The digital economy and entrepreneurial dynamics: An empirical analysis of urban regions in China☆

Shucui Wang [a], Yutong Song [a], Anna Min Du [b],[*],[1], Jia Liang [a]

[a] *Alibaba Business School, Hangzhou Normal University, Hangzhou, China*
[b] *The Business School, Edinburgh Napier University, Edinburgh, UK*

ARTICLE INFO

ABSTRACT

The economic landscape in China has evolved to what is termed a "new normal", marked by a strategic focus on the digital economy as a lever for regional entrepreneurship. This change is considered essential for fostering shared wealth and elevating the standard of economic progress, aimed at tackling inequality and advancing inclusive finance. This article undertakes an empirical analysis of the relationship between the digital economy and entrepreneurial activities, utilising panel data from 284 prefecture-level cities in China from 2011 to 2021. The findings highlight the significant influence of the digital economy in stimulating entrepreneurial activity. In particular, the digital economy is found to boost urban entrepreneurial endeavours by improving the quality of urban human capital. Further investigation reveals a varied impact of the digital economy on urban entrepreneurial activity, with the eastern region exhibiting a more marked effect in facilitating urban entrepreneurship.

1. Introduction

Since the initiation of reform and opening policies in the 1980s, China has experienced rapid development, significantly increasing its economic size to become the world's second-largest economy and the biggest developing country, which could partly benefit from the support of various government policies (Ashraf and Goodell, 2022). However, the nation faces persistent challenges related to unbalanced and inadequate development. With the progression of urbanization, China's economy has transitioned into a "new normal", encountering significant hurdles, especially in the post-epidemic era, which brought unprecedented economic damage (Goodell, 2020; Boubaker et al., 2023), including the diminishing demographic dividend, a mismatch between supply and demand, and shifts in industrial structure.

To address these challenges, China has consistently explored and implemented innovative strategies to foster entrepreneurship. Successfully tackling these issues through the promotion of entrepreneurship has become a critical and complex task for both central and local governments. In recent years, China's burgeoning digital economy has created a supportive environment for entrepreneurial activities. The launch of the "National Big Data Strategy" in 2015 catalyzed the expansion of the digital economy, alongside the continuous development and execution of digital transformation policies. By 2017, the "digital economy" was highlighted in the government work report for the fourth consecutive year. The 2020 government work report clearly stated the necessity of introducing

sustained support policies, comprehensively advancing the "Internet +" initiative, and building new advantages in the digital economy. In 2023, China's digital economy reached 56.1 trillion yuan, marking an 11.75 % increase from the previous year and comprising approximately 44.50 % of the country's GDP.

Additionally, in 2015, China released the "Government Work Report of the State Council," which clearly stated that the "mass entrepreneurship and innovation initiative" has fostered a thriving trend in the country's entrepreneurial sector. Entrepreneurship fundamentally entails the innovative recombination of production factors to create and commercialize new products, thereby generating commercial and social value. This process is rooted in innovation, as articulated by Schumpeter (1934), and serves as a critical driver for enhancing household incomes (Suhaimee et al., 2020), fostering innovation capabilities, and promoting societal welfare. Entrepreneurial activities contribute significantly to economic expansion, the reinforcement of social equity, and the facilitation of social mobility. Moreover, entrepreneurship plays a pivotal role in augmenting employment opportunities, addressing job scarcity, and elevating the quality of life for individuals (Wahyono et al., 2022). The level of entrepreneurial activity within a region is a crucial indicator of its entrepreneurial dynamism. The average number of newly registered companies in Chinese cities has steadily increased, rising from 30,936 in 2011–97,880 in 2021. Within this context, it is anticipated that the digital economy and urban entrepreneurship will grow synergistically, driving high-quality economic and social development.

This study aims to investigate the impact of the digital economy on regional entrepreneurial activities through an empirical analysis, utilising panel data from 284 prefecture-level cities in China from 2011 to 2021. Practically, it offers a scientific basis for the government to formulate more effective digital economy and entrepreneurship policies, aids businesses in capitalising on opportunities presented by the digital economy to enhance entrepreneurship success rates and achieve sustainable development, and helps individuals better adapt to the digital economy and improve their entrepreneurial capabilities. Theoretically, it has the potential to enrich the body of research on digital economy and entrepreneurship theory. Additionally, the exploration of intermediary mechanisms provides new insights for related research fields. Lastly, the heterogeneity test reveals the varied impact of the digital economy across different regions, deepens the understanding of the relationship between the digital economy and urban entrepreneurship, and opens new avenues for future research.

2. Theoretical analysis and research hypotheses

Currently, scholars offer various definitions of the digital economy, with one of the most notable being from the "G20 Digital Economy Development and Cooperation Initiative." This initiative characterizes the digital economy as a novel economic model where digital technology and the real economy are deeply intertwined. Key elements include digital knowledge and information as crucial production factors, digital technology innovation as the primary driving force, and modern information networks as significant carriers. By leveraging digitalization, networking, and intelligence, the digital economy has significantly improved the production efficiency and competitiveness of traditional industries (Jiao and Sun, 2021). Contemporary scholarly discourse also has increasingly focused on the role of the digital economy in the optimization of industrial structures (Anser et al., 2020; Su et al., 2021; Hao et al., 2023), the enhancement of green total factor productivity (Pan et al., 2022; Gao et al., 2022), the development of low-carbon innovation (Hunjra et al., 2024), and the promotion of high-quality economic development (Zhang et al., 2021; Yang et al., 2022; Chen et al., 2023).

Currently, start-ups play an increasingly important role in an economy (Abbasi et al., 2021). Entrepreneurship can provide more jobs, and serve as a critical driver for enhancing household incomes (Suhaimee et al., 2020). Research has identified a plethora of factors influencing entrepreneurial activity that are contextually varied (Dabić et al., 2020), spanning both micro and macro dimensions. At the microscale, investigations predominantly concentrate on the determinants impacting the entrepreneurial pursuits of individuals, families, or firms. This includes exploring the nexus between personal entrepreneurial endeavors and environmental factors (Grundstén, 2004), the correlation between housing prices and the propensity for urban entrepreneurship (Kerr et al., 2022), the effect of institutional elements (Urbano et al., 2020), and the relationship between climate change and innovation in small and medium-sized enterprises (Alam et al., 2022). Conversely, at the macroscale, research is typically directed towards national, provincial, and municipal levels. Through the lens of innovation-driven policy frameworks in national creative cities, Bai and Zhang (2022) analyzed the policy's efficacy in stimulating urban entrepreneurial activity, uncovering a pronounced effect in non-productive service sectors and cities with superior administrative rankings and strategic locations. Employing NCA and QCA methodologies within an institutional configuration paradigm, Du et al. (2020) assessed how the entrepreneurial ecosystem's business environment influences entrepreneurial activities, revealing the significance of governmental efficiency and identifying four distinct business ecosystem types conducive to entrepreneurship.

2.1. The direct impact of digital economy on urban entrepreneurial activity

Starting a business in the digital economy is becoming increasingly accessible, reducing costs and risks, especially for underprivileged individuals (Li et al., 2024). To boost regional entrepreneurial activity, it is essential to foster entrepreneurial opportunities by addressing both supply and demand dynamics. The digital economy is pivotal in enhancing the external environment and stimulating internal motivations, thereby fostering innovation and entrepreneurship (Ben Arfi and Hikkerova, 2021). It revitalizes traditional industries through its high efficiency and intelligence, accelerating their development (Liu and Chen, 2021). Regarding the external environment, the amalgamation of the digital economy with traditional sectors transforms the conventional, singular market role of consumers. It enables consumer engagement through online multifaceted channels like real-time feedback, personalised customisation, and private domain sharing in the phases of product development, innovation, and marketing (Sturgeon, 2021). This

2

diversification stimulates varied consumer needs across different roles, enhancing societal demand at large.

Furthermore, organisations can rapidly improve, update, and reconfigure products, services, and platforms due to the inherent characteristics of digital technology—such as functional expansibility, open connectivity, and reprogrammability (Yoo et al., 2010). This process facilitates a more effective reallocation of resources (Maraveas et al., 2022), leading to the emergence of innovative services and business models, which, in turn, bolsters entrepreneurial activity.

In terms of endogenous motivation, the proliferation of the digital economy has accelerated the exchange of information and elevated the quality of information. This advancement mitigates the challenge of information asymmetry, equipping entrepreneurs with ample information for identifying and capitalising on market opportunities, thereby securing competitive edges for their organisations (Pernagallo, 2024). The application of big data technologies in streamlining business processes, establishing expedited channels, and reducing temporal and spatial barriers supports the entrepreneurial journey, enhancing entrepreneurs' confidence and optimism. Following these considerations, Hypothesis 1 is posited.

Hypothesis 1. . The expansion of the digital economy exerts a positive effect on urban entrepreneurial activity.

2.2. Enhancing urban entrepreneurship through talent dynamics: The catalytic role of the digital economy in human capital development

Entrepreneurship can enhance people's lives, notably by strengthening a country's educational capacities. Existing study has discovered that individuals or families have a significant impact on the expansion of entrepreneurial activities (Stam and Van de Ven, 2021). Talent, as carriers of knowledge and technology, constitutes the core resource directly engaged in production and operational activities, playing a pivotal role in accelerating innovation and identifying entrepreneurial opportunities. A significant body of scholarly work has highlighted the digital economy's capacity to refine the human resource framework. This article posits that the digital economy facilitates the expansion of both the supply and demand for high-caliber talent.

On the supply side, the evolution of the digital economy diversifies the channels for acquiring, transforming, and applying knowledge, introduces novel educational methodologies, broadens the scope of learning, enhances the equitable distribution of educational resources, and augments the efficiency and capabilities of individual learners. This, in turn, enriches the reservoir of human capital knowledge (Miethlich et al., 2020), transitions labour from simple to complex tasks, fosters the development of interdisciplinary high-end talents, enables opportunities for lifelong learning, and elevates the overall quality of the workforce.

On the demand side, the inherent social interactivity of the digital economy optimises the recruitment, development, management, and incentivisation of talent. As digitisation within industries and the digitalisation of industries themselves expand, there is an escalated demand for a sophisticated labour force, encompassing technical, innovative, and interdisciplinary talents (Frank, 2018). This trend encourages the concentration of professional human capital and knowledge dissemination, narrows the temporal and spatial divide, decreases the costs associated with information transactions, and fosters talent exchange and collaboration. Consequently, this enhances the efficiency of talent utilisation, conferring a competitive advantage to entrepreneurial ventures. Hence, Hypothesis 2 is proposed.

Hypothesis 2. The expansion of the digital economy exerts a positive impact on urban entrepreneurial activity through the enhancement of urban human capital.

3. Models and variables

3.1. Model setting

To test the hypothesis 1 stated above, this paper develops the following model (1) to investigate the impact of digital economic development on urban entrepreneurial activity.

$$\text{EntreAct}_{i,t} = a_0 + a_1 \text{DigEco}_{i,t} + a_2 \text{Controls}_{i,t} + \gamma_i + \mu_t + \varepsilon_{i,t} \tag{1}$$

Among them, "i" represents the urban individual, and "t" represents the year. "EntreAct" is the explained variable, that is, the urban entrepreneurial activity; "DigEco" is the core explanatory variable, that is, the comprehensive degree of digital economy growth; and "Controls" represent the urban economy, society, culture, and the policies described earlier. "γ" indicates the city individual control effect, "μ" indicates the year control effect, and "ε" represents the random disturbance term. If "a_1" is significantly more than 0, it indicates that hypothesis 1 is supported.

To evaluate hypothesis 2, this article refers to the testing method of Wen et al. (2004), introduces the intermediary variable "HumanCap" based on Eq. (1), and builds the following model.

$$\text{HumanCap}_{i,t} = \beta_0 + \beta_1 DigEco_{i,t} + \beta_2 \sum Controls_{i,t} + \gamma_i + \mu_t + \varepsilon_{i,t} \tag{2}$$

$$\text{EnterAct}_{i,t} = \lambda_0 + \lambda_1 DigEco_{i,t} + \lambda_2 HumanCap_{i,t} + \lambda_3 \sum Controls_{i,t} + \gamma_i + \mu_t + \varepsilon_{i,t} \tag{3}$$

In the intermediary effect model, if the coefficient of model (2) is significantly positive, it indicates that the development of the digital economy has a positive promoting effect on the level of urban human capital. If the coefficient of model (3) is significantly positive, it indicates that improving human capital levels will help increase urban entrepreneurial activity. Furthermore, if the coefficient of model (3) is significant, it is assumed that the level of human capital mediates the impact of digital economic development

Table 1
Comprehensive evaluation index system of digital economy.

First level	Second level	Third level	Measurement
Comprehensive level of digital economy	Digital infrastructure	Internet broadband users per 100 people	Number of Internet broadband access users (10,000 households) / End-of-year resident population (10,000) $\times$ 100
		Number of mobile phone users per 100 people	Number of mobile phone users (10,000 households) / End-of-year resident population (10,000) $\times$ 100

First level	Second level	Third level		Measurement
	Digital industry integration	Number of fixed-telephone users per 100 people		Number of fixed-telephone users (10,000 households) / End-of-year resident population (10,000) $\times$ 100
		Postal service income per capita		Postal business income (10,000) / End-of-year resident population (10,000)
		Telecom business income per capita		Telecom business income (10,000) / End-of-year resident population (10,000)
		Proportion of employees in information transmission, computer services and software industries		Number of employees in the information transmission, computer services and software industries (10,000) / Number of employees in the unit at the end of the year (10,000) $\times$ 100
		Proportion of employees in transportation, warehousing and postal industries		Number of employees in the transportation, warehousing and postal industries (10,000) / Number of employees in the unit at the end of the year (10,000) $\times$ 100
	Digital development environment	Digital inclusive financial development index		Digital financial inclusion index calculated by Peking University Digital Finance Research Center
		Government science and technology support		Science and technology expenditure / Local general public budget expenditure $\times$ 100
		Proportion of high-tech enterprises		Number of high-tech enterprises / Number of industrial enterprises above designated size $\times$ 100

on the enhancement of entrepreneurial activity. If the coefficient in model (3) is not significant, it indicates that human capital may play a complete mediating function.

3.2. Variable selection

3.2.1. Independent variables

Entrepreneurial activity serves as a critical metric for assessing the extent of entrepreneurship within a region, encapsulating the breadth, depth, and impact of a city's entrepreneurial endeavours. This parameter not only mirrors the quality of the city's innovation and entrepreneurial ecosystem but also its economic dynamism. Diverse methodologies have been employed in scholarly research to quantify urban entrepreneurial activity. These methods range from calculating the aggregate of registered private enterprises and individual proprietorships (Tang and Zhao, 2022), to estimating the prevalence of self-employment (Zhan and Li, 2022), utilising the "China Regional Innovation and Entrepreneurship Index" published by Peking University as an indicator of new enterprise formation (Sun and You, 2023), and applying web scraping technologies to compile data on new enterprise registrations from the Qichacha database (Bai et al., 2022).

Moreover, to address variances in population sizes across regions, three principal standardization techniques have been identified: demographic standardization, labour market standardization, and ecological research standardization. Drawing upon the foundational regression analysis conducted by Bai et al. (2022), this article adopts a measure of urban entrepreneurial activity based on the number of new firms per 1000 inhabitants within a given year, offering a refined approach to quantifying and comparing entrepreneurial dynamics across different urban settings.

3.2.2. Core explanatory variables

According to Zhao et al. (2020), digitalization involves converting traditional materials and information into digital formats. This process encompasses the use of digital technology, the processing and storage of digital data, and more. The digital economy, on the other hand, refers to economic activities that leverage digital technology for production, communication, transactions, and consumption. Therefore, digitization forms the foundation of the digital economy, enabling a variety of activities such as digital production, consumption, and transactions. This article builds on the research by Zhao et al. (2020), identifying three key dimensions: digital infrastructure, digital industry integration, and digital development environment, further subdivided into ten indicators. The paper employs the entropy method in the baseline regression to assess the development of the digital economy. Table 1 presents the unique measurement dimension system.

Table 2
Regression results.

ta	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	EntreAct	EntreAct	HumanCap	EntreAct	EntreAct	EntreAct
DigEco	0.8340***	0.3987***	0.0138***	0.2021***		0.3795***
	(0.016)	(0.024)	(0.002)	(0.022)		(0.026)
DigEco2					0.0368***	
					(0.002)	
HumanCap				0.9729***		
				(0.187)		
EcoDensity		0.0593***	0.0046***	0.1900***	0.0608***	0.0781***
		(0.004)	(0.001)	(0.009)	(0.004)	(0.004)
FinDev		0.0068***	0.0006**	0.0200***	0.0118***	0.0079***
		(0.001)	(0.000)	(0.002)	(0.001)	(0.002)
PopSize		-0.0100***	-0.0244***	0.1399***	-0.0125***	-0.0013
		(0.002)	(0.002)	(0.020)	(0.002)	(0.002)
Urban		0.1301***	0.0137***	0.1914***	0.0956***	0.1409***
		(0.014)	(0.002)	(0.021)	(0.015)	(0.015)
Edu		0.0040	-0.0044	-0.2494***	0.0257	-0.0358
		(0.037)	(0.006)	(0.055)	(0.038)	(0.039)
Open		0.1648**	0.0002	0.0320	0.2137***	0.1601**
		(0.078)	(0.011)	(0.109)	(0.079)	(0.080)
GovInter		-0.0010	-0.0124***	-0.0449	-0.0320*	0.0309*
		(0.016)	(0.003)	(0.035)	(0.016)	(0.018)
Constant	0.0201***	0.0291	0.1925***	-1.5790***	0.1056***	-0.0323
	(0.002)	(0.019)	(0.014)	(0.141)	(0.019)	(0.020)
Observations	3124	3124	3124	3124	3124	2750
	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	EntreAct	EntreAct	HumanCap	EntreAct	EntreAct	EntreAct
City FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
F test	0	0	0	0	0	0
F	2877	499.2	254.1	34.31	491.3	530.4

Notes: Standard errors are provided in parentheses. ***, ** and * represent the significance at the level of 1 %, 5 % and 10 % respectively.

3.2.3. Control variables

Economic density (EcoDensity) is defined as the ratio of a city's GDP to its urban area in that year. The financial development level (FinDev) is the ratio of the balance of deposits and loans of financial institutions at the end of the year to the city's GDP for that year. The population size (PopSize) represents the city's total registered population at the end of the year. The level of urbanization (Urban) refers to the proportion of urban residents in a city compared to the overall urban population that year. The level of education support (Edu) is the percentage of education spending in the city's public budget for the year. The amount of openness to the outside world (Open) is defined as the proportion of total foreign capital to the city's GDP that year. The degree of government intervention (GovInter) refers to the proportion of overall government spending to the city's GDP in that year. The data shown above is primarily from the "China Statistical Yearbook".

4. Analysis of empirical results

4.1. Benchmark regression results

Table 2 presents the findings of empirical research on the impact of digital economic development on urban entrepreneurial activity. Column (1) shows the estimation result without control variables. As can be observed, digital economic development has a considerable positive impact on urban entrepreneurial activity. The results in column (2) show that the impact coefficient of the digital economy on urban entrepreneurial activity is 0.3987, which is considerably positive at the 1 % level. This demonstrates that the expansion of the digital economy has a positive effect on urban entrepreneurial activity, which supports hypothesis 1. The main reasons are that, firstly, the development of the digital economy helps improve the innovation capabilities and competitiveness of enterprises, thereby stimulating entrepreneurial enthusiasm. Secondly, the digital economy lowers the threshold for entrepreneurship, allowing more people to participate in entrepreneurial activities. Finally, the digital economy may promote the optimization and upgrading of the industrial structure, providing more opportunities. Thus, the growth of the digital economy has a substantial positive effect on urban entrepreneurial activity. This finding has significant practical implications for China's digital economic growth plan and the implementation of associated legislative initiatives.

4.2. Mechanism test

This article uses the mediating effect test model to introduce the degree of urban human capital as a mediating variable. The results are presented in Table 2. When the level of human capital is utilized as an intermediary variable, the impact coefficient of digital economy development on human capital is 0.0138, which is significant at the 1 % level, as shown in column (3). According to the findings in column (4), the influence coefficients of the digital economy and human capital level on urban entrepreneurial activity are both significantly positive at the 1 % level, showing that human capital level serves as a partial intermediate. The digital economy has the potential to enhance the pool of high-quality talent on both the supply and demand sides. On the supply side, the development of the digital economy has diversified knowledge sources, transformation channels, and application scenarios. It has introduced new educational methods, broadened learning opportunities, promoted equitable distribution of educational resources, and improved individual learning abilities and efficiency. This increases the knowledge reserve of human capital, facilitates the transition from simple to complex labor, cultivates more cross-disciplinary high-end talent, enables lifelong learning, and raises the overall skill level of the workforce. On the demand side, the digital economy encourages high social interactivity and optimizes the processes of talent introduction, cultivation, management, and motivation. As industry digitization and digital industrialization expand the employment scope of technology-intensive manufacturing sectors, the demand for high-end labor, such as technical, innovative, and comprehensive talents, is rising. This promotes the professional concentration of human capital and the flow of knowledge, shortens distances in time and space, reduces information transaction costs, fosters talent exchanges and cooperation, improves talent utilization, and enhances entrepreneurial opportunities by leveraging the advantages of skilled human resources.

The expansion of the digital economy has brought about the popularization of information technology, allowing people to acquire knowledge and skills more conveniently, consequently boosting the level of human capital. A workforce with higher levels of human capital is more likely to create fresh entrepreneurial ideas and is better able to turn those ideas into actual entrepreneurial operations.

4.3. Robustness check

This article uses two robustness testing methods. The first way is to replace the method for measuring the core explanatory variable. The original core explanatory variable, DigEco, measures the level of development of the digital economy using the entropy technique. Thus, the principal component analysis method is used to recalculate the urban digital economy development level as a substitute. Second, given that municipalities and autonomous regions have special policies compared to other cities, this article excludes samples from the four municipalities of Beijing, Shanghai, Tianjin, and Chongqing, as well as the Guangxi Zhuang Autonomous Region, Inner Mongolia Autonomous Region, Ningxia Hui Autonomous Region, Tibet Autonomous Region, and Xinjiang Uygur Autonomous Region, to lessen the impact of special administrative status on this regression analysis. Columns 5 and 6 of Table 2 show that the findings are significantly positive, demonstrating the robustness of the prior regression results. The rise of the digital economy has definitely boosted urban entrepreneurial activity.

4.4. Heterogeneity analysis

Because of their geographical position and natural conditions, Chinese cities have varying resource endowments and economic development statuses, resulting in variances in the external repercussions of the digital economy. To determine whether there are differences in the extent to which the digital economy promotes urban entrepreneurial activity across regions, the entire sample was divided into four major regions: eastern, central, western, and northeastern, using the National Bureau of Statistics' classification method. The regression results are presented in Table 3.

Data suggest that the digital economy has a beneficial impact on entrepreneurial activity in four regions of China. Among them, the explanatory variable coefficient in the eastern region is 0.4687; the explanatory variable coefficients in the central and western regions are similar, 0.3156 and 0.3158, respectively; and the western region is 0.0851, all of which are 1 % significant. Comparatively, the facilitative impact of the digital economy on entrepreneurial activity is most pronounced in the eastern region, exhibits a moderate level in the central and western regions with comparable effects, and is weakest in the northeastern region. Several factors may elucidate this distribution: Primarily, the eastern region boasts the most advanced stage of digital economy development, underscored by its superior digital infrastructure, well-organized industrial chain, and robust digital economy talent cultivation programs. These elements collectively constitute a conducive environment for entrepreneurial ventures, thereby elevating the significance of the digital economy in bolstering entrepreneurial activities. Additionally, the eastern region benefits from enhanced resources and a more supportive legislative framework for innovation and entrepreneurship, which further amplifies the intensity of entrepreneurial endeavors. This gradient of digital economy effects across regions underscores the interplay between regional digital economy maturity, infrastructure, talent development, and policy environment in fostering entrepreneurial activity.

Secondly, in the central and western regions, where the digital economy is at a more formative stage, it nonetheless exhibits effects that bolster entrepreneurial activities, similar to those observed in more advanced areas. This phenomenon could be linked to the specific economic development levels, industrial structures, and phases of development characteristic of these regions. Despite the existence of a development gap in digital economic maturity compared to the eastern region, targeted strategic support aimed at elevating the central region and cultivating growth in the western territories is catalyzing the digital economy's momentum. Consequently, its influence on enhancing entrepreneurial activity is progressively becoming more apparent. As these regions navigate the expansion of their digital economies, they have strategically capitalized on policy incentives and resource endowments, focusing efforts on bridging gaps within the industrial chain to facilitate rapid advancements. Although faced with challenges such as less developed digital infrastructure and smaller talent reservoirs, the deployment of targeted policy support and efforts to streamline the industrial chain are beginning to offset these disadvantages. This approach has elevated the role of the digital economy in stimulating entrepreneurial activity to a moderate level, illustrating the significant potential of policy intervention and industrial chain improvement in activating regional entrepreneurial ecosystems.

Finally, the efficacy of the digital economy in stimulating entrepreneurial activity within the Northeast remains subdued, which can be ascribed to several factors including underdeveloped digital economic infrastructure, challenges in industrial restructuring, and talent exodus. The digital economy in the Northeast has not yet succeeded in forging a comprehensive industrial chain and ecosystem,

Table 3
Heterogeneity analysis.

VARIABLES	(Eastern) EntreAct	(Central) EntreAct	(Western) EntreAct	(Northeastern) EntreAct
DigEco	0.4687***	0.3156***	0.3158***	0.0851**
	(0.055)	(0.041)	(0.035)	(0.042)
EcoDensity	0.0241***	0.0556***	0.1109***	0.0883***
	(0.008)	(0.011)	(0.018)	(0.021)
FinDev	0.0019	-0.0022	0.0090***	0.0110***
	(0.004)	(0.003)	(0.002)	(0.002)
PopSize	-0.0270***	0.0082**	-0.0186***	0.0068*
	(0.006)	(0.004)	(0.003)	(0.004)
Urban	0.2909***	0.1938***	0.1084***	0.0306*
	(0.041)	(0.032)	(0.019)	(0.016)
Edu	-0.1959*	-0.1850***	-0.0462	-0.1433*
	(0.110)	(0.072)	(0.056)	(0.078)
Open	0.9564***	0.2322**	-0.7224***	-0.0917
	(0.215)	(0.108)	(0.191)	(0.104)
GovInter	-0.1382**	0.1182***	0.0320	0.0184
	(0.066)	(0.044)	(0.020)	(0.025)
Constant	0.1399***	-0.0790**	0.0803***	0.0196
	(0.053)	(0.035)	(0.025)	(0.030)
Observations	935	880	935	374
R-squared	0.584	0.428	0.537	0.400
City FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
F test	0	0	0	0
F	162.3	81.54	134.3	30.40

Notes: Standard errors are provided in parentheses. ***, ** and * represent the significance at the level of 1 %, 5 % and 10 % respectively

rendering the support for entrepreneurship somewhat inadequate. Moreover, relative to other regions, the Northeast exhibits certain shortcomings in policy support and talent development initiatives, leading to a marginal role of the digital economy in fostering entrepreneurial endeavors. Additionally, the Northeast represents China's most established industrial stronghold, dominated by traditional sectors. The incursion and evolution of the digital economy within such a context encounter substantial barriers, thereby exerting a limited influence on invigorating entrepreneurial activities. This scenario underscores the imperative need for targeted interventions aimed at enhancing digital infrastructure, innovating upon existing industrial compositions, and arresting the brain drain to unlock the potential of the digital economy as a driver of entrepreneurship in the Northeast.

5. Conclusions and implications

5.1. Conclusions

This paper elucidates several key findings regarding the relationship between the digital economy and urban entrepreneurial activity. Firstly, it establishes that the proliferation of the digital economy exerts a substantial positive influence on urban entrepreneurial endeavors. The widespread adoption and popularisation of digital technologies are fostering an environment where entrepreneurship and startups are flourishing in increasingly diverse locales. Secondly, it identifies the level of human capital as a critical mediating factor in the nexus between the digital economy's expansion and the augmentation of urban entrepreneurial activity. The evolution of the digital economy represents not only a paradigm of technological innovation but also a process of talent cultivation and acquisition. As the level of human capital within a city enhances, so does its capacity for entrepreneurial activity. Thirdly, the study finds that the digital economy's stimulatory impact on entrepreneurial activity is most significant in the eastern region, moderate in the central and western regions—with both exhibiting comparable levels of influence—and weakest in the northeastern region. This discrepancy is likely reflective of the eastern region's advanced economic development status, which facilitates a more fertile ground for the digital economy's impact on entrepreneurship. This comprehensive analysis underscores the multifaceted role of the digital economy in shaping urban entrepreneurial landscapes, highlighting the importance of human capital and regional disparities in economic development.

This study makes five significant contributions to the existing body of knowledge on the digital economy and its impact on urban entrepreneurial activity, highlighting the intricate dynamics between technological advancements and entrepreneurship across various regions in China. First, this study significantly enriches the academic landscape by offering a comprehensive empirical analysis of the digital economy's influence on urban entrepreneurial activities across China. Utilizing panel data from 284 prefecture-level cities over a decade, it uncovers a positive correlation between digital economic growth and the enhancement of urban entrepreneurship. This key finding not only bridges a gap in existing literature but also highlights the catalytic role of digitalization in spurring entrepreneurial ventures.

Second, a novel contribution of this research is its exploration of human capital as a mediating factor in the relationship between the digital economy and urban entrepreneurship. The study reveals the dual function of the digital economy in driving technological innovation and facilitating talent development. This insight expands our understanding of the mechanisms through which the digital economy impacts entrepreneurial activities, underscoring the critical role of human capital in this dynamic.

Third, the research delves into the regional disparities in the effects of the digital economy on entrepreneurship. By identifying the pronounced impact in the eastern region compared to the moderate and minimal impacts in the central, western, and northeastern regions, respectively, the study draws attention to the geographical nuances of digital economic development. This differentiation emphasizes the necessity for region-specific policies to exploit the digital economy's potential in fostering entrepreneurship, thus contributing valuable perspectives to the discourse on regional economic development and policy formulation.

Fourth, the study also provides actionable policy and strategic implications for various stakeholders, including government agencies, enterprises, and individuals. It advocates for targeted digital economy strategies tailored to local contexts, encourages enterprise-academia collaboration to promote innovation, and highlights the importance of entrepreneurial skill development among individuals. These recommendations offer practical insights for leveraging the digital economy to stimulate entrepreneurial growth.

Fifth, this research lays a foundation for future inquiries into the intricate relationships between the digital economy, human capital, and entrepreneurship. It calls for further investigation into the specific mechanisms at play and how these can be optimized across different regions and contexts. By so doing, the study not only contributes to academic discourse but also offers a strategic roadmap for policymakers, business leaders, and scholars interested in harnessing technology, talent, and innovation for entrepreneurial success.

Future studies could further explore the differential impact of the digital economy on urban entrepreneurship, aiming to establish a foundation for region-specific entrepreneurship strategies. Additionally, research could focus on identifying the key skills and attributes necessary for entrepreneurs in the digital economy, thereby providing a basis for entrepreneurship education and training programs. Furthermore, examining the international competitiveness of urban entrepreneurship within the digital economy context could offer a framework for enhancing digital economy entrepreneurship on a global scale.

5.2. Implications

The findings of this study suggest several important implications. Firstly, there is a pivotal role for governmental leadership in policy formulation. Governmental entities must acknowledge the profound influence of the digital economy on urban entrepreneurial activities, continuously monitor its evolving trends, and devise digital economic strategies that align with the unique attributes of their

cities. To propel the digital economy's growth, the government could introduce supportive policies, including tax incentives and financial support. Moreover, policies should be dynamically adjusted in response to the intensifying market competition and the saturation within the entrepreneurial landscape to ensure sustainable and robust development of the digital economy.

Secondly, there is a significant opportunity for enterprises to engage in collaboration with academic and research institutions, enhancing technological partnerships and fostering innovation. Such collaborations can facilitate the transformation of scientific and technological advancements into tangible productivity gains. Furthermore, enterprises should commit to talent development, offering internships and practical experiences that align with the company's requirements, thereby enhancing students' practical skills and laying a groundwork for their professional future. Additionally, companies should foster a culture of innovation among employees through effective incentive mechanisms and by providing platforms for innovation and entrepreneurship.

Lastly, on an individual level, there is a call for the cultivation of an innovative mindset and entrepreneurial vigilance. Individuals should remain attuned to industry trends, market dynamics, and technological advancements, capitalizing on emerging market opportunities and entrepreneurial ventures. Enhancing entrepreneurial competencies through participation in training programs and networking events is also crucial. Together, these implications highlight a collaborative ecosystem involving government, enterprises, and individuals, each playing a crucial role in nurturing the digital economy and its potential to drive urban entrepreneurial activity.

CRediT authorship contribution statement

Jia Liang: Data curation, Writing – original draft. **Anna Min DU:** Writing – review & editing, Validation, Supervision, Project administration, Conceptualization. **Yutong Song:** Writing – original draft, Methodology, Data curation. **Shucui Wang:** Investigation, Formal analysis, Conceptualization.

Declaration of Competing Interest

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

Data availability

Data will be made available on request.

Acknowledgement

References

Abbasi, K., Alam, A., Du, M.A., Huynh, T.L.D., 2021. FinTech, SME efficiency and national culture: evidence from OECD countries. Technol. Forecast. Soc. Change 163, 120454. https://doi.org/10.1016/j.techfore.2020.120454.

Alam, A., Du, A.M., Rahman, M., Yazdifar, H., Abbasi, K., 2022. SMEs respond to climate change: evidence from developing countries. Technol. Forecast. Soc. Change 185, 122087. https://doi.org/10.1016/j.techfore.2022.122087.

Anser, M.K., Khan, M.A., Awan, U., Batool, R., Zaman, K., Imran, M., Indrianti, Y., Khan, A., Bakar, Z.A., 2020. The role of technological innovation in a dynamic model of the environmental supply chain curve. Processes 8, 1033. https://doi.org/10.3390/pr8091033.

Ashraf, B.N., Goodell, J.W., 2022. COVID-19 social distancing measures and economic growth: distinguishing short-and long-term effects. Financ. Res. Lett. 47, 102639 https://doi.org/10.1016/j.frl.2021.102639.

Bai, J.H., Zhang, Y.X., 2022. Does innovation-driven policy increase entrepreneurial activity in cities–evidence from the national innovative city pilot policy. China Ind. Econ. 61–78. https://doi.org/10.19581/j.cnki.ciejournal.2022.06.016.

Ben Arfi, W., Hikkerova, L., 2021. Corporate entrepreneurship, product innovation, and knowledge conversion: the role of digital platforms. Small Bus. Econ. 56 (3), 1191–1204. https://doi.org/10.1007/s11187-019-00262-6.

Boubaker, S., Goodell, J.W., Kumar, S., Sureka, R., 2023. COVID-19 and finance scholarship: a systematic and bibliometric analysis. Int. Rev. Financ. Anal. 85, 102458 https://doi.org/10.1016/j.irfa.2022.102458.

Chen, Y., Xu, S., Lyulyov, O., Pimonenko, T., 2023. China's digital economy development: incentives and challenges. Technol. Econ. Dev. Econ. 29 (2), 518–538. https://doi.org/10.3846/tede.2022.18018.

Dabić, M., Vlačić, B., Paul, J., Dana, L.P., Sahasranamam, S., Glinka, B., 2020. Immigrant entrepreneurship: a review and research agenda. J. Bus. Res. 113, 25–38. https://doi.org/10.1016/j.jbusres.2020.03.013.

Du, Y.Z., Liu, Q.C., Cheng, J.Q., 2020. What kind of ecosystem for doing business will contribute to city-level high entrepreneurial activity? A research based on institutional configurations. J. Manag. World 36, 141–155. https://doi.org/10.19744/j.cnki.11-1235/f.2020.0143.

Frank, L., 2018. Computers and populism: Artificial intelligence, jobs, and politics in the near term. Oxf. Rev. Econ. Policy 34, 393–417. https://doi.org/10.1093/oxrep/gry004.

Gao, D., Li, G., Yu, J., 2022. Does digitization improve green total factor energy efficiency? Evidence from Chinese 213 cities. Energy 247, 123395. https://doi.org/10.1016/j.energy.2022.123395.

Goodell, J.W., 2020. COVID-19 and finance: agendas for future research. Financ. Res. Lett. 35, 101512 https://doi.org/10.1016/j.frl.2020.101512.

Grundstén, H., 2004. Entrepreneurial intentions and the entrepreneurial environment: A study of technology-based new venture creation. Helsinki University of Technology, Espoo, Finland.

Hao, X., Li, Y., Ren, S., Wu, H., Hao, Y., 2023. The role of digitalization on green economic growth: does industrial structure optimization and green innovation matter? J. Environ. Manag. 325, 116504 https://doi.org/10.1016/j.jenvman.2022.116504.

Hunjra, A.I., Zhao, S., Goodell, J.W., Liu, X., 2024. Digital economy policy and corporate low-carbon innovation: evidence from a quasi-natural experiment in China. Financ. Res. Lett. 60, 104910 https://doi.org/10.1016/j.frl.2023.104910.

Jiao, S.T., Sun, B.Q., 2021. Research on the influence of digital economy development on the upgrading of industrial structure in China. J. Ind. Technol. Econ. 40 (5), 146–154.

Kerr, S.P., Kerr, W.R., Nanda, R., 2022. House prices, home equity and entrepreneurship: evidence from US census micro data. J. Monet. Econ. 130, 103–119. https://doi.org/10.1016/j.jmoneco.2022.06.002.

Li, C., Li, D., Liang, Y., Wang, Z., 2024. Underdog entrepreneurship in the digital era: the effect of digital servitization on household entrepreneurship in China. Heliyon 10 (2). https://doi.org/10.1016/j.heliyon.2024.e24154.

Liu, Y., Chen, X.D., 2021. The effect of digital economy on industrial structure upgrade in China. Res. Econ. Manag. 42 (8), 15–29. https://doi.org/10.13502/j.cnki.issn1000-7636.2021.08.002.

Maraveas, C., Piromalis, D., Arvanitis, K.G., Bartzanas, T., Loukatos, D., 2022. Applications of IoT for optimized greenhouse environment and resources management. Comput. Electron. Agric. 198, 106993 https://doi.org/10.1016/j.compag.2022.106993.

Miethlich, B., Kvitka, S., Ermakova, M., Bozhko, L., Dvoryankin, O., Shemshurina, S., Kalyakina, I., 2020. Correlation of educational level, labor potential and digital economy development in Slovakian, Ukrainian and Russian experience.

Pan, W., Xie, T., Wang, Z., Ma, L., 2022. Digital economy: an innovation driver for total factor productivity. J. Bus. Res. 139, 303–311. https://doi.org/10.1016/j.jbusres.2021.09.061.

Pernagallo, G., 2024. Overcoming asymmetric information: a data-driven approach. Edward Elgar Publishing: Cheltenham, United Kingdom.

Schumpeter, J.A., 1934. The theory of economic development: an inquiry into profits, capital, credit, interest, and the business. Harvard University Press, Cambridge, England.

Stam, E., Van de Ven, A., 2021. Entrepreneurial ecosystem elements. Small Bus. Econ. 56 (2), 809–832. https://doi.org/10.1007/s11187-019-00270-6.

Sturgeon, T.J., 2021. Upgrading strategies for the digital economy. Glob. Strateg. J. 11 (1), 34–57. https://doi.org/10.1002/gsj.1364.

Su, J., Su, K., Wang, S., 2021. Does the digital economy promote industrial structural upgrading?—A test of mediating effects based on heterogeneous technological innovation. Sustainability 13 (18), 10105. https://doi.org/10.3390/su131810105.

Suhaimee, S., Zaidi, M.A.S., Ismail, M.A., Sulaiman, N., 2020. Social innovation and social entrepreneurship as mediators of the relationship between social capital and income level of b40 households. Int. J. Bus. Soc. 21 (2), 837–856. https://doi.org/10.33736/ijbs.3297.2020.

Sun, Y., You, X., 2023. Do digital inclusive finance, innovation, and entrepreneurship activities stimulate vitality of the urban economy? Empirical evidence from the Yangtze River Delta, China. Technol. Soc. 72, 102200 https://doi.org/10.1016/j.techsoc.2023.102200.

Tang, H.M., Zhao, J., 2022. Digital inclusive finance, entrepreneurial activity and inclusive growth. J. Tech. Econ. Manag. 12, 74–80.

Urbano, D., Audretsch, D., Aparicio, S., Noguera, M., 2020. Does entrepreneurial activity matter for economic growth in developing countries? The role of the institutional environment. Int. Entrep. Manag. J. 16 (3), 1065–1099. https://doi.org/10.1007/s11365-019-00621-5.

Wahyono, T., Imaningsih, E.S., Permana, D., Priyono, P., Arijanto, A., Soelton, M., 2022. Significant and substantial opportunity in family entrepreneurship. ICCD 4 (1), 539–543. https://doi.org/10.33068/iccd.v4i1.518.

Wen, Z.L., Chang, L., Hau, K.T., Liu, H.Y., 2004. Testing and application of the mediating effects. Acta Psychol. Sin. 36 (05), 614–620.

Yang, Q., Ma, H., Wang, Y., Lin, L., 2022. Research on the influence mechanism of the digital economy on regional sustainable development. Procedia Comput. Sci. 202, 178–183. https://doi.org/10.1016/j.procs.2022.04.025.

Yoo, Y., Henfridsson, O., Lyytinen, K., 2010. Research commentary—the new organizing logic of digital innovation: An agenda for information systems research. Inf. Syst. Res. 21, 724–735. https://doi.org/10.1287/isre.1100.0322.

Zhan, Y., Li, S., 2022. Smart city construction, entrepreneurial vitality and high-quality economic development: analysis based on the GTFP perspective. J. Financ. Econ. 48, 4–18. https://doi.org/10.16538/j.cnki.jfe.20211015.101.

Zhang, W., Zhao, S., Wan, X., Yao, Y., 2021. Study on the effect of digital economy on high-quality economic development in China. PloS One 16 (9), e0257365. https://doi.org/10.1371/journal.pone.0257365.

Zhao, T., Zhang, Z., Liang, S.K., 2020. Digital economy, entrepreneurship, and high-quality economic development: empirical evidence from urban China. Front. Econ. China 17 (3), 393. https://doi.org/10.3868/s060-015-022-0015-6.