Can digital economy inspire entrepreneurial innovation spirit?

——A study on the incentive effect of the "Broadband China" policy

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Abstract. Based on panel data from 255 cities between 2009 and 2019, the research treats implementation of the "Broadband China" policy as a quasi-natural experiment, and uses period-by-period difference-in-differences model to study the incentive effects of policy shocks on entrepreneurial innovation spirit at the city level. The results indicate that the "Broadband China" policy can stimulate entrepreneurial innovation spirit, and this conclusion holds after a series of robustness tests. Heterogeneity analysis indicates that the incentive effect of the policy on the spirit is mainly manifested in non-smart cities in the eastern coastal regions, whose industries are dominated by the secondary sector.

Keywords: Broadband China; Entrepreneurial innovation spirit; Placebo test; Heterogeneity analysis

1 Introduction

1.1 Research background and status

In the new normal of China's economy shifting towards high-quality development, entrepreneurs' spirit has become a crucial driving force for promoting economic growth, improving people's well-being, and fostering overall societal prosperity[1].

Studying the impact of the 'Broadband China' policy on entrepreneurs' spirit is of great significance in the field of economics. In the current researches on the causal identification of the policy shock effects of the 'Broadband China' policy, scholars have focused on the incentive effects of the policy on entrepreneurship and industrial upgrading at the macro city level and the meso enterprise level. They have explored the objective factors and mechanisms behind the policy transmission effects, such as reducing information asymmetry[2] among enterprises, improving urban informatization[3], and enhancing talent aggregation[4]. As for 'entrepreneurs' spirit' at the micro level, it has mainly been treated as an explanatory or mediating variable, emphasizing its crucial role in driving corporate strategic transformation[5], promoting high-quality development of enterprises[6], and enhancing regional economic resilience[7].

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1.2 Marginal contribution of this study

This study considers "entrepreneurial innovation spirit" as the dependent variable, and utilizes panel data from Chinese cities spanning 2009 to 2019. By constructing an econometric model that combines the "Broadband China" policy in selected cities with the number of patents granted, it measures the stimulating effect of the policy on entrepreneurial innovation spirit. The study also conducts robustness tests to validate the conclusions. Furthermore, it explores the heterogeneity of policy effects among cities with different regional characteristics and industrial structures. The aim is to provide theoretical references for future digitalization.

2 Theoretical hypothesis

Entrepreneurs are leaders of business innovation. Whether entrepreneurs possess innovative spirit directly determines their level of enthusiasm for innovation, which in turn influences the overall atmosphere for innovation within the entire company[8]. This relationship is crucial for the smooth progress of transforming innovative outcomes into tangible results, thereby maintaining a competitive advantage in the market.

The reality shows that entrepreneurial innovation spirit needs to be stimulated and reinforced through external policy incentives. Based on relevant research findings and different economic level of regions in China, this study proposes the following hypothesis:

Thesis 2.1 The implementation of the "Broadband China" policy has a positive effect on the encouragement of entrepreneurial innovation spirit.

Thesis 2.2 The extent of the incentive effect of the policy on entrepreneurial innovation spirit is positively correlated with the level of regional economic development.

Thesis 2.3 The effectiveness of policy incentives varies across cities with different industrial structures.

3 Equations

To examine the impact of the "Broadband China" policy on entrepreneurial innovation spirit in cities, this study treats the implementation of the policy as a quasi-natural experiment. The study utilizes a panel double-difference model to investigate the differences in entrepreneurial innovation spirit between pilot and non-pilot cities before and after the implementation of the policy. The model is as follows, in Eq. (1).

$$\mathrm{patent}_{it} = \alpha + \beta \mathrm{did}_{it} + \gamma \mathrm{Control} + \lambda_i + \mu_t + \varepsilon_{it} \quad (1)$$

In the equation provided: patent_{it} represents the total number of patent applications in region i in year t. did_{it} denotes whether region i is designated as a pilot city under the "Broadband China" policy in year t. The coefficient β is of particular interest in this study, as it measures the treatment effect of the policy. A significant positive β indicates that the implementation of the policy promotes entrepreneurial innovation spirit in the

pilot cities, while a negative sign suggests a suppressive effect on the spirit. Control represents a set of control variables used in the analysis, chosen consistently with the benchmark regression. λ_i and μ_t represent the fixed effects for cities and years, respectively. ε_{it} is the random error term, which is independently and identically distributed.

4 Variables and descriptive statistics

The sample used in this study consists of panel data from 255 cities spanning the years 2009 to 2019. City data are primarily sourced from the 《China City Statistical Yearbook》, patent data are obtained from the National Intellectual Property Office's patent database, digital word frequency data are derived from government work reports of corresponding regions, and the list of cities selected as pilot ones under the "Broadband China" policy and the corresponding periods are compiled by the author based on information from government websites.

- Outcome variable. The total number of patent applications in a specific region (patent) is chosen as a proxy variable to measure the strength of entrepreneurial innovation spirit there.
- Explaining variable. The variable "did" represents the "Broadband China" policy. At the same time, samples with missing data for certain regions and years were excluded from the analysis.
- Control variables. The level of information network and the construction degree of infrastructure in the region: measured by the number of mobile phone users at the end of the year (phouser), the number of Internet users (netuser) and the number of employees in the information transmission, computer service and software industry (ITlabor). The local government's emphasis on the development of science and technology education: measured by the expenditure of science (techpay) and education(edupay)in the area. The regional industrial structure: measured by the proportion of employees in the secondary industry (Lsecper), the proportion of employees in the tertiary industry (Lthiper), the proportion of value-added of the secondary industry in GDP (secindgdp) and the proportion of value-added of the tertiary industry in GDP (thiindgdp). The financial wealth of local government: measured by logarithm of the revenue in the general budget of local finance(locfin).

Descriptive statistics of the main variables are shown in Table 1.

Table 1. Descriptive statistics of major variables

VARIABLES	size	mean	median	sd	min	max
patent	2805	7876	1724	19099	12	253338
phouser	2805	463.0	318	493.7	17	4076
netuser	2805	980601	560000	1566565	237	51740000
techpay	2805	106542	25538	353558	1198	5549817
edupay	2805	663405	453761	875756	53261	11360185
locfin	2805	2333079	1016000	5140103	48443	71650984
ITlabor	2805	1.230	0.370	4.901	0.0280	85.91

Lthiper	2805	53.23	53.32	13.05	9.910	91.14
Lsecper	2805	44.73	44.98	13.84	7.430	84.40
thiindgdp	2805	40.32	39.27	9.822	14.36	83.52
secindgdp	2805	47.64	47.80	9.952	10.68	82.24

5 Regression results and analysis

5.1 Benchmark regression

Based on the previous equation and variables, this section explores the impact of the "Broadband China" policy on entrepreneurial innovation spirit. The results of the benchmark regression are shown in Table 2, where the regression results use city-level cluster standard errors. Column(1) and (2) represent results in fixed effects that do not control for cities and years, and column(3) and (4) vice versa.

Before and after controlling for covariates, the regression coefficients of outcome variables on the policy variable are significant at the 1% level. Column(4) shows the regression coefficient of "patent" on the policy variable "did" is estimated to be 1321.9926, which is significant at the 1% level. It indicates that the policy can motivate patent applications in the respective regions, with an increase of 1322 granted. Since "patent" is the proxy variable for entrepreneurial innovation spirit, it can be said that the implementation of the "Broadband China" policy promoted the entrepreneurial innovation spirit in the respective regions. **Thesis 2.1** is proved.

To validate the significance of the results, Table 3 employs a regression method without using clustered standard errors. It indicates that even without considering standard errors, the research findings still hold.

Table 2. Reference regression results (clustered)

	(1)	(2)	(3)	(4)
VARIABLES	patent	patent	patent	patent
did	17,634.5570***	2,653.7951**	7,913.3878***	1,321.9926**
	(3,450.9764)	(1,024.2221)	(1,914.0104)	(621.4925)
Constant	4,808.2197***	-5,815.3003	6,499.4605***	40,603.0045***
	(549.6305)	(3,971.4682)	(332.9900)	(12,672.8469)
Control	no	yes	no	yes
Observations	2,805	2,805	2,805	2,805
R-squared	0.123	0.855	0.802	0.960

Note: *, **, and *** represent significance levels of 10%, 5%, and 1%, respectively. Standard errors clustered at the industry level are shown in parentheses. Results of the control variable regression are presented for reference. The same applies to the following tables.

Table 3. reference regression results (unclustered)

	(1)	(2)	(3)	(4)
VARIABLES	patent	patent	patent	patent
did	17,634.5570***	2,653.7951***	7,913.3878***	1,321.9926***
	(891.2497)	(403.5757)	(676.5135)	(316.5831)
Control	no	yes	no	yes
Constant	4,808.2197***	-5,815.3003*	6,499.4605***	40,603.0045***
	(371.7430)	(3,087.5284)	(205.7688)	(6,497.9028)
Observations	2,805			
R-squared	0.123	0.855	0.802	0.960

5.2 Parallel trends test

An important premise for using the difference-in-differences (DID) model is to satisfy the parallel trends assumption. To exclude influence of other heterogeneous factors and accurately assess the effects of the policy, this study conducted a parallel trends test on the treatment and control groups before and after the policy intervention. The specific model is as follows, in Eq. (2).

$$\text{patent}_{\text{it}} = \alpha + \sum_{\text{j}=-6}^{5} \beta_{\text{j}} \text{year}_{it} + \gamma \text{Control} + \lambda_{\text{i}} + \mu_{\text{t}} + \varepsilon_{\text{it}} \qquad (2)$$

The variable "year" is a relative yearly policy variable generated with reference to the year of pilot. The year of policy implementation is denoted as year=1, the years before the pilot year are marked as negative values (-6, -5, -4, -3, -2, -1) and the years after the pilot year are marked as positive values (1, 2, 3, 4, 5). Figure 1 presents the result of the parallel trends test, indicating that the two groups satisfy the parallel trends assumption. Additionally, there is a time-lag between the implementation of the "Broadband China" policy and the increase in the number of patent applications in the region. It may because that it takes time for entrepreneurs to adjust their actions to the new policy, and the transformation of innovative ideas into patented inventions also requires a certain period of incubation.

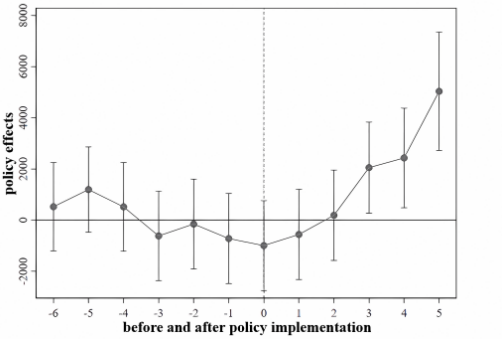

Fig. 1. Parallel trends test of “Broadband China”policy

5.3 Robustness test: Placebo test

To mitigate the non-random effects of policy shocks, author conducted a placebo test[9]. Author artificially and randomly assigned cities adopted "Broadband China" policy, and the number of cities assigned as placebos matched the actual number of regions where the policy was implemented in that year. This process was repeated 600 times to construct "pseudo-strategy implementation dummy variables." Eq. (1) was then re-estimated using this pseudo-dataset to examine the coefficient estimates and the distribution of p-values.

According to figure 2, the coefficient estimates obtained from the random samples is centered around zero and closely resembled a normal distribution. Furthermore, the majority of the p-values are greater than 0.05, and there are substantial differences between the average coefficient estimates of the randomly generated samples and the true values. These findings indicate that the effects of the "Broadband China" policy are not coincidental.

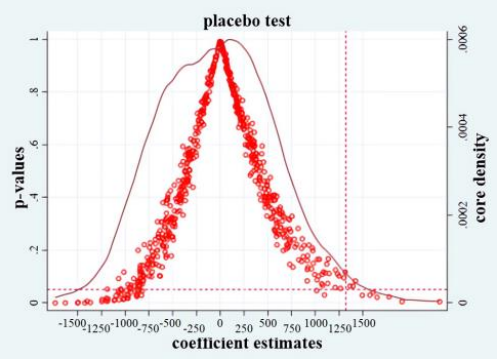

Fig. 2. Placebo test of random samples

5.4 Heterogeneity analysis

5.4.1 Regional heterogeneity analysis

In order to examine the influence of the location characteristics of cities on the policy effects, this study divided the samples into three regions: East, Central, and West. The results from Table 4 indicate the policy effect is more significant in the East than Central. One possible reason for this is the huge disparities between the Central and the East region in terms of technological level, infrastructure, financing capacity, and institutional environment, which may have limited the policy's effectiveness in the Central region. On the other hand, the "Broadband China" policy did not have a significant impact in the West. This could be attributed to factors such as fewer number of companies, outdated industrial structure, lower technological level, and stricter financing constraints.

Table 4. Regional heterogeneity analysis

	(1)	(2)	(3)
	East	Mid	West
VARIABLES	patent	patent	patent
did	2,800.3697***	1,075.6884***	-298.1524
	(849.3627)	(199.3495)	(379.0921)
Constant	142,251.4503***	10,094.0429***	310.1542
	(29,901.3493)	(3,485.5624)	(9,387.4939)
Observations	913	1,221	660
R-squared	0.962	0.942	0.964
Control	no	yes	yes

5.4.2 Urban heterogeneity analysis

Author categorized the samples into "smart cities" and "non-smart cities" based on the construction status of "smart cities" according to official documents. The results reported in Table 5 indicate that the effect of the policy is limited in "smart cities". This could be due to the fact that "smart cities" have better infrastructure, higher government focus on digitization and more favorable institutional environments, making it difficult for the policy to make a significant marginal contribution there. However, in "non-smart cities" where the situation is reversed, the policy effects are highly significant, indicating a positive impact on the entrepreneurs' spirit in these cities. **Thesis 2.2** is proved.

Table 5. Urban heterogeneity analysis

	(1)	(2)
VARIABLES	patent	patent
did	518.4476	650.3569***
	(957.0532)	(242.4945)
Constant	111,236.4163*	27,374.2943***
	(63,691.4120)	(4,282.6571)
Observations	671	2,134
R-squared	0.969	0.915
Control	yes	yes

5.4.3 Industrial structure heterogeneity analysis

In the analysis of industrial structure heterogeneity, the proportion of tertiary industry value-added to GDP is chosen as the criterion. According to Table 6, column(1) presents the results for cities where the proportion of tertiary industry value-added is greater than or equal to the median, while column(2) is vice versa. It can be observed that the "Broadband China" policy has a more significant impact on cities where the proportion of tertiary industry value-added is below the median. One possible reason for this could be that the secondary industry generates more patents compared to the tertiary industry. **Thesis 2.3** is proved.

Table 6. Industrial structure heterogeneity analysis

	(1)	(2)
VARIABLES	patent	patent
did	1,620.1500**	639.7830***
	(653.1772)	(229.5308)
Constant	45,669.3994***	7,535.7679**
	(16,884.8968)	(3,696.0925)
Observations	1,368	1,396
R-squared	0.965	0.863
Control	yes	yes

6 Conclusions

According to the study, the "Broadband China" policy has a positive effect on stimulating entrepreneurial innovation spirit and significantly increases the number of patent applications in the areas where it is implemented. This conclusion holds even after undergoing a series of robustness tests such as placebo test. Moreover, this study verifies that the incentive effect of the policy on the spirit varies across different regions, industrial structures, and city types. To some extent, it can provide scientific support for the digital development and transformation of a country.

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