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Unlocking Economic Resilience: A New Methodological Approach and Empirical Examination under Digital Transformation

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Abstract: Economic resilience is crucial for urban sustainability as it ensures stability and growth in the face of external shocks, promotes social cohesion and inclusivity, fosters environmental sustainability, and enhances cities' adaptability to future challenges. This study expands the conventional perspective on economic resilience beyond the context of shocks, focusing on the inherent resilience of regional economic systems. A novel method for quantifying economic resilience is introduced, emphasizing system sensitivity and adaptability. Using Chinese prefecture-level city data and an econometric model, we empirically examine how Fintech, a major digital transition in current urban systems, affects economic resilience. The findings reveal that Fintech has a substantial positive effect on economic resilience, primarily through the upgrading of industrial structures and technological innovation. Furthermore, there is significant regional heterogeneity in the impact of Fintech on economic resilience, with more pronounced contributions in the east, central, and western regions of China, as opposed to the northeast. Additionally, the impact of Fintech on economic resilience is more substantial in large-scale cities. The promotion of economic resilience through digital transformation serves as a potent risk prevention measure. Understanding the role of economic resilience in urban systems holds valuable implications for countries worldwide.

Keywords: economic resilience; urban systems; digital transition; regional heterogeneity; China

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1. Introduction

Urban sustainability encompasses the ability of a city to maintain economic, social, and environmental well-being while meeting the needs of its current and future residents. In urban systems, the development trajectories of regional economies are constantly evolving and subject to various shocks. To examine the resilience of regional economic systems to these shocks, scholars have drawn upon system equilibrium models from the fields of physics and ecology [1–3] and have proposed the concept of "economic resilience", which builds upon the principles of engineering and ecological resilience [4]. This concept has gained traction due to its ability to capture the holistic and dynamic nature of socioeconomic systems and its potential to inform policy and academic research [5,6]. Resilience is considered an important expression of sustainability and is vividly referred to as the emergency room of sustainability [7]. The importance of economic resilience for urban sustainability lies in its ability to maintain stability and foster growth amidst external disturbances, while also bolstering social unity and inclusivity, promoting environmental sustainability, and strengthening cities' capacity to adapt to future challenges [5,8]. Recent years have witnessed heightened global uncertainty, stemming from events such as the 2008 financial crisis, trade tensions between China and the United States, the COVID-19 pandemic, and wars and conflicts, as well as other shocks that have generated ongoing

economic turmoil. The ability of regions to withstand uncertainties in the economic system has become an increasingly pressing concern for governments and academics alike [9,10].

Financial development is a crucial driver of economic growth and prosperity. During the digital transition, the rise of financial technology (Fintech)[1], which integrates technology and financial services, provides new opportunities for the development of the traditional financial system [12]. Digital transactions powered by Fintech optimize financial resource allocation, drive technological innovation, and facilitate the transformation and upgrading of financial infrastructure [13]. This integration enhances financial efficiency, inclusivity, and innovation, satisfying the personalized financial needs of diverse businesses [14]. According to the World Bank, global Fintech investment soared from less than $10 billion annually before 2013 to $215 billion in 2019 and then decreased to $122 billion in the 2020 pandemic year. By the first half of 2021, global investments in Fintech had reached $98 billion [15]. Although existing studies have explored the impact of financial development on economic resilience [16] and the influence of regional technological structures [17,18], as well as the effects of smart city construction, including its digital transitions, on economic resilience [19], research specifically examining the direct impact of Fintech on economic resilience remains limited [20,21].

This study aims to examine economic resilience within the context of digital transformation in the financial sector. While past research has predominantly focused on economic resilience in response to shocks, we aim to broaden the horizon by examining the inherent resilience of regional economies and its relationship with Fintech innovation. In an era where Fintech is transforming traditional financial systems and playing an increasingly pivotal role in economic development, understanding its direct influence on economic resilience, regional variations, and its underlying mechanisms becomes not only relevant but also crucial. This understanding has the potential to provide valuable insights for policy decisions and strategic investments in a rapidly evolving urban and technological landscape.

To address this research aim, this study commences by constructing a quantification method to assess regional economic resilience. Subsequently, it empirically examines the impact of Fintech on economic resilience using data from Chinese prefecture-level cities during the period from 2011 to 2020 (Figure 1). The research delves into the underlying mechanisms, taking into consideration aspects like technological innovation and industrial structure upgrading, to explain this impact. Additionally, it employs cross-sectional analysis to accommodate the variations arising from geographical locations and city scales. The reasons for selecting China as the empirical case study region are as follows. The diverse geographic and economic landscape of China provides a rich and varied context for analyzing how different regions leverage technological innovation and industrial upgrades to enhance their economic resilience. In addition, China's rapid digital transformation, especially in the financial sector, with widespread adoption of Fintech solutions like mobile payments and digital banking, presents a unique opportunity to explore how such technologies influence economic stability. This setting allows for a detailed examination of the dynamic interplay between digital transition and economic resilience across varying urban scales and geographical locations.

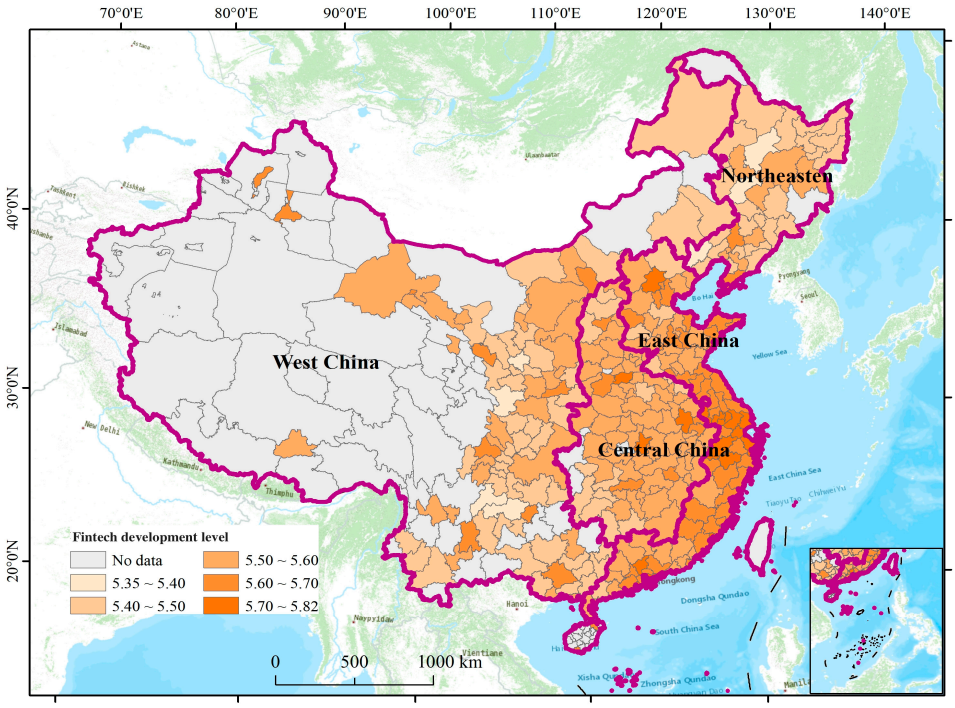

Figure 1. Location and Fintech development of sample cities in China (2020).

2. Literature Review and Conceptual Development

2.1. Economic Resilience and Its Operationalization

2.1.1. The Notion of Economic Resilience

The concept of economic resilience, as it is understood in the context of regional economics and economic geography, does not have a singular point of origin but rather evolved over time. It emerged from the broader discussion of resilience in various disciplines, including ecology, psychology, and engineering [4]. The term began to gain more prominence in economic discussions particularly following global economic challenges, such as financial crises, which underscored the need to understand how economies can withstand and recover from shocks [22,23].

Over the years, the conceptualization of economic resilience in regional contexts has evolved into a multifaceted and dynamic discourse, highlighting the complex nature of regional economic resilience and its multi-dimensional and adaptive qualities. Boschma [24] and Bristow and Healy [25] underscore the adaptive nature of regional economies, arguing that resilience involves not just "bouncing back" but also "bouncing forward" through adaptation and transformation in response to shocks. Hu and Hassink [26] further argue that adaptation, seen as a continuous, evolving process, plays a pivotal role in how regions respond to economic challenges and disturbances. These perspectives align with the evolutionary approach to resilience, which sees regional economies as dynamic systems constantly adapting to their changing economic landscapes.

Evenhuis [27], Martin and Sunley [28], and Sutton and Arku [29,30] contribute by examining the dimensions of regional economic resilience. They emphasize the importance of regional specificities and the role of external and internal factors, such as policy, institutional settings, and socio-economic structures, in shaping a region's resilience. Their work highlights that resilience is not a static attribute but a process that evolves over time, influenced by a region's unique characteristics and its ability to adapt to changing circumstances.

The previous research provides a comprehensive view of regional economic resilience, framing it as a dynamic, adaptive, and multi-dimensional concept that varies across regions and over time. The emphasis on adaptation and transformation, as well as the recognition of the diverse factors that influence resilience, marks a significant evolution in the

understanding of economic resilience in regional contexts. While some scholars suggest that regional economic resilience should only be examined in the context of shocks [5], this study conceptualizes resilience as the ability to sense and adapt to both shocks and slow-burning pressures [31] and places its empirical research within a broader context.

2.1.2. Evolutionary and Equilibrium Perspective of Resilience

In the literature on regional economic resilience, two distinct perspectives are highlighted: the equilibrium and the evolutionary approaches [29]. The equilibrium approach assumes that economies naturally gravitate towards a steady state, and following a disturbance, they can return to or reach a new equilibrium [32–34]. The evolutionary approach, in contrast, posits that economies are constantly adapting, without an inherent steady state, and resilience involves their capacity to evolve in the face of shocks [22,25,35].

This study aligns with the equilibrium perspective, which can be justified according to its focus on measurable outcomes, such as GDP, allowing for the assessment of resilience as a system's return to its pre-shock state or its shift to a new stable state after a disruption. This perspective provides a structured framework for analysis, making it possible to evaluate economic performance systematically. A distinctive feature of this study is the conceptualization of resilience as an intrinsic attribute of a system, allowing for the examination of resilience under normal conditions, not just in the aftermath of shocks. This approach facilitates a proactive understanding of resilience and enables the development of strategies to strengthen economic systems in preparation for potential disruptions.

Due to the varying conceptualization of economic resilience among scholars discussed before, the methods of operationalizing economic resilience also differ[2]. Two common quantitative approaches to characterizing economic resilience are using the sensitivity index developed by Martin et al. [3,23,38,39] and the development of a comprehensive indicator system to measure economic resilience [40–42]. However, the sensitivity index measures the resilience of a single city (system) based on its spatial divergence from other cities (systems), ignoring temporal differences. And the comprehensive indicator system primarily evaluates resilience based on static attributes, disregarding the dynamic nature of the concept of resilience itself and the adaptability of the assessed system. Accordingly, this study proposes constructing a new economic resilience measurement method.

2.1.3. Sources/Determinants of Economic Resilience

The determinants of resilience within regional economies are complex, multifaceted, and crucial for understanding why some regions recover from shocks more quickly or effectively than others. Martin et al. [3] elaborate on how regional economic structures, the diversity and quality of resources, and capabilities, along with institutional support, are crucial determinants that shape the capacity of regions to withstand and recover from economic shocks. Evenhuis [27] adds to the dialogue by emphasizing adaptability—the capability of regional economic systems to maintain and restore their structure in the face of disturbances, which acts as a self-regulating mechanism for maintaining stability.

Sutton and Arku [30] further explore the multi-scalar interactions of various factors within regions, including the role of economic actors, policymakers, and practitioners, and how these interactions influence the resilience of a region's economic structure and workforce. Sutton et al. [29] identify the determinants of resilience as being dynamic, multi-scalar, and spatially dependent, shaped by a wide range of socio-economic and political-institutional factors that are influenced by regions' inherent and inherited resources, capabilities, and characteristics. These factors, such as human capital, agglomerations, entrepreneurship, and innovativeness, not only bolster regions' resilience in turbulent times but also tend to enhance their growth potential and competitiveness during stable periods.

This study, set within the burgeoning context of China's digital transformation in the financial technology sector, seeks to uncover new sources of economic resilience within financial arrangements. It asserts that financial arrangements can be a significant source

of resilience (in alignment with Martin et al., 2016 [3]), offering novel insights into how economic systems can leverage financial innovations and structures to enhance their stability and adaptability in the face of economic perturbations. This way of conceptualizing resilience—not merely as a response to adverse events but as an inherent attribute of the economic system itself—is one of the distinctive features of this study. By focusing on financial arrangements, this study extends the discourse on economic resilience, providing a unique angle on how digital transitions contribute to the resilience of regional economies.

2.2. Fintech and Economic Resilience

Financial development is a pivotal driver of sustainable economic growth, exerting its influence across the economic spectrum by facilitating fund allocation. Consequently, it plays a crucial role in bolstering economic resilience. Furthermore, the fusion of financial development with digital technology has spawned Fintech, heralding both fresh prospects and hurdles in fortifying economic resilience [43]. This synergistic blend holds promise in propelling sustainable economic expansion and bolstering the adaptive and recovery capabilities of regional economies amidst shocks and disruptions.

2.2.1. Fintech's Impact on Economic Resilience

The rise of Fintech has transformed traditional finance, introducing innovative services, scenarios, and models. These advancements bridge the gap between financial supply and demand, reducing mismatches and expanding the financing options for businesses. Consequently, financing costs decrease, profitability increases, and enterprise sustainability improves [44,45]. Fintech's technological efficiency accelerates fund matching, aiding rapid enterprise recovery and adaptation during financial crises [46].

Moreover, Fintech's global reach extends financial services to underdeveloped regions via digital platforms, enhancing inclusivity, streamlining financing, and improving capital turnover, thus enhancing resource allocation efficiency [12,47,48]. Fintech's role in reducing the information asymmetry between institutions and markets enhances risk management, crucial for economic resilience during shocks.

Fintech's technology and knowledge transfer stimulate structural optimization and industrial advancement, fostering cross-regional flows and scalability, essential for market resilience [49]. By facilitating swift adjustments to economic shifts, Fintech enhances enterprises' adaptive capacity, supporting strategic realignment amidst changing landscapes. This emphasis on adaptability underscores Fintech's transformative role, positioning it as a fundamental enabler of resilient economic structures capable of thriving through financial crises and downturns.

Based on the above analysis, we propose the following hypothesis in the empirical investigation of this study:

H1: *Fintech development has a positive impact on economic resilience.*

2.2.2. The Influence Mechanism

The outputs of science, technology, and innovation (STI) often entail high inputs, lengthy cycles, and considerable uncertainty, posing challenges in accessing financing within traditional financial systems. Fintech, as a disruptive financial innovation [48], is bolstering technological innovation behaviors among market participants, enhancing financial market efficiency, and reducing operational costs while identifying prospects and risks through advanced technologies [50]. By tailoring financial services to specific market needs, Fintech improves risk management and recovery, thereby enhancing economic resilience.

Furthermore, Fintech facilitates the timely and accurate delivery of STI project information to financial institutions, reducing information asymmetry and enabling flexible access to financial services for market players [51]. This, in turn, fosters technological innovation activities, promoting the development of science and technology industries and fortifying economic resilience. Additionally, in line with evolutionary economics, firms

utilize technological innovation to respond to external market shocks, revitalizing economic ecosystems and forging new development pathways [52]. Hence, we posit the hypothesis:

H2: *Fintech can enhance economic resilience by improving technological innovation.*

Moreover, Fintech's impact extends beyond technological innovation to optimize industrial structures [50]. By diversifying financing channels and facilitating efficient resource allocation, Fintech propels the transformation and upgrading of traditional industries, particularly in China, where incentives for structural innovation may be lacking [53]. Through enhanced factor mobility, information dissemination, and coordination within industrial chains, Fintech promotes industrial restructuring, bolstering the economy's resilience to risks. Additionally, the development of financial technology spurs the emergence of new models and industries, elevating the industrial structure to higher levels. The spillover effects of digital financial services provide enterprises with superior credit services and stimulate employment growth, particularly in burgeoning service and production sectors. Thus, continuous industrial restructuring yields high value-added outputs, enhancing "structural dividends" and propelling both economic growth and quality development [54]. Building on these insights, we propose the following hypothesis:

H3: *Fintech can enhance economic resilience by improving the industrial structure.*

The conceptual framework in Figure 2 illustrates Fintech's direct impact on regional economic resilience (H1), accounting for regional disparities and city-scale differences. Additionally, the study explores its indirect effects through the mediating roles of technological innovation (H2) and industrial structure (H3).

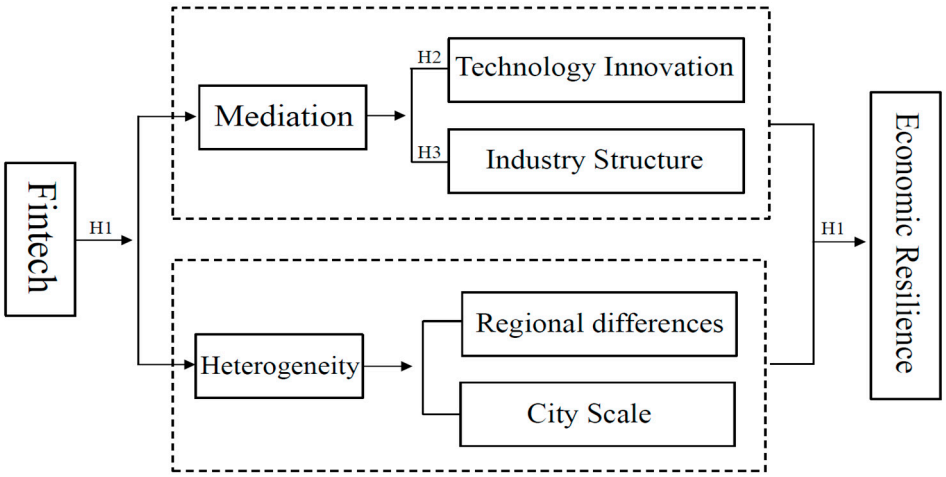

Figure 2. Conceptual framework of Fintech's impact on economic resilience.

3. Economic Resilience Measurement Method

3.1. Selection of Economic Resilience Indicators

In the previous research, the two most crucial indicators for measuring economic resilience have been identified as GDP and employment. While data on employment offer valuable insights at the individual level [55], GDP serves as a comprehensive measure of a city's overall economic performance. This broader perspective is vital for fully understanding the resilience of urban economies, capturing not only employment status but also the economic activities and outputs that sustain the livelihoods of the city's inhabitants.

Specifically, GDP analysis presents an appropriate means of measuring economic resilience by scrutinizing the capacity of an economy to withstand shocks. This involves examining changes in GDP growth rates over time and comparing them with pre-shock levels. In this study, we used the GDP indicator to measure regional economic resilience

and construct an economic resilience index, which will be elaborated in the following sub-section.

3.2. Construction of an Economic Resilience Index

3.2.1. Sensitivity

Sensitivity refers to how responsive a system is to disruptions during its regular operation. It is a relative index that measures regional/local economies' performance compared to the national performance [3,23]. This study employs GDP to represent the functionality of the economic system, and system sensitivity is measured by analyzing the year-to-year changes in the GDP, reflecting the extent of deviation of each year's GDP from the average value across the years within the system. The formula for calculation is expressed as follows:

$$S_{it} = \frac{\left|P_{it} - \overline{P_i}\right|}{\overline{P_i}} \quad (1)$$

where i is the region, and P_{it} is the GDP value in region i in year t. $\overline{P}_i$ is the mean value of the GDP in region i across years. S is the sensitivity index, which reflects the dispersion of the GDP relative to the mean value over a specific period.

To demonstrate sensitivity more visually, we plotted Figure 3 using data from the empirical case of 286 Chinese cities, where the x axis is the sample city ranked from the lowest average GDP to the highest average GDP from left to right and the y axis is the GDP value. The red line in the figure represents $\overline{P}_i$, the mean value of the GDP in each city from 2011 to 2020. And the blue dot represents the GDP value of each city in 2016, i.e., P_{it}. The vertical distance from the blue dot to the red line is the numerator of Equation (1).

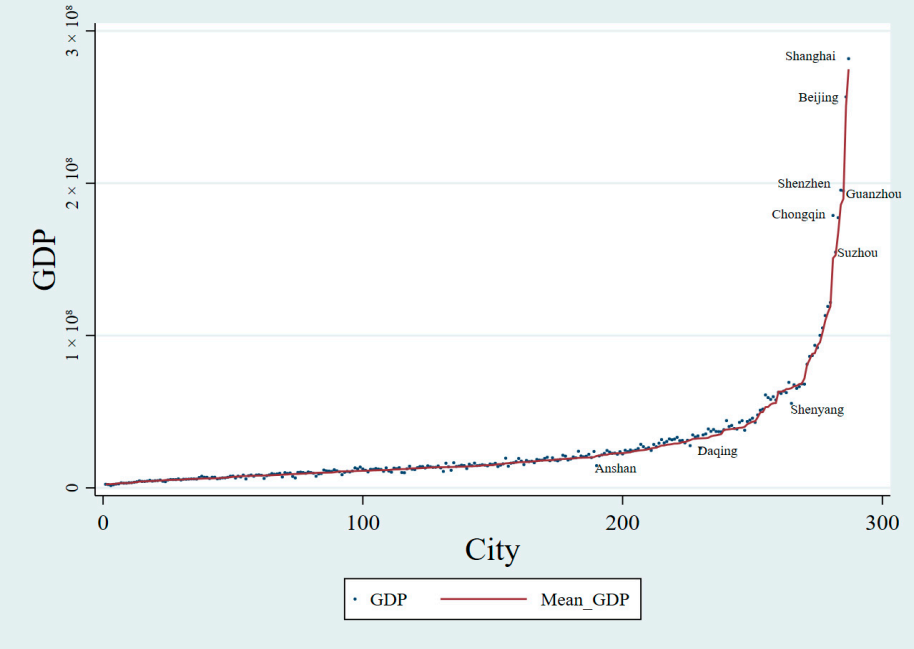

Figure 3. Sensitivity index evaluation results of the empirical case.

3.2.2. Adaptability

Adaptability refers to the ability of an economic system to maintain and restore its structure in the face of disturbances [26]. It can also be seen as a self-regulating mechanism for maintaining the system's relatively stable state. Within a certain period, the trend in the variability in a system is used to measure its deviation from the stable state, which is the system's adaptation. If the trend in its variability decreases or remains stable, the system tends towards relative stability. Increased variability indicates that an unstable system is adapting to changes, which may also indicate an increase in vulnerability.

Over a certain period, adaptability, which is the self-regulating capacity of the system, can be expressed as the slope of a linear trend line fitting the interannual variability in the GDP. In this study, adaptability is represented by the slope of a linear trend line fitting the interannual variability in the GDP during the study period.

$$y = A_i x + B_i \tag{2}$$

$$y = P_{it} - \overline{P_i} \tag{3}$$

where x represents the time series, corresponding to the study period; y represents the interannual variability in the GDP, which is the absolute change in the GDP each year, calculated as the difference between the value of the GDP for each year and the average value of the GDP during the study period. A represents the trend in the GDP's variability, which is the regression slope of the data set y and x and serves as the index of system adaptability. B represents the intercept.

For a more visual representation, we have selected three Chinese cities, Shanghai, Beijing, and Shenzhen, and plotted Figure 4 to show the fit of adaptation in these three cities, where the x axis is the year and the y axis is the calculation results of Equation (3). The blue dot is the interannual variability in the GDP, i.e., the y in Equations (2) and (3). And the red line is the linear fitting of the data set y and x. Thus, the A index is the slope of the red line.

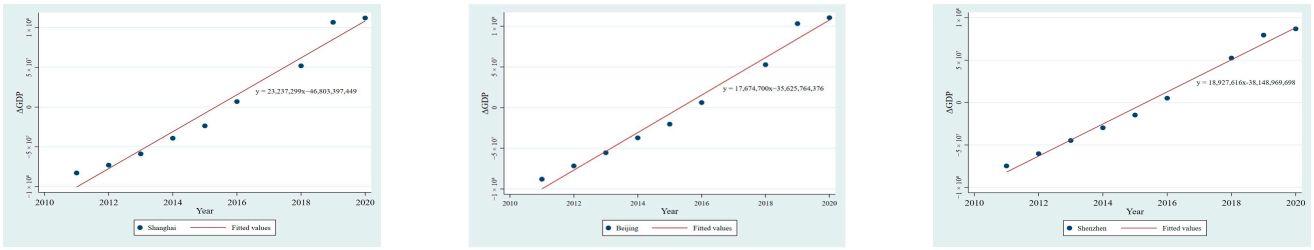

Figure 4. Adaptability index evaluation results of the empirical case. Note: The year 2017 is excluded with no data in the year 2017 from the original data source.

3.2.3. Economic Resilience

Resilience is determined by the system's sensitivity and adaptability, which is inversely correlated with sensitivity and positively correlated with adaptability. To compare regional differences in resilience, the results of sensitivity and adaptability should be standardized before calculating resilience. The formula for calculating resilience is as follows:

$$R = A - S \tag{4}$$

where R is system resilience, S is the sensitivity index, A is the adaptability index.

The proposed methodology refines and advances existing frameworks by presenting a sophisticated approach to the measurement of economic resilience. This approach diverges from the models suggested by Martin et al. [3,23], which primarily evaluate regional performance relative to national benchmarks. Instead, it delves into a comprehensive examination of regional variability and stability via GDP temporal variation analysis within one single economy. Furthermore, while this study adopts an equilibrium perspective for the conceptualization and quantification of resilience, the economic resilience index developed herein adeptly encapsulates the sensitivity and adaptability inherent to economic systems. This index portrays resilience not merely as a reactive capacity but as an inherent attribute of the system, enabling it to navigate and adapt to both immediate disruptions and ongoing changes effectively.

4. Empirical Analysis

4.1. Economic Resilience of Chinese Cities

To empirically apply the economic resilience index, we conducted an analysis using data from 286 Chinese cities for the years 2011, 2014, 2016, and 2020[3]. The ArcGIS platform was employed to visualize the assessment results. The economic resilience results have been divided into five levels: high (>1.5), mid-high (0.5~1.5), medium (−0.5~0.5), mid-low (−1.5~−0.5), and low (<−1.5) (Figure 5).

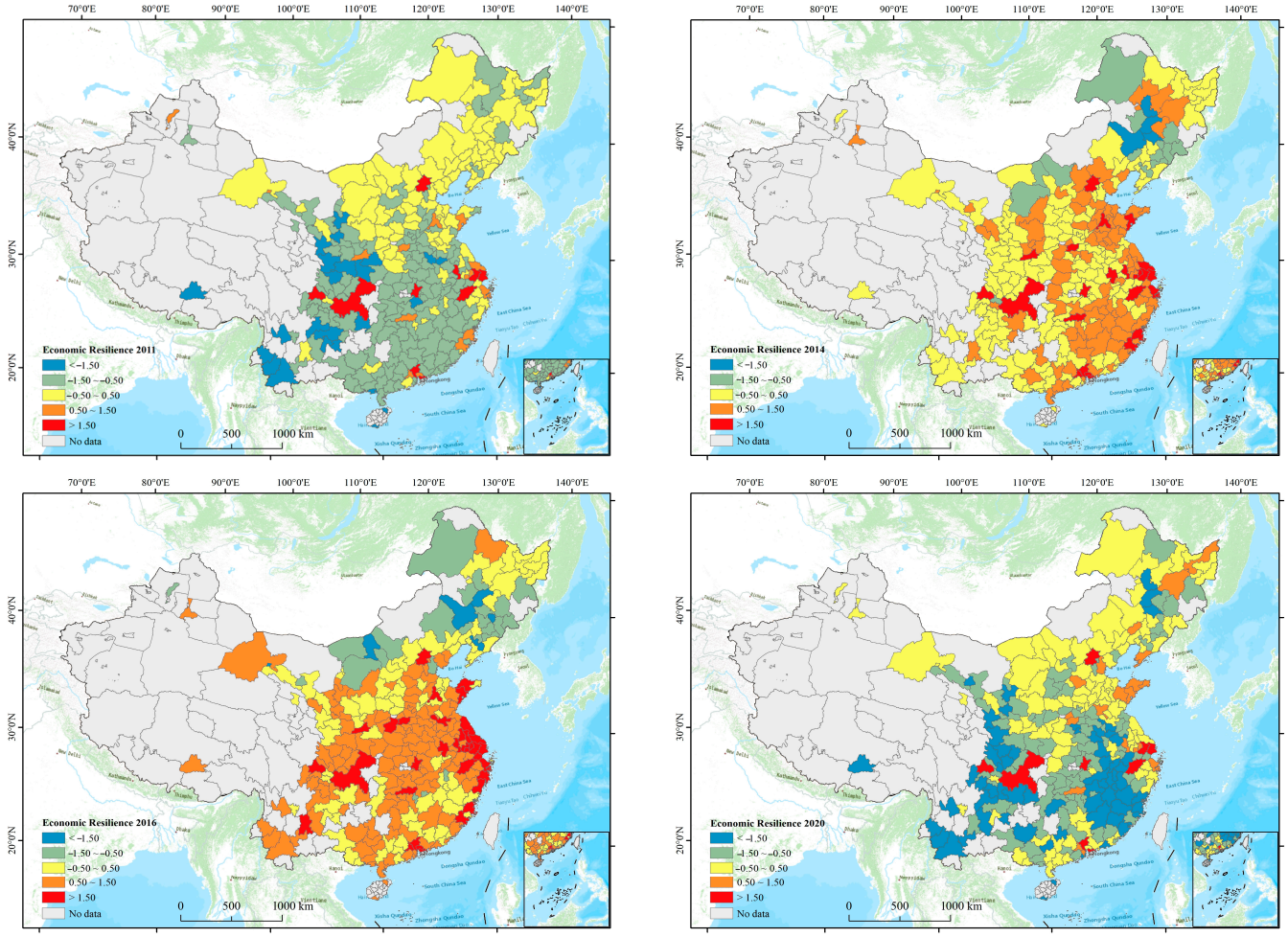

Figure 5. Economic resilience of 286 prefecture-level cities in China from 2011 to 2020.

From 2011 to 2016, economic resilience in Chinese cities is generally increasing. Meanwhile, the progressive expansion of red–orange areas (high and mid-high resilience) until 2020 suggests a significant shock to the economic resilience of each prefecture-level city in China, possibly due to the unforeseen black swan event of the Covid pandemic. In terms of spatial heterogeneity, though the study period, cities with a relatively higher level of economic resilience are mainly concentrated major urban agglomerations like the Beijing–Tianjin–Hebei region, the Yangtze River Delta region, and the Pearl River Delta region. In addition, the findings of our study also corroborate prior research indicating that regional economic resilience in China exhibits spatial heterogeneity, with municipalities and provincial capitals tending to display higher levels of resilience [56,57]. The evaluation results contribute to a deeper understanding of the spatio-temporal evolution of economic resilience in China and may inform future policy decisions.

4.2. Relationship between Fintech and Economic Resilience

Following the comprehensive analysis of the spatio-temporal variations in economic resilience across cities, the focus of this study shifts towards exploring the intricate relationship between Fintech and economic resilience. This transition marks a critical juncture in our research, bridging the gap between the foundational understanding of how cities withstand and adapt to economic fluctuations and the role of Fintech in enhancing or transforming these resilience capacities.

From 2011 to 2016, the relationship between Fintech and economic resilience grew stronger, but by 2020, this relationship had weakened (Figure 6). Despite this, the overall trend still indicates that enhancements in Fintech are positively correlated with higher economic resilience. However, other determinants of economic resilience became more significant in 2020, which may reflect the increasing influence of other economic and social factors alongside the rapid development of Fintech. Therefore, in the following sub-section, we will delve deeper into the dynamics of this relationship, incorporating additional control variables to provide a more nuanced analysis.

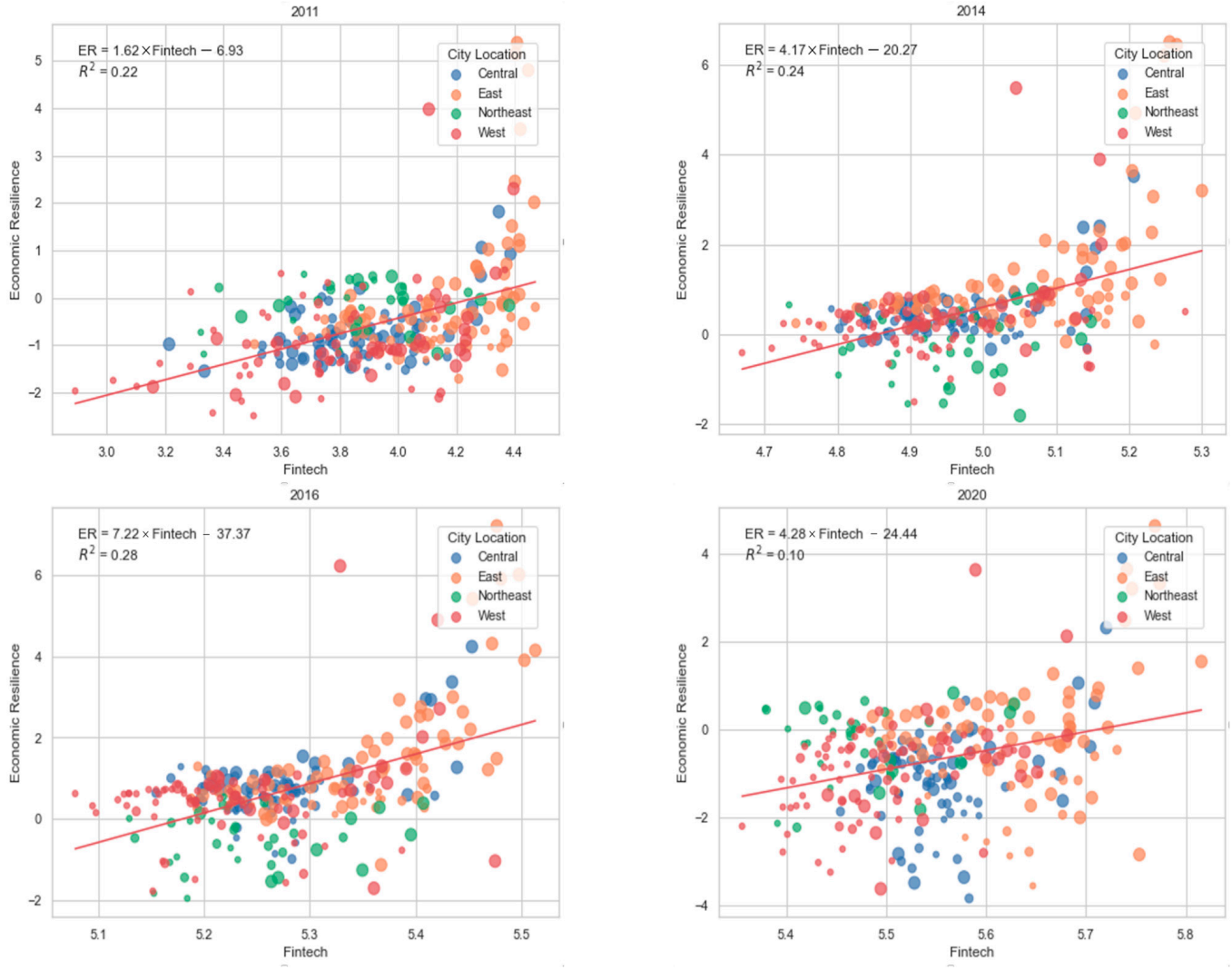

Figure 6. Analysis of the relationship between Fintech and economic resilience in Chinese cities from 2011 to 2020. **Note**: The size of the dots in the graph indicates the size of the city, while the color of the dots represents the city's location.

4.3. Finding New Sources of Economic Resilience: Fintech

4.3.1. Data Source and Description

To standardize the data, the sources for each indicator were primarily drawn from the China City Statistical Yearbook, the Digital Inclusive Finance Index of Peking University, and the China Statistical Yearbook. To investigate the impact of Fintech on economic resilience, we selected indicators relevant to Fintech and economic resilience across 286 prefecture-level cities in China from 2011 to 2020. Furthermore, to mitigate the effects of outliers on the study's findings, we conducted winsorization for continuous variables at the 1% level.

4.3.2. Variable Selection

The variables used in this study are shown in Table 1. *Explained variable*: Economic resilience (ER), measured based on the economic resilience index in Section 3. The assessment results are illustrated in Figure 5 in the previous sub-section. *Explanatory variable*: Financial technology (Fintech). In this research, referring to Zhou et al. [58] and Guo et al. [59], we select the total index of China's digital inclusive finance published by the Institute of Digital Finance at Peking University as the measure of Fintech[4], which can comprehensively reflect the progress of China's digital financial inclusion and the development level of Fintech in prefecture-level cities. *Control variables*: In this study, we identified four control variables, including financial development (FD), economic openness (Open), human capital (HC), and fiscal position (FS). By controlling for these variables, we can isolate the effect of the independent variable on economic resilience while accounting for the effects of other confounding factors.

Table 1. Variable definitions.

Variable Types	Variable Name	Variable Symbol	Variable Selection
Explained variable	Economic resilience index	ER	Self-constructed economic resilience index
Explanatory variables	Financial science and technology	Fintech	Digital Financial Inclusion Index
Control variables	Financial development	FD	(Year-end financial institution deposit balance + year-end financial institution loan balance)/GDP
	Economic openness	Open	(Goods imports million yuan + goods exports million yuan)/regional GDP
	Human capital	HC	The number of college students per 10,000 students is added by 1 and the natural logarithm is taken
	Financial status	FS	Local fiscal general budget expenditure/regional GDP

4.3.3. Econometric Model

Referring to the study by Mai et al. [39], we use a panel regression model to study the impact of Fintech on economic resilience. In the model, the economic resilience index (ER) is the explanatory variable, the level of Fintech is the explanatory variable, and CV is the control variable.

$$ER_{it} = \alpha_0 + \beta_1 Fintech_{it} + i\beta CV_{it} + \varepsilon_{it} \quad (5)$$

where i represents the 286 prefecture-level cities in China, and t represents the year. ε represents a random perturbation term.

5. Results and Discussion

5.1. Descriptive Statistics

The results on the descriptive statistics of the variables are shown in Table 2. Panel A provides a descriptive overview. The analysis reveals that economic resilience varies considerably across regions in China. This variation highlights the differences in the ability of regional economies to withstand risks and external shocks. Similarly, the Fintech variable exhibits substantial spatial imbalance. The large difference between the minimum and maximum values indicates that the level of Fintech is unevenly distributed across regions. Panel B

presents the evolutionary trends in economic resilience and Fintech from 2011 to 2020. The mean values show that economic resilience fluctuates over time, with a decline in 2020 due to the sudden outbreak of the epidemic in 2019, which negatively impacted the Chinese economy. In contrast, the Fintech variable displays a steady upward trend from 2011 to 2020.

Table 2. Descriptive statistics.

Panel A								
Variable	**Obs**	**Mean**	**SD**	**Min**	**P25**	**Median**	**P75**	**Max**
ER	2573	−0.004	1.234	−2.897	−0.735	−0.008	0.646	4.917
Fintech	2573	5.025	0.518	3.533	4.784	5.152	5.434	5.700
FD	2573	2.458	1.162	0.987	1.661	2.142	2.874	7.017
Open	2573	0.051	0.138	0.000	0.000	0.000	0.028	0.919
HC	2573	2.635	2.506	0.000	0.000	3.384	4.989	6.964
FS	2573	0.204	0.102	0.077	0.135	0.177	0.241	0.626
Panel B								
Variable		**Year**	**Min**		**Max**	**Mean**	**Standard error**	
ER		2011	−2.897		4.704	−0.781	1.062	
		2014	−1.818		4.917	0.625	0.908	
		2016	−1.909		4.917	0.850	1.106	
		2020	−2.897		4.053	−0.845	1.312	
Fintech		2011	3.533		4.472	3.938	0.262	
		2014	4.978		5.300	4.978	0.122	
		2016	5.078		5.513	5.279	0.089	
		2020	5.356		5.700	5.546	0.084	

5.2. Benchmark Regression

We conducted benchmark regression using panel data from 286 prefecture-level cities in China to examine the relationship between Fintech and economic resilience. Our stepwise regression approach initially did not incorporate any relevant control variables. The results from Table 3, Column (1) demonstrate a significant enhancing effect of Fintech on economic resilience. Results in Column (2) of Table 3 suggest that the positive effect of Fintech on economic resilience remains unchanged after introducing control variables. Specifically, a 1% increase in the Fintech innovation level can lead to a 0.835% increase in economic resilience. These findings contribute to the growing body of literature on Fintech and its implications for economic development, particularly in the context of China's prefecture-level cities.

Table 3. Benchmark regression.

	(1)	**(2)**
	ER	ER
Fintech	0.412 ***	0.835 ***
	(9.25)	(17.08)
FD		0.230 ***
		(7.60)
Open		−0.354
		(−1.21)
HC		0.188 ***
		(15.26)
FS		−2.273 ***
		(−9.44)
_cons	−2.074 ***	−4.779 ***
	(−9.63)	(−19.08)
N	2573	2573
R^2	0.031	0.222

Note: Robust t-statistics in brackets. *** $p < 0.01$.

5.3. Endogenous Test

Current scholarly consensus suggests that Fintech development is positively associated with economic growth [60]. However, research also indicates that the rate of technological innovation is contingent upon national economic development [61,62]. In times of economic prosperity, economies tend to allocate more capital to technological innovation activities, whereas during economic downturns, capital tends to be redirected towards investment to stimulate economic growth. Therefore, a causal endogenous relationship exists between Fintech and economic resilience. Economic resilience, as a macro-level variable, is influenced by multiple factors, and the presence of control variables in the current data may not prevent the occurrence of omitted variables. Potential issues of reverse causality and omitted variable bias necessitate an instrumental variable approach to addressing endogeneity and isolating the true effect of Fintech on economic resilience.

With reference to Ding et al. [12], the instrumental variable chosen to measure the level of Fintech development in this study is the geographical distance from each prefecture-level city to Hangzhou. This is because Hangzhou is the headquarters of Alibaba, the largest Fintech service provider in China with a highly developed Fintech level. By using geographic distance, which is a physical variable, the authors argue that this variable is less correlated with economic resilience and consistent with the characteristics of instrumental variable selection. To further strengthen the validity of the instrumental variable selection, we logarithmically processed the instrumental variables to eliminate the influence of magnitude. The results of the instrumental variables are presented in Table 4, and the test results are consistent with the benchmark regression. The use of geographic distance as an instrumental variable is particularly noteworthy, as it is less likely to be affected by confounding factors that may affect the relationship between Fintech development and other economic variables.

Table 4. Endogeneity test.

	(1)	**(2)**
	Fintech	ER
ER	0.622 ***	
	(3.25)	
Hdis		−0.112 ***
		(−3.23)
FD	−0.084	0.333 ***
	(−1.29)	(16.36)
Open	0.383 ***	−0.148
	(3.34)	(−0.80)
HC	−0.173 ***	0.090 ***
	(−9.42)	(8.92)
FS	1.062 *	−2.642 ***
	(1.86)	(−10.69)
_cons	5.453 ***	0.247
	(53.83)	(1.06)
N	2573	2573
R^2	0.384	0.161

Note: Robust t-statistics in brackets. *** $p < 0.01$, * $p < 0.10$.

5.4. Robustness Test

5.4.1. Alternative Proxies

The Fintech index can be classified into three dimensions: coverage breadth, usage depth, and digitization level [59]. Coverage breadth refers to the extent of electronic account coverage, including major Internet payment accounts and the number of associated bank accounts. Usage depth pertains to the actual use of Internet financial services in various areas, such as credit, investment, insurance, and payment. Digitization level, on the other hand, represents the mobility, affordability, convenience, and credit characteristics of Fintech innovation. To assess the

impact of Fintech on economic resilience, we conducted regression analyses between each of the three Fintech dimensions and economic resilience, as presented in Table 5. The findings indicate that Fintech continues to play a significant positive role in bolstering economic resilience.

Table 5. Alternative proxies.

	(1)	(2)	(3)
	ER	ER	ER
Breadth	0.669 ***		
	(16.91)		
Depth		0.699 ***	
		(13.05)	
Digitization			0.584 ***
			(13.79)
FD	0.221 ***	0.263 ***	0.292 ***
	(7.21)	(8.90)	(9.70)
Open	−0.298	−0.343	−0.246
	(−1.02)	(−1.18)	(−0.86)
HC	0.168 ***	0.179 ***	0.167 ***
	(13.94)	(13.86)	(13.81)
FS	−2.074 ***	−2.271 ***	−2.987 ***
	(−8.47)	(−9.15)	(−12.36)
_cons	−3.862 ***	−4.123 ***	−3.563 ***
	(−18.86)	(−14.53)	(−15.61)
N	2573	2573	2573
R^2	0.219	0.201	0.217

Note: Robust t-statistics in brackets. *** $p < 0.01$.

5.4.2. Fixed Effect

In addition, to verify the robustness of our results, we also use a fixed model for regression, adding fixed effects to control for multiple unobservable local specific features to better verify the accuracy of our results. It should be noted that in the fixed effects test, we only control for city fixed effects but not time fixed effects because our economic resilience is calculated based on temporal variation, and controlling for time fixed effects would compromise the validity of economic resilience. The results are shown in Table 6. In Column (1), we control for city fixed effects only; in Column (2), we control for city-related factors and control for city fixed effects. The results in both columns remain consistent with the baseline regression.

Table 6. Individual fixed effects test.

	(1)	(2)
	ER	ER
Fintech	0.190 ***	0.761 ***
	(9.91)	(19.74)
FD		−0.028
		(−0.44)
Open		−1.641 ***
		(−8.07)
HC		0.139 ***
		(17.79)
FS		1.615 **
		(1.99)
_cons	−0.956 ***	−4.370 ***
	(−9.92)	(−20.08)
N	2579	2579
R^2	0.317	0.080

Note: Robust t-statistics in brackets. *** $p < 0.01$, ** $p < 0.05$.

5.5. Mechanism Test

Drawing on theoretical insights, we firstly investigate technological innovation as a mediating mechanism. The efficacy of science and technology innovation is fundamentally determined by the actual benefits it produces [63]. Patents, as tangible outcomes of innovation, are highly indicative of the level of regional science and technology innovation. Furthermore, the utilization of patents and the technology spillover effects that stem from them can be readily applied to the market and translated into tangible outcomes. Consequently, we follow Chen et al.'s [64] research and utilize the natural logarithm of the number of granted patents (R&D) in prefecture-level cities as a proxy variable for science and technology innovation. The larger the number of granted patents, the higher the level of science and technology innovation.

Secondly, we examine industrial structure as another mediating mechanism. Given the technological characteristics of Fintech, we posit that the optimization of the industrial structure driven by Fintech development should manifest in the high-end of the industrial structure, i.e., the proportion of strategic emerging industries should continue to increase, and high value-added industries should continue to emerge. The development of digital technology propels the economic structure towards the service industry; thus, the process of upgrading the high-end industrial structure is essentially the process of increasing the output value of the tertiary industry. Consequently, we adopt the proportion of the value added of the tertiary industry to the value added of the secondary industry to measure industrial structure upgrading (IS). Table 7 presents the findings of the mechanism test, which suggests that Fintech has a positive impact on technological innovation and industrial structure upgrading.

Table 7. Mechanism test.

	(1)	**(2)**
	R&D	IS
Fintech	1.656 ***	0.134 ***
	(23.95)	(6.69)
FD	0.095 *	0.238 ***
	(1.90)	(15.76)
Open	9.571 ***	0.146
	(15.47)	(1.54)
HC	−0.669 ***	−0.026 ***
	(−27.33)	(−5.46)
FS	−1.501 ***	1.404 ***
	(−2.94)	(10.79)
_cons	−4.410 ***	−0.463 ***
	(−12.32)	(−4.31)
N	2573	2573
R^2	0.667	0.459

Note: Robust t-statistics in brackets. *** $p < 0.01$, * $p < 0.10$.

5.6. Heterogeneity Test

China's regional economy displays a marked degree of spatial heterogeneity, with the eastern region exhibiting robust development, while the middle and western regions manifest weaker growth. Concurrently, the growth of Fintech in China is rapid, yet significant disparities exist among prefectures and cities, yielding an imbalanced spatial distribution featuring an evident step-like pattern at the regional level. These regional distinctions may also engender regional-level variations in the influence of Fintech on economic resilience. To further scrutinize the impact of Fintech on economic resilience at the regional level, this study focuses on two facets, namely the region and city scales.

To begin with, we adopt a regional/locational perspective by categorizing Chinese prefecture-level cities into eastern, central, western, and northeastern regions (Figure 1) and analyzing them through grouped regressions. Our findings, as presented in Table 8, reveal that Fintech exerts a notable impact on economic resilience, with a more significant effect observed in the east in comparison to the central and western regions. This differential

impact may be attributed to the eastern region's inherent location advantages and resource endowments, as well as its sound economic development foundation and robust innovation activities, all of which enhance the promotional effects of Fintech on economic resilience. In contrast, Column (4) demonstrates the negative impact of Fintech on economic resilience in the northeastern region, which has traditionally served as a prominent industrial base in China, with a comparatively slow development of the financial sector. Consequently, the impact of Fintech on economic resilience in the region is not substantial.

Table 8. Locational heterogeneity.

	(1)	(2)	(3)	(4)
	East	Central	West	Northeast
Fintech	1.011 ***	0.987 ***	0.910 ***	−0.173 *
	(8.80)	(14.31)	(11.58)	(−1.69)
FD	0.529 ***	0.207 ***	0.038	0.178 ***
	(7.25)	(4.11)	(1.06)	(3.56)
Open	−1.094 ***	−5.162 ***	−0.214	0.469
	(−2.71)	(−4.62)	(−0.47)	(0.86)
HC	0.165 ***	0.165 ***	0.199 ***	0.074 ***
	(6.49)	(7.77)	(10.08)	(3.15)
FS	−5.191 ***	−3.773 ***	−1.334 ***	0.574
	(−6.24)	(−5.38)	(−4.24)	(1.23)
_cons	−5.648 ***	−5.157 ***	−5.012 ***	−0.092
	(−10.13)	(−14.20)	(−12.23)	(−0.19)
N	777	720	776	306
R^2	0.313	0.268	0.189	0.068

Note: Robust t-statistics in brackets. *** $p < 0.01$, * $p < 0.10$.

Table 9 present the results of the impact of Fintech on economic resilience in cities of different sizes. The findings indicate a positive and significant effect of Fintech on resilience across all city size classes, while the impact is most significant in large cities, followed by medium cities, and finally small cities. One possible explanation for this pattern is that larger cities tend to have greater economies of scale, which can promote technological innovation and foster the development of Fintech. In turn, the greater adoption of Fintech in larger cities may enhance economic resilience by improving access to financial services, facilitating entrepreneurship and innovation, and boosting overall economic growth. The heterogeneity results in this study are consistent with other relevant empirical studies [65].

Table 9. City-scale heterogeneity.

	(1)	(2)	(3)
	Small	Median	Big
Fintech	0.667 ***	0.711 ***	1.177 ***
	(8.41)	(11.80)	(11.45)
FD	−0.026	0.022	0.224 ***
	(−0.39)	(0.58)	(5.07)
Open	−1.145 **	−1.585 ***	0.131
	(−2.51)	(−4.66)	(0.29)
HC	0.157 ***	0.133 ***	0.219 ***
	(9.42)	(9.46)	(8.71)
FS	−0.151	−1.363 ***	−2.937 ***
	(−0.41)	(−2.86)	(−3.49)
_cons	−3.934 ***	−3.827 ***	−6.354 ***
	(−10.21)	(−12.53)	(−11.30)
N	715	928	936
R^2	0.120	0.143	0.224

Note: Robust t-statistics in brackets. *** $p < 0.01$, ** $p < 0.05$.

6. Conclusions and Enlightenment

This study ventured to enhance urban sustainability by examining economic resilience and digital transformation, aiming to broaden and redefine the traditional perception of economic resilience beyond mere shock response. It delved into economic resilience within the digital transformation of the financial technology sector, proposing a fresh perspective on navigating the complexities of modern urban development. We first introduced and employed an innovative conceptualization of economic resilience, framing it as an inherent attribute of regional economic systems. This novel perspective facilitates the analysis of economic resilience not only in the context of external disturbances but also as a fundamental characteristic, enabling a proactive assessment of a system's inherent economic stability and robustness. This shift towards recognizing resilience as a constant feature provides deeper insights into the foundational strength of economic systems, allowing for a more comprehensive understanding of their capacity to withstand and adapt to changes.

Secondly, this study developed a new method for quantifying economic resilience that adeptly captures the sensitivity and adaptability of economic systems without the prerequisite of a shock. This methodological innovation represents a significant leap forward in the quantification of economic resilience, offering a tool that can be applied universally, across various contexts and scenarios. Our empirical investigation, utilizing panel data from 286 prefecture-level cities in China from 2011 to 2020, demonstrates the utility of this method in examining the influence of Fintech on economic resilience and sheds light on the underlying mechanisms and the regional heterogeneity of this influence.

The empirical findings of this study reveal that the digital tools of Fintech significantly bolster economic resilience, serving as a new source of resilience through their facilitation of technological innovation and industrial structure upgrading. This underscores the critical role of Fintech in supporting the recovery, restructuring, and renewal of economies, thereby promoting high-quality economic growth. Our research aligns with and extends the findings of Zhou et al. [58] and Shi et al. [66], reinforcing the idea that Fintech is a pivotal catalyst for sustainable economic development.

However, this study is not without its limitations. Primarily, the measurement of economic resilience in this analysis was anchored solely on GDP as the input indicator. This choice, albeit grounded in the widespread availability and comparability of GDP data, may not fully encapsulate the multifaceted nature of economic resilience. Future studies could enrich our understanding of economic resilience by incorporating a broader spectrum of economic indicators, such as employment rates, industrial diversity, and innovation metrics. These additional indicators could offer a more nuanced and comprehensive view of the economic system's resilience, capturing aspects of economic health and adaptability beyond mere output.

Furthermore, the methodology employed to calculate economic resilience indicators relied on annual aggregated GDP data, leading to a uniform adaptability value being assigned to each city throughout the study period. This approach, while facilitating a streamlined analysis, may not accurately reflect the dynamic nature of cities' economic resilience, which can fluctuate significantly within shorter time frames due to various factors, including policy changes, market shifts, and external shocks. To address this limitation and enhance the granularity of resilience assessment, future research could leverage monthly data, or other more frequent economic indicators, to better capture the temporal variations in city's adaptability values. Such an approach would allow for a more detailed and responsive analysis of economic resilience, providing insights into the immediate impacts of economic policies and external events on regional economies.

In summary, this research makes significant strides in the conceptualization and quantification of economic resilience and further applies this methodology to empirical examination, highlighting the transformative potential of Fintech in enhancing the resilience of economic systems. While acknowledging the limitations of the current study, we advocate for further exploration into this complex relationship, suggesting that the economic resilience calculation method proposed here can be adapted and applied in diverse

contexts to explore various dimensions of resilience. This study not only contributes to academic discourse but also offers practical insights for policymakers and practitioners interested in leveraging digital transitions to fortify urban sustainability across different scales and regions.

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Notes

[1] There are various ways to define Fintech; according to the World Bank, Fintech is broadly defined as "advances in technology that have the potential to transform the provision of financial services, spurring the development of new business models, applications, and processes, and products" [11].

[2] For different types of resilience analysis methodologies, refer to Doran and Fingleton [36] and Modica and Reggiani [37].

[3] The exclusion of 2017 was due to the unavailability of GDP data from the China City Statistical Yearbook.

[4] To eliminate the influence of the data outline, we add "1" to the original index and take the natural logarithm as the proxy variable of Fintech in this study. The larger the value, the higher the level of Fintech.

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