Technology in Society 84 (2026) 103146

Contents lists available at ScienceDirect

Technology in Society

journal homepage: www.elsevier.com/locate/techsoc

Government innovation subsidies and enterprise digital transformation: Evidence from Chinese listed companies

Zhen Han [a,1], Erga Luo [b,1], Xuezhen Xiong [c,1], Jinkai Li [d,*]

[a] School of Accountancy, Shandong University of Finance and Economics, Jinan, 250014, China
[b] China Academy for Rural Development (CARD), School of Public Affairs, Zhejiang University, Hangzhou, 310000, China
[c] School of Government Administration, Beijing Normal University, Beijing, 100875, China
[d] College of Economics and Management, China Agricultural University, Beijing, 100083, China

ARTICLE INFO

JEL:
H32
O32
O38

Keywords:
Government innovation subsidies
Enterprise digital transformation
Digital technology
Resource effect
Signaling effect
China

ABSTRACT

Government innovation subsidies have become a key policy instrument for fostering enterprise innovation and accelerating digital transformation. However, their effectiveness in promoting digital transformation remains insufficiently understood, particularly in emerging economies. Using panel data from Chinese A-share listed enterprises from 2010 to 2021, this study examines how government innovation subsidies influence digital transformation. The results show that such subsidies significantly enhance enterprise digital transformation. Mechanism analysis reveals that subsidies operate through both resource and signaling effects—strengthening R&D investment, expanding technical staff, and accumulating digital assets, while increasing managerial digital attention and market recognition. Furthermore, heterogeneity analysis indicates that the effect is more pronounced for state-owned and small enterprises, as well as those in earlier life-cycle stages. These findings provide evidence that targeted innovation subsidies can serve as effective policy tools for promoting digital transformation, offering practical insights for designing adaptive and differentiated innovation policies in both emerging and advanced economies.

1. Introduction

Since the beginning of the 21st century, emerging digital technologies such as artificial intelligence, blockchain, and cloud computing have advanced rapidly and become deeply integrated into industrial production, everyday life, and social systems (Wang, et al., 2024; Xia & Johar, 2025). These technologies are transformation business models and organizational processes, positioning digitalization as a key driver of economic and social transformation (Wu et al., 2025; Zu et al., 2025). As fundamental microeconomic agents, enterprises play a pivotal role in this process. The extent to which their digital transformation progresses effectively is of critical importance for achieving high-quality economic growth and enhancing national technological and economic competitiveness (Ding et al., 2025; Jiang et al., 2025).

In response, many governments have gradually introduced targeted policies to support enterprise-level digital transformation. For example, Germany launched the Mittelstand-Digital initiative, which provides small and medium-sized enterprises (SMEs) with financial support, consulting services, and capacity-building programs. Similarly, the United States enacted the CHIPS and Science Act to enhance fiscal incentives and provide strategic support for high-tech enterprises. China, initiatives such as the Intelligent Manufacturing Grading Cultivation Action and the Digital Transformation Pilot Program for SMEs have established a comprehensive policy framework driven by multiple forms of support.

However, enterprise digital transformation, as a form of disruptive innovation, entails not only the adoption of advanced technologies but also a fundamental reconfiguration of organizational structures, resource allocation, and strategic objectives (Fang & Liu, 2024; Omrani et al., 2024). This process often involves substantial sunk costs, significant technological and managerial uncertainties, and pronounced positive externalities (Cheng et al., 2024; Wang & Shao, 2024). Consequently, many enterprises—particularly in developing and transitional economies—face challenges such as limited internal resources and insufficient strategic motivation to pursue meaningful digital transformation (David et al., 2025; Tariq et al., 2025). As a

* Corresponding author.
E-mail addresses: hanzhen825@163.com (Z. Han), leg@zju.edu.cn (E. Luo), xiongcas2019@163.com (X. Xiong), jinkai.li@cau.edu.cn (J. Li).
[1] These authors equally contribute to the study and jointly share the first authorship.

https://doi.org/10.1016/j.techsoc.2025.103146
Received 1 May 2024; Received in revised form 27 October 2025; Accepted 3 November 2025
Available online 4 November 2025

representative emerging economy, China has actively addressed these challenges by strengthening policy support for enterprise digital transformation, exemplifying the proactive role of developmental-state governments in overcoming structural constraints (Jiang et al., 2025).

Among various policy instruments, government innovation subsidies have played a pivotal role in alleviating financial constraints, mitigating transformation risks, and encouraging enterprises to engage more strategically in digital transformation (Pan et al., 2024; Shao & Wang, 2023; Yang et al., 2024). However, despite their widespread implementation, the effectiveness of these subsidies—particularly those designed as targeted and performance-oriented instruments—remains insufficiently examined in the context of digital transformation. This research gap is notable, as digital transformation constitutes a disruptive and resource-intensive process that demands substantial public support and sustained investment. Clarifying how government innovation subsidies drive this process, and identifying the specific mechanisms through which they operate, is therefore crucial for policymakers seeking to enhance the effectiveness of fiscal incentives and to better facilitate enterprise digital transformation across industries.

This study employs panel data of listed enterprises from China's A-share markets (2010–2021) to empirically examine the impact, mechanisms, and heterogeneity of government innovation subsidies in promoting enterprise digital transformation. It responds to growing theoretical and practical calls for more nuanced assessments of policy effectiveness in complex, innovation-driven contexts by focusing specifically on the role of targeted innovation subsidies in fostering digital upgrading.

This study makes three main contributions. First, it provides new micro-level evidence that innovation-oriented government subsidies significantly promote enterprise digital transformation. By distinguishing innovation-targeted subsidies from general fiscal support, the analysis substantiates the theoretical linkage between government incentives and enterprise digital transformation, thereby enriching the literature on policy-driven innovation and clarifying how differentiated fiscal instruments effectively foster digital upgrading at the enterprise level.

Second, this study advances both theoretical and empirical understanding by developing an integrated mechanism framework grounded in resource-based and signaling theories to explain how government innovation subsidies promote enterprise digital transformation. The resource effect highlights how subsidies strengthen transformational capabilities by increasing R&D investment, expanding technical staff, and accumulating digital assets. More importantly, the signaling effect—less explored in previous research, especially from both internal and external perspectives—operates through two channels: internally, by increasing managerial digital attention, and externally, by enhancing market attention. This dual signaling mechanism provides a dynamic perspective on how government subsidies convey credibility and strategic direction, thereby deepening theoretical insights into the multiple pathways through which public innovation support drives enterprise digital transformation.

Third, the heterogeneity analysis provides practical insights into how enterprise characteristics—such as ownership, size, and life cycle stage—shape the effectiveness of innovation subsidies. The results suggest that policy design should account for enterprise heterogeneity rather than relying on uniform subsidy strategies. In particular, small, state-owned and early-stage enterprises benefit more from targeted fiscal support. These differentiated findings enhance both theoretical understanding and policy relevance, offering guidance for developing more adaptive and effective subsidy instruments at the intersection of innovation governance and enterprise transformation.

2. Literature review and hypotheses

2.1. Literature review

The existing literature relevant to this study can be broadly divided into two main strands. The first strand of literature examines the effects of government innovation subsidies. From the positive-effect perspective, grounded in resource-based theory, these subsidies are viewed as critical external resources that enhance enterprises' innovation capabilities (Lyu et al., 2024; Guo et al., 2025). By alleviating financial constraints and mitigating underinvestment in R&D, innovation subsidies enable enterprises to acquire, accumulate, and deploy technological resources necessary for sustained innovation (Shao & Wang, 2023; Zhao et al., 2024). Complementarily, signaling theory suggests that receiving government subsidies conveys positive signals to external stakeholders—such as investors, partners, and customers—regarding an enterprise's legitimacy, growth potential, and policy alignment (Wu, 2017; Zhang et al., 2024). This signaling effect enhances enterprises' access to complementary resources and strengthens their market reputation. Conversely, the negative-effect perspective emphasizes the potential inefficiencies and distortions stemming from government subsidies (Cheang, 2023; Cao et al., 2025). Drawing on institutional theory and agency theory, scholars have argued that subsidies may lead to rent-seeking, adverse selection, and moral hazard due to information asymmetries between enterprises and policymakers (Bei et al., 2024; Meunier & Ponssard, 2024). Under such circumstances, enterprises may seek subsidies for short-term gains or engage in symbolic compliance rather than substantive innovation, resulting in the misallocation of public resources (Duan et al., 2024; Lai et al., 2025). Moreover, excessive reliance on government support can crowd out private investment and weaken enterprises' long-term incentives for independent technological advancement (Ngo & Stanfield, 2022; Yang & Yuan, 2024).

The second strand focuses on the determinants of enterprise digital transformation. Existing studies primarily analyze these drivers from both internal and external perspectives. Internally, factors such as enterprise size (Wu et al., 2024), financial capacity, and executive characteristics (Porfírio et al., 2021; Tuyen et al., 2025) have been shown to significantly influence digital transformation. Externally, infrastructure development (Jia et al., 2024), market competition (Bresciani et al., 2021), policy orientation (Cheng & Masron, 2023; Yang et al., 2025), and government fiscal interventions (Ding et al., 2025; Li et al., 2025) have been identified as key enablers of digital transformation. Within this context, a growing body of research highlights the importance of fiscal tools. For example, Wang et al. (2023) emphasized that government subsidies and tax incentives serve as critical catalysts for digital transformation by reducing financial barriers and encouraging technological upgrading.

In summary, the existing literature offers valuable insights into the effects of government innovation subsidies and the factors influencing enterprise digital transformation. However, several important gaps remain. First, although many studies have examined the general impact of such subsidies on corporate development, few have focused specifically onthe distinct role of innovation-oriented subsidies with targeted incentive structures in facilitating enterprise digital transformation. Second, the mechanisms through which these subsidies influence digital transformation are still insufficiently explored. Existing research often lacks theoretical integration—particularly of resource-based and signaling perspectives—and provides limited systematic evidence on how government subsidies shape firms' digital transformation trajectories.

2.2. Research hypothesis

In examining how government innovation subsidies influence enterprise digital transformation, this study draws on two complementary theoretical perspectives: resource-based theory and signaling theory.

Resource-based theory posits that government innovation subsidies provide critical external resources that can increase enterprises' R&D investment, expand technical staff, and accumulate digital intangible assets, thereby fostering enterprise digital transformation (Barney et al., 2021). Meanwhile, signaling theory emphasizes the informational role of subsidies, which convey positive signals both internally and externally—heightening managerial attention within firms and increasing market recognition from investors and stakeholders (Connelly et al., 2024). Together, these perspectives provide a coherent theoretical foundation for understanding how government innovation subsidies promote enterprise digital transformation.

2.2.1. Government innovation subsidies and enterprise digital transformation

Government innovation subsidies represent one of the most important fiscal policy instruments for promoting enterprise innovation and transformation. By providing direct financial support, these subsidies help mitigate the high sunk costs and uncertainties inherent in digital transformation, thereby strengthening enterprises' financial capacity and motivation to pursue digital transformation (Henderson, 2020; Lyu et al., 2024). Digital transformation often involves long investment cycles and considerable technological risks (Hao et al., 2025; Yin et al., 2024). Government innovation subsidies alleviate financing constraints, share the risks associated with uncertain returns, and create favorable conditions for enterprises to explore emerging digital technologies and applications (Shao & Chen, 2022; Shao & Wang, 2023). Such policy support not only encourages the adoption of digital tools in production and management but also stimulates organizational learning and innovation capabilities—factors that are essential for achieving sustainable transformation in the digital era (Yang et al., 2024). Hence, this study proposes the following hypothesis.

Hypothesis 1. Government innovation subsidies can significantly promote enterprise digital transformation.

2.2.2. The resource effect of government innovation subsidies

From the perspective of resource-based theory, digital transformation represents a resource-intensive strategic initiative that requires enterprises to access, configure, and integrate both tangible and intangible resources to generate sustained competitive advantage (Nie et al., 2024; Xia et al., 2025). Government innovation subsidies serve as an important external resource that enhances enterprises' internal capabilities for transformation (Lin & Xie, 2023; Zhao et al., 2024). These subsidies not only provide direct financial resources but also indirectly encourage enterprises to increase their own R&D investment, attract and retain skilled technical staff, and accumulate digital-related intangible assets.

Specifically, in terms of financial resources, government innovation subsidies promote enterprises to expand R&D investment (Boeing et al., 2022; Wang et al., 2025); in terms of human resources, they enhance enterprises' capacity to recruit, develop and retain technical staff (Stavlöt & Svensson, 2025); and in terms of intangible assets, they facilitate the accumulation of proprietary software, patents, and data resources, which together form the foundation for sustained digital transformation (Guo et al., 2016; Zhu et al., 2025). Through these resource channels, government innovation subsidies strengthen both the inputs necessary for digital transformation and the internal capabilities required to sustain it, thereby accelerating enterprises' overall transformation process. This study proposes the following hypothesis.

Hypothesis 2. Government innovation subsidies exert resource effects that promote enterprise digital transformation by increasing R&D investment, expanding technical staff, and accumulating digital assets.

2.2.3. The signaling effect of government innovation subsidies

From the perspective of signaling theory, government innovation subsidies not only serve as financial incentives but also transmit clear signals to corporate management regarding national policy priorities and development directions (Luo & Wang, 2025; Wu, 2017). As an external policy signal, these subsidies are allocated through standardized application and evaluation procedures that convey explicit information about national development priorities and strategic orientations. Such signaling encourages enterprise management to align internal strategies with government objectives, enhance digital awareness, and make more forward-looking innovation and transformation decisions.

At the same time, government innovation subsidies act as credible external signals to market stakeholders, demonstrating the recipient enterprise's innovation capability and alignment with policy goals (Zhu et al., 2024). The rigorous evaluation and approval process underlying such subsidies implies governmental endorsement of the recipient enterprise's technological potential and reliability (Khurshid et al., 2025; Tolliver et al., 2021). Consequently, these subsidies send positive signals to both internal and external stakeholders—enhancing managerial attention within the enterprise and attracting greater attention from external markets, investors, and analysts, ultimately fostering the enterprise digital transformation (Szücs, 2020; Cai et al., 2023). Accordingly, this study formulates the following hypothesis.

Hypothesis 3. Government innovation subsidies exert signaling effects that promote enterprise digital transformation by increasing internal managerial digital attention and external market attention.

In summary, the theoretical framework of this study is illustrated in Fig. 1.

3. Data and methodology

3.1. Data description

To empirically investigate the impact of government innovation subsidies on enterprise digital transformation, this study focuses on enterprises listed on the main boards of China's A-share market. Given that the majority of real-sector enterprises are concentrated in the Shanghai and Shenzhen stock exchanges, the sample comprises listed enterprises from these two markets over the period 2011 to 2021. Prior research has noted that these exchanges are broadly representative of China's publicly traded enterprises, covering a wide range of industries, regions, and ownership structures—thus providing comprehensive and reliable data for empirical analysis (Peng & Tao, 2022; Shao & Wang, 2023). The chosen timeframe also captures a critical period in China's digital transformation agenda, marked by intensified policy initiatives and public investments in digital innovation. Therefore, the sample is both policy-relevant and data-complete, offering suitable conditions for assessing the effectiveness of government innovation subsidies.

The original data are obtained from the China Stock Market and Accounting Research (CSMAR) database and the Wind Financial Terminal. Both CSMAR and Wind are widely used, high-quality economic and financial databases in China, frequently cited in academic research (Chen et al., 2022; Jiang & Li, 2024). The CSMAR database provides extensive data on macroeconomics, industry performance, company characteristics, stock markets, and funds. It offers detailed information on corporate executives, stock trends, and financial indicators. Meanwhile, the Wind Financial Terminal covers global listed enterprises, including data on stocks, bonds, futures, foreign exchange, funds, indices, warrants, macroeconomic indicators, and nearly 2,000 specialized financial metrics. Details on the data cleaning process are provided in Appendix Note A1.

3.2. Definitions of variables

This section defines the key variables used in the empirical analysis, including the dependent, independent, control, and mechanism variables. All variable definitions follow established literature to maintain theoretical coherence and ensure empirical robustness.

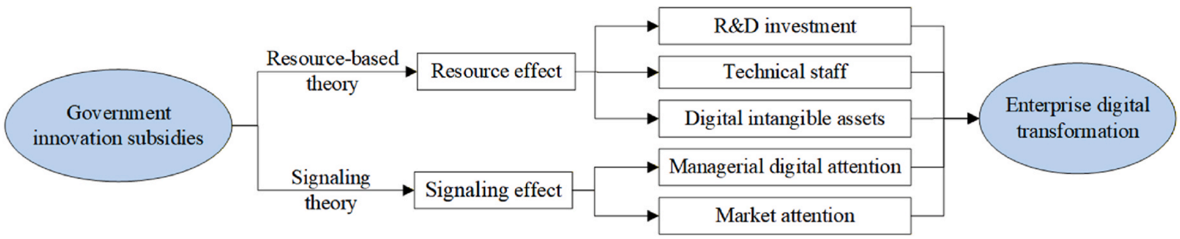

Fig. 1. Theoretical analysis framework.

3.2.1. *Enterprise digital transformation*

Information on digital transformation is often reflected in the strategic and narrative content of corporate annual reports. Following prior studies (Wu et al., 2021; Yuan et al., 2021), this study adopts a keyword frequency approach to measure the degree of digital transformation, which is considered both feasible and scientifically grounded. First, Python was used to crawl the annual reports of all A-share listed companies on the Shanghai and Shenzhen stock exchanges. Second, the Java PDFBox library was used to extract the full text from these reports, which served as the text corpus for subsequent feature term selection. Third, based on prior work, we constructed a set of relevant keywords to capture digital transformation activities. Specifically, the identified keywords include terms such as digital technology, Internet of Things, machine learning, blockchain, cloud platform, e-commerce, digitization, Internet+, artificial intelligence, and smart manufacturing.

3.2.2. *Government innovation subsidies*

To measure the degree of an enterprise's access to government innovation subsidies, this study uses the ratio of total innovation subsidies to total assets, following established practice in the literature (Guo, 2018; Shao & Chen, 2022). Specifically, data on government innovation subsidies are extracted from the annual financial statements disclosed by listed companies. These subsidies are typically reported under the "non-operating income" section, within a subsection titled "Details of Government Subsidies." The innovation-related portion is identified by reviewing all line items related to R&D and innovation support and summing the corresponding amounts.

3.2.3. *Control variables*

This study controls for the following variables to eliminate the confounding factors related to the issuance of government innovation subsidies and enterprise digital transformation decisions (Appendix Table A1). (1) Enterprise size (Lnass): The natural logarithm of total assets. (2) Capital structure (Lev): The debt-to-asset ratio. (3) Profitability (Roa): Return on assets, measured as net profit divided by total assets. (4) Growth (Grow): Growth rate of operating income. (5) Enterprise age (Age): Number of years since the enterprise was listed. (6) Board size (Lnboard): Natural logarithm of the number of board members. (7) CEO duality (Merge): A dummy variable equal to 1 if the CEO also serves as board chair, and 0 otherwise. (8) Audit quality (Big4): A dummy variable equal to 1 if the enterprise is audited by a Big Four accounting enterprise, and 0 otherwise.

3.2.4. *Mechanism variables*

The mechanism variables are categorized into two dimensions: the resource effect and the signaling effect. The resource effect includes R&D investment, technical staff, and digital intangible assets, respectively. Specifically, R&D investment is measured as the ratio of R&D investment to operating revenue, while technical staff is measured as the ratio of R&D personnel to total employees. Digital intangible assets are represented by the logarithm of the total amount of digital intangible assets.

The signaling effect, in turn, reflects the informational and perceptual influences of government innovation subsidies and is measured by managerial digital attention and market attention, respectively. Managerial digital attention is measured by the logarithm of the frequency of digital-related keywords extracted from management meeting minutes and other internal documents. Market attention is measured by analyst coverage, expressed in logarithmic form.

3.3. *Descriptive statistics*

Table 1 presents the descriptive statistics for the main variables used in the analysis. For enterprise digital transformation, the mean, standard deviation, minimum, and maximum values are 35.32, 58.18, 0, and 340, respectively, indicating considerable variation in the level of digitalization across enterprises. The mean and standard deviation of government innovation subsidies (as a share of total assets) are 0.0752 and 0.156, respectively, reflecting a relatively high degree of dispersion. This variation may be influenced by enterprise-specific characteristics such as size, industry, region, and policy exposure.

3.4. *Model specification*

This section presents the empirical models employed to estimate the impact of government innovation subsidies on enterprise digital transformation. Specifically, it introduces the multi-dimensional fixed effects model and the instrumental variable two-stage least squares (IV-2SLS) method.

3.4.1. *Multi-dimensional fixed effects model*

Based on previous literature (Wen & Deng, 2023), this study uses a multi-dimensional fixed-effect model to examine the impact of government innovation subsidies on enterprise digital transformation. Specifically, this study employs a panel regression model with enterprise-level controls, industry and regional fixed effects, and industry-time interaction to mitigate potential endogeneity concerns. To empirically investigate the effects of government innovation subsidies on enterprise digital transformation, this study establishes the following econometric model:

Table 1
Descriptive statistics of variables.

Variable	Mean	SD	Min	Max
Digital	35.3230	58.1812	0.0000	340.0000
Subsidies	0.0752	0.1556	0.0000	0.9770
Lnass	21.8909	1.1055	19.9415	25.1021
Lev	0.3897	0.2011	0.0463	0.8731
Roa	0.0410	0.0577	−0.2346	0.1863
Grow	0.3399	0.7517	−0.6484	4.8040
Age	2.7742	0.3575	1.6094	3.4340
Lnboard	2.1257	0.1887	1.6094	2.6391
Merge	0.3041	0.4593	0.0000	1.0000
Big4	0.0261	0.1595	0.0000	1.0000
R&D investment	4.9209	4.5196	0.0600	26.5000
Technical staff	16.9869	13.6701	0.5600	69.6800
Intangible assets	6.14325	1.9065	0.8755	10.5109
Managerial digital attention	1.9780	1.4482	0	6.8265
Market attention	1.5636	1.1215	0	3.6889

$$Digital_{i,t} = \beta_0 + \beta_1 Subsidies_{i,t} + \gamma CVs_{i,t} + \lambda_j + \varphi_m + \mu_{m,t} + \phi_{j,t} + \eta_t + \varepsilon_{i,t} \tag{1}$$

where $Digital_{i,t}$ represents the digital transformation level of enterprise i in year t; $Subsidies_{i,t}$ represents the ratio of innovation subsidies to total assets of enterprise i in year t; $CV_{i,t}$ represents a series of enterprise-level control variables of enterprise i in year t; λ_j represents industry fixed effects that control for the effects of time-invariant confounders at the industry level. φ_m represents province fixed effects, which control for time-invariant confounders at the provincial level. η_t represents year fixed effects that control for time-varying common shocks at the macro level. $\mu_{m,t}$ represents province-year fixed effects that control for time-varying confounders at the provincial level. $\varnothing_{j,t}$ represents industry-year fixed effects that control for time-varying confounders at the industry level. These multi-dimensional fixed effects and interaction fixed effects can remove external confounding factors to a large extent, thus obtaining more robust and accurate estimation results. $\varepsilon_{i,t}$ is the idiosyncratic error term. Robust standard errors are clustered at industry-year level. β_1 is the coefficient of our interest, which measures the impact of the effects of government innovation subsidies on enterprise digital transformation.

3.4.2. Instrumental variable method

This study examines the impact of government innovation subsidies on enterprise digital transformation using observational data within an ex-post facto research framework. However, potential endogeneity issues may bias the estimation results. First, omitted variable bias may arise if unobserved factors simultaneously influence both the likelihood of receiving innovation subsidies and the extent of digital transformation (Cinelli & Hazlett, 2020). For instance, governments may be more likely to allocate subsidies to enterprises with particular characteristics—such as industry leadership or prior innovation experience—which may themselves be correlated with digital transformation outcomes. Second, reverse causality may exist, as the government's decision to allocate innovation subsidies could be influenced by enterprises' past performance or expected progress in digital transformation (Leszczensky & Wolbring, 2019).

To address these endogeneity concerns, this study employs a two-stage least squares (2SLS) approach to implement the instrumental variable (IV) estimation. The IV-based estimation results are reported in Section 4.2.2. Specifically, the local government's fiscal revenue in the previous year (denoted as *Fiscal*) is used as the instrumental variable. The rationale is that local fiscal revenue is positively associated with the government's capacity to offer innovation subsidies, thereby satisfying the relevance condition. At the same time, fiscal revenue is unlikely to directly influence a specific enterprise's digital transformation outcomes, thus meeting the exogeneity condition.

In the first stage, government innovation subsidies are regression on the instrumental variable and control variables:

$$Subsidies_{i,t} = \alpha_0 + \alpha_1 lnfiscal_{k,t-1} + \gamma_0 CVs_{i,t} + \lambda_j + \varphi_m + \mu_{m,t} + \phi_{j,t} + \eta_t + \varepsilon_{i,t} \tag{2}$$

Where $lnfiscal_{k,t-1}$ represents the logarithm of government revenue at the city k in year $t-1$; other symbols are consistent with (1). α_1 is the coefficient capturing the effect of instrument variable on government innovation subsidies.

In the second stage, the digital transformation level of enterprise is regressed on the predicted values of government innovation subsidies from the first stage, along with the control variables, estimating the causal impact of government innovation subsidies on enterprise digital transformation:

$$Digital_{i,t} = \beta_0' + \beta_1' \widehat{Subsidies}_{i,t} + \gamma' CVs_{i,t} + \lambda_j + \varphi_m + \mu_{m,t} + \phi_{j,t} + \eta_t + \varepsilon_{i,t} \tag{3}$$

Where $\widehat{Subsidies}_{i,t}$ represents predicted values of government innovation subsidies of enterprise i in year t from the first stage; other symbols are consistent with (1). β_1' is the coefficient capturing the causal effect of government innovation subsidies on enterprise digital transformation with the instrumental variable.

4. Empirical analysis

4.1. Benchmark results

Table 2 presents the regression results on the impact of government innovation subsidies on enterprise digital transformation. The analysis follows an incremental approach by gradually adding control variables and fixed effects across columns (1) to (5). Specifically, adding control variables accounts for firm-level heterogeneity in size, profitability, growth, and governance structure, which may independently influence digital transformation. Incorporating industry, year, province, and interaction fixed effects further isolates the effect of innovation subsidies by controlling for unobservable factors such as macroeconomic shocks, regional policy differences, and industry-specific technological trends. This comprehensive fixed-effects framework substantially enhances the precision and validity of the estimates.

In all specifications, the coefficients of government innovation subsidies remain significantly positive at the 1 % level, indicating that such subsidies consistently promote digital transformation. In the fully controlled model (column 5), the coefficient of Subsidies is 18.4178, suggesting that a 1 % increase in innovation subsidies is associated with an increase of approximately 18.42 units in the digital transformation. This finding supports Hypothesis 1, confirming the positive association between government innovation subsidies and enterprise digital transformation.

These results are consistent with prior studies. For example, Wang et al. (2023) emphasized that government subsidies and tax incentives are key enablers of digital transformation. Similarly, Zhao et al. (2024) found that innovation subsidies significantly enhance digital transformation in manufacturing enterprises. Building on this evidence, the present study contributes new evidence by focusing specifically on innovation-targeted subsidies and examining their micro-level impacts on digital transformation among Chinese listed companies.

4.2. Endogeneity analysis

To ensure the robustness and credibility of the estimation results, this study addresses potential endogeneity concerns that may arise from reverse causality or omitted variables. Following common practice, two complementary approaches are employed: a lagged-variable specification to mitigate simultaneity bias, and an instrumental variable method using lagged municipal fiscal revenue to strengthen causal identification.

4.2.1. Lagged variables

To further address potential endogeneity concerns, this study examines the lagged effects of government innovation subsidies on enterprise digital transformation. An enterprise's digital transformation capability may influence its likelihood of receiving subsidies, leading to reverse causality. To mitigate this bias, one-year and two-year lagged terms of the core explanatory variable—government innovation subsidies—are introduced, denoted as L.Subsidies and L2.Subsidies. This specification captures delayed policy effects while improving causal identification along the time dimension. As reported in Columns (1) and (2) of Table 3, the coefficients on L.Subsidies (19.1710, $p < 0.01$) and L2.Subsidies (18.8677, $p < 0.01$) remain significantly positive, confirming the persistence and robustness of the baseline findings. These results indicate that government innovation subsidies exert a sustained and positive influence on enterprise digital transformation even after

Table 2
The impacts of government innovation subsidies on enterprise digital transformation.

Variables	(1)	(2)	(3)	(4)	(5)
Subsidies	37.0459***	34.3098***	13.8311***	12.6839***	18.4178***
	(4.6004)	(3.9654)	(3.3505)	(3.2741)	(2.9999)
Lnass		4.1280***	7.1347***	6.7139***	6.3162***
		(0.7018)	(0.8455)	(0.7964)	(0.8046)
Lev		−21.3887***	−7.2687***	−5.9676**	−5.8492**
		(4.6634)	(2.6291)	(2.6852)	(2.7457)
Roa		−37.8831***	−24.2282***	−20.6228**	−7.0955
		(13.1677)	(8.6690)	(8.6370)	(8.4272)
Grow		9.1665***	2.8886***	2.3464***	2.6355***
		(1.5887)	(0.6593)	(0.6581)	(0.6812)
Age		−8.8931***	−3.1721**	−3.2590**	−4.0649***
		(1.3153)	(1.3105)	(1.3426)	(1.3526)
Lnboard		−12.7808***	−4.6890**	−4.2721**	−4.8277**
		(2.6196)	(2.0317)	(1.9946)	(2.0501)
Merge		7.2820***	4.6789***	4.7736***	4.5871***
		(1.0889)	(0.9019)	(0.9011)	(0.9050)
Big4		−4.2884**	−7.8908***	−8.6503***	−9.1076***
		(2.0804)	(1.5942)	(1.6655)	(1.6344)
constant	32.5381***	−1.1109	−101.5031***	−93.3304***	−82.2104***
	(2.0536)	(12.1376)	(18.3372)	(17.7867)	(18.0253)
Year fixed effect	Yes	Yes	Yes	No	No
Industry fixed effect	No	No	Yes	Yes	Yes
Province fixed effect	No	No	No	Yes	Yes
Industry × Year fixed effect	No	No	No	Yes	Yes
Province × Year fixed effect	No	No	No	No	Yes
N	16354	16354	16353	16246	16258
R^2	0.0963	0.1215	0.4039	0.4107	0.4621

Note: The robust standard errors are clustered at the industry-year level reported in parentheses. Significance level: *p < 0.1, **p < 0.05, ***p < 0.01.

Table 3
The results of lagged terms and IV.

Variables	(1) Digital	(2) Digital	(3) Subsidies	(4) Digital
Subsidies				348.3191***
				(55.9593)
lnfiscal			0.0081***	
			(0.0016)	
L. Subsidies	19.1710***			
	(3.7109)			
L2. Subsidies		18.8677***		
		(4.1397)		
Control variables	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes
N	13200	10745	14131	14131
R^2	0.4741	0.4818	0.1887	0.4491
Kleibergen-Paap rk Wald F statistic			25.345	
Cragg-Donald Wald F-statistic			21.634	
Stock-Yogo weak ID test critical values (10 %)			16.38	

Note: The robust standard errors are clustered at the industry-year level reported in parentheses. Significance level: *p < 0.1, **p < 0.05, ***p < 0.01.

accounting for potential simultaneity bias.

4.2.2. *Instrumental variable method*

As mentioned in Section 3.4.2, to address potential endogeneity in estimating the impact of government innovation subsidies on enterprise digital transformation, we employ the lagged logarithm of municipal-level fiscal revenue (i.e., fiscal revenue from the previous year) as an instrumental variable for current innovation subsidies. This choice is grounded in both institutional rationale and empirical relevance. Fiscal revenue reflects the financial capacity of local governments and is a key determinant of their ability to implement industrial support policies, particularly through innovation-related subsidies. Municipalities with stronger fiscal capacity tend to allocate more innovation subsidies, thereby establishing a strong first-stage relationship and satisfying the relevance condition for a valid instrument. To meet the exclusion restriction, we exploit the lag structure of the instrument to mitigate concerns of reverse causality. Moreover, our empirical specification includes an extensive set of fixed effects—province, year, province-by-year, and enterprise fixed effects—as well as comprehensive enterprise-level controls. This design ensures that identification relies on within-province, cross-city variation in lagged fiscal revenue, after accounting for unobserved heterogeneity at the enterprise level and time-varying shocks at the provincial level.

Taken together, our IV strategy provides a credible framework for isolating exogenous variation in innovation subsidies and identifying their causal impact on enterprises' digital transformation. The results of the IV regressions, reported in columns (3) and (4) of Table 3, show that the coefficients on the instrumental variables are statistically significant. Both the Kleibergen-Paap rk Wald F statistic and the Cragg-Donald Wald F statistic exceed the 10 % critical values provided by the Stock-Yogo weak identification test, indicating that the instruments are sufficiently strong and that weak instrument bias is unlikely to be a concern. The coefficients on government innovation subsidies remain significantly positive, reinforcing the conclusion that these subsidies robustly promote enterprise digital transformation, even after accounting for endogeneity.

4.3. *Robustness analysis*

To ensure the reliability of the findings, this section conducts several robustness checks, including variable substitution, sample adjustments, and alternative estimation methods. These complementary tests confirm that the positive relationship between government innovation subsidies and enterprise digital transformation remains stable across different specifications, reinforcing the robustness of the results.

4.3.1. *Replace the core dependent and independent variables*

First, this study redefines the core dependent variable, enterprise digital transformation, across five dimensions: artificial intelligence, big data, cloud computing, blockchain, and digital technology application.

Using this alternative indicator, robustness checks are conducted. The regression results, reported in Column (1) of Table 4, show that government innovation subsidies remain positively and significantly associated with the revised measure of digital transformation. Second, the core independent variable, government innovation subsidies, is replaced with the natural logarithm of the total subsidy amount. As shown in Column (2), the coefficient remains significantly positive, yielding results consistent with the benchmark analysis.

4.3.2. Change the sample size

To address potential bias arising from administrative-level differences, the sample is refined by excluding enterprises located in the four municipalities—Beijing, Shanghai, Tianjin, and Chongqing—where policy and fiscal environments differ significantly from those in other regions. The regression results, shown in Column (3) of Table 4, indicate that the positive association between government innovation subsidies and digital transformation remains robust. Additionally, to account for potential industry-specific bias, the study excludes electronic information enterprises, as their core operations are inherently aligned with digital technologies and may systematically favor digital transformation. After removing these enterprises, the re-estimated results in Column (4) show coefficients similar in magnitude and significance to the benchmark estimates, confirming that the main findings are not driven by this specific industry subset.

4.3.3. Add control variables

In the process of enterprise digital transformation, not only enterprise-specific factors but also macro-level conditions—such as regional economic development and the strength of the information industry—may influence managerial decisions regarding transformation. Therefore, based on Model (1), this study introduces additional control variables, including regional GDP, the share of industrial output, and the proportion of employees in the information industry. As reported in Column (5) of Table 4, the regression results show that even after controlling for city-level economic development, industrial structure, and information industry conditions, the effect of government innovation subsidies on enterprise digital transformation remains significantly positive, confirming the robustness of the baseline findings.

4.3.4. Use the alternative estimation model

Since several enterprises in the sample report zero values for the digital transformation indicator—particularly those at the early stages of transformation—the ordinary least squares (OLS) regression used in the benchmark analysis may be subject to censoring bias. To address this issue, the model is re-estimated using a Tobit regression, which is more appropriate for handling limited dependent variables. As shown in Column (6) of Table 4, the coefficient on government innovation subsidies remains positive and statistically significant, reinforcing the robustness of the main findings under an alternative estimation approach.

4.4. Mechanism analysis

Based on previous studies, this section employs a theory-driven mechanism approach to examine how government innovation subsidies promote enterprise digital transformation (Rotemberg, 2019; Feng & Yuan, 2025; Wang et al., 2024). The primary idea of mechanism analysis is to determine whether the addition of the core explanatory variable leads to changes in the coefficient of the key mechanism variables, thus verifying the existence of the mechanism. This design avoids unnecessary causal assumptions while providing a theoretically grounded explanation of how subsidies operate through distinct pathways. This will help to identify the relationship between government innovation subsidies and mechanism variables.

Grounded in resource-based theory and signaling theory, two main mechanisms are considered. The resource effect captures how subsidies enhance enterprises' resource endowments—reflected in higher R&D investment, expanded technical staff, and greater accumulation of digital intangible assets. The signaling effect reflects how subsidies convey institutional and market signals that raise both internal managerial attention and external market recognition. These mechanism tests will offer a more nuanced understanding of how government innovation subsidies facilitate enterprise digital transformation in practice.

4.4.1. Resource effect mechanism

Depending on the theoretical analysis, this study argues that government innovation subsidies generate a resource effect by increasing R&D investment, expanding technical staff, and accumulating digital assets, thereby facilitating enterprise digital transformation. The empirical results are reported in Columns (1)–(3) of Table 5. In Column (1), the regression coefficient of government innovation subsidies is 4.9857 ($p < 0.01$), indicating that government innovation subsidies significantly promote R&D investment. In Column (2), the coefficient is 8.5009 ($p < 0.01$), suggesting that government innovation subsidies significantly increase the number of technical staff. In Column (3), the coefficient is 0.5207 ($p < 0.01$), showing that government innovation subsidies significantly enhance enterprises'' digital intangible assets.

In summary, these findings demonstrate that government innovation subsidies provide essential resource support, enabling enterprises to expand financial and human capital investments in R&D and accumulate digital intangible assets. Such strengthened resource endowments constitute an important foundation for advancing enterprise digital transformation. Therefore, Hypothesis 2 is supported.

4.4.2. Signaling effect mechanism

Theoretical research suggests that government innovation subsidies can facilitate enterprise digital transformation by strengthening both internal managerial digital attention and external market attention. As shown in column (4) of Table 5, government innovation subsidies have a significantly positive effect on managerial digital attention (coefficient = 0.3779, $p < 0.01$). Similarly, column (5) shows that government innovation subsidies significantly increase market attention (coefficient = 0.3585, $p < 0.01$).

These results indicate that government innovation subsidies generate

Table 4
The results of other robustness tests.

Variables	(1)	(2)	(3)	(4)	(5)	(6)
Subsidies	5.6883***		21.9945***	20.1805***	18.2255***	18.9408***
	(1.3452)		(3.8201)	(4.1673)	(4.1503)	(2.4127)
lnSubsidies		0.4432***				
		(0.0752)				
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
N	16258	16258	13287	13246	12057	16354
R^2	0.4533	0.4617	0.3965	0.3207	0.4426	

Note: The robust standard errors are clustered at the industry-year level reported in parentheses. Significance level: *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

Table 5
Results of mechanism analysis.

Variables	(1)R&D investment	(2) Technical staff	(3) Intangible assets	(4)Managerial digital attention	(5) Market attention
Subsidies	4.9857***	8.5009***	0.5207***	0.3779***	0.3585***
	(0.4123)	(1.9231)	(0.0921)	(0.0971)	(0.0464)
Control variables	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes
N	13799	8499	12661	9333	16103
R^2	0.4587	0.4358	0.5092	0.4141	0.4187

Note: The robust standard errors are clustered at the industry-year level reported in parentheses. Significance level: *p < 0.1, **p < 0.05, ***p < 0.01.

a signaling effect, which enhances managerial focus on digital development within enterprises and boosts recognition from external stakeholders such as investors and analysts. By improving both internal and external attention toward digitalization, government subsidies help create a supportive environment for continuous transformation. Therefore, Hypothesis 3 is supported.

4.5. Heterogeneity analysis

While the previous analysis shows that government innovation subsidies are generally linked to improved digital transformation, their effects may differ across types of enterprises. In practice, enterprise characteristics such as ownership, size, and stage of development can shape how enterprises respond to policy support. To explore this potential variation, this section investigates whether and how the effects of government innovation subsidies differ across subgroups of enterprises, focusing on three dimensions: ownership structure (state-owned vs. non-state-owned), enterprise size (large vs. small), and development stage (growth, maturity, and decline). These comparisons help clarify which types of enterprises benefit most from innovation subsidies in driving digital transformation.

4.5.1. Heterogeneity analysis by enterprise ownership

State-owned enterprises (SOEs) and non-state-owned enterprises (NSOEs) differ substantially in terms of access to policy resources, institutional legitimacy, and market orientation. To investigate whether ownership structure moderates the effect of government innovation subsidies, the sample is stratified by ownership type. The regression results, shown in columns (1) and (2) of Table 6, indicate that innovation subsidies are positively and significantly associated with digital transformation for both SOEs and NSOEs. However, the magnitude of the effect is notably greater for SOEs. This differential effect can be attributed to the institutional advantages enjoyed by SOEs, including more stable financing channels, stronger government ties, and lower perceived risk, which collectively enhance their capacity to absorb and operationalize external policy support. In the context of China's national strategy to cultivate a robust digital economy, SOEs are more likely to act as policy executors, aligning closely with governmental priorities and receiving preferential treatment. As a result, they are better positioned to leverage innovation subsidies to accelerate their digital transformation trajectories.

4.5.2. Heterogeneity analysis by enterprise scale

Enterprises of different sizes exhibit substantial variation in their capacities for risk management, technological innovation, and resource allocation. To capture this dimension, the study categorizes enterprises into small and large enterprises based on the average number of employees. The regression results, presented in columns (3) and (4) of Table 6, indicate that government innovation subsidies significantly promote the digital transformation of small enterprises, whereas the effect on large enterprises is relatively weaker. This asymmetry may stem from the fact that large enterprises generally possess more abundant financial resources, sophisticated technological capabilities, and mature strategic planning systems, which enable them to pursue digital transformation with less dependence on external policy incentives. Conversely, small enterprises typically face more pronounced constraints in digital infrastructure, human capital, and innovation financing. For these enterprises, government subsidies serve as a critical external stimulus—functioning as a "timely intervention"—by alleviating financial burdens, reducing innovation risk, and enhancing both the willingness and capacity to undertake digital transformation. Accordingly, the marginal utility of government innovation subsidies is more pronounced for smaller enterprises.

4.5.3. Heterogeneity analysis by enterprise development stage

Building on enterprise life cycle theory, which posits that enterprises encounter varying degrees of resource constraints and strategic priorities at different stages of development (Mueller, 1972; Wu et al., 2021), this section examines whether the effects of government innovation subsidies differ across the growth, maturity, and decline stages. As reported in columns (5), (6), and (7) of Table 6, the results reveal that the positive impact of innovation subsidies on digital transformation is most pronounced during the growth stage. This finding is theoretically consistent: growth-stage enterprises typically lack a mature industrial chain, stable profit model, or internal innovation capacity, making them more agile but also more vulnerable to external constraints. Government subsidies, by alleviating financial, technological, and human capital limitations, serve as a critical enabler for these enterprises to pursue digital transformation. In contrast, mature and declining enterprises often face path dependencies, entrenched cost structures, and higher adjustment costs, which may reduce the marginal effectiveness of subsidy-induced transformation. Therefore, the catalytic role of government support is significantly stronger among enterprises in the growth phase, where policy incentives are more likely to overcome structural barriers and generate transformative outcomes.

Table 6
Heterogeneity analyses.

Variables	(1) State-owned	(2) Non-state-owned	(3) Large	(4) Small	(5) Growth stage	(6) Maturity stage	(7) Decline stage
Subsidies	40.8793***	9.9723***	9.0694*	20.6857***	24.9315***	12.6644**	11.6977*
	(8.6533)	(2.5348)	(5.1377)	(3.8686)	(5.5268)	(5.0530)	(6.3158)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	4869	11201	7861	7833	7766	4609	3420
R^2	0.5236	0.4721	0.5711	0.4338	0.4892	0.5223	0.5221

Note: The robust standard errors are clustered at the industry-year level reported in parentheses. Significance level: *p < 0.1, **p < 0.05, ***p < 0.01.

5. Discussion and conclusions

5.1. Findings

This study investigates how government innovation subsidies influence enterprise digital transformation, using panel data of Chinese A-share listed enterprises from 2010 to 2021. The analysis provides several key insights. First, government innovation subsidies significantly promote enterprise digital transformation. This relationship remains stable across all robustness checks, including instrumental variable estimation, lagged specifications, variable substitution, sample adjustments, and alternative estimation methods. The consistently positive and significant coefficients confirm that well-designed targeted subsidies can serve as an effective policy instrument for promoting enterprise-level digital transformation.

Second, the mechanism analysis demonstrates that government innovation subsidies operate through two channels—the resource effect and the signaling effect. On the one hand, subsidies enhance enterprises' resource endowments by increasing R&D investment, expanding technical staff, and accumulating digital intangible assets, thus providing the material and technological foundations for digital transformation. On the other hand, subsidies convey positive signals both internally and externally: internally, they raise managerial attention toward digital transformation; externally, they enhance market recognition and investor confidence. These findings reveal that innovation subsidies not only provide tangible financial resources but also create intangible incentives that align managerial behavior and market expectations with policy priorities.

Third, the heterogeneity analysis indicates that the positive influence of government innovation subsidies on digital transformation varies across enterprise types. The effect is stronger among state-owned enterprises, small enterprises, and those in the growth stage, reflecting their higher dependence on external policy resources and fiscal support. This heterogeneity underscores that subsidy effectiveness is conditioned by ownership structure, firm size, and life cycle characteristics, suggesting that targeted fiscal design should be promoted to improve policy precision and efficiency.

5.2. Theoretical contributions

This study makes several theoretical contributions to the literature on innovation policy and enterprise digital transformation. It addresses key gaps in both the empirical focus on digital transformation outcomes and the theoretical understanding of the mechanisms through which government support enhances enterprise digital transformation.

First, existing literature on government innovation subsidies has largely focused on their direct effects on traditional corporate innovation activities, such as patent applications and R&D investment (Guo et al., 2016), or the role of macro-level policies in promoting industrial transformation. Given that digital transformation is a disruptive and complex form of innovation, it is crucial to explore how government support facilitates this process. By systematically analyzing enterprise-level data from Chinese listed companies, this study provides the fresh empirical evidence of a significant positive relationship between government innovation subsidies and enterprise digital transformation. This finding aligns with recent studies (Zhang et al., 2024), reaffirming the role of government support as a key driver of digital transformation, with innovation subsidies playing a crucial role (Wang et al., 2023; Zhao et al., 2024). It also expands the literature on the micro-level effects of government subsidies by emphasizing their unique role in advancing digital technology adoption, strengthening industrial integration, and fostering innovation in non-traditional areas.

Second, this study enriches theoretical understanding by integrating resource-based theory and signaling theory to explain how government innovation subsidies promote digital transformation through multi channels. Prior research has mainly relied on resource-based theory, emphasizing financial support as the key driver of innovation capability (Boeing, 2016). However, few studies have systematically examined the broader mechanisms through which government support contributes to digital transformation, particularly from the perspective of signaling theory. Beyond providing financial resources, signaling theory emphasizes how government innovation subsidies convey credibility and commitment both internally—by enhancing managerial attention and strategic confidence—and externally—by improving market recognition and investor trust. Building on the integration of resource-based and signaling perspectives, this study extends prior research by revealing the multi-dimensional pathways through which government innovation subsidies facilitate digital transformation. These results are consistent with prior literature on the channels through which policy support influences enterprise-level innovation and technological upgrading (Wan & Ding, 2024; Yang et al., 2024). Overall, this integrated perspective offers a more comprehensive understanding of how public interventions drive digital transformation, moving beyond the traditional focus on financial resource provision.

Finally, while this study is grounded in the Chinese context, its insights have clear international relevance. Many emerging and transitional economies face similar challenges—such as limited resources, institutional uncertainty, and low market trust—that hinder enterprise digital transformation. By identifying how government innovation subsidies strengthen R&D investment, expand technical staff, accumulate digital assets, and increase both internal managerial attention and external market recognition, this study deepens theoretical understanding of how public policy can effectively foster digital transformation. It extends existing theory by illustrating how targeted innovation subsidies help overcome structural constraints, particularly in developing contexts. Moreover, it contributes to comparative research on digital industrial policy by offering a conceptual framework applicable to diverse national settings, thus enriching global discussions on state-led innovation and digital transformation.

5.3. Practical implications

Building on the empirical findings, this study provides actionable implications for both policymakers and enterprises seeking to accelerate digital transformation. At the policy level, the results underscore the importance of designing differentiated and adaptive innovation subsidy programs that account for enterprise heterogeneity in ownership, size, and life-cycle stage. Policymakers should move beyond uniform allocation mechanisms and target small and early-stage enterprises that typically lack the financial and technical capacity for digital upgrading. Strengthening program supervision and establishing dynamic performance evaluation systems are also crucial to ensure that funds are used efficiently, implementation bottlenecks are identified promptly, and subsidies achieve sustained policy outcomes.

At the enterprise level, the findings highlight the dual resource and signaling effects of government innovation subsidies. Beyond providing financial resource support, subsidies convey credibility and strategic commitment that can strengthen both internal and external dimensions of enterprise transformation. Internally, they heighten managerial digital awareness and strategic confidence; externally, they enhance market recognition and investor trust. Enterprises can amplify these benefits by improving transparency in subsidy utilization and proactively disclosing related information. Such practices can reinforce corporate reputation, attract further financing, and promote a virtuous cycle between market trust and digital upgrading. In addition, enterprises should deepen collaborations with universities, research institutes, and technology partners to facilitate knowledge exchange, expand technological capacity, and mitigate risks associated with digital transformation.

Beyond the Chinese context, these findings offer valuable reference for other emerging economies facing similar resource and institutional constraints. The evidence demonstrates that well-targeted innovation subsidies can serve as effective policy tools for promoting inclusive and sustainable digital transformation when adapted to local institutional environments. Policymakers in other countries can draw lessons from China's experience to develop context-sensitive and performance-oriented subsidy mechanisms that balance direct resource provision with indirect signaling effects.

5.4. Limitation

While this study provides valuable insights into how government innovation subsidies promote enterprise digital transformation, several limitations should be noted. First, the analysis is based on Chinese A-share listed enterprises, reflecting the country's specific institutional and policy environment. While this context provides a rich empirical setting for studying policy-driven digital upgrading, it may limit the generalizability of the findings to smaller firms or other national contexts. Future research could incorporate cross-country or cross-industry comparisons to examine whether similar patterns and mechanisms apply under different institutional frameworks. Second, although digital transformation is measured through keyword analysis and technology-related indicators, these proxies may not fully capture the multidimensional and strategic nature of digital change. Subsequent studies could combine text-based metrics with survey data, digital disclosure indices, or composite indicators that better reflect the scope, intensity, and outcomes of enterprise digitalization. Third, the mechanism analysis in this study focuses primarily on verifying the existence of resource and signaling pathways but does not evaluate their causal strength or relative contribution. Future research could employ causal mediation analysis to disentangle the direct and indirect effects of government subsidies and compare the relative importance or contribution of different mechanisms. This would provide a more rigorous and nuanced understanding of how public policy interventions shape enterprise digital transformation.

CRediT authorship contribution statement

Zhen Han: Writing – original draft, Methodology, Formal analysis, Conceptualization. **Erga Luo:** Writing – review & editing, Methodology, Formal analysis, Conceptualization. **Xuezhen Xiong:** Writing – review & editing, Data curation, Conceptualization. **Jinkai Li:** Writing – review & editing, Writing – original draft, Supervision, Conceptualization.

Acknowledgement

The authors declare no competing interests. This study is supported by the National Social Science Fund of China (23CZZ023),the Key Program of National Natural Science Foundation of China (72033009), the National Natural Science Foundation of China (72403235), the 2024 National Statistical Research Projects (2024LY078).

Appendix

Appendix Table A1
Variable description.

Variables	Symbol	Operate Mode
Enterprise digital transformation	Digital	Keyword frequency in annual reports
Government innovation subsidies	Subsidies	Ratio of government innovation subsidies to assets
Enterprise size	Lnass	Logarithmic value of the enterprise assets
Capital structure	Lev	Debt-to-equity ratio
Profitability	Roa	Return on assets, net profit/total assets
Growth	Grow	Growth rate of operating income
Enterprise age	Age	The age of the company listed to date
Board size	Lnboard	Logarithm of the number of board members
CEO duality	Merge	1 if CEO and chairman are the same, 0 otherwise
Audit quality	Big4	1 if audited by a "Big 4" accounting enterprise, 0 otherwise
R&D investment	R&D investment	Ratio of R&D investment to operating revenue
Technical staff	R&D personnel	The number of R&D personnel to total staff
Digital Intangible assets	Intangible assets	The logarithm of the total amount of digital-related intangible assets
Managerial digital attention	Managerial digital attention	The frequency of digital-related keywords extracted from management meeting minutes and other internal documents
Market attention	Market attention	Logarithm of analyst coverage

Appendix Note A1. The procedure of data cleaning and sample selection.

First, companies labeled as "Special Treatment (ST)", "*Special Treatment (*ST)", "Particular Transfer (PT)", and delisted enterprises are excluded. Second, enterprises operating in regulated industries, such as financial services, are removed. Third, enterprises with missing values in key variables, including government subsidies and digital transformation indicators, are omitted. Fourth, all continuous enterprise-level variables are winsorized at the 1 % and 99 % levels to mitigate the influence of extreme values. After these refinements, our final dataset consists of 2,637 listed enterprises and 16,354 enterprise-year observations.

Data availability

The data that has been used is confidential.

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