Digital Economy, Enterprise Financing and Innovation: A Quasi-natural Experiment of "Broadband China" Pilot Policy

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Abstract. Based on the digital economy and enterprise innovation, this paper uses the data of China's A-share listed companies from 2010 to 2021 to empirically test the influence of "Broadband China" and uses the multiphase DID model. The results show that the construction of "Broadband China" pilot cities significantly and steadily increased the level of enterprise innovation activities. Meanwhile, the mechanism test result verifies that the new development of digital economy can promote enterprise innovation output by easing the financing constraints. Further heterogeneity analysis shows that the innovation output activities of non-state-owned enterprises are more significantly affected by the development of digital economy, and the broadband China strategy mainly promotes gradual innovations, but has no significant impact on substantive innovations. The conclusions of this paper not only provide empirical support for promoting the construction of network infrastructure, but also enrich the research of digital economy.

Keywords: Digital Economy; "Broadband China" Strategy; Multiphase DID; Financing Constraint.

1. Introduction

New infrastructure is an important part of the modern infrastructure system. We should accelerate the implementation of innovation-driven development strategy and further establish the leading position of enterprises in innovation. On August 17, 2013, the "Broadband China" strategy was issued by State Council of China and implement officially, making broadband a national strategic public infrastructure for the first time. Globally, broadband network is driving a new wave of informatization development. Many countries have taken the development of broadband network as a priority field of strategic deployment and an important measure to seize the commanding heights of international economic, technological and industrial competition in the new era (Zhang, 2021).

Network infrastructure construction such as Broadband China has provided strong support for the development of digital economy and promoted the digital transformation of enterprises (Liu & Wang, 2019). Technology is the fundamental driving force of sustainable development of enterprises and the inexhaustible source of profit growth. However, innovation activities are often risky and have a long R&D cycle, which requires enterprises to invest a large amount of capital and human resources (Chen et al., 2020). Therefore, whether new developments in the digital economy can promote technological innovation by easing corporate financing constraints is a question worthy of further exploration.

This paper selects Chinese A-share listed companies from 2010 to 2021 as the research sample to explore the impact of digital economy on enterprise innovation output. The natural experiment of "Broadband China" was conducted, and the multi-phase DID model was used for the empirical test. Considering the importance of corporate financing to R&D and innovation activities, this paper takes corporate financing constraints as a mechanism test variable to study its transmission mechanism. The marginal contributions of this paper are as follows: Firstly, the network infrastructure construction is selected as the entry point to deeply study the impact of the digital economy on the innovation activities of enterprises. Secondly, based on the heterogeneity of firm ownership and innovation output, we analyze the differential impact of the digital economy on firm innovation. Thirdly, this paper empirical test that new developments in the digital economy can promote enterprise innovation by easing firm financing constraints.

2. Literature Review and Research Hypothesis

2.1 Digital Economy and Enterprise Innovation

With the continuous popularization of digital technology, the digital economy era has come. Digital innovation is defined as the new combination of digital and physical components to produce new products (Yoo et al, 2010). Economists are also beginning to study the long-term complex economic effects of this new wave of technology.

The digital economy has an innovation-driven effect on the sustainable development of regional total factor productivity (Pan et al. 2022), which not only changes the direction of strategic planning, but also provides them with more opportunities to seek breakthroughs in technological innovation (Vial, 2019). Different from traditional economy, digital economy breaks the time-space restriction of the connection between economic entities, and fundamentally changes the way and structure of economic development through resource sharing, universal benefits and win-win results (Bertani et al., 2021). The rapid development of digital economy can effectively expand the subject boundary of enterprise innovation, and the acquisition of external knowledge has become an important source of enterprise innovation resources (Cohen & Levinthal,1990), Emerging digital technologies make it possible for enterprises to conduct personalized and customized research and development, and bring consumers directly into the product research and development process (Theilmann & Hukauf,2014). Customers, suppliers and even competitors can be deeply involved in the innovation process (Nambisan et al, 2019).

With the support of broadband China policy, China's digital economy has developed rapidly. Chen et al. (2015) studied the impact of broadband speed on innovation in the context of "Broadband China" and found that broadband speed significantly increased the number of patents. Li et al. (2022) and Wang & Wei (2023) take the data of Chinese manufacturing enterprises as an example and find that digital economy has a significant positive effect on enterprise innovation. In addition, Peng et al. (2023) based on the study of digital economy and enterprise innovation, analyze regional heterogeneity and find that different regional digital economy has different effects on enterprise innovation. Hence, this study develops the following Hypothesis.

Hypothesis 1(H1). Digital economy can promote enterprise innovation and development.

2.2 Digital Economy, Corporate Financing and Corporate Innovation

Holmstrom (1989) pointed out that innovation activities are often accompanied by strong unpredictability, large capital demand and long R&D cycle, and substantial innovation results often require long-term sufficient capital and human input. The development of digital economy can effectively improve the problem of information asymmetry, improve market expectations, strengthen internal control and financial stability, and finally ease the financing constraints of enterprises.

Existing studies generally believe that financing constraints are one of the key factors hindering enterprise innovation, and external financing is an important source of capital for enterprise R&D investment (Czarnitzki et al., 2011). And a large number of studies have proved that the financing constraints of enterprises will affect the R&D input of enterprises, thus reducing the innovation ability of enterprises. Xu et al. (2020) takes listed companies in strategic emerging industries as the research object, uses KZ index to measure the degree of financing constraints, and finds that the degree of financing constraints is negatively correlated with the R&D input of enterprises. Roller et al (2001) finds that the construction of network infrastructure can provide more powerful financial support for enterprise innovation by reducing financing costs, and the improvement of network infrastructure can help to break the communication barriers between enterprises and the outside, thus improving the ability of enterprises to engage in innovative activities. Based on the above analysis, the second hypothesis of this paper is proposed.

Hypothesis 2(H2). The digital economy can promote the innovation development of enterprises by reducing their financing constraints.

3. Research Design and Empirical Analysis

3.1 Sample and Variable Selection

3.1.1 Data Source

Considering that the pilot cities of "Broadband China" were respectively implemented in the year of 2014, 2015 and 2016, this paper selects the data of China's A-share non-financial listed companies from 2010 to 2021 as the initial sample, and excludes the enterprises with ST and *ST during the sample period, and the listed companies with data seriously missing financial data or other indicators. The list of pilot cities for "Broadband China" is from the Ministry of Industry and Information Technology of China. Other information on administrative divisions is from the China City Statistical Yearbook. Financial data of listed companies all come from CSMAR database. In order to avoid the influence of extreme values on the estimation results, all the continuous variables were reduced tail at the 1% and 99% quantile levels.

3.1.2 Variable Definition

(1) Explained variables

Enterprise innovation activity is the explained variable, which is measured by the natural logarithm of "total patent grant of firm +1".

(2) Explanatory variables

The core explanatory variable of this paper is the implementation of "broadband China" strategy, measured by dummy variables treat and post, and the cross-multiplying term of the two, represents a policy variable for the implementation of the Broadband China strategy. It is emphasized that this paper excluded all samples of municipalities, urban areas and county-level cities, and only samples of cities at prefecture level and above were retained, in order to enhance the robustness of the econometric model. At the same time, samples from autonomous prefecture and Linzhi City have many missing values, so they are also removed. Finally, the sample includes 105 cities affected by the implementation of "Broadband China" strategy.

(3) Mechanism test variables

The mechanism test variable of this paper selects enterprise financing constraints and adopts SA index to measure them. The specific calculation formula is as follows:

$$\mathrm{SA}_{\mathrm{it}} = -0.737 \times \mathrm{Size}_{\mathrm{it}} + 0.043 \times \mathrm{Size}_{\mathrm{it}}^{2} - 0.040 \times \mathrm{Age}_{\mathrm{it}} \tag{1}$$

(4) Control variables

Table 1. Variable definitions

	VARIABLES	Definition
Dependent variable	*Patent*	Natural logarithm of (the total number of patents granted for invention, utility model and design+1)
Independent variable	*treat×post*	Core explanatory variables. It represents the interactive item of issuing broadband and time dummy variable
Mechanism test variable	*SA*	Reflect the degree of corporate financing constraints
Control variables	*Lev*	Total liabilities at the end of the year/total assets at the end of the year
	ROE	Net profit/Shareholders Equity * 100%
	Cashflow	Net cash flow from operating activities/operating income
	Top1	Number of shares held by the largest shareholder/total number of shares
	Seperation	Proportion of control - proportion of ownership
	TobinQ	(Market value of tradable shares + number of non-tradable shares × net asset value per share + book value of liabilities)/ total assets
	FirmAge	The natural logarithm of (Current Year - Year of establishment +1)

According to the existing literature, the control variables selected in this paper are as follows: asset-liability ratio (Lev), return on equity (ROE), cash flow ratio (Cashflow), equity concentration (Top1), separation of two rights (Seperation), TobinQ and Years of establishment of the company (FirmAge).

Table 1 reports the definition of variables. Table 2 reports the descriptive statistics of the main variables used in this paper. The sample size of baseline regression in this paper was 21869, the mean value of Patent is 2.479, and the mean value of dummy variable treat×post is 0.3565. In addition, control variables were basically consistent with the existing research.

Table 2. Descriptive statistics of main variables

VARIABLES	Observations	Mean	Std. Dev	Min	Max
Patent	21869	2.4790	1.5471	0	6.7639
treat×post	21869	0.3565	0.4790	0	1
SA	19751	-3.6948	0.2609	-5.6000	-2.1126
Lev	21869	0.3734	0.1950	0.0569	0.8919
ROE	21869	0.0768	0.1193	-0.6993	0.3829
Cashflow	21869	0.0973	0.1656	-0.7392	0.7149
Top1	21869	34.8487	14.5840	9	75.26
Seperation	21869	4.2081	6.9918	0	28.2718
TobinQ	21869	2.0736	1.2352	0.8754	8.1364
FirmAge	21869	2.7563	0.3649	0	4.1589

3.2 Model Setting

3.2.1 Setting of Baseline Model

In this paper, "Broadband China" was used as a quasi-natural experiment to construct a benchmark regression model, and the constructed multi-phase DID model was shown as follows:

$$\ln Patent_{i,t+1} = \beta_0 + \beta_1 treat_i \times post_t + \delta control_{i,t} + \mu_i + \varphi_i + \varepsilon_i \tag{2}$$

3.2.2 Setting of Mechanism Inspection Model

Considering that enterprise innovation requires a large amount of capital input and has a critical impact, this paper selects financing constraints as the mechanism test variable to explore the mechanism path of the impact of digital economy on enterprise innovation.

$$SA_{i,t+1} = \beta_0 + \beta_1 treat_i * post_t + \sum \delta Control_{i,t} + \mu_i + \varphi_t + \varepsilon_{i,t} \tag{3}$$

Where, β_0 is a constant term, $\varepsilon_{i,t}$ is a random error term, μ_i and φ_t mean city and year fixed effect respectively, and subscripts i and t are city and year respectively. In addition, the standard errors in all regression models are clustered with the firm dimension to reduce potential heteroscedasticity and sequence-dependent effects.

3.3 Regression Analysis

3.3.1 Baseline Regression Analysis

Table 3 reports the regression results of baseline model. Columns (1) and (2) are shown as baseline regressions without control variables, and columns (3) and (4) are the baseline regression after the addition of control variables. In column (2) and (4), individual and time fixed effects are add-ed, and cluster robust standard error is used. The results show that the coefficient of treat×post is significantly positive at the level of 1% regardless of whether control variables or two-way fixed effects are added, indicating that the new development of digital economy has a positive effect on the increase of enterprise innovation activities, H1 is verified.

3.3.2 Regression Analysis of Mechanism Test Model

Table 4 reports the regression results of Model 2. Similar to Table 3, the results show that the coefficient of treat×post is significantly negative at the 1% level regardless of whether the control variable is added or the two-way fixed effect, indicating that the development of digital economy can alleviate the problem of enterprise financing constraints, and has significant economic significance, H2 has been verified.

Table 3. Estimation results of baseline regression

	(1)	(2)	(3)	(4)
VARIABLES	Patent	Patent	Patent	Patent
treat×post	0.254***	0.049**	0.225***	0.056***
	(11.82)	(2.22)	(10.51)	(2.62)
Lev			1.333***	1.806***
			(22.02)	(34.64)
ROE			1.278***	1.291***
			(12.97)	(15.28)
Cashflow			-0.323***	0.100*
			(-4.48)	(1.73)
Top1			-0.001*	0.004***
			(-1.72)	(5.51)
Seperation			-0.000	0.001
			(-0.13)	(0.58)
TobinQ			-0.042***	-0.083***
			(-4.89)	(-10.17)
FirmAge			0.289***	-0.110***
			(9.75)	(-3.80)
Constant	2.388***	0.317***	1.172***	-0.045
	(180.94)	(3.20)	(13.25)	(-0.36)
Year	NO	YES	NO	YES
Industry	NO	YES	NO	YES
Observations	21,869	21,869	21,869	21,869
R-squared	0.006	0.298	0.048	0.348

Notes: The robust standard error clustered at the firm level is shown in parentheses. *** Denotes 1 % significance level. ** Denotes 5 % significance level. * Denotes 10 % significance level.

Table 4. Financing constraints principal regression

	(5)	(6)	(7)	(8)
VARIABLES	SA	SA	SA	SA
treat×post	-0.124***	-0.020***	-0.025***	-0.012***
	(-34.73)	(-5.34)	(-11.40)	(-4.79)
Lev			0.054***	0.017***
			(7.23)	(2.63)
ROE			-0.014	-0.022**
			(-1.43)	(-2.28)
Cashflow			0.034***	0.028***
			(4.64)	(3.79)
Top1			0.001***	0.001***
			(10.92)	(8.93)
Seperation			-0.001***	-0.001***
			(-8.76)	(-7.52)
TobinQ			0.008***	0.010***
			(7.26)	(8.67)
FirmAge			-0.545***	-0.532***
			(-107.74)	(-94.78)
Constant	-3.646***	-3.470***	-2.269***	-2.304***
	(-1,474.52)	(-213.49)	(-153.63)	(-126.09)
Year	NO	YES	NO	YES
Industry	NO	YES	NO	YES
Observations	19,751	19,751	19,751	19,751
R-squared	0.054	0.265	0.609	0.653

4. Robustness Analysis

4.1 Parallel Trend Test

The differential model needs to satisfy the parallel trend hypothesis, that is, the level of enterprise innovation activities of the experimental group and the control group has the same trend before the issuance of the "Broadband China" strategic policy. At the same time, the baseline model is only a static analysis, so we cannot know the dynamic impact of broadband China strategy on enterprise innovation activities. Therefore, this paper further examines the dynamic effect of the new development of digital economy on enterprise innovation output.

Figure 1 shows that before the implementation of the "Broadband China" strategy, the coefficient is no different from 0 at the 5% level, indicating that there is no significant difference in the output of innovation activities between the companies in the experimental and the control groups before implementing the policy, which establishes the parallel trend test. After the implementation of the policy, there was a significant difference between the experimental group and the control group, indicating that the dynamic effect test results were established. Further, the implementation of the "Broadband China" policy means that the new development of the digital economy can increase the output of enterprises' innovative activities, and the development of the digital economy has a lasting effect on it.

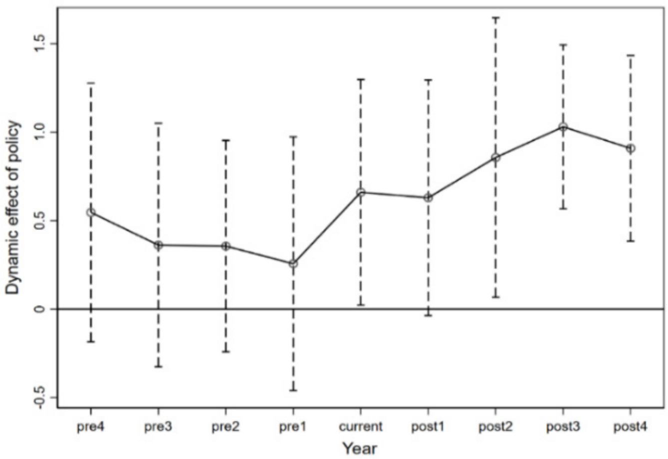

Fig 1. Parallel trend test graph

4.2 Placebo Test

Randomly select the experimental group and randomly change the digital economy pilot, and construct a pseudo-policy time point and a pseudo-experimental group. The process was randomly simulated 500 times, and the results are shown in Figure 2. It reveals that the estimated results of the pseudo-policy time point and the pseudo-experimental group are not significant, while the result of our baseline regression is an obvious outlier. The placebo trial further excluded the influence of other random factors.

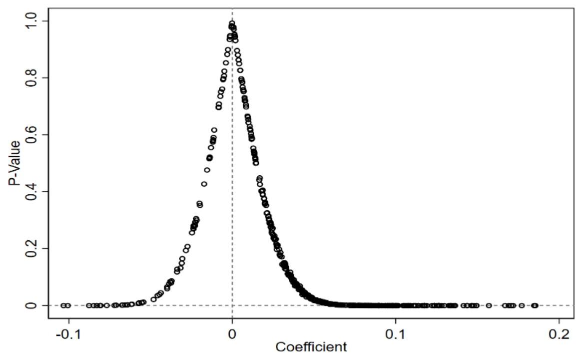

Fig 2. Placebo test graph

4.3 Replace Explained Variables

We refer to Tang et al. (2022) and use the natural logarithm of "enterprise patent grant +1" (Apply_Patent) to measure the level of enterprise innovation activities. Column (9) in Table 5 show that the coefficient of the core explanatory variable is still significantly positive at the 1% level after replacing the explained variable, and the value of the estimated coefficient is not much different, indicating that the estimated results are robust.

4.4 One-stage Lag Inspection

In order to ensure the reliability of the research conclusions, the explanatory variables were delayed by one stage to generate instrumental variables in this paper, in order to deal with the endogeneity problem. Column (10) in Table 5 shows that the treat×post coefficient lagging one period is still significantly positive at the 1% level, indicating that the hypothesis H1 above is robust.

Table 5. Robustness analysis

	(9)		(10)
VARIABLES	Apply_Patent	*VARIABLES*	Patent
treat×post	0.076***	*L.treat×post*	0.044*
	(3.34)		(1.91)
Lev	1.902***	*Lev*	1.746***
	(34.59)		(30.07)
ROE	1.695***	*ROE*	1.442***
	(18.78)		(15.62)
Cashflow	0.143**	*Cashflow*	0.036
	(2.26)		(0.54)
Top1	0.003***	*Top1*	0.004***
	(4.62)		(5.62)
Seperation	0.001	*Seperation*	0.001
	(0.90)		(0.55)
TobinQ	-0.086***	*TobinQ*	-0.101***
	(-9.88)		(-11.25)
FirmAge	-0.113***	*FirmAge*	-0.158***
	(-3.69)		(-4.65)
Constant	0.055	*Constant*	0.194
	(0.38)		(1.38)
Year	YES	*Year*	YES
Industry	YES	*Industry*	YES
Observations	21,869	*Observations*	18,038
R-squared	0.327	*R-squared*	0.351

5. Heterogeneity Analysis

5.1 Differences in the Nature of Enterprise Ownership

According to the differences in the nature of enterprise ownership and the research methods of Wang & Zhang (2022) and Jia et al. (2022), the sample is divided into two categories: state-owned and non-state-owned. The results in column (11) and (12) show that the innovation output of non-state-owned enterprises increases significantly after the financing constraints are eased. One possible explanation is that, compared with SOEs, non-SOEs themselves have greater financing constraints, and the new development of the digital economy brought about by broadband infrastructure construction has a greater boost to the innovation output of non-SOEs, while it has no significant effect on SOEs.

5.2 Innovation Output Differences

In terms of technology, innovation can be divided into two categories: substantive innovation and incremental innovation. Substantive innovation means that an enterprise fundamentally changes the technological trajectory and related organizational capacity (He et al, 2004), which is often manifested as the increase of invention patents. On the other hand, incremental innovation is mainly to improve the existing technology through the reuse of the existing innovation resources (Benner et al, 2003), which is usually the increase of design patents. This paper uses the natural logarithm of "number of invention patents granted +1" to measure the substantial innovation level of enterprises (In_Patent), and the natural logarithm of" total number of utility model and design patents +1" to measure the progressive innovation level of enterprises (Ap_Patent).

The empirical results in column (13) and (14) show that the broadband China strategy mainly promotes the incremental innovation of enterprises, but has no significant impact on the substantive innovation of enterprises such as invention patents. One possible explanation is that substantive innovation has a longer operating cycle, higher risks, unpredictable returns, more prominent financing constraints and agency problems. However, incremental innovation has lower technical requirements, less capital required, relatively controllable risks and stable expected returns, which is more conducive to the performance reputation of the management, financing constraints and agency conflicts.

Table 6. Heterogeneity analysis

	State-owned nature of enterprise		Type of patent	
	(11)	(12)	(13)	(14)
VARIABLES	Patent	Patent	In_Patent	Ap_Patent
treattime	-0.039	0.109***	0.004	0.091***
	(-0.79)	(4.68)	(0.20)	(4.15)
Lev	1.807***	1.588***	1.316***	1.798***
	(15.45)	(26.22)	(29.50)	(33.86)
ROE	1.848***	1.165***	0.832***	1.232***
	(9.52)	(12.42)	(12.57)	(14.44)
Cashflow	-0.055	0.132**	0.145***	0.082
	(-0.43)	(2.03)	(3.26)	(1.41)
Top1	0.010***	-0.002***	0.003***	0.004***
	(6.99)	(-2.84)	(4.59)	(5.63)
Seperation	-0.010***	0.007***	0.003***	-0.001
	(-3.41)	(4.71)	(2.87)	(-0.58)
TobinQ	-0.137***	-0.073***	-0.026***	-0.091***
	(-6.86)	(-8.05)	(-3.76)	(-10.92)
FirmAge	-0.438***	-0.001	-0.041*	-0.108***
	(-6.09)	(-0.03)	(-1.73)	(-3.66)
Constant	0.379	0.039	-0.646***	-0.110
	(1.48)	(0.27)	(-6.86)	(-0.90)
Year	YES	YES	YES	YES
Industry	YES	YES	YES	YES
Observations	4,873	16,994	21,869	21,869
R-squared	0.502	0.323	0.203	0.350

6. Conclusion

Taking "Broadband China" demonstration city construction as a quasi-natural experiment, this paper studies the impact of digital economy on enterprise innovation through multi-phase DID model. The results show that the "broadband China" demonstration city construction significantly increased the enterprise innovation outputs, and mainly through the mechanism of easing corporate financing constraints to affect. Heterogeneity test shows that non-state-owned enterprises' innovation activities are more significantly affected by the digital economy, and the form of innovation is mainly progressive innovation rather than substantive innovation.

The conclusions of this paper have the following policy implications: Firstly, it is necessary to further strengthen the construction of network infrastructure and expand the dividend range of "broadband China" policy. Secondly, broadening the financing channels for enterprises and reducing the financing constraints will help further enhance the innovation promotion role of network infrastructure construction. Finally, we must attach great importance to the problem of "digital divide" to avoid the widening gap of network infrastructure, which will lead to the exacerbation of regional economic imbalance.

References

[1] Bertani, F., Ponta, L., Raberto, M., Teglio, A., & Cincotti, S. (2021). The complexity of the intangible digital economy: an agent-based model. Journal of business research, 129, 527-540. https:// doi. org/ 10. 1016/ j. jbusres.2020.03.041.

[2] Benner, M. J., & Tushman, M. L. (2003). Exploitation, exploration, and process management: The productivity dilemma revisited. Academy of management review, 28(2), 238-256. https:/ /doi. org/ 10. 5465/ amr.2003.9416096.

[3] Chen, H., Zhong, T., & Lee, J. Y. (2020). Capacity reduction pressure, financing constraints, and enterprise sustainable innovation investment: Evidence from Chinese manufacturing companies. Sustainability, 12(24), 10472. https://doi.org/10.3390/su122410472.

[4] Chen, Y., Wang, Y., Nevo, S., Benitez-Amado, J., & Kou, G. (2015). IT capabilities and product innovation performance: The roles of corporate entrepreneurship and competitive intensity. Information & Management, 52(6), 643-657. https://doi.org/10.1016/j.im.2015.05.003.

[5] Cohen, W. M., & Levinthal, D. A. (1990). Absorptive capacity: A new perspective on learning and innovation. Administrative science quarterly, 128-152. https://doi.org/10.2307/2393553.

[6] Czarnitzki, D., & Hottenrott, H. (2011). R&D investment and financing constraints of small and medium-sized firms. Small business economics, 36, 65-83. https://doi.org/10.1007/s11187-009-9189-3.

[7] Hadlock, C. J., & Pierce, J. R. (2010). New evidence on measuring financial constraints: Moving beyond the KZ index. The review of financial studies, 23(5), 1909-1940. https://doi.org/10.1093/rfs/hhq009.

[8] He, Z. L., & Wong, P. K. (2004). Exploration vs. exploitation: An empirical test of the ambidexterity hypothesis. Organization science, 15(4), 481-494. https://doi.org/10.1287/orsc.1040.0078.

[9] Holmstrom, B. (1989). Agency costs and innovation. Journal of Economic Behavior & Organization, 12(3), 305-327. https://doi.org/10.1016/0167-2681(89)90025-5.

[10] Jia, X., Xie, B., & Wang, X. (2023). The impact of network infrastructure on enterprise digital transformation--A quasi-natural experiment from the “broadband China” Strategy. Applied Economics, 1-18. https://doi.org/10.1080/00036846.2023.2176450.

[11] Li, R., Rao, J., & Wan, L. (2022). The digital economy, enterprise digital transformation, and enterprise innovation. Managerial and Decision Economics, 43(7), 2875-2886. https://doi.org/10.1002/mde.3569.

[12] Liu, C., & Wang, L. (2019). Does national broadband plan narrow regional digital divide? Evidence from China. Chinese Journal of Communication, 12(4), 449-466. https:// doi.org/ 10.1080/ 17544 750. 2019. 1609539.

[13] Nambisan, S., Wright, M., & Feldman, M. (2019). The digital transformation of innovation and entrepreneurship: Progress, challenges and key themes. Research Policy, 48(8), 103773. https://doi. org/10. 1016/j.respol.2019.03.018.

[14] Pan, W., Xie, T., Wang, Z., & Ma, L. (2022). Digital economy: An innovation driver for total factor productivity. Journal of Business Research, 139, 303-311. https://doi.org/10.1016/j.jbusres.2021.09.061.

[15] Peng, S., Jiang, X., & Li, Y. (2023). The impact of the digital economy on Chinese enterprise innovation based on intermediation models with financing constraints. Heliyon, 9(3). https://doi.org/ 10.1016/ j. heliyon. 2023.e13961.

[16] Röller, L. H., & Waverman, L. (2001). Telecommunications infrastructure and economic development: A simultaneous approach. American economic review, 91(4), 909-923. 10.1257/aer.91.4.909.

[17] Tang, Y., Wang, Y., & Tang, C. (2022). Digital Economy, Market Structure and Innovation Performance. China Industrial Economics, 10, 62-80. https://doi.org/10.1016/j.enpol.2022.112927.

[18] Theilmann, C., & Hukauf, M. (2014). Customer integration in mass customisation: a key to corporate success. International Journal of Innovation Management, 18(03), 1440002. https://doi.org/ 10.1142/ S1363919614400027.

[19] Vial, G. (2019). Understanding digital transformation: A review and a research agenda. The journal of strategic information systems, 28(2), 118-144. https://doi.org/10.1016/j.jsis.2019.01.003.

[20] Wang, C., & Zhang, M. (2022). The road to change: Broadband China strategy and enterprise digitization. Plos one, 17(5), e0269133. https://doi.org/10.1371/journal.pone.0269133.

[21] Wang, Q., & Wei, Y. (2023). Research on the Influence of Digital Economy on Technological Innovation: Evidence from Manufacturing Enterprises in China. Sustainability, 15(6), 4995. https://doi. org/ 10. 3390/ su15064995.

[22] Xu, K., Geng, C., Wei, X., & Jiang, H. (2020). Financing development, financing constraint and R&D investment of strategic emerging industries in China. Journal of Business Economics and Management, 21(4), 1010-1034. https://doi.org/10.3846/jbem.2020.12727.

[23] Yoo, Y., Henfridsson, O., & Lyytinen, K. (2010). Research commentary--the new organizing logic of digital innovation: an agenda for information systems research. Information systems research, 21(4), 724-735. https: //doi.org/10.1287/isre.1100.0322.

[24] Zhang, X. (2021). Broadband and economic growth in China: An empirical study during the COVID-19 pandemic period. Telematics and Informatics, 58, 101533. https://doi.org/10.1016/j.tele.2020.101533.