FROM CONNECTIVITY TO CORPORATE VALUE: DIGITAL DEVELOPMENT, COMPLEMENTARY CONDITIONS, AND FIRM OUTCOMES IN CHINA*

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Abstract

This study aimed to: (1) examine whether city-level digital development is associated with corporate profitability and market valuation in the Chinese A-share market; (2) investigate whether infrastructure, human capital, and firm R&D intensity strengthen the effect of regional digital development on firm outcomes; and (3) analyze whether the digital-development effect is stronger for high-tech firms, increases over time, and is reflected in the Broadband China policy pilot. This study employed a quantitative archival research design using panel data. The sample consisted of Chinese A-share listed nonfinancial firms during 2008–2024. After excluding financial firms, ST and *ST firms, and observations with missing values, and after winsorizing continuous variables at the 1st and 99th percentiles, the final sample comprised 41,600 firm-year observations. Data were analyzed using fixed-effects panel regression models and a difference-in-differences (DID) approach.

The findings revealed that: (1) regional digital development was positively and significantly associated with both return on assets (ROA) and Tobin's Q; (2)

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infrastructure, human capital, and R&D intensity significantly strengthened the effect of digital development on firm outcomes; and (3) the digital-development effect was stronger for high-tech firms, increased over time, and was consistent with positive post-policy effects under the Broadband China pilot. The results suggest that the value of digital development depends not only on digital connectivity but also on complementary conditions that enable firms to transform digital resources into corporate value.

Keywords: regional digital development, firm performance, Tobin's Q, human capital, innovation capability, Broadband China

Introduction

The expansion of the digital economy has transformed how firms coordinate production, access markets, manage information, and evaluate investment opportunities. In China, digital development has become a major regional agenda, yet cities differ considerably in digital infrastructure, platform penetration, and supporting services. As firms operate within local digital ecosystems rather than a uniform national environment, these regional differences influence information flows, market matching, knowledge spillovers, and business opportunities (Goldfarb & Tucker, 2019).

Although prior studies have examined firm-level digital transformation and information transparency, they provide limited explanation for why similar firms obtain different benefits from digital opportunities. Firms located in digitally advanced regions can access richer digital services and more efficient information networks. However, digital development alone does not automatically generate value. Firms still require supporting infrastructure, skilled labor, and innovation capabilities to convert digital opportunities into improved performance and market value.

This study therefore focuses on how regional digital development translates into corporate value. The central argument is that digital development creates potential value, but its realization depends on complementary conditions. Infrastructure enables implementation, human capital supports effective use of digital technologies, and R&D intensity reflects absorptive capacity that helps firms transform external knowledge into innovation and growth opportunities (Cohen & Levinthal, 1990). Moreover, digital technologies often require complementary organizational investments before productivity gains and value creation become fully realized (Brynjolfsson, Rock, & Syverson, 2021).

Using Chinese A-share listed firms, this study links firm-level outcomes to city-level digital conditions based on firms' headquarters locations. Corporate value is measured by both return on assets (ROA) and Tobin's Q, capturing current operating performance and future market expectations, respectively.

This article contributes to the literature in three ways. First, it conceptualizes regional digital development as a local enabling ecosystem rather than solely a firm-level transformation process. Second, it identifies complementary factors that explain variation in the value effects of digital development across firms and regions. Third, it integrates baseline, moderating, heterogeneity, dynamic, and policy analyses within a unified framework, providing a more focused explanation of how regional digital development contributes to corporate value.

Objectives

1. To examine whether regional digital development is positively associated with firm performance and firm value in the Chinese A-share market.

2. To investigate whether infrastructure, human capital, and firm R&D intensity strengthen the relationship between regional digital development and firm outcomes.

3. To analyze whether the digital-development effect is stronger for high-tech firms, strengthens over time, and is reflected in the Broadband China policy pilot.

Literature Review

1. Regional Digital Development and Corporate Outcomes

Regional digital development refers to the maturity of the local digital environment, including connectivity, digital services, platform diffusion, internet penetration, and data-enabled coordination. The general-purpose technology perspective provides a useful theoretical foundation. Bresnahan and Trajtenberg (1995) argue that general-purpose technologies diffuse broadly, improve continuously, and stimulate complementary innovation. Digital technologies fit this logic because they reduce information frictions, change the cost of search and communication, and reorganize economic activity across sectors (Goldfarb & Tucker, 2019).

At the firm level, digital development can improve operating performance through several channels. It can enhance coordination with suppliers and customers, reduce inventory and transaction costs, improve data-based decision-making, and expand access to online markets. It can also create new growth options by supporting platform participation, data-driven innovation, and scalable business models. Therefore, digital development should be associated not only with ROA, which captures realized profitability, but also with Tobin's Q, which reflects investor expectations about future growth and risk.

The business value of information technology is also conditional. Brynjolfsson and Hitt (2000) emphasize that IT produces value when combined

with organizational transformation and complementary investments. Bresnahan, Brynjolfsson, and Hitt (2002) further show that IT use is related to workplace organization and skilled labor. This literature cautions against a technological-determinist interpretation: a digitally advanced region may not generate strong corporate outcomes unless firms and local environments possess the complementary assets needed to use digital resources effectively.

Based on this reasoning, the first hypothesis is proposed: Hypothesis 1 (H1). Regional digital development is positively associated with firm performance and firm value.

2. Complementary Conditions: Infrastructure, Human Capital, and R&D Intensity

The conversion of digital development into firm outcomes requires complementary conditions. Infrastructure is the first such condition. Although digital transformation is often discussed as a virtual process, digital coordination frequently depends on physical execution. E-commerce requires logistics, platform-based services depend on mobility, and digitally managed manufacturing requires reliable transportation and delivery systems. Infrastructure therefore helps firms translate information advantages into actual production, distribution, and service outcomes.

Human capital is the second complementary condition. Digital technologies tend to be skill-complementary. Acemoglu (1998), Autor, Levy, and Murnane (2003), and Akerman, Gaarder, and Mogstad (2015) show that new technologies and broadband connectivity often complement skilled labor. A more educated workforce can interpret digital information, redesign work routines, apply analytics, and integrate digital systems into operations. Accordingly, regional digital development should generate stronger firm outcomes in regions with higher human capital.

Firm R&D intensity is the third complementary condition. Cohen and Levinthal (1990) define absorptive capacity as the ability to recognize, assimilate,

and apply external knowledge. Digital environments increase the flow of information and external opportunities, but firms require internal knowledge routines to convert them into process improvement and innovation. R&D intensity therefore represents a firm-level capability that can magnify the value of regional digital resources. Teece, Pisano, and Shuen (1997) similarly argue that dynamic capabilities allow firms to sense, seize, and reconfigure resources in response to technological change.

Therefore, the second hypothesis is proposed: Hypothesis 2 (H2). Infrastructure, human capital, and R&D intensity positively moderate the relationship between regional digital development and firm outcomes.

3. Industry Salience, Time Dynamics, and Policy Exposure

The value of regional digital development is also likely to vary across industries. High-tech firms depend more heavily on knowledge recombination, software capability, digital coordination, and intangible assets. They are therefore more likely to convert regional digital ecosystems into product innovation, process improvement, and growth options. This leads to the following hypothesis: Hypothesis 3 (H3). The positive association between regional digital development and firm outcomes is stronger for high-tech firms.

Digital dividends may also strengthen over time. David (1990) argues that transformative technologies often require complementary organizational adjustment before their productivity effects become visible. Brynjolfsson, Rock, and Syverson (2021) describe a productivity J-curve in which intangible investments and adjustment costs occur before later gains. In regional settings, local ecosystems also mature as digital service providers, skilled workers, standards, and complementary institutions develop. Accordingly, the fourth hypothesis is proposed: Hypothesis 4 (H4). The positive association between regional digital development and firm outcomes strengthens over time.

Finally, place-based digital policy can provide additional evidence. Broadband infrastructure improves communication, reduces coordination costs, expands access to digital services, and can create new growth opportunities. Prior research links telecommunications and broadband infrastructure to economic development and growth (Roller & Waverman, 2001; Czernich et al., 2011). The Broadband China pilot therefore provides a policy setting for examining whether a digital infrastructure intervention is associated with positive changes in firm outcomes. The fifth hypothesis is proposed: Hypothesis 5 (H5). The Broadband China pilot is positively associated with post-policy changes in firm performance and firm value.

Methodology

1. Research Design

This study employs a quantitative panel-data design using firm-year observations. Fixed-effects regressions are used to examine the relationship between regional digital development and firm outcomes. Firm and year fixed effects control for unobserved heterogeneity and common shocks, while standard errors are clustered at the city level. The Broadband China analysis further applies a difference-in-differences (DID) approach.

2. Population and Sample

The sample consists of Chinese A-share listed firms from 2008–2024. Financial firms, ST firms, and *ST firms are excluded. After removing missing observations and winsorizing variables at the 1st and 99th percentiles, the final sample includes 41,600 firm-year observations. Firm-level data are matched with city-level variables based on headquarters location and year.

3. Variable Measurement

Table 1 Variable Definitions and Measurement

Variable	Symbol	Level	Measurement	Role
Return on assets	ROA	Firm-year	Net income divided by total assets	Dependent variable
Tobin's Q	TobinQ	Firm-year	(Market capitalization + total liabilities) / total assets	Dependent variable
Regional digital development	DigEcon	City-year	Entropy-based composite index of internet and digital indicators	Core explanatory variable
Infrastructure	Infra	City-year	Log of road area per capita	Moderator
Human capital	Hcap	City-year	Average years of schooling	Moderator
R&D intensity	RDint	Firm-year	R&D expenditure divided by sales	Moderator
High-tech industry	HighTech	Firm-level	Indicator equal to 1 for high-tech industries	Heterogeneity
Time trend	Trend	Year	Monotonic time trend	Dynamic test
Broadband China DID	BC2016_DID	Firm-year	Treatment x post indicator for Broadband China pilot	Policy test
Firm size	Size	Firm-year	Natural logarithm of total assets	Control
Leverage	Lev	Firm-year	Total liabilities divided by total assets	Control
Growth	Growth	Firm-year	Year-on-year sales or revenue growth	Control

Note: The table reports the core variables used in the article. Continuous variables are winsorized at the 1st and 99th percentiles.

4. Data Collection and Cleaning

Firm-level financial and market data are obtained from listed-company databases, while city-level digital development, infrastructure, and human capital data are collected from statistical yearbooks and CNRDS sources. Policy exposure is identified by matching Broadband China pilot cities with firms' headquarters locations.

The sample excludes financial firms, ST and *ST firms, and observations with missing values. Continuous variables are winsorized at the 1st and 99th

percentiles, resulting in a balanced firm-year panel suitable for fixed-effects analysis.

5. Data Analysis

1. Baseline Analysis: Fixed-effects regressions examine the impact of regional digital development on ROA and Tobin's Q.

2. Moderation Analysis: Interaction terms with infrastructure, human capital, and R&D intensity test complementary effects.

3. Heterogeneity Analysis: The HighTech interaction examines differences between high-tech and non-high-tech firms.

4. Dynamic Analysis: A time-trend interaction evaluates whether digital-development effects change over time.

5. Policy Analysis: A DID approach based on the Broadband China policy assesses the impact of broadband expansion on firm outcomes.

Results

This section presents the empirical findings in accordance with the three research objectives. The analysis begins with descriptive statistics, followed by baseline regressions, moderation tests, heterogeneity and dynamic tests, and policy-pilot evidence.

1. Descriptive Statistics

Table 2 Descriptive Statistics of Main Variables

Variable	N	Mean	Std. Dev.	Min	P50	Max
ROA	41,600	0.038	0.033	-0.085	0.037	0.178
Tobin's Q	41,600	1.401	0.556	0.600	1.365	3.431
DigEcon	41,600	0.447	0.225	0.000	0.402	0.994
Infrastructure	41,600	1.910	0.164	1.410	1.914	2.415
Human capital	41,600	8.701	0.584	7.000	8.700	10.480
R&D intensity	41,600	0.017	0.013	0.000	0.015	0.066
Firm size	41,600	5.285	0.711	2.422	5.292	7.883

Leverage	41,600	0.387	0.065	0.154	0.386	0.653
Growth	41,600	0.061	0.221	-0.629	0.024	1.500
BC2016_DID	41,600	0.303	0.460	0.000	0.000	1.000

Note: The selected descriptive statistics are based on the final matched firm-year panel. DigEcon is a city-level digital-development index.

Table 2 shows that the sample contains meaningful variation in both outcomes and explanatory variables. ROA has a mean of 0.038, while Tobin's Q has a mean of 1.401, indicating that the two dependent variables capture different dimensions of firm outcomes. DigEcon ranges from 0.000 to 0.994, showing substantial variation in city-level digital development. The presence of variation in infrastructure, human capital, R&D intensity, and policy exposure provides the empirical basis for testing complementarity, heterogeneity, and policy-pilot effects.

2. Objective 1: Regional Digital Development and Firm Outcomes

Objective 1 examines whether regional digital development is associated with firm performance and firm value. Table 3 reports fixed-effects regressions using ROA and Tobin's Q as dependent variables.

Table 3 Baseline Effects of Regional Digital Development

Variable	ROA	Tobin's Q
Regional digital development (DigEcon)	0.018** (2.364)	1.088*** (5.396)
Size	0.003** (2.074)	-0.006 (-0.385)
Leverage	-0.039*** (-9.549)	-1.106*** (-14.948)
Growth	0.001 (1.265)	-0.004 (-0.547)
Firm FE	Yes	Yes
Year FE	Yes	Yes

Clustered SE	hq_city	hq_city
Observations	41,600	41,600
Within R-squared	0.006	0.079

*Note: t-statistics are reported in parentheses. Significance levels: *** p<0.01, ** p<0.05, * p<0.10.*

The coefficient on DigEcon is positive and significant in both models. In the ROA model, the coefficient is 0.018 and significant at the 5% level. In the Tobin's Q model, the coefficient is 1.088 and significant at the 1% level. These results support H1 and indicate that regional digital development is associated with both realized operating profitability and forward-looking market valuation.

The larger and more statistically significant coefficient in the Tobin's Q model suggests that capital markets may price digital development as a growth-option channel. A more developed digital environment may expand firms' future opportunities through platform access, information flow, and data-enabled innovation even before all operating gains are fully reflected in accounting profitability.

3. Objective 2: Complementary Conditions in the Digital Channel

Objective 2 examines whether the digital-development effect becomes stronger when infrastructure, human capital, and R&D intensity are present. Table 4 reports the focal interaction terms for ROA and Tobin's Q.

Table 4 Complementarity Tests for Regional Digital Development

Focal interaction	ROA coefficient	ROA t-stat	Tobin's Q coefficient	Tobin's Q t-stat	Conclusion
DigEcon x Infrastructure	0.018***	4.320	0.438***	5.455	Supported
DigEcon x Human Capital	0.004***	4.442	0.120***	5.717	Supported
DigEcon x R&D Intensity	0.664***	7.155	7.900***	6.547	Supported

*Note: All models include firm size, leverage, growth, firm fixed effects, year fixed effects, and standard errors clustered by headquarter city. Significance levels: *** p<0.01, ** p<0.05, * p<0.10.*

The interaction between regional digital development and infrastructure is positive and significant for both ROA and Tobin's Q. This result supports the digital-physical complementarity argument. Digital coordination creates value more effectively when firms can translate information into reliable logistics, delivery, and operational execution.

The interaction between regional digital development and human capital is also positive and significant for both outcomes. This result shows that local skills help firms use digital tools, interpret data, redesign routines, and implement analytics-based decisions. Digital development is therefore more valuable when the local workforce provides the knowledge base required for effective adoption.

The strongest interaction is observed for R&D intensity. The coefficient on DigEcon x RDint is 0.664 for ROA and 7.900 for Tobin's Q, both significant at the 1% level. This finding supports the absorptive-capacity mechanism. Firms with stronger R&D routines are better positioned to identify useful external information, experiment with digital applications, and convert regional digital resources into innovation and market value.

4. Objective 3: Industry Salience, Time Dynamics, and Broadband Policy

Objective 3 examines whether digital dividends vary by firm type, strengthen over time, and appear in a digital-infrastructure policy setting. Table 5 reports the high-tech interaction, time interaction, and Broadband China DID estimates.

Table 5 Additional Evidence on Digital Dividends

Test	Focal variable	ROA coefficient	ROA t-stat	Tobin's Q coefficient	Tobin's Q t-stat	Conclusion
Industry salience	DigEcon x HighTech	0.034***	6.124	0.636***	5.631	Supported
Time dynamics	DigEcon x Trend	0.059***	12.762	0.583***	4.604	Supported
Policy pilot	BC2016_DID	0.008***	3.327	0.113***	3.555	Supported

*Note: All models include firm size, leverage, growth, firm fixed effects, year fixed effects, and city-clustered standard errors. Significance levels: *** p<0.01, ** p<0.05, * p<0.10.*

The high-tech interaction is positive and significant for both ROA and Tobin's Q. This result supports the technological-salience argument. High-tech firms rely more heavily on knowledge recombination, digital coordination, and intangible assets, making them better able to convert regional digital development into profitability and valuation gains.

The DigEcon x Trend coefficient is positive and significant for both outcomes. This indicates that the digital-development effect strengthens over time. The finding is consistent with the view that digital dividends are cumulative: firms and regions need time to build complementary assets, skilled routines, service ecosystems, and data-enabled business processes.

The Broadband China DID coefficient is positive and significant for both ROA and Tobin's Q. This result indicates that firms exposed to the Broadband China policy pilot experienced favorable post-policy changes in operating performance and market valuation relative to control firms within the fixed-effects DID design. The result should be interpreted cautiously because DID estimates depend on identifying assumptions, but it provides policy-related evidence consistent with the digital-infrastructure mechanism.

Discussion

1. Discussion of Objective 1

The results for Objective 1 indicate that regional digital development positively affects both accounting profitability and market valuation. This suggests that digital development is not merely a regional characteristic but a value-relevant external condition that enhances firms' operational efficiency and future growth prospects. The significance of DigEcon for both ROA and Tobin's Q implies that digital development improves current performance while strengthening market expectations regarding future opportunities. This finding is consistent with Goldfarb and Tucker (2019), who argued that digital technologies reduce information frictions and improve economic coordination.

2. Discussion of Objective 2

The moderation results show that the benefits of digital development depend on complementary conditions. Infrastructure, human capital, and R&D intensity all strengthen the positive effect of digital development on firm value. Infrastructure facilitates implementation, human capital supports effective use of digital technologies, and R&D enhances firms' ability to transform external knowledge into innovation. These findings support the complementarity perspective proposed by Brynjolfsson, Rock, and Syverson (2021), who emphasized that digital technologies create greater value when combined with organizational capabilities and intangible investments. The results imply that firms should invest in skills and innovation capabilities, while policymakers should combine digital-development initiatives with talent and innovation policies.

3. Discussion of Objective 3

The results show that digital dividends are stronger in high-tech industries, where business models rely more heavily on knowledge, innovation, and digital coordination. The dynamic analysis further suggests that the benefits of digital

development accumulate over time as firms adapt and integrate digital technologies into their operations. In addition, the positive Broadband China policy effect indicates that digital infrastructure expansion can improve firm performance and value. This finding is consistent with Hjort and Poulsen (2019), who found that faster internet connectivity generates significant economic benefits by improving access to information and expanding economic opportunities.

Limitations

This study has several limitations. First, digital development is measured using a city-level index, which may not fully capture firm-specific digital implementation. Second, city-level conditions are matched based on headquarters locations, although large firms may operate across multiple regions. Third, while the fixed-effects and DID approaches help address unobserved heterogeneity, potential omitted-variable bias and policy-related confounding factors may still remain. Finally, because the sample is limited to Chinese A-share listed firms, the findings may not be fully generalizable to private firms, unlisted firms, or other institutional settings.

Recommendation

1. Local governments should promote digital development as an integrated ecosystem by combining digital infrastructure, logistics systems, talent development, and innovation support.

2. Firms should strengthen internal capabilities, particularly R&D, digital skills, and data management, to effectively convert regional digital resources into firm value.

3. Policymakers should align digital-development strategies with education and workforce policies to ensure an adequate supply of skilled labor for the digital economy.

4. High-tech firms should consider locating operations in digitally advanced regions, where stronger digital ecosystems can enhance innovation and firm value.

5. Investors should incorporate regional digital-development conditions into firm valuation, particularly when evaluating high-tech and innovation-oriented firms.

Future Research Directions

1. Future studies may incorporate firm-level digitalization measures, such as software investment, digital patents, or digital-transformation disclosures, to complement regional digital indicators.

2. Future research can apply more rigorous causal approaches, including event-time DID or staggered DID designs, to evaluate digital-policy effects.

3. Future studies may investigate mediating mechanisms through which digital development influences firm value, such as innovation output, financing costs, supply-chain efficiency, and information transparency.

4. Future research can compare listed and unlisted firms to examine whether capital-market exposure influences the value effects of digital development.

5. Future studies may extend the analysis to other emerging economies to assess the generalizability of the complementarity between digital development, human capital, and innovation capability.

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