after demonstration status. When $j < 0$, β_j is expected to be insignificant from 0 because it means no statistical difference in employment outcomes of demonstration cities and regular cities before the treatment. When $j \geq 0$, β_j reflects the dynamic effects of Broadband China Strategy on employment outcomes. Definitions of other variables are the same as in eq. (1).

Meanwhile, to address the limitation of the TWFE method in testing parallel trends during the event-study analysis, we also employ the CSDID method to estimate the coefficients of the event study. Fig. 3 presents the estimated coefficients and confidence intervals of TWFE and CSDID. The results indicate that the estimated coefficients for each period are relatively consistent for both estimators. The results also show that the demonstration and regular cities have no significant differences in employment quality outcomes before the treatment. However, after being selected as Broadband China demonstration cites, labor contract signing rates, pension participation rates and medical insurance participation rates exhibit a dramatic increase in demonstration cities, further providing evidence for our benchmark model. Parallel trend tests for the low-skilled and high-skilled workers are shown in Appendix Fig. A2. Finally, we use this approach to investigate the dynamic effects of the Broadband China Strategy on broadband penetration and the number of broadband subscribers at the city level, as shown in Appendix Fig. A3. The figure shows that the demonstration cities' broadband penetration rates and broadband subscribers increase significantly after the treatment.

4.4. Placebo test

Another concern regarding the DID model used in this paper is the interference of other unobservable time-varying characteristics or policies on employment. Therefore, we used a placebo test to investigate potential interference of this type. First, according to eq. (3), the expression of coefficient $\widehat{\beta_1}$, which reflects the placebo effect, is as follows:

$$\widehat{\beta_1} = \beta_1 + \gamma \times \frac{cov\left(treat_c \times period_{ct}, \mu_{ijt}|Z\right)}{var(treat_c|Z)} \tag{3}$$

where $treat_c$ is the treatment dummy, which equals 1 if city c is a Broadband China demonstration city and 0 otherwise. $period_{ct}$ is the dummy, which equals 1 if the city c has implemented the Broadband China policy at time t, 0 otherwise. Z denotes all control variables and fixed effects, and γ is the effect of unobserved factors on the dependent variables. If γ is not significantly different from 0, it indicates that the unobserved factors do not affect the estimation results and $\widehat{\beta_1}$ is unbiased.

The above hypothesis cannot be tested directly, and thus, we adopt an indirect approach to conduct the placebo test following La Ferrara, Chong, and Duryea (2012). We replace $treat_c \times period_{ct}$ in the benchmark model by finding a pseudo-variable that does not theoretically affect the dependent variable. Because the pseudo-variable is randomly generated, it is reasonable to expect that $\widehat{\beta_1}$ should be equal to 0. Conversely, if $\widehat{\beta_1}$, it is not equal to 0, indicating that other unobserved factors interfere with the results.

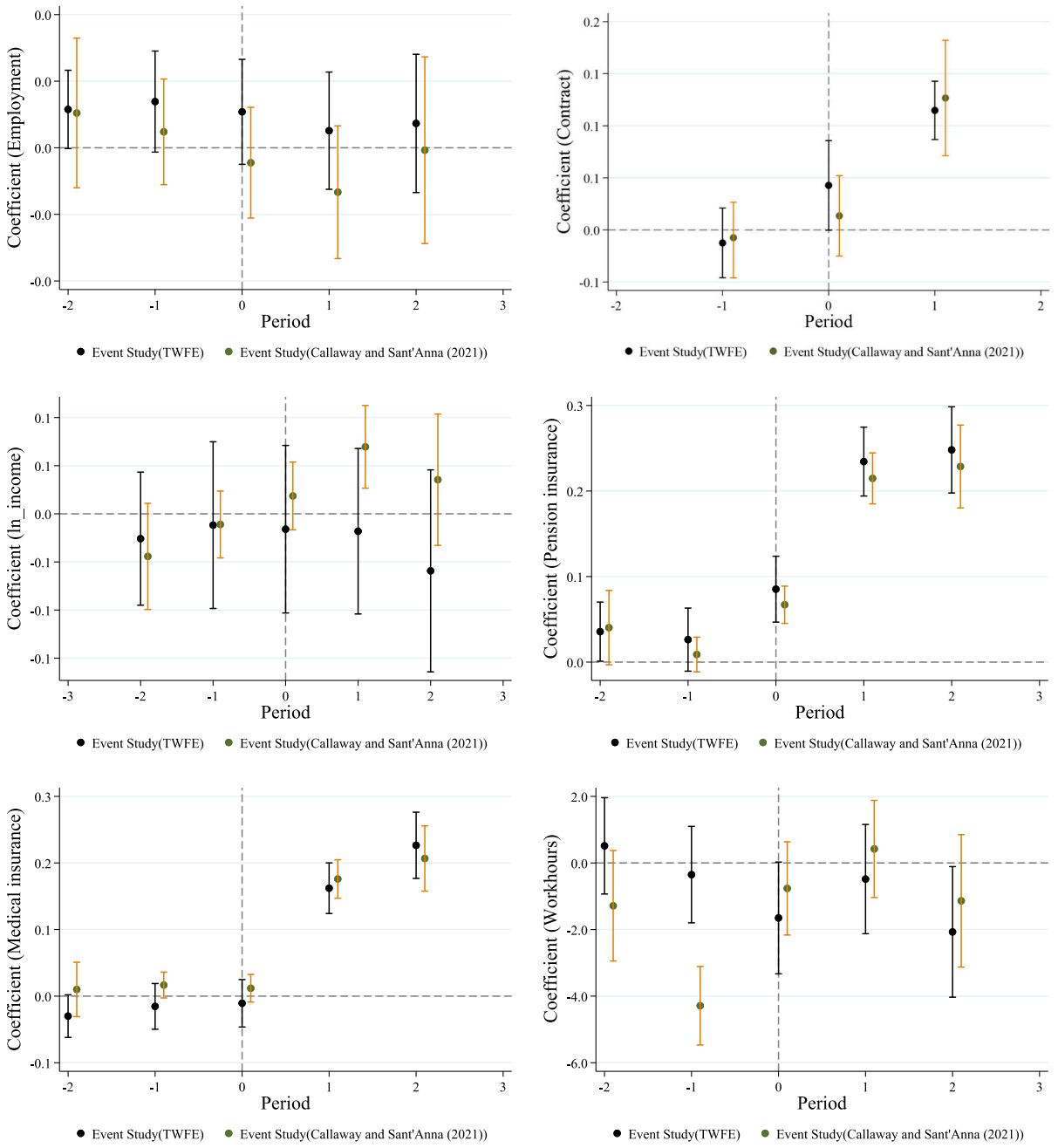

Fig. 3. Parallel trend test.
Notes: The dependent variables are contract, income, pension, medical insurance, and weekly workhours respectively. Since whether the worker sign a contract can be only obtained from 2014, 2016 and 2018 wave of CFPS, therefore worker-year observations here are from 2014 to 2018, and we drop the 4 years after policy (post_4) as the reference period. When dependent variables are income, pension, medical insurance, and weekly workhours, the worker-year observations are from 2010 to 2018, and we drop the 2 years before policy (pre_2) as the reference period. The dotted line indicates the 95% Confidence Interval (CI) of the estimated coefficient.

Because 46 cities implemented the "Broadband China" strategy from 2014 to 2018, our sample randomly selected 46 cities as the fictitious experiment group. Following the two policy implementation time points (2014 and 2016), we randomly assign a policy implementation time point to each fictitious experiment city after randomly selecting the experimental group. We can obtain 500 estimated coefficients $\widehat{\beta_1}$ with the corresponding *p*-values after repeating the above process 500 times. The results of the placebo test are presented in Fig. 4.

For each dependent variable, $\widehat{\beta_1}$ is distributed around 0 and obeys a normal distribution; most of their p-values are >0.10. Besides,

when the dependent variables are medical insurance, pension insurance, and contract, the real estimated coefficient (the vertical red line) is significantly far from the center of the distribution, indicating that it is a very evident outlier in the placebo test and the probability of obtaining the aforementioned baseline regression coefficients based on random samples or policies is low. The results of the placebo test indicate that our results are not seriously disrupted by unobserved time-varying factors; our results are robust.

4.5. Other robustness checks: alternative dependent variable

Some scholars have raised concerns that evaluating employment quality from only an objective perspective may be one-sided and that workers' subjective employment satisfaction can provide a more comprehensive measure of overall employment quality because it

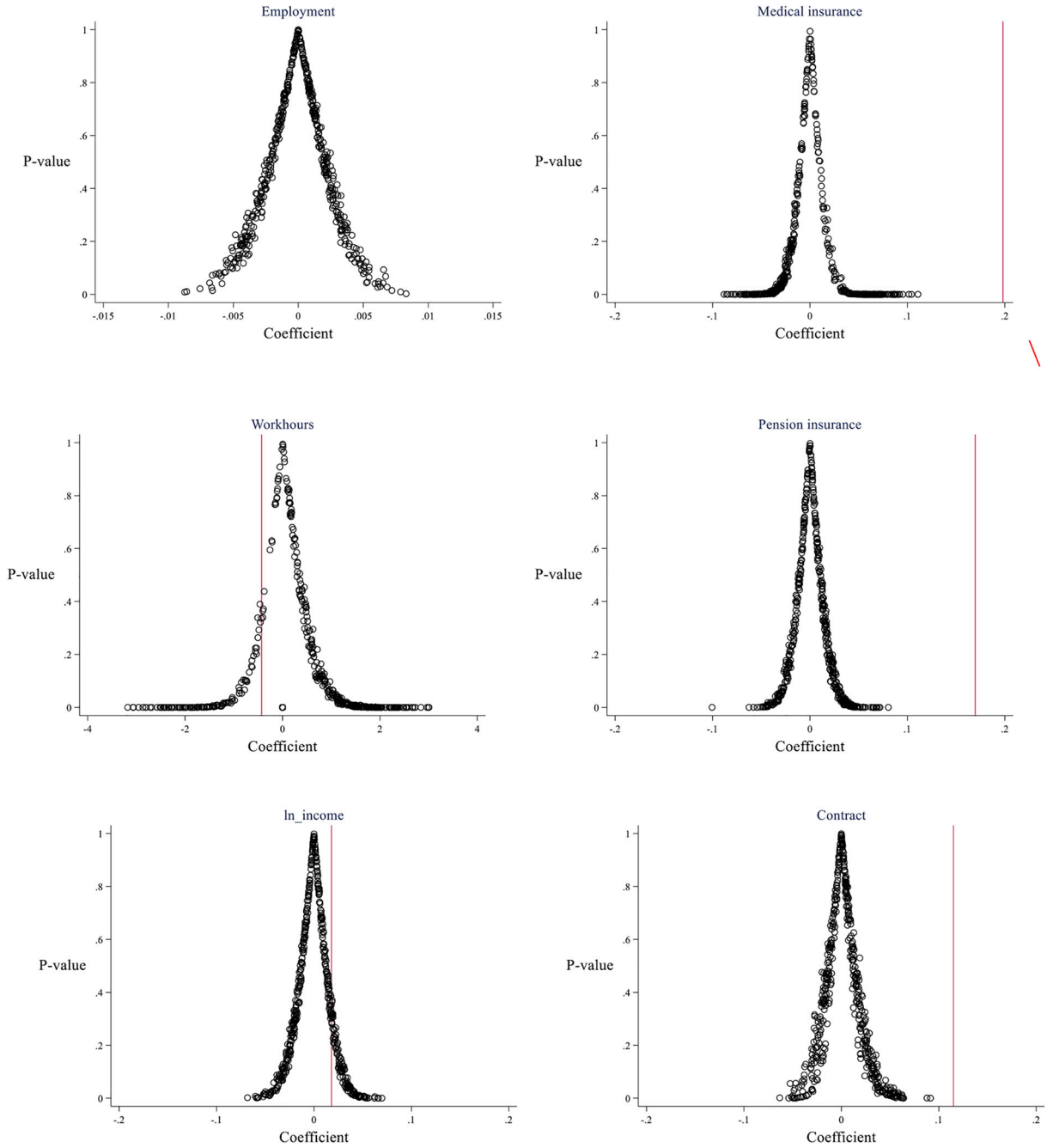

Fig. 4. Placebo test.
Notes: The red vertical line indicates the real coefficients estimated in the baseline.

is influenced by factors such as wage level, job autonomy, and participation in social security programs (Bustillo, Fernández-Macías, Esteve, & Antón, 2011; Dieckhoff, 2011; Gallie, 1996). To investigate the effect of broadband Internet development on the subjective employment satisfaction of laborers, we introduce three new dependent variables: overall job satisfaction, job income satisfaction, and working time satisfaction. All three variables are represented by ordered numbers 1–5; larger numbers indicate higher respondents' job satisfaction. The results of the estimations are shown in Table 4. It indicates that broadband internet development can significantly increase the subjective employment satisfaction of low-skilled workers, which is consistent with the findings of the baseline analysis.

Finally, in the Appendix, we determine the potential labor rights protection-related laws or regulations that may affect our results during 2014–2018. Although these regulations may affect workers' employment quality, the impact of such regulations on the regression results can be excluded because these regulations differ significantly from the Broadband China policy in terms of temporal and spatial changes.

4.6. Mechanism test

4.6.1. Mitigate information friction

First, implementing the Broadband China Strategy has increased broadband internet development and mitigated information friction.

Specifically, because low-skilled workers typically originate from rural areas,[6] their social networks tend to be of lower quality when compared to those of high-skilled workers (Cappellari & Tatsiramos, 2015; Chen, Wang, & Zhang, 2018). As a result, they rely primarily on the secondary labor market or some other informal job search method to secure employment under the traditional employment model (Zhou, 2013), which presents significant disadvantages in job searching, particularly compared to their high-skilled workers.

The broadband Internet's popularity and usage have potential benefits for low-skilled laborers in expanding their job search channels and alleviating employment constraints resulting from information asymmetry. In particular, compared to the traditional job search mode of depending on social networks, the Internet can improve information dissemination efficiency, enable low-skilled laborers to access plentiful and high-quality employment information at a reduced cost, and substantially increase their employment options, thereby helping them secure better employers and more stable jobs.

Unfortunately, the CFPS database does not provide evidence that can directly demonstrate whether the development of broadband internet has increased the quality and quantity of job-related information available to low-skilled workers. Hence, our paper validates the mechanism through two indirect ways. First, we verify the effect of broadband internet development on laborers' employment information channels based on the question, "How important do you think the Internet is for your access to information". Results in Table 5 show that the Broadband China policy has increased the importance of the Internet in the process of information access for low-skilled laborers, with a coefficient of 0.0819 and significant at the 5% statistical level, indicating that broadband internet development expanded the employment information channels of the labor force. More online employment information can help these low-skilled laborers achieve higher-quality employment.

We also verify the effect of broadband internet development on how the labor force seeks jobs. Specifically, we use respondents' job search mode as the explanatory variable and assign it to 1 if respondents obtain their current job through their independent search; otherwise, the new explanatory variable is assigned to 0 when respondents rely on their past social relationships to obtain their current job.

The identification logic behind this approach is that if broadband internet development increases the quality and quantity of information available to low-skilled laborers, it also will increase the proportion of laborers that obtain jobs independently through job market information and, correspondingly, decrease the likelihood of relying on their social network to get jobs. The new regression results are reported in Table 6. It demonstrates that the probability of low-skilled workers choosing to find jobs independently increases significantly in places with higher Internet penetration, which can confirm our speculation that the Internet reduces low-skilled workers' reliance on social networks by providing them with more quality information at higher quantities, thus allowing them to find better jobs. The above mechanism was similarly demonstrated in the paper by Qi and Jiang (2023).

4.6.2. Promote online learning to low-skilled workers

The Broadband China policy has also increased the probability of labor exposure and use of broadband internet, which may lead to further accumulation of human capital through online learning and eventually obtain better quality employment opportunities.

To verify the above speculation, we alter the dependent variable in eq. (1) into a binary variable indicating whether the responder uses the Internet for learning. The new regression results are represented in Table 7. The results indicate that the Broadband China Strategy significantly increased the likelihood of workers using the Internet for studying. Specifically, this probability significantly increases by 3.4% after the policy implementation. Regression of subsamples demonstrates that only low-skilled workers are significantly affected, consistent with our baseline results. This conclusion seems counterintuitive but is still explainable. As shown in Table A2 (Appendix), low-skilled workers may have a much higher budget constraint and a much lower Internet usage rate before Broadband China implementation (Fig. 2). Therefore, the lower broadband fee based on the Broadband China Strategy may have a larger marginal effect on low-skilled workers and promote them to learn on the Internet. Eventually, as more low-skilled workers use

[6] Descriptive statistics for our sample indicate that 75% of the low-skilled laborers are rural registration and only 25% are urban registration; in contrast, only 25% of the high-skilled laborers are rural registration and 75% are urban registration

Table 4
Effects of broadband internet development on workers' subjective employment satisfaction.

Dependent Var.	Overall job satisfaction		Job income satisfaction		Working time satisfaction	
	High-skill	Low-skill	High-skill	Low-skill	High-skill	Low-skill
[Mean]	[3.5384]	[3.4187]	[3.2790]	[3.1597]	[3.3986]	[3.6131]
	(1)	(2)	(3)	(4)	(5)	(6)
Broadband China	0.0044	0.0496**	0.0900	0.1025*	0.0268	0.0972**
	(0.0531)	(0.0206)	(0.1046)	(0.0551)	(0.0750)	(0.0459)
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes
Individual FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Sample Weights	Yes	Yes	No	No	Yes	Yes
Obs	6551	24,499	3490	12,351	3491	12,353

Notes: $*p < .10$, $**p < .05$, $***p < .01$. Estimates are based on the model in eq. (1), using worker-year observations over the period 2014, 2016 and 2018. Only employed workers are included. In column (1), the dependent variables are workers' overall job satisfaction, expressed by ordered 1–5 ("1" as "very dissatisfied", "2" as "a little unsatisfied", "3" as "neutral", "4" as "a little satisfied", "5" as "very satisfied"). In column (2), the dependent variables are workers' job income satisfaction, expressed by ordered 1–5 ("1" as "very dissatisfied", "2" as "a little unsatisfied", "3" as "neutral", "4" as "a little satisfied", "5" as "very satisfied"). Independent variables in both column (1) and (2) are the city's internet penetration rates (unit: %). In column (3), the dependent variables are workers' working time satisfaction, expressed by ordered 1–5 ("1" as "very dissatisfied", "2" as "a little unsatisfied", "3" as "neutral", "4" as "a little satisfied", "5" as "very satisfied"). All regressions include fixed effects for individual and year, as well as the individual sample weights. The robust standard errors are in parentheses.

Table 5
Effect of broadband internet development on the labors' employment information channels.

Dependent Var.	Importance of the internet for obtaining information	
	High skill	Low skill
	(1)	(2)
Broadband China	0.0324	0.0819**
	(0.0567)	(0.0414)
Control Variables	Yes	Yes
Individual FE	Yes	Yes
Year FE	Yes	Yes
Obs	4935	19,898

Notes: $*p < .10$, $**p < .05$, $***p < .01$. Estimates are based on the model in eq. (1), using worker-year observations over the period 2014, 2016 and 2018. Only employed workers are included. The dependent variable is importance of the internet for obtaining information, denoted by ordered number 1–5. High-skilled denotes workers who have at least college degree (15 years or more of Education). Low-skilled denotes workers whose highest education background is high school (12 years or less of Education). Individual whose education is between 12 and 15 are assign as high-skilled or low-skilled workers according to proximity principle. All regressions include fixed effects for individual and year. The robust standard errors are in parentheses.

Table 6
Effect of broadband internet development on the labors' ways to find job.

Dependent Var.	Find job independently (Yes = 1, No = 0)		
	Full sample	High skill	Low skill
	(1)	(2)	(3)
Broadband penetration	0.0014	−0.0042	0.0028**
	(0.0010)	(0.0025)	(0.0011)
Control Variables	Yes	Yes	Yes
Individual FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Sample Weights	Yes	Yes	Yes
Obs	3719	983	2725

Notes: $*p < .10$, $**p < .05$, $***p < .01$. The dependent variables are binary variables that indicate whether the workers look for job independently. Only employed workers are included. Estimates are based on the model in eq. (1). Because only 2014, 2016 and 2018 wave of CFPS asked responders about this question, worker-year observations here are from 2014 to 2018. High-skilled denotes workers who have at least college degree (15 years or more of Education). Low-skilled denotes workers whose highest education background is high school (12 years or less of Education). Individual whose education is between 12 and 15 are assign as high-skilled or low-skilled workers according to proximity principle. All regressions include fixed effects for individual and year, as well as the individual sample weights. The robust standard errors are in parentheses.

Table 7
Broadband China increases probability of online learning.

Dependent Var.	Use internet to learn (Yes = 1, No = 0)		
	Full Sample	High-skill	Low-skill
[Mean]	[0.2614]	[0.4877]	[0.2032]
	(1)	(2)	(3)
Broadband China	0.0340**	−0.0441	0.0774***
	(0.0144)	(0.0435)	(0.0139)
Control Variables	Yes	Yes	Yes
Individual FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Sample Weights	Yes	Yes	Yes
Obs	24,103	4936	19,167

Notes: * $p < .10$, ** $p < .05$, *** $p < .01$. The dependent variables are binary variables that indicate whether the worker use the internet for learning, and estimates are based on the model in eq. (1). Because only 2014, 2016 and 2018 wave of CFPS asked responders about this question, worker-year observations here are from 2014 to 2018. High-skilled denotes workers who have at least college degree (15 years or more of Education). Low-skilled denotes workers whose highest education background is high school (12 years or less of Education). Individual whose education is between 12 and 15 are assign as high-skilled or low-skilled workers according to proximity principle. All regressions include fixed effects for individual and year, as well as the individual sample weights. The robust standard errors are in parentheses.

the Internet for learning, the human capital gap between low-skilled and high-skilled workers will be reduced, ultimately improving the quality of low-skilled workers' employment.

4.6.3. Benefit some industries with intensity of low-skilled workers

Another potential mechanism is that the Broadband China Strategy promoted the adoption of broadband in some industries, which may increase their productivity and promote the labor demand, finally benefitting workers (Commander, Harrison, & Menezes-Filho, 2011; Hjort & Poulsen, 2019). Specifically, the development of broadband internet has changed the organizational structure of enterprises, making production and management more efficient, which can improve the efficiency of enterprises by reducing transaction and production costs (Afuah, 2003; Bartel, Ichniowski, & Shaw, 2007; Bloom, Sadun, & Van Reenen, 2012; Duggal, Saltzman, & Klein, 2007). Second, broadband internet development can stimulate consumer demand, help enterprises use existing resources to expand production scale and increase enterprise revenue (Goldin & Katz, 1998). Third, broadband internet development can boost the demand for labor among firms, evidence of which can be found in China (e.g., Chen, Liu, and Song (2020)) and Africa (e.g., Hjort and Poulsen (2019)).

We plot the employment industries of the low-skilled workers in Fig. 5 to verify the above speculation. The figure shows that the industry distribution of low-skilled labor developed significantly from 2014 to 2018, and a significant reduction in the share of employment in the construction industry occurred. By our calculations, 41.38% of low-skilled workers who transitioned out of manufacturing moved from the construction industry to the manufacturing industry. An important reason for this trend may be attributed to the "pull" effect of broadband internet development, which increased productivity in the manufacturing industry and generated a higher demand for labor. Furthermore, according to Appendix Table A7, the employment quality in the manufacturing industry is significantly higher than that in the construction industry, which contributes to the quality of employment of the low-skilled workforce.

We take this industry as an example to investigate how broadband internet development affects some industries and benefits workers. The reasons we take the manufacturing industry as an example are because 1) manufacturing is the industry with the highest concentration of low-skilled labor, as shown in Figs. 5 and 2) China's manufacturing industry is relatively mature and has been largely influenced by broadband internet development because broadband usage in manufacturing has been increasing in recent years (Feng, Guo, Ji, & Wang, 2023). Appendix Fig. A4 shows a dramatic increase in broadband use in manufacturing sectors in recent years.[7]

China's third national economic census, conducted in 2013, and the fourth national economic census, conducted in 2018, provided information on the operations of manufacturing firms. Using the following model, we constructed city-level panel data involving two years and validated the impact of broadband internet development on the manufacturing sector.

$$Y_{ct} = \beta_0 + \beta_1 Broadband\ China_{ct} + C_{ct}^{'}\omega + \delta_c + \gamma_t + \varepsilon_{ct} \quad (4)$$

[7] While more than one-third of the low-skilled labor force is employed in the manufacturing industry, it is important to note that the analysis based on this industry may not be fully representative of all industries.

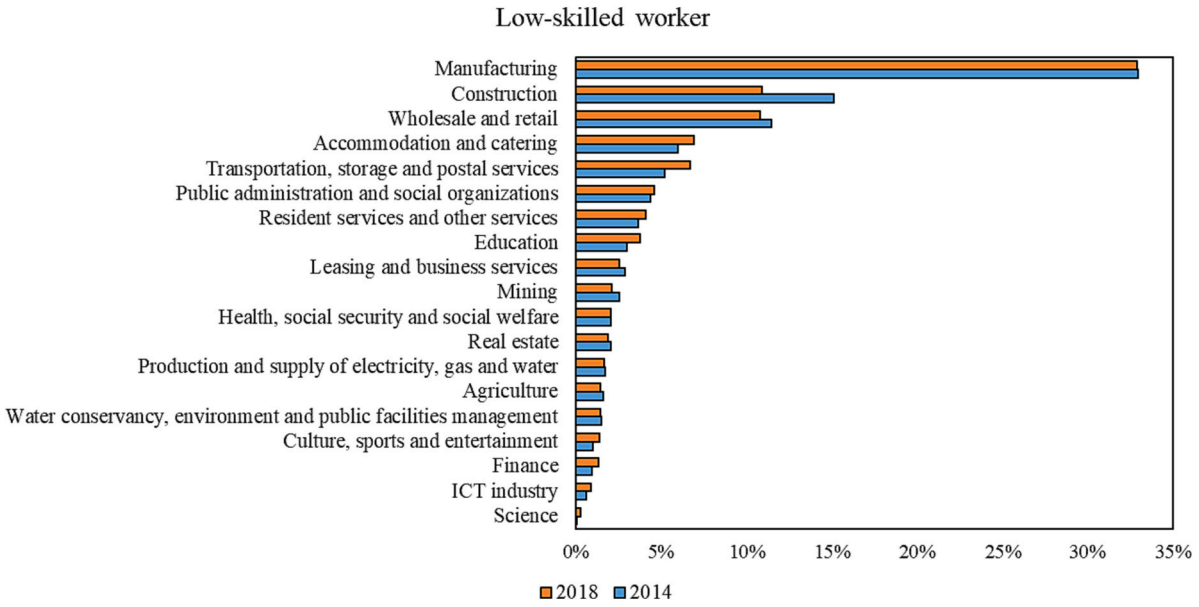

Fig. 5. Employment structure distribution of low-skilled workers in 2014 and 2018.
Source: Author calculated by CFPS.

where *c* denotes city and *t* denotes year. *Broadband China*$_{ct}$ is a binary indicating whether city *c* is selected as a demonstration city in year *t*. Other variables' definitions are as same as in eq. (1). Y_{ct} is the dependent variable, and we focus on four outcomes: (1) Unit product revenue, calculated as the ratio of revenue to outputs of the manufacturing industry.[8] (2) Unit product costs, calculated as the ratio of administrative costs and selling costs to outputs in the manufacturing industry. (3) Unit product profits, calculated as the ratio of profits to outputs in the manufacturing industry. (4) Total employers in the manufacturing industry. The regression results are reported in Table 8.

Column (1) of Table 8 shows that broadband significantly promotes the unit product revenue by approximately 31.8, and the coefficient is significant at 5%. Columns (2) and (3) indicate that the unit product costs decrease significantly with broadband development. In column (3), although the coefficient of interest is positive, the large standard error makes it statistically insignificant. Finally, column (5) results also align with our speculation. It demonstrates the demands for workers have risen significantly because the total number of employees increased by approximately 164%. The above points contribute to the employment quality of low-skilled workers.

In summary, the mechanism of effects of broadband internet development on the employment of low-skilled labor can be concluded in Fig. A5 (Appendix). Broadband internet development has mitigated information friction and increased the probability of online learning for low-skilled workers. The expansion has also promoted business revenue and labor demands in the most concentrated industry for low-skilled workers, namely the manufacturing industry. These aspects have jointly contributed to improving the employment quality of low-skilled workers.

4.7. Heterogeneity

We further explore the heterogeneity of the impact of broadband internet development on the employment quality of low-skilled workers in three aspects: gender, age, and hukou. To make the comparison between different subgroup samples more direct, this paper conducts heterogeneity tests by introducing interaction terms between the Broadband China Strategy dummy and the three aspects based on eq. (1). The results are reported in Table 9.

First, the results in columns (1)–(3) show no significant difference in the effects of broadband internet development on employment quality between males and females. In other words, broadband technology treats males and females equally, at least in the labor markets.

Second, because of the extensive differences between new and old workers regarding education level and employment structure (Li, Liu, Luo, Zhang, & Rozelle, 2010), we interact with the age with a Broadband China dummy. The coefficients of the interaction term in

[8] For example, with the proliferation of broadband technology, goods produced by manufacturing companies can be sold around the world through online shopping, which has increased market demand and the profits of manufacturing companies, as well as the employment absorption capacity of the manufacturing industry, allowing laborers who were originally in the informal employment sector to achieve formal employment and improve the quality of employment.

Table 8
Broadband internet development benefits manufacturing industry.

Dependent Var.	Revenue /Output	Administrative costs/Output	Selling costs/Output	Profits/Output	Number of Employees (log)
[Mean]	[52.7129]	[2.1795]	[0.9646]	[0.0003]	[11.6308]
	(1)	(2)	(3)	(4)	(5)
Broadband China	31.7980**	−2.6637***	−0.6002**	0.0008	1.6426**
	(13.7635)	(0.5746)	(0.2244)	(0.0007)	(0.6995)
City FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Obs	218	224	224	218	224

Notes: * $p < .10$, ** $p < .05$, *** $p < .01$. Estimates are based on the model in eq. (3), using city-year observations over the period in 2013 and 2018. The data is from China's 3rd national economic census conducted in 2013 and the 4th national economic census conducted in 2018. The dependent variable in column (1) ratio of revenue to outputs of manufacturing industry. The dependent variable in column (2) is the ratio of administrative costs to outputs in manufacturing industry. The dependent variable in column (3) is the selling costs to outputs in manufacturing industry. The dependent variable in column (4) is the ratio of profits to outputs in manufacturing industry. The dependent variable in column (5) is total number of employers (log-form) of manufacturing industry. All regressions include fixed effects for city and year. The robust standard errors are in parentheses.

Table 9
Heterogeneity effects of broadband internet development (Full samples).

Dependent Var.	Contract	Pension	Medical insurance	Contract	Pension	Medical insurance	Contract	Pension	Medical insurance
[Mean]	[0.4970]	[0.3917]	[0.3133]	[0.4970]	[0.3917]	[0.3133]	[0.4970]	[0.3917]	[0.3133]
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Broadband China	0.0626***	0.0800***	0.0932***	0.2269***	0.1941***	0.2700***	0.0465***	0.0808***	0.0808***
	(0.0231)	(0.0215)	(0.0219)	(0.0484)	(0.0662)	(0.0805)	(0.0138)	(0.0093)	(0.0093)
Broadband China × Male	0.0033	−0.0009	0.0195						
	(0.0277)	(0.0304)	(0.0303)						
Broadband China × Age				−0.0026**	−0.0028*	−0.0040**			
				(0.0012)	(0.0015)	(0.0018)			
Broadband China × Rural							0.0514***	0.0255*	0.0255*
							(0.0186)	(0.0143)	(0.0143)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sample Weights	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Obs	20,262	29,703	29,356	20,262	29,703	29,356	20,262	29,703	29,356

Notes: * $p < .10$, ** $p < .05$, *** $p < .01$. Estimates are based on the model in eq. (1), and introduce the interaction term of person traits and Broadband China dummy, using worker-year observations over the period 2010–2018. Only employed workers are included. Column (1) to column (15) consider the samples of workers aged 18–65 years who are recorded in CFPS survey. The dependent variables in column (1), (4), and (7) are binary variables that indicate whether the worker sign a contract, only 2014, 2016 and 2018 wave of CFPS asked responders whether they sign a contract, therefore worker-year observations here are from 2014 to 2018. The dependent variables in column (2), (5), and (8) are binary variables that indicate whether the worker has pension insurance. The dependent variables in column (3), (6), and (9) are binary variables that indicate whether the worker has medical insurance. Male is a binary that reflect whether the responder is a male. Age is a continuity variable. Rural is a binary that reflect whether the responder is from rural (judged by hukou). All regressions include fixed effects for individual and year, as well as the individual sample weights. The robust standard errors are in parentheses.

columns (4)–(6) are significantly negative, demonstrating that the positive impact of broadband internet development on employment quality is gradually diminishing as the age of workers increases, the benefit gained by the elderly labor force in the broadband internet development is significantly lower than that of the young labor force. This result may be because the younger workers have better digital literacy. Besides, it may also be because the younger workers have a stronger sense of rights (Chan, 2010), forcing companies to treat them more fairly and legally. Unfortunately, we cannot prove this point through empirical research due to data limitations.

Third, we also investigate the heterogeneity effects of broadband internet development between rural and urban workers. We set a binary variable *Rural* that reflects whether the responders have rural registration (hukou) and interact *Rural* with the Broadband China dummy. The coefficients of the interaction term in columns (7)–(9) are significant and positive, indicating that broadband internet development benefits rural workers significantly more.

5. Conclusions and implication

This paper provides evidence on how broadband internet development affects workers' employment in China. A combined dataset

with a staggered DID approach shows that broadband internet development will not affect employment rates for low-skilled workers and the high-skilled labor force. Then, we confirm that a rise in broadband penetration will significantly increase workers' contract signing rates and pension and medical insurance participation rates. This effect is reflected mainly in low-skilled labor groups, but no significant effect on high-skilled workers improves employment equality. Second, when we change the TWFE estimator in the staggered DID model into other novel methods, the coefficients are similar to benchmark regression, except for income. Third, the potential mechanism can be divided into micro and macro aspects. On the one hand, a micro aspect, broadband internet development, has increased the quality and quantity of job-related information available to low-skilled labor. It also increased the probability of online learning for low-skilled workers.

On the other hand, at the macro aspect, broadband internet development also promoted business revenue and labor demands in low-skilled, most concentrated industries (i.e., the manufacturing industry). The two aspects have jointly realized the improvement of the employment quality of low-skilled workers. Finally, young and rural workers benefit more from broadband internet development, but no difference was observed between males and females.

Our findings have important implications for the debate on the externalities of broadband internet infrastructure investment in developing countries. Our estimates suggest that developing countries should increase investment in broadband infrastructure, which will help reduce the employment inequality between low-skilled and high-skilled workers. At the same time, governments should pay attention and give more support to elderly workers to help them better benefit from broadband internet development.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Acknowledgement

All authors contributed equally and are ordered alphabetically.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.chieco.2023.102038.

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