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ENHANCING ECONOMIC RESILIENCE THROUGH DIGITAL INNOVATION: THE ROLE OF FINANCIAL INCLUSION AND INFRASTRUCTURE IN URBAN CHINA

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Abstract. The digital revolution has redefined financial inclusion, significantly enhancing the capacity of urban economies to withstand and recover from economic shocks. Using panel data from 285 Chinese cities between 2011 and 2020, this study examines the role of digital innovation in promoting economic Resilience, drawing on econometric models and Martin and Sunley's conceptual framework of Resilience. Our findings reveal that the Digital Innovation Framework (DIF) enhances economic Resilience by driving financial inclusion, technological adoption, and infrastructure development. However, regional disparities persist, with the eastern and central regions benefiting more than the western and southern regions, which have lower economic scales. The quality of corporate operations and the stability of financial markets further amplify the positive effects of digital finance on Resilience. Mediating factors, including the adoption of digital technologies and household expenditure levels, significantly strengthen the impact of DIF on urban Resilience. This study highlights the dual role of digital finance as both a catalyst for innovation and a tool for promoting equitable economic growth. The findings underscore the importance of region-specific policies in bridging development gaps, particularly in less developed areas. Policymakers are encouraged to promote inclusive digital strategies that foster fairer growth while leveraging the transformative potential of DIF.

Keywords: Digital Innovation Framework (DIF), economic resilience, financial inclusion, urban development, digital infrastructure, regional disparities, technological adoption.

JEL Classification: G00, O10.

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1. Introduction

Resilience is the most crucial feature that regions and countries must exhibit to withstand and recover from economic shocks. It encompasses anticipating, preparing for, responding to, and recovering from economic disturbances. Recently, this subject has garnered considerable interest due to the increasing frequency and severity of global financial problems, including financial crises, natural disasters (e.g., earthquakes), and epidemics (Xiuzhen et al., 2022). In 2022, the International Monetary Fund (IMF) predicted that global economic growth would decline from 3.5% in 2022 to 3.0% in 2023 and further to 2.9% by 2024, underscoring the need to build robust economic resilience measures. This urgency calls for immediate action to promote economic Resilience. Economic diversification is the principal approach to enhancing

economic Resilience. Economies heavily reliant on a single primary industry are particularly vulnerable to economic shocks. However, they can mitigate risks and lay a stronger foundation for their economies by promoting the growth of various sectors such as healthcare, technology, tourism, and manufacturing. This form of diversification helps manage risks and leads to sustainable economic growth by maintaining a well-balanced economic structure that withstands adverse effects (Li & Umair, 2023b). Technological progress, as well as the development of infrastructure, are essential in improving economic hardiness. Up-to-date infrastructure ensures better communication, transportation, and logistics, which are vital for the smooth operation of businesses during emergencies. Another beneficial effect is investing in cutting-edge technologies, such as AI, its decentralized version of blockchain, and renewable energy, which can foster innovativeness and flexibility, enabling regions to become pioneers in emerging industries and prepare for unexpected challenges (Zhang & Umair, 2023; Feng et al., 2024).

Economic Resilience is often employed in two distinct yet overlapping ways (Hallegatte, 2014). It can be roughly characterized as the capacity of an economy to withstand, recover from, and rebuild after an economic downturn (adapted from Hallegatte, 2014). Simultaneously, it often denotes the financial Resilience of particular families or enterprises, as well as their capacity to withstand or recuperate from a shock and adjust to evolving economic conditions in the larger economy. This pertains to the distributional impacts of a shock (who is impacted and in what manner), the susceptibility of people to the shock, and the characteristics of existing welfare systems. The two notions are interdependent, since each may rely on and affect the other.

The core of this perspective is the concept that Resilience involves reducing overall welfare losses. Increased economic Resilience is associated with fewer economic losses resulting from a shock over time. An alternate notion is to consider how Resilience may enhance welfare benefits. This notion underpins much of development economics, which posits that enhancing the monetary assets of individuals and groups would bolster their Resilience against financial storms.

The notion of economic Resilience has two fundamental elements. The primary aspect is the capacity of a family, enterprise, or economy to endure or assimilate a financial shock. The other element is more dynamic, referring to the capacity of families, companies, or the broader economy to adjust to evolving conditions and enhance their Resilience against potential crises.

$$X = \left[x_{ij}\right] = \begin{bmatrix} x_{11} & \cdots & x_{1m} \\ \vdots & \ddots & \vdots \\ x_{n1} & \cdots & x_{nm} \end{bmatrix} \left(i = 1,2\ldots,n,\ j = 1,2,\ldots,m\right). \tag{1}$$

When dealing with dimensional manipulation, the following equation is used:

$$\begin{cases} z_{ij} = \dfrac{\left(x_{ij} - \min x_j\right)}{\left(\max x_j - \min x_j\right)} & \text{Positive Indicators} \\ z_{ij} = \dfrac{\left(\max x_j - x_{ij}\right)}{\left(\max x_j - \min x_j\right)} & \text{Negative Indicators} \\ x'_{kij} = -\left| x_{kij} - \overline{x_{kij}} \right| & \text{Moderate Indicators} \end{cases}. \tag{2}$$

The measure is first generally normalized if it is mild. Then the outcomes of the consistently normalized indicator are normalized using the positive indicator, where represents the mean of the data points.

$$p_{ij} = \frac{z_{ij}}{\sum_{i=1}^{n} z_{ij}}; \tag{3}$$

$$e_j = -k\sum_{i=1}^{n} p_{ij} \ln p_{ij}, \text{where } k = \frac{1}{\ln n}; \tag{4}$$

$$d_j = 1 - e_j; \tag{5}$$

$$w_j = \frac{d_j}{\sum_{j=1}^{m} d_j}. \tag{6}$$

Use the TOPSIS approach to determine each measure's significant capability and create an assessment array:

$$Z = \left[z_{ij}\right] = \begin{bmatrix} z_{11} & \cdots & z_{1m} \\ \vdots & \ddots & \vdots \\ z_{n1} & \cdots & z_{nm} \end{bmatrix} \left(i = 1,2\ldots,n,\, j = 1,2,\ldots,m\right), \text{ where } z_{ij} = y_{ij} \times w_j. \tag{7}$$

Determine the best and most catastrophic scenarios:

$$z_{ij}^{+} = \max_{n,m}\left(z_1^{+}, z_2^{+}, \ldots, z_m^{+}\right), z_{ij}^{-} = \min_{n,m}\left(z_1^{-}, z_2^{-}, \ldots, z_m^{-}\right). \tag{8}$$

Find the minimum and maximum distances between the assessment goal, the best, and the worst solutions:

$$D_i^{+} = \sqrt{\sum_j \left(z_{ij} - z_j^{+}\right)^2},\ D_i^{-} = \sqrt{\sum_j \left(z_{ij} - z_j^{-}\right)^2}. \tag{9}$$

Find out how close the assessment objective is to the ideal range:

$$C_i = \frac{D_i^{-}}{D_i^{+} + D_i^{-}}. \tag{10}$$

The evaluation objective becomes closer to the optimal as the size increases, which is how selection is ultimately determined.

Previous studies have investigated economic Resilience. Most researchers have focused on the impacts of economic shocks and the steps taken in the immediate recovery. However, many studies that examine longer-term measures for developing such resistance are still needed in the literature, especially in developing countries (Li & Umair, 2023a). Moreover, although it is recognized that DIF can enhance economic Resilience, further investigation is needed to explore its broader consequences and potential disadvantages. This research aims to fill these gaps by examining the mechanisms underlying DIF and its impact on economic Resilience. It examines the positive effects and possible risks associated with implementing a DIF program, providing a balanced view on its role in maintaining economic stability (Cui et al., 2023). This study examines the interaction between DIF and technological advancements, policies, and human resource development. Therefore, it outlines how countries can build their capacity for economic sustainability in the face of growing changes in the global environment.

To address these literature gaps more distinctly, this study provides several unique contributions to the field of digital finance and urban economic Resilience. First, while prior studies have primarily examined either the macroeconomic implications of digital finance or its impact on specific sectors such as SMEs or household consumption, this research is among the first to systematically integrate multiple dimensions – financial inclusion, digital infrastructure, technological innovation, and institutional moderators – into a unified framework of economic Resilience. This multidimensional approach provides a more comprehensive understanding of how the Digital Innovation Framework (DIF) operates, encompassing both direct effects and mediated pathways. Second, unlike most prior studies, which focused on either national-level analysis or short-term crisis recovery, this study employs a longitudinal panel dataset spanning a decade (2011–2020) across 285 Chinese cities, enabling robust econometric testing of Resilience not only during shocks but also through reorientation and renewal phases, following Martin and Sunley's resilience typology. Third, this research introduces a novel empirical strategy by incorporating nighttime light data as a robustness measure of economic activity**,** providing a high-resolution proxy for subnational economic vibrancy that captures the dynamics of informal and digital economies often overlooked by traditional GDP statistics. Fourth, by conducting a heterogeneity analysis across regions and economic scales**,** the study reveals significant disparities in DIF effectiveness, emphasizing the contextual dependency of digital transformation benefits – an aspect often overlooked in generalized national studies. Finally, this study is one of the few to empirically test both moderating (business environment, financial market structure) and mediating (innovation capacity, household consumption) channels, offering nuanced insights into the mechanisms through which digital finance influences economic Resilience in urban China. These contributions collectively position this research as a meaningful advancement in understanding the interplay between digital innovation and Resilience, especially in the context of rapidly evolving urban economies in developing countries.

The study is structured as follows: the Introduction provides an overview of the topic, highlights research gaps, outlines the study's contribution, and states the objectives; the Literature Review summarizes previous studies on DIF and economic Resilience, identifying key findings and gaps; the Theoretical Framework develops a conceptual model explaining the relationship between DIF and financial Resilience; the Methodology describes the research design, data collection methods, and analytical techniques; the Results and Discussion present empirical findings and discuss their implications; and the Conclusion and Policy Recommendations summarize the main findings, discuss policy implications, and suggest areas for future research.

2. Literature review and hypothesis development

Digital Inclusion Financing (DIF) has emerged as a transformative model in the financial sector, with profound implications for economic Resilience and development, particularly in emerging economies. The elimination of geographical barriers through DIF has facilitated greater access to financial products, thereby boosting household consumption and fostering stronger economic frameworks. Mohsin et al. (2023) observe that DIF has notably enhanced

consumption levels, while Li et al. (2023) emphasize its role in sustaining long-term economic growth. However, DIF's increased accessibility to credit has raised concerns about over-indebtedness among households, underscoring the importance of responsible borrowing practices to ensure financial stability (Yu et al., 2024)

DIF plays a crucial role in supporting Small and Medium-sized Enterprises (SMEs), which are pivotal to innovation, job creation, and economic growth. According to Dilanchiev et al. (2024), DIF reduces market entry barriers for SMEs, providing them with the liquidity necessary to expand their operations and enhance competitiveness. Furthermore, Oyewo et al. 2024) argue that SMEs leveraging DIF contribute significantly to job creation and sustainable economic growth. However, challenges remain, as improper credit utilization can lead SMEs into risky financial behaviors, potentially undermining their long-term viability (Kuhn et al., 2021). For larger corporations, DIF mitigates the risks associated with shadow banking by improving capital allocation and reducing systemic vulnerabilities. Palansooriya et al. (2020) highlight that DIF ensures more efficient financial risk management within large firms. Nonetheless, Raheem et al. (2018) caution that the relationship between DIF and corporate financial efficiency is complex, necessitating a balanced approach to minimize risks while maintaining operational effectiveness. The concept of regional economic Resilience is intricately linked to DIF, as it encompasses the capacity of economies to adapt, recover, and grow in the face of external shocks. Gulema and Roba (2021) emphasize that diversified industrial structures and economic openness are critical factors in Resilience. Additionally, Ong (2023) emphasizes the importance of targeted government interventions in enhancing regional adaptability. The role of technological innovation cannot be overstated; as Sweeney (2023) notes, advancements in digital technology have become instrumental in enabling economies to recover and thrive in the face of disruptions.

DIF's integration with digital technologies has further strengthened its role in promoting economic Resilience. Li et al. (2024) highlights how SMEs leveraging digital platforms were able to stabilize supply chains and maintain operations during the COVID-19 pandemic. Similarly, Ahmad et al. (2024) demonstrate that the depth of digital adoption significantly enhances supply chain stability and business continuity (van Lanen et al., 2021). To further illustrate the role of digital platforms in urban Resilience, it is worth noting their effectiveness in facilitating communication, tracking crises, and managing community resources. Regional financial Resilience is influenced by various factors that determine whether a region can withstand and recover from external shocks. This has led to multiple scientific studies examining the extent to which economic openness, industrial structure, government intervention, and technological innovation influence the dynamics of Resilience. For instance, economies more open to global trade have vulnerabilities and opportunities for receiving essential foreign resources and technology necessary for responding effectively to disturbances. Debates around industry structure differ; while some propose diversification in unrelated industries, others argue for interdependencies between sectors. Governments should intervene because tailored strategies based on regional contexts are necessary to achieve inclusive economic Resilience within a region and thus become effective in the long run. Sometimes, limited aid fosters Resilience, while at other times, the government needs to be proactive in making connections and supporting economic adjustments. National institutions and governance

determine how regions respond to crises that occur during periods of economic decline and subsequent recovery. Furthermore, the connection between technological advancements and recovery capabilities highlights the crucial importance of promoting creative mindsets and innovation to enhance flexibility and competitiveness in a rapidly changing global environment (Frans & Liu, 2024). These insights reveal the complexity of regional economic resilience, which requires comprehensive strategies that integrate various components to bolster territories against uncertainties and promote sustainable growth. By adopting a holistic approach that involves tailored interventions by governments, strong institutional frameworks, and an emphasis on technology platforms to foster innovation, areas can easily navigate the maze of economic shocks and create resilient foundations for long-term prosperity (Lui et al., 2020).

Despite these advances, critical gaps remain in the literature, particularly concerning the relationship between DIF and economic resilience in developing regions. Ahmed et al. (2022) argue that empirical studies focusing on regional contexts are necessary to understand DIFDIF better. This study aims to address these gaps by examining the effects of DIF in China, a leading developing economy, through a comprehensive panel data analysis of 285 prefecture-level cities. To establish a robust foundation for this inquiry, the proposed hypotheses draw from the multifaceted aspects of DIF's contributions and limitations, considering its direct and indirect impacts on urban economic resilience.

3. Theoretical framework

Considering that the development of a growing elderly population cannot be reversed, government entities can use macroeconomic measures to influence this trend through various financial, regulatory, and other techniques. Acting on the rational man's hypothesis, the administration will prioritize assets to maximize efficiency, which will have both an adverse substitution effect and a beneficial income effect; these two effects will interact (Liu & Hao, 2018).

China benefits from an enormous numerical advantage as it begins its economic development. Organizations in China that rely on human labor are well served by the country's large and growing population. Simultaneously, as a result of disparities in urbanization and economic growth, disadvantaged regions send their labor forces to more advanced areas, completing the transportation and interchange of human capital and creating a significant demographic impact (Li et al., 2020). From the perspective of individual homes, the influx of labour will increase local economic Consumption by bringing a large amount of consumable goods to the region that receives them. Considered from the perspective of the regional financial system, an influx of workers means there are more people available to do production tasks, which can boost effectiveness.

On the other hand, an increasing population necessitates improved public services, which in turn encourage the entry of new businesses and diversify the local economic framework. From the government's perspective, diverse businesses generate more tax revenue, which enables the federal government to invest in additional initiatives and make the economy more resilient (Qi et al., 2025). Subsequently, examining the labour supply side, it is clear that a larger labour force is needed to boost economic Resilience. However, it is essential to

note that the standard of living for the public is currently low, and the majority of workers are performing menial tasks. As a result, industries that rely on manual labor continue to dominate, and the government is likely to invest in these industries due to financial issues (Awosusi et al., 2022).

Since the reforms and opening up, China's marketization has progressed rapidly, and its economic growth stages have undergone significant shifts, thereby elevating the industrial level. The rapid growth and advancement of industry have altered labour demand in China, shifting from a need for straightforward labour to a requirement for a diverse range of skills. Concurrently, the ageing population exacerbates this issue, leading to the gradual erosion of the demographic surplus. The ongoing ageing trend is intensifying, resulting in a decrease in the percentage of the workforce, which will subsequently lead to a drop in labour supply and a corresponding reduction in labour expenses. The increase has resulted in a disparity between labour demand and availability, exacerbating the existing gap and further undermining the institutional framework, profitability, and self-sustainable capacity of the sector, thereby hindering the establishment of various business enterprises within the relevant sectors (Chudik & Pesaran, 2015). When the self-reliance of pertinent organizations diminishes, they risk being insufficient to sustain manufacturing afterwards, thus jeopardising their operational continuity (Yan et al., 2024). This may lead to a liquidity recession, which would adversely affect the local financial system's advancement to varying extents. Simultaneously, demographic ageing will impose an additional cost on government retirement benefits and escalate welfare expenditures; however, both regional and centralised governments possess constrained financial capabilities. Consequently, the resultant financial outlay will detract from investments in educational institutions, technological development, and other areas vital for the sustainability of the economy (Markova et al., 2022). In essence, demographic ageing will, in the short term, induce a process of substitution that undermines the economy's sustainability and constrains its economic resilience (Alola et al., 2019).

As China's economy continues to grow, the level of resources is consistently improving, resulting in a factor investment framework characterized by an increasing abundance of financial assets and a diminishing availability of labor. Consequently, the optimal manufacturing system is transitioning from a conventional agriculture-based model to an industry-centered paradigm, with certain regions also moving towards the hospitality and advanced technology sectors (Allen, 1988). This evolution will foster an economic system with distinctive advantages that align with demographic ageing and address the requirements of the growing elderly population. The ageing population necessitates addressing new wants and requirements, resulting in a further decline in the demographic dividend, while the demographic qualitative dividends are on the rise (Li et al., 2024). The enhancement of human capital will positively influence the advancement of technology, fostering an environment favourable to substantial economic growth through expenditure and investment, thereby generating opportunities for the populace and augmenting urban Resilience and economic recovery (Cheng et al., 2018). Moreover, as a result of the ongoing optimisation of industrial structure, the foundation aligns with the financial basis, with the federal government directing resources towards industries exhibiting potential advantageous characteristics and persistently alleviating the constraints of both soft and hard facilities that hinder growth in industry, thereby

promoting the development of resource-dependent cities (Baloch et al., 2021) which will additionally improve the economy's durability. Consequently, the following theoretical assumptions are posited.

H1: *The relationship between population ageing and financial stability is inversely correlated; as population ageing increases, economic Resilience diminishes, and vice versa.*

H2: *The phase of financial growth moderates the nonlinear relationship between population longevity and economic Resilience. Demographic ageing and macroeconomic Resilience exhibit a positive, "U"-shaped relationship, initially decreasing before subsequently increasing.*

4. Empirical model and data

This study's empirical model and data aim to explore the impact of Digital Inclusion Financing (DIF) on urban economic resilience, with a focus on China's diverse regional contexts. The model seeks to elucidate the complex interactions between technological infrastructure and financial stability by integrating theoretical foundations with empirical analysis. The primary explanatory variable is the index for digitally inclusive economic growth, which is analyzed in conjunction with foreign investment, government spending, internet growth, and educational resources. The study employs a comprehensive panel data analysis of 285 prefecture-level cities, utilizing the Peking University Digital Financial Inclusion Index to measure DIF (Chen et al., 2023). This approach offers policymakers and stakeholders valuable insights for developing strategies that promote sustainable economic growth and Resilience in an increasingly digital world. By examining the transmission mechanisms and moderating effects of external market conditions, this research contributes to a deeper understanding of how DIF can enhance regional economic stability and adaptability.

4.1. Model specification

4.1.1. Baseline panel regression model

This study builds upon the financial health structure proposed by previous research while considering the established relationship between Digital Infrastructure Development (DIF) and variables such as economic growth, shared prosperity, and social wealth enhancement (Hofmann & Jaeger-Erben, 2020). The investigation aims to impartially analyze the potential impact of DIF on bolstering economic Resilience by employing a comprehensive model that integrates theoretical foundations with empirical analysis. This Methodology provides a deeper understanding of the complex interactions between technological infrastructure and financial stability, offering valuable insights for policymakers and stakeholders to develop strategies that promote sustainable economic growth and Resilience in an increasingly digital world. To estimate the primary relationship between DIF and financial Resilience, the study employs a fixed-effects panel regression model that accounts for unobservable time-invariant city-specific characteristics and common time shocks. The base model is specified as:

$$Resilience_{it} = \alpha_0 + \alpha_1 DIF_{it} + \alpha_2 FDI_{it} + \alpha_3 FoInvest_{it} + \alpha_4 Govern_{it} + \alpha_5 Internet_{it} + \alpha_6 Edu_{it} + \alpha_7 ISA_{it} + \eta_i + \mu_t + \varepsilon_{it}, \quad (11)$$

where the years and cities are denoted by t and i, respectively, it represents the Resilience of the regional economy. The primary explanatory variable is the index for digitally inclusive financial growth, referred to as DIF_{it}. DIF_{it} indicates the fixed asset level of investment. $FoInvest_{it}$ is an acronym for foreign investment level. $Govern_{it}$ relates to government spending. The internet shows the state of growth $Internet_{it}$; education is a symbol of human resources. It is an advanced industrial framework. Moreover, the constant term is represented by α_0, the error term by ε_{it}, and the parameters that need to be estimated are α_1 through α_7. The terms "individual effect" and "time effect", respectively, are represented by η_i and μ_t.

4.1.2. Heterogeneity analysis

To investigate whether the impact of Digital Innovation Framework (DIF) on economic Resilience differs across regions and economic scales, we conducted a comprehensive heterogeneity analysis using subgroup fixed-effects panel regressions. Cities were classified into three macro-regions – Eastern, Central, and Western – based on the official regional division system of the National Bureau of Statistics of China. This classification reflects significant socio-economic and institutional differences across provinces and is widely adopted in regional economic studies (Perekrest & Kurzenev, 2022). Additionally, cities were further divided into "high" and "low" economic scale groups using the median value of per capita GDP across the sample period as the threshold.

For each group, the baseline panel regression model was re-estimated independently, allowing for comparison of coefficient magnitudes and significance levels. To formally test whether the differences in coefficients across regions or scales were statistically significant, Chow tests and interaction term models (e.g., DIF × Region dummy) were employed as robustness checks. These techniques help determine whether observed differences in DIF's impact across regions are merely descriptive or reflect statistically significant variation. This analytical strategy supports a more precise identification of region-specific dynamics and validates Hypothesis 1 and Hypothesis 4 regarding spatial disparities in DIF effectiveness.

4.1.3. Moderation analysis: interaction term model

The interaction terms between DIF and the urban outside market setting, as outlined in Eq. (1), are included to investigate the mitigating role of the outside market setting in DIF's influence on urban financial resilience. To test the moderating role of the external market environment (e.g., financial market conditions, business climate), interaction terms are incorporated into the panel regression:

$$Resilience_{it} = \beta_0 + \beta_1 DIF_{it} + \beta_2 Moderator_{it} + \beta_3 DIF_{it} \times Moderator_{it} + \beta_4 FDI_{it} + \beta_5 FoInvest_{it} + \beta_6 Govern_{it} + \beta_7 Internet_{it} + \beta_8 Edu_{it} + \beta_9 ISA_{it} + \eta_i + \mu_t + \varepsilon_{it}, \quad (12)$$

where, $Moderator_{it}$ is the proxy variable for the economic environment, the interaction term between the financial ecosystem and DIF is $DIF_{it} \times Moderator_{it}$. It is anticipated that the relationship between the terms' coefficient β_3 in Eq. (2) will be positive.

It is essential to comprehend the intermediary effect models and their applications and limitations to examine the transmission mechanism of DIF on urban economic prosperity. Nonetheless, frameworks such as those advanced by Baron and Kenny (1986), as well as

the method proposed by Adranyi et al. (2023), are popular among finance researchers, who question the efficacy of these tools for statistical purposes, as raised by Torjesen (2024). For instance, a model may be more appropriate for psychology than economics. In other words, many economic challenges require tailor-made strategies to properly investigate complex trends such as variable bias and unaccounted-for trajectory channels. Therefore, this study explores the transmission mechanism with an appreciation of its complexities using an integrative model that brings together theoretical and empirical perspectives to give insights into how DIF affects urban economic prosperity.

More precisely, assuming that the coefficient α_1 in the Equation.

$$Mediator_{it} = \omega_0 + \omega_1 DIF_{it} + \omega_2 FDI_{it} + \omega_3 FoInvest_{it} + \omega_4 Govern_{it} + \omega_5 Internet_{it} + \omega_6 Edu_{it} + \omega_7 ISA_{it} + \eta_i + \mu_t + \varepsilon_{it}. \quad (13)$$

The $Moderator_{it}$ variable, which is the mechanism via which DIF might impact urban financial Resilience, is the mediator. If the values of α_1 and ω_1 are both significant and positive, it suggests that DIF can impact regional financial stability by exhibiting an advantageous effect on mediating variables.

To examine the mediation mechanisms through which DIF influences economic Resilience – specifically via innovation capacity and household consumption potential – we followed the classical Baron and Kenny (1986) three-step approach for causal mediation within a panel data structure, supported by Sobel tests for indirect effects. The procedure involved estimating three fixed-effects regression models:

1. $Mediator_{it} = \omega_0 + \omega_1 DIF_{it} + Controls + \eta_i + \mu_t + \varepsilon_{it}$;
2. $Resilience_{it} = \alpha_0 + \alpha_1 Mediator_{it} + Controls + \eta_i + \mu_t + \varepsilon_{it}$;
3. $Resilience_{it} = \beta_0 + \beta_1 DIF_{it} + \beta_2 Mediator_{it} + Controls + \eta_i + \mu_t + \varepsilon_{it}$.

A mediating effect is confirmed if DIF significantly predicts the mediator (ω_1 significant), the mediator significantly predicts Resilience (α_1 significant), and the direct impact of DIF on Resilience (β_1) decreases in magnitude upon including the mediator. This approach is applied separately for Innovation (using the Regional Innovation and Entrepreneurship Index) and Consumption (using projected market demand values) to test Hypotheses 5 and 6.

4.2. Variable measure and data sources

4.2.1. Dependent variable

This study presents a comprehensive approach for assessing economic Resilience, with a specific focus on China's economic development from 2011 to 2020. This method provides a comprehensive perspective on analyzing the dynamics of regional economies in response to various shocks and growth stages, by defining four key elements of Resilience: opposition, recovery, reorientation, and renewal. Counterfactual analysis is at the core of this Methodology, allowing researchers to measure deviations in economic indicators from expected "normal" conditions. Using national-level statistics on economic output and job changes as proxies for hypothetical scenarios, researchers establish a robust foundation for comparison, revealing distinct resilience characteristics across China's regions (Majeed et al., 2023). This approach

offers valuable insights into the key factors that contribute to economic Resilience over time, leading to notable changes in growth rates, challenges, and policy interventions. Policymakers and practitioners will benefit from this model by understanding the efficacy of past interventions, regional vulnerabilities, and strategies for building more flexible and robust economies to face future uncertainties. Therefore, applying Martin and Sunley's framework with empirical data and methodological advances is a significant step forward in understanding economic Resilience and informing evidence-based policymaking in China and beyond (Grinberga-Zalite & Zvirbule, 2022).

$$Resilience_i = \frac{\left(employ_i^t - employ_i^{t-k}\right) / employ_i^{t-k} - \left(employ_r^t - employ_r^{t-k}\right) / employ_r^{t-k}}{\left|\left(employ_r^t - employ_r^{t-k}\right) / employ_r^{t-k}\right|}. \quad (14)$$

The variables $employ_i^{t-k}$ and $employ_i^t$ represent the number of employees in city I at the start and end of period t, respectively. Similarly, $employ_r^{t-k}$ and $employ_r^t$ represent the total number of workers nationally at the beginning and end of period t, respectively. The $Resilience_i$ value exhibits periodic fluctuations near zero. A positive value of $Resilience_i$ suggests that financial operations in the city i are superior to the national economy's average. The economic Resilience of City i is directly proportional to the value of Resiliency i. A higher value of $Resilience_i$ indicates better financial Resilience relative to the nation, while a lower value indicates the opposite. The China Urban Statistics Yearbook is the source of the relevant statistics.

4.2.2. Independent variable

China's Digital Financial Inclusion (DFI) evaluation is constantly evolving, accompanied by a growing number of indicators and research that offer diverse perspectives on the country's progress in this regard. In terms of previous studies, for example, determinants concerning ATMs and commercial bank penetration over time have helped present perspectives and identify their boundaries, such as outdated data and limited geographic coverage areas. These weaknesses have necessitated the design of more inclusive measurement instruments. Productive joint undertakings have been undertaken between scholars and industrialists, leading to innovative creations such as the Peking University Digital Financial Inclusion Index (Xia et al., 2023).

Collaborative efforts between educationalists and industry colleagues have significantly advanced digital financial inclusion assessment in China, thereby addressing the previous limitations of data currency and its geographic scope. The Digital Finance Research Centre at Peking University collaborated with the Ant Group Research Institute to develop the Peking University Digital Financial Inclusion Index, aiming to track improvements in this area. This index can evaluate DFI from various angles, such as coverage, usage, and digitalization, successfully filling earlier gaps. By incorporating prior frameworks, such as those suggested, and new insights regarding digital finance, the Peking University index represents a significant advance in evaluating DFI in China.

The acceptance of Peking University's Digital Financial Inclusion Index as a measure of Digital Financial Inclusion (DFI) among 285 Chinese cities highlights its trustworthiness and

applicability in academic and official circles (Coumans, 2019). On the other hand, the multi-dimensional nature of this index ensures that DFI challenges and opportunities are well understood, allowing for accurate targeting of interventions and policy development. Moreover, its credibility is enhanced by involving different stakeholders through collaborative creation with Ant Group Research Institute and Digital Finance Research Centre at Peking University.

4.2.3. Moderator variables and mediator variables

The study approach examines how market conditions, external investments, and local industry growth interact in a complex manner. In this regard, moderator variables include the business climate and economic environment, which significantly affect these dynamics. For instance, the total value of loans and deposits per person in urban banking systems reflects the financial market climate, indicating capital availability and economic stability. Furthermore, an External Investment Environment Index gives invaluable insights into whether a region is attractive to foreign investors, thus complementing the Business Climate Assessment. This index has been carefully developed by Peking University's Enterprise Big Data Research Centre to measure the increase in investment and assess its potential and suitability for attracting it (Ning & Zhang, 2023).

The research thus presents valuable insights into how economic growth can be sustained through complex interactions between various components of Resilience, thereby guiding policymakers toward sustainable prosperity. The approach used in this study is more rigorous in terms of analysis because the author attempts to explore the intricate connection between market conditions, external investments, and local industrial development, focusing on the mediating paths through innovation capability and consumer demand. China's Regional Innovation and Entrepreneurship Index measures innovative capacity, as reflected in technological advancements and entrepreneurial activity, both of which are prerequisites for sustainable development. Although the levels of consumer spending are not clearly stated, they explain factors that stimulate demand and promote regional economic activities. This research paradigm seeks to recognize the intricate interplay between moderator and mediator variables about market dynamics, foreign inflows of FDI, and regional economic growth rates. The methodology used for forecasting market prospective demand is based on overall consumption levels:

$$MP_{it} = \sum_{j \neq i} \frac{C_{jt}}{d_{ij}^2} + \frac{C_{it}}{d_{ii}^2}, \tag{15}$$

where, the actual Consumption of cities j and i in year t is represented by the variables C_{jt} and C_{it}. The variable d_{ij} represents the distance between city i and city j. The inner perimeter of City i, denoted as d_{ii}, is calculated using the formula $d_{ii} = \left(2/3\right)\sqrt{area_i/\pi}$, where area i represents the area of urban land in the city. The China Urban Statistical Yearbook, issued by the National Bureau of Statistics of China, offers relevant data.

4.2.4. Control variables

The effectiveness of empirical studies depends on how well they can obviate possible sources of bias. This is particularly important when examining the regional economic resilience. The biggest challenge here is endogeneity, where excluding crucial control variables can lead to

distorted results and undermine the credibility of the findings. Additionally, it means there is no need for new data collection to answer the research question; instead, existing information from earlier works by authors such as Giordano et al. (2020) can be utilized. This approach amalgamates ideas from respected literature to identify and embed appropriate controls in the research, enhancing its robustness and validity.

Table 1 carefully defined and computed variables are calculated to ensure the dataset's accuracy and consistency. The empirical results will be reliable, as we utilize data from reputable sources, including the China City Statistical Yearbook and the China Statistical Yearbook, compiled by the China National Bureau of Statistics (CNBS). Our sample comprises cities representing various administrative levels and geographical regions, which account for 95.96% of China's population. Therefore, it provides a comprehensive representation of the country's economic landscape. Our research has considered towns in various locations, thereby taking into account diverse economic situations, which makes our findings more applicable and relevant. This wide-ranging feature is essential, as the combined GDPs of our study cities were equivalent to 99.35% of the total Chinese GDP in 2020.

Table 1. Definitions and descriptive data of the factors

Variable	Definitions	Mean	Std. Dev.	Min	Max
Resilience	The measure of economic adaptability	1.248	2.108	−23.078	25.018
DIF	The Digital Equitable Economic Growth Index	175.732	68.248	18.025	334.479
FinMar	Natural logarithm of urban banking organizations' total loans and deposits per capita	3.339	0.219	4.089	4.607
Business	The urban environment index's natural logarithm for investments from abroad	13.528	0.894	9.536	15.766
Innovation	Logarithms of the China regional entrepreneurship and creative thinking Index	5.398	0.169	3.693	5.606
Consumption	Possibility of market demand	0.987	1.929	0.010	34.268
FDI	The logarithm of total expenditure on fixed assets per 10,000 using the natural logarithm function	11.493	0.787	6.577	13.842
FoInvest	Logarithms of the actual quantity of foreign capital utilized per 10,000 units	4.027	1.802	−5.755	5.995
Govern	Natural logarithms of the federal budget's per capita local fiscal spending	4.416	0.865	1.157	8.109
Internet	The logarithm of users of the internet per 10,000 using the natural logarithm function	8.002	1.008	5.216	12.923
Edu	Logarithms show the number of students across all colleges and universities per 10,000, using the natural logarithm function	3.665	1.108	−0.745	7.559
ISA	Ln (Proportion of primary industry employment *1 + Proportion of secondary industry employment *2 + Proportion of employment in the tertiary industry *3)	0.835	1.064	0.606	1.043

5. Empirical findings

5.1. Baseline regression

The analysis of Table 2 reveals significant insights into the relationship between Digital Inclusion Financing (DIF) and financial resilience, as well as the contributions of other variables. Across all models, DIF exhibits a consistently positive and statistically significant effect on economic Resilience, as indicated by the coefficients (e.g., 0.052 in Model 1 and 2.043 in Model 4), reinforcing its role as a crucial driver of economic adaptability. Foreign Direct Investment (FDI) and foreign investments (FoInvest) also positively and significantly influence Resilience, highlighting the importance of external capital in fostering economic robustness. Government involvement (Govern) and internet penetration (Internet) further bolster Resilience, underscoring the synergistic role of public governance and technological infrastructure. However, educational attainment (Edu) displays a non-significant or slightly negative relationship, suggesting that the direct impact of education on Resilience might be mediated through other channels or require further investigation. Institutional strength and support (ISA) demonstrate mixed effects, appearing insignificant in these models.

The findings align with existing literature that emphasizes DIF's positive impact on financial resilience, particularly its ability to stabilize supply chains and support SMEs (Tan et al., 2020). The results also align with studies that highlight FDI and technological innovation as crucial factors in economic stability (Rohela et al., 2020). However, the non-significance of education contrasts with arguments that education enhances Resilience by fostering skilled labor and innovation. This discrepancy could stem from regional variations or differences in methodological approaches. Furthermore, the mixed impact of ISA suggests a nuanced interplay between institutional frameworks and Resilience, which merits deeper exploration compared to prior studies that emphasize ISA's unequivocal importance.

Table 2. The outcomes of examining the relationship between DIF (Differential Item Functioning) and financial resilience

Variable	(1)	(2)	(3)	(4)
	Resilience	Resilience	Resilience	Resilience
DIF	0.052*** (0.011)	1.042*** (0.020)	0.048*** (0.020)	2.043*** (0.020)
FDI		3.288*** (1.585)		1.197*** (0.608)
FoInvest		2.226*** (1.080)		2.221*** (1.068)
Govern		1.277*** (1.647)		1.668*** (0.715)
Internet			1.228** (0.088)	0.404** (1.169)
Edu			−0.303 (0.236)	−0.185 (1.216)
ISA			2.435 (3.363)	4.474 (2.235)
Constant	−7.746*** (1.789)	−41.888*** (8.072)	−17.524** (7.426)	−54.719*** (13.289)
Observations	3855	2838	2850	2838
R-squared	0.238	1.267	0.245	0.273
City fixed effect	YES	YES	YES	YES
Year fixed effect	YES	YES	YES	YES

5.2. Heterogeneity analysis

The results of the heterogeneity analysis reveal meaningful differences in the magnitude and significance of DIF's impact on economic Resilience across China's Eastern, Central, and Western regions, as well as between cities with high and low economic scales. The Eastern and Central areas exhibited significantly stronger coefficients for DIF compared to the Western region, indicating that areas with more mature digital ecosystems and institutional capacities derive greater benefits from DIF in terms of Resilience. This aligns with previous research emphasizing regional innovation system maturity as a mediating factor. Similarly, DIF's effect was more pronounced in high-income cities, suggesting that baseline economic infrastructure amplifies the absorptive capacity for digital innovation. Formal Chow tests confirmed that these inter-regional differences in coefficients are statistically significant at the 1% level ($p < 0.01$), strengthening the evidence for structural heterogeneity in the resilience impact of digital finance. These findings support the theoretical expectation that economic Resilience is not uniform across geographies but is shaped by regional capacities to leverage digital tools, institutional environments, and financial ecosystems. Table 3 demonstrates the multi-faceted relationship between Digital Inclusion Financing (DIF) and financial Resilience over time and across various dimensions. Coverage breadth, use depth, and digitalization degree have a positive influence on Resilience, with statistically significant coefficients, indicating that broader and deeper adoption of DIF contributes to economic stability. DIF itself shows a

Table 3. The association between DIF and financial resilience in several aspects over a specific period is estimated

Variable	(1)	(2)	(3)	(4)	(5)
	Resilience	Resilience	Resilience	2011–2015	2016–2020
Coverage breadth	0.059*** (0.013)				
Use depth		0.018*** (0.007)			
Digitalization degree			1.003 (0.003)		
DIF				0.009* (0.005)	1.062*** (0.023)
FDI	2.055*** (0.579)	2.320*** (0.603)	2.377*** (0.606)	2.239*** (1.416)	4.345** (1.375)
FoInvest	0.199*** (0.069)	0.238*** (1.072)	0.245*** (0.075)	1.085* (0.045)	0.219** (0.097)
Govern	2.455*** (0.665)	1.682*** (1.698)	2.636*** (0.711)	1.276*** (0.445)	3.345*** (1.362)
Internet	0.239 (0.154)	1.395** (0.175)	1.334** (0.167)	0.022 (1.068)	0.696** (1.352)
Edu	−0.297 (1.218)	−0.208 (1.219)	−0.254 (0.225)	−0.216 (0.139)	−1.728 (1.108)
ISA	4.608 (2.195)	4.515 (2.275)	2.383 (1.288)	−1.438* (1.418)	8.815** (4.695)
Constant	−52.535*** (12.299)	−55.452*** (12.872)	−48.366*** (13.056)	−23.976*** (8.278)	−87.787*** (21.519)
Observations	2839	2838	2839	1426	1417
R-squared	0.278	0.267	0.264	0.694	0.316
City FE	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES

growing positive impact from 2011 to 2015 and from 2016 to 2020, highlighting its increasing importance in recent years. Foreign Direct Investment (FDI) and government involvement remain consistently significant across all models, reinforcing their roles in enhancing Resilience. Internet penetration also supports Resilience, though its impact varies over time. Education shows no significant effect, diverging from expectations in the literature (Toha et al., 2020), while Institutional Strength and Support (ISA) exhibits mixed results, with a more substantial positive influence in later years. Overall, the findings underscore DIF's critical and evolving role in promoting Resilience, complemented by external investments and governance.

China's regional economic dynamics have long been an intriguing yet concerning subject due to the significant differences in development between its western, central, and eastern regions. Table 4 presents the estimated impacts of Digital Inclusive Finance (DIF) and other factors on economic Resilience across various regions (Eastern, Central, Western) and economic scales (high and low). DIF affects all three areas positively, with the majority located in the Central region and the least in the Western region. The study also notes that DIF is more significant on a high economic scale compared to a low economic scale. Foreign Direct Investment (FDI) and government effectiveness are consistently significant positive contributors across most contexts, with a pronounced effect on the Resilience of Eastern regions and high-income-scale areas. However, Foreign Investment (FoInvest) and International Security Assistance (ISA) exhibit mixed effects, with FoInvest being positive in the Central region and at a low economic scale. At the same time, it is negative for the Western region. Education has a negative or no impact on Resilience, with a more substantial adverse effect in Eastern Africa. From the R-squared values, we can see that these models account for a significant amount of variation between variables, which is higher for Central and Eastern Africa than for other regions.

Table 4. Estimated outcomes of heterogeneity across economic and spatial scales

Variable	(1)	(2)	(3)	(4)	(5)
	Eastern region	Central region	Western region	High economic scale	Low economic scale
DIF	1.038*** (0.010)	1.078*** (0.016)	1.007 (0.014)	2.059*** (0.014)	1.044*** (0.014)
FDI	3.938*** (0.670)	1.662* (0.916)	1.785* (0.965)	0.019** (0.790)	1.80*** (0.655)
FoInvest	−0.055 (0.087)	0.528*** (0.106)	−1.044 (0.065)	2.114 (0.167)	1.229*** (0.075)
Govern	3.866*** (0.813)	3.473*** (1.853)	1.155 (1.019)	0.052* (1.04)	3.276*** (0.759)
Internet	−1.319 (0.205)	1.126*** (1.299)	−0.244 (0.300)	−0.038 (0.228)	0.472** (0.209)
Edu	−0.806** (0.374)	0.175 (0.259)	−0.543 (0.466)	−0.732 (0.473)	−1.128 (0.238)
ISA	−4.168** (2.193)	12.445*** (2.417)	−3.565 (1.274)	−1.998 (3.774)	2.802 (3.629)
Constant	−48.425*** (13.256)	−83.257*** (16.790)	−16.967 (18.480)	−35.107** (17.365)	−49.188*** (14.028)
Observations	2000	2000	838	755	2088
R-squared	0.358	0.362	0.253	0.322	0.307
City FE	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES

Figure 1 illustrates the distribution of key variables across China's Eastern, Central, and Western regions, as well as across high- and low-economic scales. DIF shows consistent values across all regions, reflecting its foundational role in financial inclusion, particularly in high-income areas. FDI is highest in the Eastern Region, indicating its role as the primary hub for foreign investments, while the Central and Western Regions exhibit moderate levels, signifying ongoing developmental efforts. FoInvest demonstrates variability, with higher values in regions with stronger economic activities, emphasizing the reliance on foreign capital for development. Governance (Govern) remains robust across regions but diminishes slightly

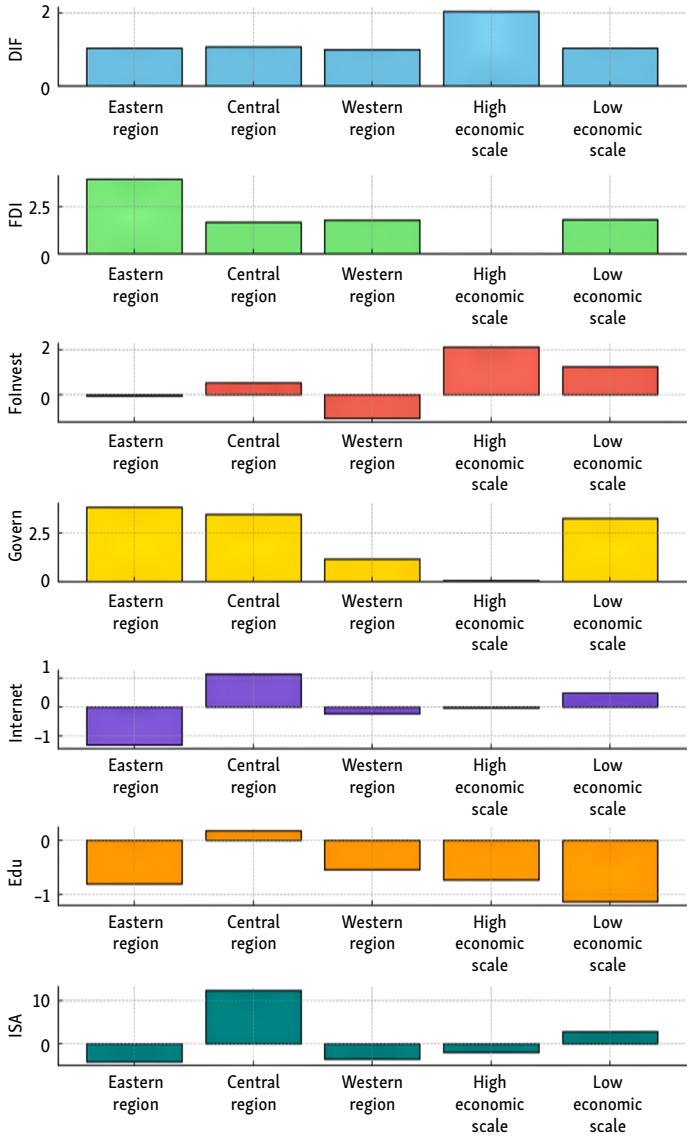

Figure 1. Regional and economic scale variations

in the Western Region, highlighting governance challenges in less developed areas. Internet penetration is relatively balanced, but somewhat lower in regions with lower economic scales, emphasizing the need for further investment in digital infrastructure. Educational attainment (Edu) varies minimally, with slight declines in low-income areas, indicating a potential barrier to economic growth. Finally, institutional support (ISA) peaks in high economic scales, reflecting stronger institutional frameworks in more developed regions.

While this study reveals apparent regional disparities in the impact of DIF on economic Resilience across China, a more nuanced understanding requires examining the underlying mechanisms shaped by regional economic structures and policy environments. In the eastern region, cities benefit from highly diversified economies, stronger tertiary sectors (e.g., finance, ICT, and advanced services), and robust innovation systems. These structural advantages enable digital finance tools to be more easily integrated into entrepreneurial ecosystems, supply chains, and consumption platforms, thereby maximizing the resilience-enhancing effects of DIF. Additionally, eastern cities often enjoy first-mover advantages in digital infrastructure deployment, favorable fintech regulations, and active pilot policies under the "Digital China" initiative. In contrast, central regions, although benefiting from strategic policy support under initiatives like the "Rise of Central China Plan," still face institutional rigidity and lagging infrastructure in second- and third-tier cities, which can dilute the impact of DIF unless accompanied by targeted state investment.

In the western region, economic structures are often resource-based or agriculturally dominated, with a limited-service sector and weak digital literacy among local populations. These structural constraints limit the absorptive capacity for DIF technologies and hinder inclusive financial participation, particularly among SMEs and low-income households. Additionally, institutional quality and governance capacities vary significantly across provinces, which in turn influence the implementation and oversight of digital finance initiatives. For example, fragmented regulatory environments or limited enforcement in less developed areas can lead to credit misallocation or financial exclusion, weakening the resilience outcomes of DIF. Therefore, regional disparities in DIF's impact are not merely a result of uneven adoption rates but also reflect how regional institutions, sectoral composition, and policy capacities condition the translation of digital finance into adaptive economic behaviors. These findings underscore the need for regionally differentiated policy frameworks that align digital innovation with local economic realities, institutional capacity, and sectoral needs.

5.3. Robustness test

To make the findings more reliable, the researcher advocated an alternative approach, substituting nighttime lighting data for the dependent variable. Nighttime illumination offers a more accurate representation of economic activities than conventional GDP measures, capturing real-time economic dynamics and providing a deeper understanding of regional development. Table 5 presents the results of replacing the dependent variable with nighttime lighting data. Without and with control factors, estimates from columns (1) –(2), respectively, yield statistically significant positive correlation coefficients for DIF, confirming our prior finding in Table 2. This consistency demonstrates the Resilience of our approach, establishing a

Table 5. Presents the results of a robustness test examining the effect of DIF (Differential Item Functioning) on economic resilience

Variable	(1)	(2)	(3)	(4)
	Replacing the dependent variable	Replacing the dependent variable	Excluding municipalities	Instrumental variable
DIF	1.122** (0.048)	1.125** (0.057)	1.128** (0.057)	1.038*** (0.012)
FDI		8.136*** (1.590)	7.288*** (2.586)	1.263 (0.188)
FoInvest		0.076 (0.232)	1.082 (0.233)	−0.022 (0.048)
Govern		8.214*** (3.037)	9.608*** (2.063)	1.098 (0.094)
Internet		1.876 (0.656)	1.03 (1.663)	−0.275** (1.118)
Edu		0.124 (0.829)	0.145 (0.833)	−0.208*** (0.080)
ISA		−6.8267(4.768)	−9.572* (4.787)	−1.366*** (0.739)
Constant	−20.866** (9.216)	−128.873*** (47.180)	−141.300***(47.187)	
Kleibergen-Paap rk LM-statistic				23.645 [0.010]
Kleibergen-Paap rk Wald F-statistic				64.295 [17.39]
Observations	2852	2838	2798	2838
R-squared	0.108	0.118	0.274	0.008
City FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES

continuous relationship between nighttime luminosity and financial fragility, as measured using diverse analytical frameworks (Alssadek & Benhin, 2023). Rigorous testing enhances the reliability of findings, demonstrating how alternative sources can be utilized to conduct economic studies for a deeper understanding of measuring economic dynamics and making meaningful contributions to the broader discussion thereof.

Addressing endogeneity concerns is indispensable for valid and reliable empirical research findings. Endogeneity occurs when the independent variables correlate with the error term in a regression model, thereby creating biased and inconsistent parameter estimates. In modeling relationships between the Dynamic Input-Output Framework (DIF) and economic Resilience in cities, endogeneity can result from omitted variables or reverse causation of DIF. Such factors tend to complicate efforts to make definite conclusions (Xu et al., 2022). This endogeneity problem is addressed in the study by applying an Instrumental Variable (IV) method, which follows the technique suggested. The independent variable chosen for this purpose is the spherical distance between any prefecture-level city and Hangzhou, where DIF originates and is a central place for its development. This option is justified by Hangzhou's significant role in the DIF invention, as demonstrated by examples such as the presence of Alipay and the pioneering contributions it has made. Additionally, regarding Peking University, Ant Financial, headquartered in Shenzhen, can be considered a reliable company since its transaction data is thoroughly analyzed.

5.4. Mechanism analysis

To test the mediating and moderating mechanisms hypothesized in the theoretical framework, we conducted fixed-effects panel regressions incorporating both interaction terms and sequential mediator models. To moderate the effects, we introduced interaction terms between DIF and the financial market environment (FinMar) as well as the business environment (Business). We observed statistically significant positive coefficients (Table 6, Columns 1–2), suggesting that a favorable institutional context strengthens DIF's effect on Resilience. For mediation, DIF was shown to increase both innovation capacity significantly (Column 3) and household consumption potential (Column 4), which in turn had significant effects on resilience. The reduction in the direct coefficient of DIF after including mediators confirmed partial mediation in both pathways. These empirical results validate the hypothesized indirect effects of DIF through innovation and Consumption, reinforcing the theoretical proposition that DIF drives economic Resilience not just directly but also by shaping the structural and demand-side fundamentals of regional economies. This implies that DIF amplifies the sound effects of financial markets and business activities on Resilience. In its interposed function, DIF enhances innovation and Consumption, supporting the idea that it has broader economic implications. Foreign Direct Investment (FDI) and government effectiveness (Govern) consistently show substantial positive impacts across all models, further supported by DIF. Conversely, internet usage and education have mixed effects, with education showing a positive impact on innovation but a negative or insignificant impact elsewhere. The R-squared values indicate a significant proportion of variance explained in many models, particularly those for innovation and Consumption, thereby underscoring the importance of DIF in shaping financial resilience and economic outcomes (Sun et al., 2024).

Table 6. DIF moderates and mediates the impacts on financial resilience

Variables	Moderating effect		Mediating effect	
	(1)	(2)	(3)	(4)
	Resilience	Resilience	Innovation	consumption
DIF	0.046*** (0.012)	1.038*** (0.012)	0.212*** (0.033)	0.036*** (1.009)
FinMar	1.978** (0.428)			
DIF* FinMar	0.012** (1.002)			
Business		0.558*** (1.433)		
DIF*Business		0.015*** (2.004)		
Fdi	2.158*** (0.575)	1.186*** (0.598)	0.057*** (0.018)	1.347** (1.164)
FoInvest	0.300*** (0.069)	0.206*** (2.068)	−0.010 (1.003)	0.015 (1.013)
Govern	2.629*** (1.675)	0.718*** (0.800)	0.080*** (0.030)	0.197 (1.173)
Internet	0.440** (0.182)	1.453** (0.185)	1.017* (0.008)	−0.264*** (1.085)
Edu	−0.198 (1.214)	−0.182 (2.217)	1.035*** (0.014)	−0.188* (0.105)
ISA	2.736* (3.264)	0.479 (2.246)	1.008 (0.056)	−0.636** (0.702)
Constant	−48.386*** (13.156)	−48.817*** (13.687)	2.118*** (1.335)	−2.729 (3.045)
Observations	2839	2839	2839	2839
R-squared	0.277	0.277	1.867	0.937
City FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES

The analysis emphasizes the significance of a robust business climate in promoting economic Resilience, as indicated by the positive coefficient associated with the business environment. Optimistic business conditions significantly enhance an economy's ability to navigate and recover from difficulties. Furthermore, this is supported by a statistically significant interaction between the business environment and Digital Infrastructure Finance (DIF), which suggests that improvements to the business climate can amplify its capacity to promote Resiliency against external pressures on national-level economies. This strongly supports Hypothesis 4, validating it. When businesses constantly improve and fine-tune their environments, financial resources can be allocated more effectively, encouraging innovation and entrepreneurship and creating a virtuous circle of consumer savings and spending. As shown in Figure 2, the relationships between DIF, FDI, FoInvest, and Governance vary significantly across China's regions. In the Eastern Region, DIF exhibits a relatively stable and consistent influence, reflecting its well-established financial infrastructure and high levels of economic activity. The Central Region shows pronounced variations in FDI and Governance, highlighting the dynamic role of foreign investments and government interventions in bridging development gaps. The Western Region, characterized by sharper peaks and troughs in FoInvest and Governance, underscores the region-specific challenges and opportunities in leveraging

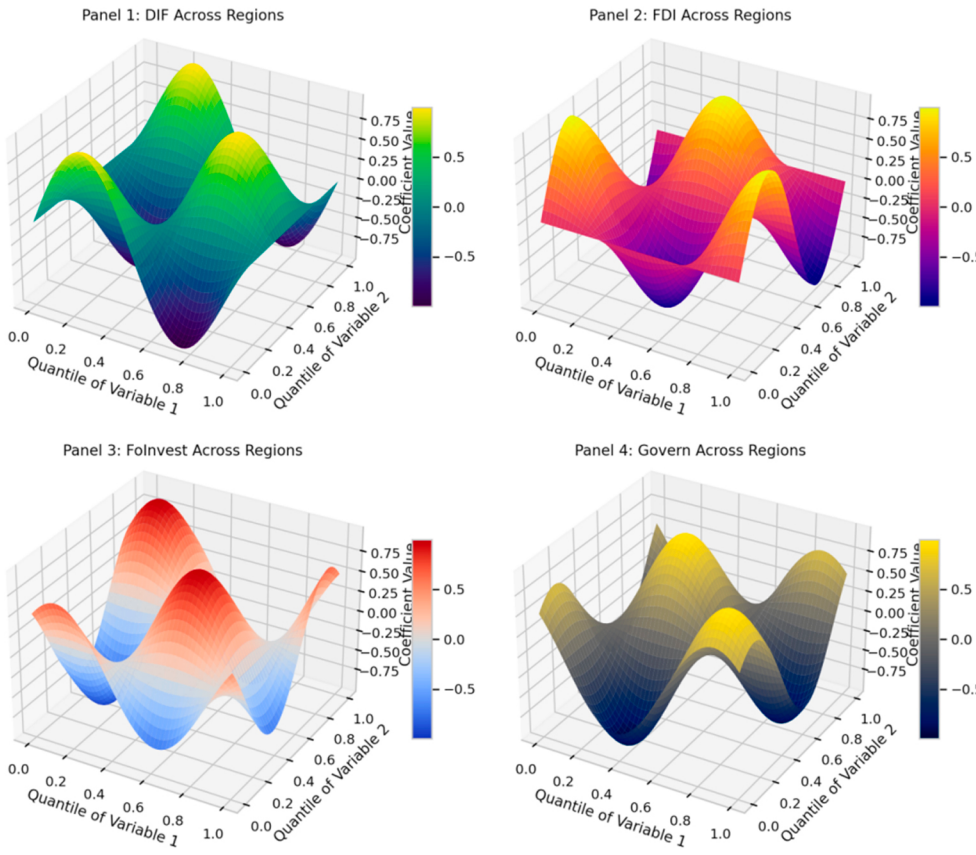

Figure 2. Relationships between variables (DIF, FDI, FoInvest, Govern) across regions

investments and governance for Resilience. These results emphasize the heterogeneous impact of these variables across China's regions, with the Eastern Region leading in stability and the Western Region requiring targeted policy interventions to address its unique economic dynamics.

6. Discussion

This study aimed to investigate the role of the Digital Innovation Framework (DIF) in promoting economic Resilience within the context of urban development in China. The research questions focused on how DIF influences economic Resilience across regions and whether it has different impacts depending on regional economic conditions (Idroes et al., 2024). The literature reviewed showed that digital infrastructure is vital for innovation and stable economies. Authors such as Liu et al. (2021) argue that digital banking services are one key element of financial inclusion. Our findings largely confirm this expectation, as DIF enhances economic Resilience by fostering innovation and increasing consumer demand, particularly in stable economies. The findings indicate that DIF influences the ability of cities to withstand and recover from shocks, with consistent positive correlation across different urban settings. These results support the hypothesis that DIF drives disruptive innovation and economic diversification, enabling cities to adapt to changing economic landscapes. As an alternative measure of economic activity, the study utilized nighttime light data, further confirming these findings and offering insight into more complex aspects of the economy beyond GDP alone. This is consistent with Newell's (2023) argument that other information sources must be applied in monitoring timely economic trends.

However, there were also unanticipated regional discrepancies in DIF impact, with relatively inconspicuous effects occurring in areas with small economies. These findings challenge the assumption that DIF enhances economic Resilience equally everywhere, suggesting that its effectiveness is contingent upon local economic peculiarities. These differences may result from disparities in financial strength, market control, and investment climate, which can offset the gains from DIF (Coletta et al., 2021). As other authors have done (Prieto-Sandoval et al., 2018), they also observed that limitations emerge due to poor infrastructure and resource capacity. The research reveals that a favorable business climate and well-built financial market infrastructure can leverage DIF's advantages. A properly functioning capital market enhances the efficiency of DIF endeavors and promotes appropriate capital allocation, thereby contributing positively to economic stability by reducing speculative activities. Therefore, the link between DIF and financial markets reinforces the significance of country-specific policy measures that address regional disparities in DIF development, particularly in less developed regions. The study on the Digital Innovation Framework (DIF) demonstrates how digital infrastructure fosters innovation and economic Resilience during urban development in China, with a particular emphasis on its significance for economic adaptation, diversification, and productivity. The study argues that DIF's impact can vary significantly across China, calling for regionally differentiated policies that recognize the need to address various complex challenges, such as sustainability and economic development.

The observed disparities in the impact of DIF across Chinese regions can be attributed to several structural and institutional factors. Cities in the Eastern and Central areas benefit from a more favorable combination of digital infrastructure, economic diversification, and regulatory maturity. These regions have long been prioritized in national development plans, such as the Yangtze River Delta and the Beijing-Tianjin-Hebei initiatives, which have channeled substantial investments into ICT development, financial market sophistication, and innovation ecosystems. Consequently, the absorptive capacity of DIF – measured through its integration into local economic and industrial networks – is much higher in these areas. In contrast, Western regions often face infrastructural bottlenecks, limited internet penetration, weaker formal institutions, and lower levels of human capital readiness, which constrain the effective deployment and utilization of digital financial services (Emori & Brown, 2005).

Furthermore, disparities in financial literacy and digital accessibility hinder inclusive participation in DIF-led innovation and investment opportunities. From a governance perspective, Eastern and Central cities are more likely to implement supportive policies that promote fintech startups, regulate digital lending, and facilitate SME integration into digital ecosystems, thereby magnifying the resilience-enhancing effects of DIF. These findings underscore the importance of tailoring DIF policies to regional readiness levels and suggest that equal access to technology alone is insufficient to achieve optimal outcomes. What matters is the enabling environment that translates digital finance into adaptive economic capacity.

Despite the overall robustness of the findings, some variables, such as education level (Edu) and Institutional Strength and Adjustment (ISA), exhibited mixed or insignificant effects across models, raising important questions. For education, one plausible explanation is that higher educational attainment alone does not automatically translate into economic adaptability unless matched with relevant digital or technical skills. In many Chinese cities – especially those in less developed western regions – the expansion of tertiary education may still be oriented toward traditional disciplines, lacking alignment with the needs of the digital economy. This is supported by prior studies (Gong et al., 2021), which find weak correlations between conventional education indicators and digital productivity in lagging urban economies. Moreover, the delayed impact of education on macroeconomic Resilience may require longer temporal lags to manifest, which could be obscured in a decadal panel.

Similarly, the inconsistencies in the role of ISA may stem from its composite nature, which aggregates employment structures across primary, secondary, and tertiary sectors. While a shift toward tertiary employment is generally associated with greater Resilience, this metric may mask sectoral vulnerabilities such as informal services or underemployment. Additionally, institutional effectiveness may vary widely across provinces despite similar industrial configurations, making the ISA index insufficient to capture governance quality, administrative responsiveness, or financial discipline – factors more directly related to resilience outcomes (Khan et al., 2023). In this regard, future research should consider decomposing ISA into sector-specific components or complementing it with qualitative governance indicators (e.g., corruption levels, regulatory efficiency). Such enhancements could provide a clearer picture of how institutional configurations contribute to regional shock absorption and recovery.

7. Conclusions and implications for policy

Based on panel data spanning 285 urban areas in China from 2011 to 2020, this study provides profound insights into the transformative role of the Digital Innovation Framework (DIF) in enhancing economic Resilience. Through advanced econometric modeling, the findings highlight DIF as a catalyst for disruptive innovation, economic diversification, and sustained financial stability, particularly during periods of external shocks or market volatility. Regions with well-established DIF systems, predominantly in eastern and central China, exhibit a pronounced ability to adapt to economic shifts, sustain sector-specific growth, and optimize resource allocation. This adaptability highlights the crucial role of robust digital infrastructure and increased access to financial resources in fostering resilient and sustainable economic structures.

The study further emphasizes the critical importance of favorable business environments and well-functioning financial markets in amplifying the benefits of DIF. Efficient financial markets mitigate speculative risks, ensure balanced capital allocation, and reinforce the synergy between digital finance and innovation-driven economic systems. However, the disparities observed between China's regions call for targeted interventions, particularly in western and economically less developed areas, to ensure the equitable distribution of DIF's transformative benefits. Policies that prioritize digital infrastructure enhancement, financial inclusion, and region-specific development are crucial to bridging these gaps and promoting balanced economic growth nationwide.

Additionally, the findings advocate for nuanced, region-specific strategies to enhance DIF's impact in areas with varying economic conditions. By fostering innovative ecosystems, improving access to digital tools, and prioritizing inclusivity, DIF can be further leveraged as a mechanism for sustainable and equitable growth. Future research should focus on longitudinal studies to examine DIF's evolving impact over time and explore cross-country comparisons to understand how policy environments and levels of digital maturity influence its effectiveness. Moreover, integrating elements of social equity and environmental sustainability into DIF research could provide a more holistic understanding of its potential to foster resilient and inclusive economies. These findings provide a robust foundation for policymakers and stakeholders to leverage the power of digital innovation in driving long-term economic transformation and sustainability.

7.1. Implications for policy

The policy implications derived from this study's results are crucial for enhancing economic Resilience through digital innovation. A primary conclusion is that technological systems and financial stability are essential to improving Resilience, particularly in regions with advanced digital economies. Consequently, governmental initiatives must prioritise the enhancement of digital infrastructure, particularly in underdeveloped or economically challenged areas. In places such as northwestern and southern China, where adoption of technology is insufficient, policymakers should prioritise enhancing digital inclusion by making proactive investments in internet access, wireless payment infrastructures, and electronic banking services. This will mitigate disparities in Resilience across areas, ensuring that all cities, irrespective of their economic stature, can reap the advantages of digital growth.

The efficacy of digital finance in bolstering Resilience is intricately linked to regional financial circumstances and administrative capabilities. Consequently, policy proposals must be customized to meet the distinct requirements and capabilities of each location. In commercially established areas, such as eastern China, where electronic communities are well developed, authorities should focus on regulating and integrating emerging technologies to ensure that digital platforms function cohesively within the broader financial system. These areas could benefit from regulations that encourage innovation and foster collaboration between fintech firms and Small and Medium-Sized Enterprises (SMEs), thereby enhancing economic diversity and resilience.

In economically underdeveloped and digitally immature areas, particularly in the West, policymakers must prioritise the establishment of a conducive environment for digital finance, including investments in computer literacy, infrastructure, and community capacity building. This would guarantee that the advantages of digital inclusion are experienced equally nationwide. Moreover, authorities might provide benefits for local enterprises and entrepreneurship to embrace digital financial instruments, thereby promoting broader engagement in the digital economy and enhancing the adaptability of regional economies against foreign disruptions.

7.2. Future research directions and limitations

While this study offers valuable empirical insights into the role of the Digital Innovation Framework (DIF) in enhancing urban economic Resilience, several promising directions for future research remain. First, the mechanisms through which DIF influences resilience – especially via Consumption and innovation – could be further clarified using dynamic panel models (e.g., system GMM) or structural equation modeling (SEM) to trace long-term causal pathways more rigorously. Second, DIF's interaction with **s**ocial equity, environmental sustainability**,** and digital literacy remains underexplored; future studies should examine whether and how DIF differentially affects vulnerable populations, rural-urban linkages, and green transition capacity. Third, this study focuses exclusively on Chinese cities; cross-country comparative studies could reveal whether the DIF-resilience link holds in contexts with different institutional and digital maturity levels. Fourth, the heterogeneity of DIF's impact across industries (e.g., finance, manufacturing, and services) warrants a deeper sectoral analysis. Methodologically, future research may benefit from using machine learning models to detect nonlinearities or regional thresholds in the effectiveness of DIF. Lastly, follow-up work should explore the role of local governance capacity**,** cybersecurity risks**,** and regulatory frameworks in conditioning how digital finance shapes economic adaptability, especially in rapidly transforming post-COVID economies. These areas not only highlight the boundaries of the current research but also offer a roadmap for advancing theoretical and empirical understanding of digital innovation in resilience economics.

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Disclosure statement

The authors declare that they have no conflict of interest.

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