The role of financial drivers on regional economic resilience: Does information technology level matter?

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ABSTRACT

Economic globalization has intensified economic volatility around the world, and the importance of economic resilience has become increasingly prominent in the face of rising uncertainty due to frequent domestic and foreign shocks. Based on provincial panel data in China from 2008-2019, a comprehensive indicator system is constructed to measure regional economic resilience (RER), and the impact of financial driver (FD) on RER is explored from staged, pathway and non-linear perspectives. The main findings are as follows. (1) Both national and regional levels of FD and RER show an upward trend, and the impact of FD on RER has an "inverted-U" shape: as the capacity of FD increases, its impact on regional economic resilience shifts from promoting to inhibiting. The RER has significant spatial agglomeration characteristic. (2) Interestingly, staged analysis shows FD can significantly promote RER only when it is in the "recovery stage". (3) The pathway analysis of its effect on regional economic resilience shows the following characteristics: financial scale > financial efficiency > financial deepening. (4) From different regions, there are significant differences in the effect of FD on the promotion of regional economic resilience: central region > western region > eastern region. Finally, the corresponding suggestions were provided.

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1. Introduction

Since the financial crisis in 2008, the "reverse globalization" caused by the supply chain disruption and other economic changes, so that the economic development of all countries is facing increased uncertainty and risk. In this context, strengthening economic resilience and enhancing the economy's ability to cope with the risks of internal and external shocks have become one of the key concerns of the Chinese government and all sectors of society. Although under great pressure from changes, China's economy is resilient and has sufficient potential. It is important to note that this cannot be done without the support of rapid financial development. In the effective market economy system, the central bank has flexibly adjusted its financial policies according to the actual situation, allowing financial resources to keep flowing to competitive enterprises and stimulating their vitality and resilience. Simultaneously, the rise of financial technology has driven the innovation level and industrial structure upgrading, which contribute to economic growth and become an important support for economic resilience. However, technology-driven financial innovation has also brought new risks to the financial system such as data security, regulatory arbitrage and information leakage, and the fairness and stability of economic development has thus been greatly affected.

Meanwhile, China has been applying the new development philosophy and enhancing its economic resilience. As external shocks of economic uncertainty gather over global economy, China shows strong economic resilience and injects certainty into the world economy. China's economic engine has always been roaring ahead. From 2008 to 2021, China's GDP grew from 31.92 trillion yuan to 114.4 trillion yuan.

Notably, due to geographical location, economic foundations, technological and historical reasons, there are significant regional heterogeneities in financial driver and regional economic resilience in China. Therefore, what are the changing characteristics of financial driver and regional economic resilience levels? What is the specific effect or linear relationship between the two? Is there a non-linear characteristic in the process? What is the underlying driving mechanism or pathway? Is this effect characterized by regional heterogeneity? The scientific answers to the above questions can help promote the steady improvement of regional economic resilience via the sustainable financial driver.

The remainder is organized as follows: part 2 is literature review; part 3 is mechanism analysis; part 4 is model setting and variable selection; part 5 is empirical results and analysis; part 6 is robustness testing; the seventh part is further analysis; and the last part is conclusions and policy implications. The research framework is shown in Fig.1.
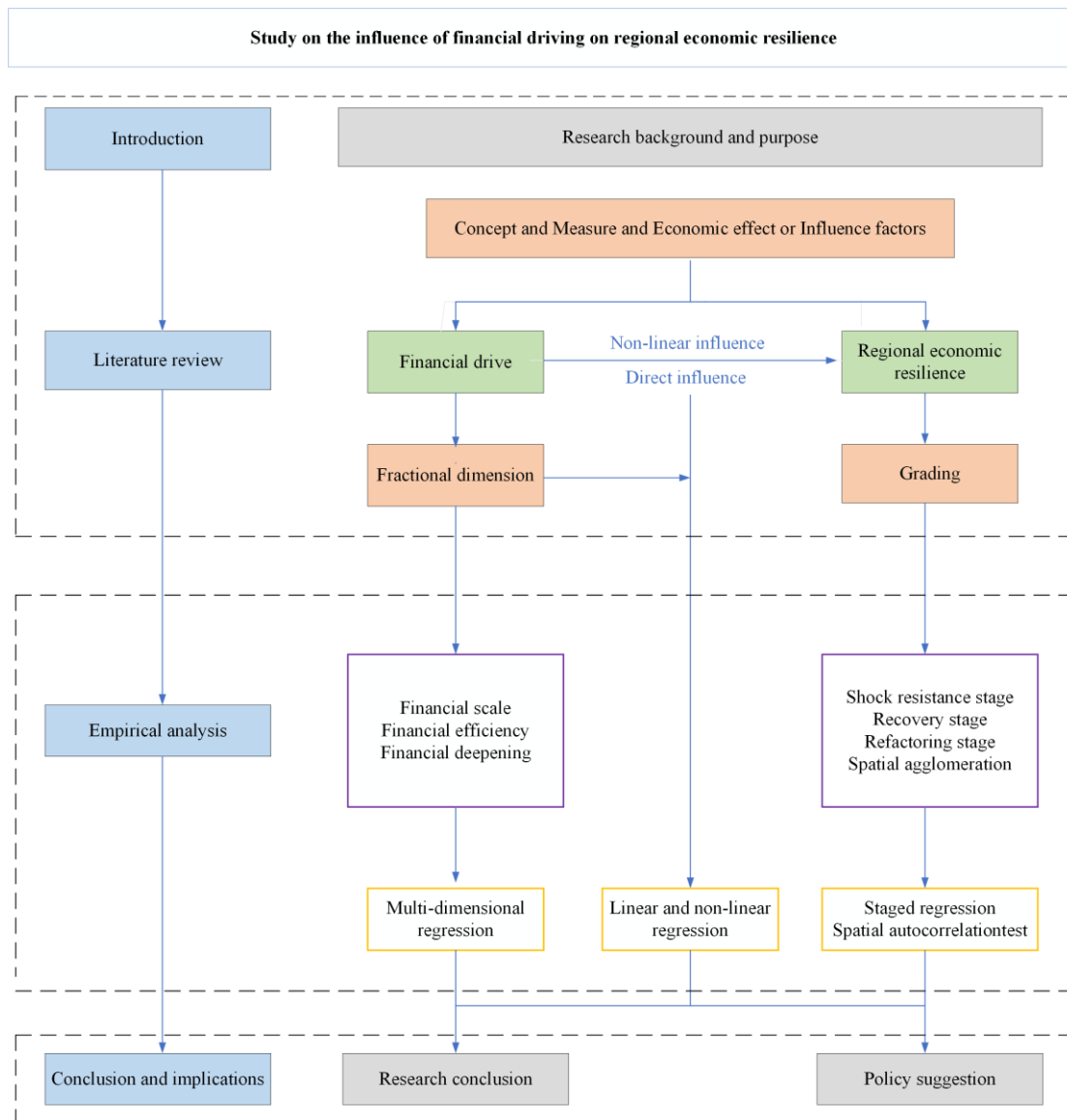
Figure 1. Research framework diagram.

2. Literature review

The relevant literature on financial driver is mainly around following aspects: the concept and measurement of financial development (Gurley et al., 1967; Arestis & Demetriades, 1997; Rajan & Zingales, 1998; Demetriades & Rousseau, 2016), economic effects of financial development (De & Guidotti, 1995; Benhabib & Spiegel, 2000; Loayza & Ranciere, 2006; Fernández & Tamayo, 2017), financial development and poverty reduction (Jalilian & Kirkpatrick, 2002; Rewilak, 2017; Rashid & Intartaglia, 2017; Cepparulo et al., 2017), the impact of financial development on environment (Shahbaz et al., 2016; Acheampong, 2019; Khan & Ozturk, 2021). Gurley et al. (1967) proposed the concept of financial development, and then scholars gradually improved the theoretical system of financial development (Greenwood et al., 1990). Financial development mainly refers to the development of financial systems such as financial instruments, financial institutions and financial markets, which is an important driver of a country's economic development. As for the measurement of the degree of financial development, most scholars favor specific dimensions: the scale (Fang et al., 2020), efficiency (Yuan et al., 2022), and dynamism (Levine et al., 1998) of the financial system. Some scholars favor specific sectors such as stock markets and commercial banks

(Beck et al., 1999). Meanwhile, scholars have paid considerable attention to the economic effects of financial development on international trade ((Beck, 2002), regional growth (Pal et al., 2022), industrial structure optimization and upgrading (Xu et al.,2020), carbon emission performance (Cao, 2022; Samargandi et al., 2022), energy efficiency improvement (Qu et al., 2020), green transformation of low carbon economy (Li et al., 2022) and innovation efficiency improvement (Pradhan et al., 2016; Tang et al., 2021).

Research on regional economic resilience has focused on the concept, measurement (Hallegatte, 2014; Tóth, 2015; Martin & Sunley, 2015) and influencing factors such as industrial diversity (Brown & Greenbaum, 2017; Hu et al., 2022). The definition of its concept has broadly gone through three stages: engineering resilience, ecological resilience and adaptive resilience. Among them, adaptive resilience is widely accepted in economics (Hu et al., 2017), which focuses on the ability of economic systems to maintain their core functions after a shock (Marcos et al., 2008; Hill et al., 2012; Briguglio, 2016; Sensier et al., 2016). On this basis, Martin et al. (2016) further generalized economic resilience as resistance, ability to adapt and adjust, and ability to develop new growth paths. The measurement of economic resilience mainly includes two kinds of measures, namely the construction of resilience index and comprehensive indicator system. Scholars mostly choose the regional sensitivity (the ratio of regional to national GDP change rate and employment change rate) as the resilience index to measure regional economic resilience based on Martin's method (2012), while they also choose different indicators based on different perspectives to construct a system of economic resilience indicators (Briguglio et al., 2009; Faggian et al, 2018; Xie et al., 2018; Wang et al.,2021). With the increasing research on economic resilience, the factors affecting economic resilience have been gradually revealed, mainly including industrial structure diversification (Brown et al., 2017), government intervention (Wang et al., 2022), innovation capacity (Bristow et al., 2018), productive infrastructure development (Christopherson et al.,2010), etc.

What's more, Lai et al. (2021) found that financial market information is an important factor for sustained and stable economic growth. Cui (2021) found that digital finance has a significant positive contribution to economic resilience. Based on the spatial Durbin model Zhang and Zhao (2021) found that the increase in financial agglomeration contributes to the economic resilience of local area and its neighboring areas.

However, the role of comprehensive and sub-dimension financial drivers in improving regional economic resilience lacks due attention. Most of the existing literature mainly discusses financial development and economic growth in terms of effects and mechanisms. Economic resilience is distinguished from economic growth. The specific effect of financial drivers (FD) on regional economic resilience (RER), the non-linear relationship, its heterogeneous effect at different stages of economic resilience and the impact mechanism lacks due attention. Based on this, the marginal contributions of this paper are as follows. (1) The level of economic resilience in different regions is quantified via constructing a comprehensive evaluation system, and its spatial agglomeration characteristic is explored. (2) Construct an exploratively analytical framework to empirically investigate the impact of FD on RER, as well as the nonlinear relationship. (3) FD is further divided into three dimensions of financial scale, financial efficiency and financial deepening and the impact pathway is analysed. (3) According to the dynamic change characteristics of economic resilience, it is divided into shock resistance stage, recovery stage and reconstruction stage, and the heterogeneous effects of FD on economic resilience at different stages were analyzed.

3. Mechanism analysis

3.1. Direct impact of FD on RER

This study defines regional economic resilience as the ability of a regional economic system to cope with external shocks to maintain or improve its original economic operating model. The FD has three main aspects of influence on RER, as shown in Figure 2.

3.1.1. Financial scale and RER

The contribution of financial scale to RER is mainly reflected in the economies of scale it brings: economies of scale in financial institutions, financial products and financial services. First of all, financial institutions can adopt the strategy of expanding the scale of their operations to optimize the financial structure by expanding the scale of the stock market and bank credit (Xu et al., 2021), and providing diversified financing channels. Therefore, increasing the savings rate and the amount of investment provides strong financial support for regional enterprises in the event of external shocks, which further enhances the rapid adjustment, recovery and innovation of enterprises aftershocks. This will enhance the RER by improving the ability of enterprises to adjust, recover and innovate quickly after external shocks (Pashapour et al., 2019). Secondly, financial institutions, empowered by technology, take the initiative to accelerate innovation in financial products and services and provide convenient and flexible financing models. The financial needs of individual customers with small, decentralized and high frequency are better meet, which enhances the financing capacity of enterprises and promotes regional economic growth and economic resilience.

3.1.2. Financial efficiency and RER

Financial efficiency means the efficiency of regional financial resources allocation, and its improvement helps to reduce macroeconomic volatility (Yuan et al., 2022). Firstly, in the process of exerting the same scale effect, the capital use or demand will decrease due to the turnover speed. Then, under the condition of the same capital use, the higher the financial efficiency, the greater the scale effect will be, and the more obvious the role of promoting regional economic resilience will be. Besides, the allocation efficiency of financial resources is directly related to the allocation efficiency of other factors. The effective use, management and decision-making of financial resources by economic agents can lead to the flow of factors such as capital and labor to projects with higher investment returns, effectively reducing the degree of distortion of market factors, promoting stable economic development and enhancing economic resilience.

3.1.3. Financial deepening and regional economic resilience

Most scholars have suggested that financial deepening can promote economic growth (Dahiya, S., 2022; Sugiyanto, C. et al., 2020). Financial deepening refers to the degree of monetization of the economy, and the process of monetization is the reaction of economic activities that are not traded monetarily through the medium of money. A higher degree of economic monetization means that the greater the financial assets are, the more developed the commodity economy is. The government can employ the price mechanism in guiding, promoting and regulating social production activities through the formulation of a reasonable monetary policy, which helps to enhance economic resilience. At the same time, a higher degree of financial deepening also means a more mature financial system and a higher attractiveness to foreign investors (Liu, H. et al., 2020), which will enable industries to get more financial support in their production and operation activities. It helps solve the problems of financing difficulties when enterprises face shocks, thus promoting the development and growth of the regional economy and maintaining a better economic resilience.

3.2. Non-linear relationship of FD and RER

It has been demonstrated that financial development has asymmetric and non-linear influence on economic growth (Shahbaz, M. et al., 2022), so does the FD also have such an impact on RER? The rapid development of the financial sectors can effectively regulate the investment of savings capital from financial institutions in other areas by providing diversified financing channels, self-interested information advantages and innovative and diversified financial products and services. It will further balance demand and supply across markets, achieve efficient

allocation of limited resources in time and space, effectively promote technological progress and boost industrial upgrading, thus driving economic growth. However, during the economic boom and the rise of digital technology, excessive financialization can cause the economy to "de-realize". Speculators and arbitrageurs will use the huge amount of capital to make huge profits, forming excessive credit and leverage. Once the external shock comes, the virtual economy "bubble" bursts, the lack of capital supply in the real economy is exposed, and with the transmission effect of financialization, the economy will be plunged into a series of unsustainable productions, unemployment and bankruptcy. The instability of the economy is self-evident.

3.3. The effect of financial driver on different stages of regional economic resilience

Output loss and economic growth rate in different stages can be used to portray economic resilience (Zheng et al., 2022). In the short-term period when the economy suffers from external shocks, enterprises facing liquidity difficulties can rely on the investment transformation function of financial institutions to get financial support to cope with external shocks. But at the same time, financial institutions also face pressure from the increase in non-performing loans, and the support role is limited. When the economy enters the recovery stage, the financial institutions' capital turnover begins to gradually improve, and the role of helping enterprises is enhanced, while the enterprises' own production and operation have also recovered to a certain extent, so they can maintain a better resilience to continue to resist shocks. Although the economy has a strong economic resilience in the reconstruction stage, but with the widespread use of financial technology and digital economy technology, the flow of funds began to "de-realize", a variety of new financial risks gradually emerged. The instability of economic development is intensified, economic resilience is thus weakened.
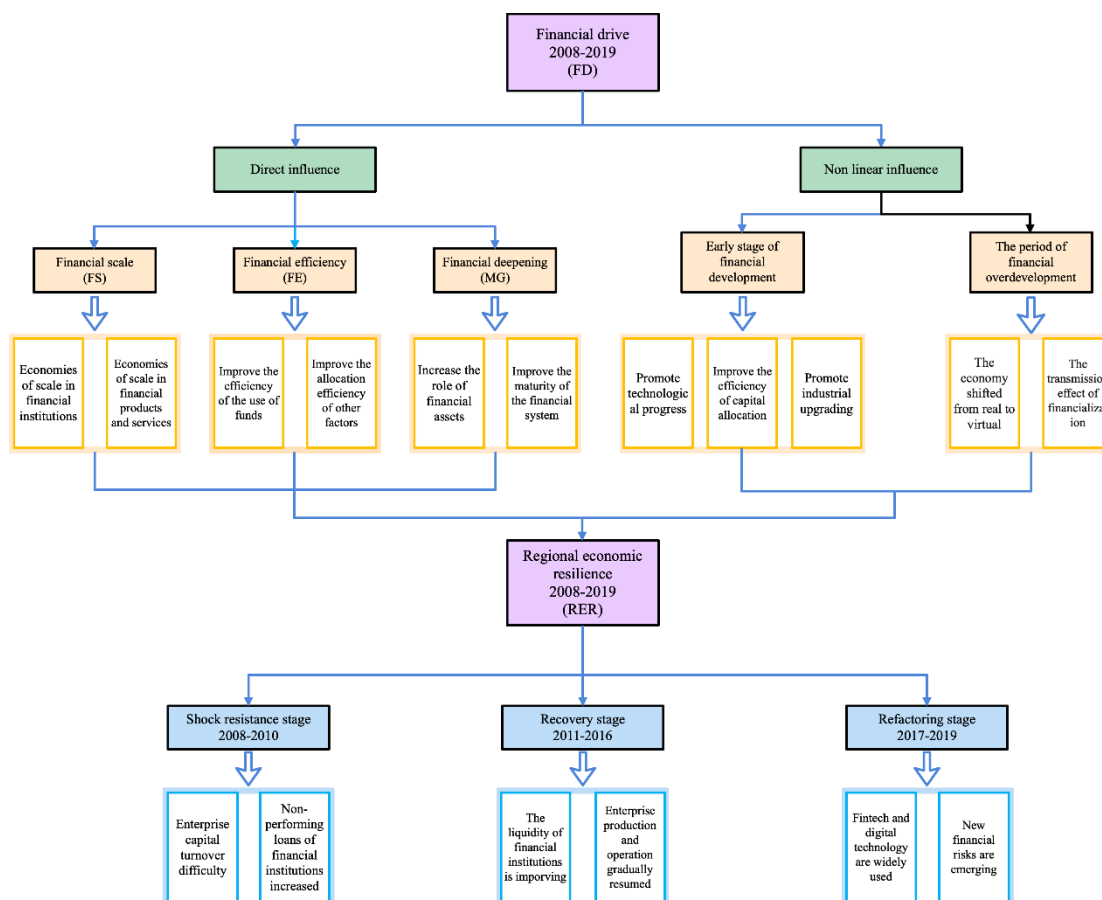

Figure 2. Mechanism analysis diagram.

4. Research Design

4.1. Benchmark regression model

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(1) To verify the linear relationship of FD and RER, the following benchmark regression model is constructed.

$$RER_{it} = C + \alpha FD_{it} + \sum_{j=1}^{n} \beta X_{it} + \mu_i + \varepsilon_{it} \tag{1}$$

Where: RER_{it} is regional economic resilience; FD_{it} is financial drive; X_{it} is other control variables that may affect regional economic resilience; α and β are estimated coefficients of financial driver and other control variables, respectively; μ_i is province fixed effect; ε_{it} is random error term; i and t are province and time, respectively; C is constant term.

(2) Meanwhile, to test the non-linear characteristic, the following model is constructed.

$$RER_{it} = C + \delta_1 FD_{it} + \delta_2 FD_{it}^2 + \sum_{j=1}^{n} \beta X_{it} + \mu_i + \varepsilon_{it} \tag{2}$$

Where: FD_{it}^2 is the squared term of financial drive; through δ_1 and δ_2, the impact of FD on RER at different stages can be analyzed. The rest of variables and symbols have the same meaning as equation (1).

4.1.2. Sub-dimensional regression model

In addition, referring to Zhang et al. (2017), decompose model (1) into three models to analyze the pathway of *FD* on *RER* in a deeper way.

$$RER_{it} = C + \alpha_1 FS_{it} + \sum_{j=1}^{n} \beta X_{it} + \mu_i + \varepsilon_{it} \tag{3}$$

$$RER_{it} = C + \alpha_2 FE_{it} + \sum_{j=1}^{n} \beta X_{it} + \mu_i + \varepsilon_{it} \tag{4}$$

$$RER_{it} = C + \alpha_1 MG_{it} + \sum_{j=1}^{n} \beta X_{it} + \mu_i + \varepsilon_{it} \tag{5}$$

Where, FS_{it} is financial size; FE_{it} is financial efficiency; MG_{it} is financial deepening, and the remaining variables and signs are as above.

4.1.3. Spatial Moran's I index

At the same time, to further study the spatial distribution characteristics of regional economic resilience, the spatial correlation of regional economic resilience should be analyzed via the *Moran's I* index, set as follows:

$$Moran's\ I = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(x_i-\bar{x})(x_j-\bar{x})}{S^2 \sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}} \tag{6}$$

Where, n is the number of spatial individuals, *n*=30 in this paper, S^2 is the overall variance of the sample, x_i represents the economic resilience of region i, $\bar{x}$ is the mean value of RER, and w_{ij} is the spatial weight element. In this paper, the adjacent index is used to construct the spatial weight matrix. If space unit i is adjacent to space unit j, the spatial weight value w_{ij}=1; otherwise, it is 0.

The value range of the global *Moran's I* is between -1 and 1. If its value is greater than 0, it indicates that it has a spatial agglomeration feature (Anselin, 1995; Du et al., 2022). The larger the value, the more obvious the spatial agglomeration trend. If it is less than 0, there is no spatial agglomeration feature. The smaller the value, the more discrete the regional economic resilience will be.

4.2. Variable description

4.2.1. Dependent variable: regional economic resilience (RER)

To comprehensively examine the multiple attributes of RER, this paper draws on relevant studies (Martin et al., 2016; Gao et al., 2022), and by constructing a comprehensive evaluation index system, the RER level from 2008-2019 is measured in three dimensions: resistance and recovery capacity, adaptation and adjustment capacity, and innovation and transformation capacity measurement, as shown in Table 1.

Table 1. Regional economic resilience evaluation index system.

Objective Layer	Criteria layer	Indicator layer	Attributes
Regional economic resilience	Resistance and Resilience	GDP per capita	+
		Registered Urban Unemployment Rate	-
		Foreign Trade Dependence	-
		Per capita disposable income of urban residents	+
		Share of local fiscal expenditure	+
	Ability to adapt and regulate	Social fixed asset investment	+
		Total retail sales of consumer goods	+
		Growth of Gross National Product	+
	Innovation and transformation capabilities	Total number of patent applications granted	+
		Industry Structure Diversity	+
		Technology Market Turnover	+
		Population Urbanization Rate	+

To measure regional economic resilience more objectively and scientifically, the entropy value method is used.

①Standardization of data. Since the units of the original data between the 12 indicators involved in this index system are inconsistent and the expression forms are different, standardize the original data, the formula is as follows：

Positive indicators：

$$x_{ij} = \frac{x_j - x_{min}}{x_{max} - x_{min}} \tag{7}$$

Negative indicators：

$$x_{ij} = \frac{x_{max} - x_j}{x_{max} - x_{min}} \tag{8}$$

Where x_j is the value of the j indicator, x_{min} is the minimum value of the j indicator, and x_{max} is the maximum value of the j indicator.

In addition, to ensure the integrity and credibility of the data, a 0.001 shift is applied to the values that are equal to 0 after normalization in this paper.

② Calculate the weight of the indicator value of province i under the j indicator w_{ij}.

$$w_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \ (0 \le w_{ij} \le 1) \tag{9}$$

③ Calculate the entropy value e_j of the j indicator.

$$e_j = -\frac{1}{\ln m} \sum_{i=1}^{m} w_{ij} \ln Y_{ij} \tag{10}$$

④ Calculate the coefficient of variability d_j of the j indicator. the coefficient of variability indicates the role played by the indicator to the evaluation object.

$$d_j = 1 - e_j \tag{11}$$

⑤ Calculate the weight c_j of the j indicator. use the variability coefficient of the indicator to determine the size of the weight of the indicator, the higher the variability coefficient, the greater the weight of the indicator.

$$c_j = \frac{d_j}{\sum_{j=1}^{n} d_j} \tag{12}$$

⑥ Calculate the integrated regional economic resilience evaluation index Q_i.

$$Q_i = \sum_{j=1}^{n} c_j x_{ij} \tag{13}$$

Q_i indicates the comprehensive value of the I province, n indicates the number of indicators, and c_j indicates the weight of the j indicator. The larger the Q value, the higher the comprehensive evaluation index and the better the evaluation effect.

Meanwhile, this paper takes the 2008 financial crisis as the shock event and defines 2008-2010 as the shock resistance stage, 2011-2016 as the recovery stage, and 2017-2019 as the reconstruction stage based on the changes in real GDP growth rate and employment rate. In addition, the trend of economic resilience in three regions is analyzed based on the calculated regional economic index, as shown in Fig. 3.
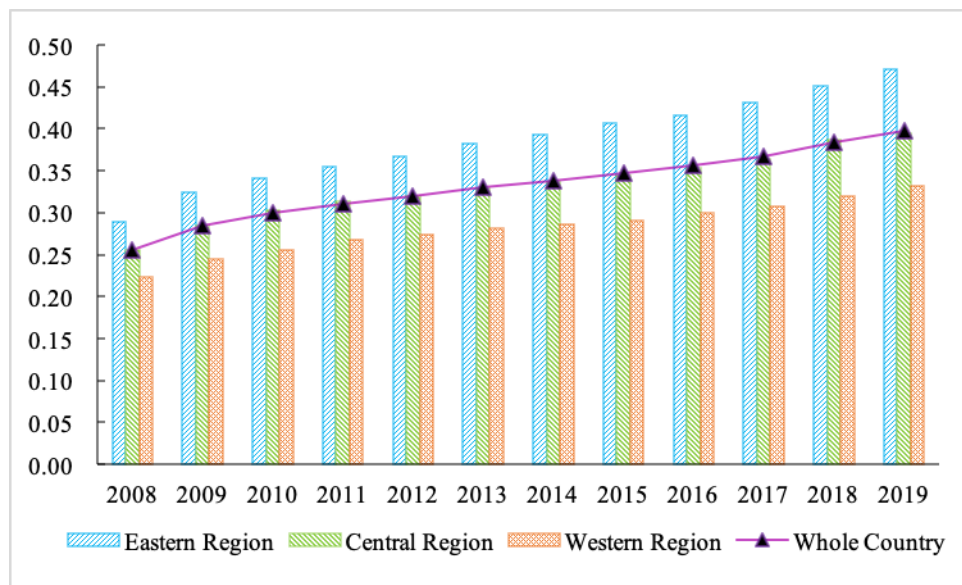
Figure 3. National and regional trends in economic resilience.

On the whole, the national economic resilience has shown a steady growth from 2008-2019, with RER rising from 0.256 to 0.398, an increase of 55.47%, indicating that the national economy's ability to resist external shocks and recover quickly has increased.

By stages, the national and regional economic resilience has experienced faster growth during the shock resistance stage, steady growth during the recovery period and rapid rise during the reconstruction stage. In the shock-resistance stage, industries are severely affected, but the initial accumulation of capital enables them to maintain a certain degree of resilience; in the recovery stage, business conditions begin to gradually improve, and the social economy shows stable development and growth; while in the reconstruction stage, technological innovation promotes economic growth by enhancing production efficiency, and economic resilience can be rapidly enhanced, but also accompanied by new types of financial risks.

From a regional perspective, the economic resilience of the three major regions maintains an upward trend with regional differences. *RER* in the eastern region is higher and has the fastest growth rate, with a rise of 62.98%. In the central region, it is basically in line with the overall national level movement trend, while the western region has the slowest growth rate.

4.2.2. Core explanatory variable: financial driver (FD)

The financial driver is divided into three levels:

(1) Financial scale (FS): The ratio of financial sector value added to GDP in each province is selected to measure the size of financial scale. The trend of national and regional financial scale changes is shown in Fig. 3: overall the financial scale expands gradually during the period under examination, and the degree of financial scale in each region always maintains the changing pattern of "eastern region > western region > central region".
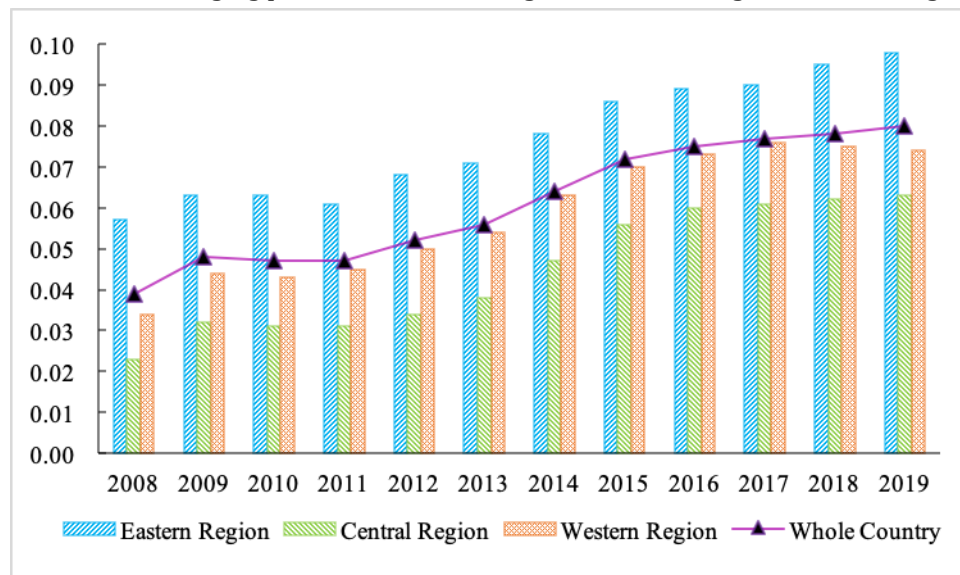
Figure 4. National and regional financial scale trends.

(2) Financial efficiency (FE): The financial sectors mostly use the input-output ratio from the perspective of investment and financing to express financial efficiency, so this paper selects the ratio of loans of financial institutions to deposits of financial institutions to measure financial efficiency. The ratio indicates the ability of the financial system to convert savings into investment (Wang & Zhao, 2019). The national and regional financial efficiency trends are shown in Fig. 5. Overall financial efficiency shows a fluctuating upward trend during the period, and the financial efficiency of each region basically maintains the changing pattern of "western region > eastern
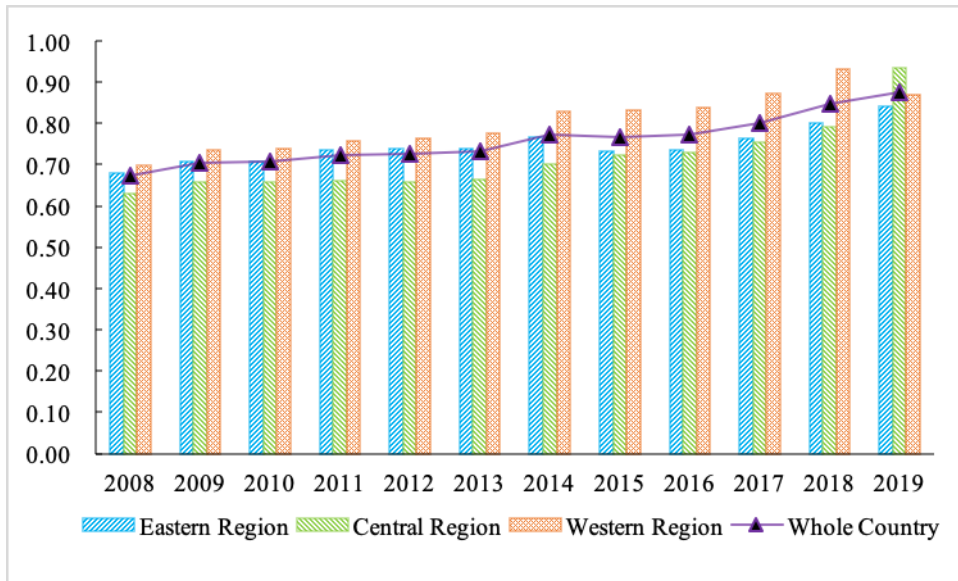
region > central region".

Figure 5. National and regional trends in financial efficiency.

(3) Financial deepening (MG): In this paper, referring to the relevant study of Rostow (1974), the ratio of broad money to national income (M2/GDP) is selected to measure financial deepening. Usually, it indicates the monetization of the economy and financial deepening level. The trend of national and regional financial deepening is shown in Fig. 6, the level of financial deepening in all regions has maintained an upward trend (except for 2011) and always maintains the change pattern of eastern region > western region > central region.
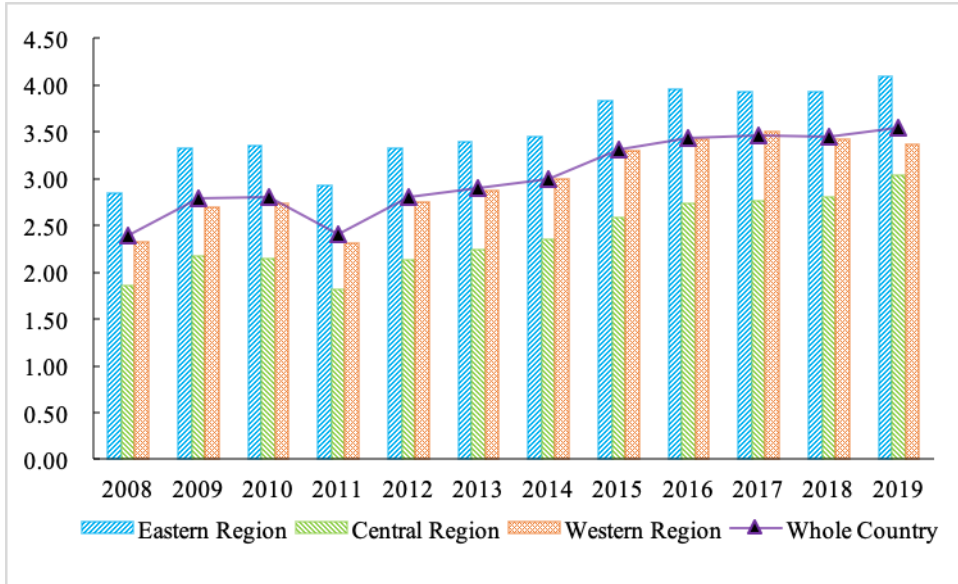
Figure 6. National and regional trends in financial deepening.

(4) Comprehensive financial driver index (FD)

The financial driver index is the average of the three sub-variables, representing the financial system as a whole to examine the impact on *RER*. This paper analyzes the trends of national and regional financial drivers, as shown in Figure 7. The national and regional financial drivers show an overall increase during the period, except for 2011, when the global economy was generally recovering from the crisis and emerging market economies were facing

high inflationary pressure. The impact of intensifying European crisis slowed down the growth of the international trade. And with the increased openness of China and the development of financial markets, the impact of the volatility of the international financial markets has gradually increased.

From a regional perspective, the level of financial driver in the eastern region is significantly higher; the western region is higher than the central region, and the growth trend is basically the same as that of the whole country, and has a downward trend since 2017; the central region has the weakest level of financial drive, but the growth rate should not be underestimated, and has approached the western region at the end of the examination period. The financial undertakings in this region have been developed significantly, and especially the rapid development of the Chengdu-Chongqing economic circle has injected strong momentum. Compared with other regions, the central region needs more large policy support from central government to promote financial development.
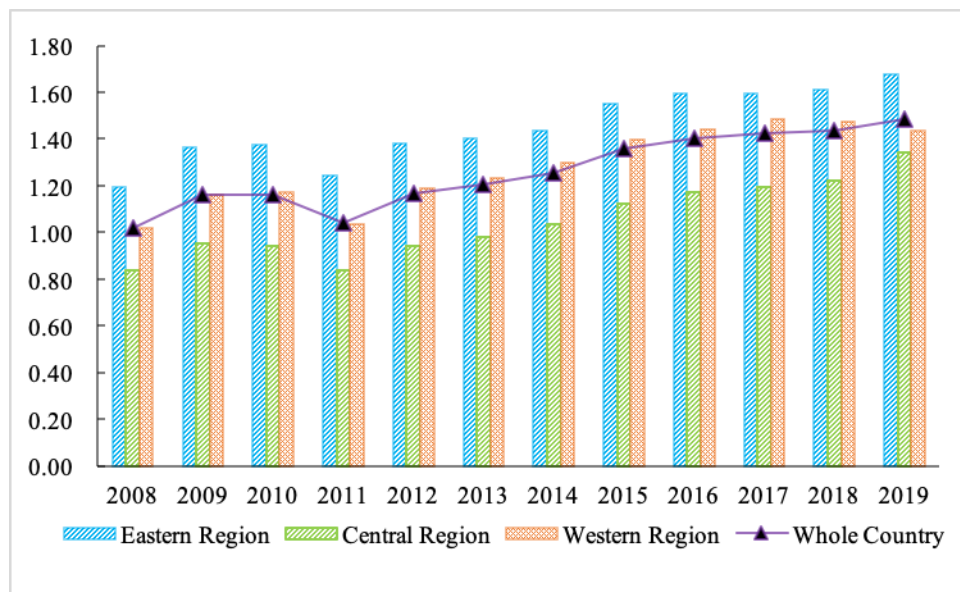

Figure 7. National and regional levels of financial driver.

Although the financial growth in the western region has been faster, the financial efficiency is not high, so there is a downward trend at the end, while the financial development in the central region is slower, but the financial efficiency is higher compared to the western region.

4.2.3. Control variables

In addition to financial drivers, regional economic resilience is influenced by the following control variables:

(1) Physical capital (CAP). Physical capital input can effectively improve the region's ability to withstand uncertainty shocks by driving sustained economic growth, and therefore it is a direct manifestation of economic resilience (Gao et al., 2022). In this paper, it is characterized by the amount of completed fixed asset investment and take the logarithm.

(2) Information technology level (INF). Informatization can enhance innovation efficiency by effectively reducing corporate innovation costs and optimizing corporate resource allocation (Han et al., 2014; Wu et al., 2021), thus enhancing the overall economy's ability to achieve stable growth again after suffering from external shocks. It is measured in this paper by telecommunication services per capita.

(3) Openness to the outside world (OPEN). The proportion of FDI to GDP is used to characterize openness level. The higher ration of FDI indicates that the regional economy is more dependent on the outside world and

more vulnerable to external shocks (Wang et al., 2022).

(4) Innovation level (RD). Innovation is the core driver of economic development and can reflect the rapid recovery ability of the regional economy after external shocks. In this paper, the number of invention patents per 10,000 populations is used to characterize.

4.3. Data Sources

Based on the availability and scientific nature of the data, 30 provinces (cities and districts) in China are selected as the research objects in this paper, with the sample spanning 2008-2019, and the variables involved are subject to descriptive statistics using Stata 16.0, as shown in Table 2. Data are from *China Statistical Yearbook, China City Statistical Yearbook, China Financial Statistical Yearbook, China Fixed Asset Investment Statistical Yearbook, China Statistical Yearbook of Science and Technology*, etc. The missing values in the above data are filled by interpolation method.

Table 2. Descriptive statistics of the variables.

Variable type	Indicator	Abbr.	obs	mean	sd	min	max
Explained variable	Regional economic resilience	*RER*	360	0.3328	0.0835	0.1830	0.6240
Independent variable	Financial driver	*FD*	360	0.6226	0.1279	0.3409	0.9841
	Financial scale	*FS*	360	0.0614	0.0311	0.0000	0.1850
	Financial efficiency	*FE*	360	0.7581	0.1353	0.4490	1.1640
	Financial deepening	*MG*	360	3.0214	1.1435	1.3820	8.1310
Control variables	Physical capital	*CAP*	360	8.5030	2.6381	0.1289	11.0237
	Information technology level	*INF*	360	0.0524	0.0375	0.0102	0.2311
	Openness to the outside world	*OPEN*	360	0.2926	0.3239	0.0128	1.5973
	Innovation level	*RD*	360	1.5470	1.0432	0.2300	6.3100

5. Empirical Results and Analysis

5.1. Baseline regression of linear relationship

To verify the linear relationship of FD and RER, based on equations (1), the estimation results are shown in Table 3. Among them, columns (1) to (5) verify the baseline regression results by gradually adding control variables.

Table 3. Regression results of linear relationship.

Variables	(1)	(2)	(3)	(4)	(5)
	RER	*RER*	*RER*	*RER*	*RER*
FD	0.1532***	0.1517***	0.1553***	0.1147***	0.0615***
	(5.45)	(5.43)	(5.53)	(4.49)	(2.94)
CAP		0.0008***	0.0010***	0.0007***	0.0005**
		(3.78)	(5.06)	(3.75)	(2.59)

INF			-0.0885*	-0.0528	-0.0331
			(-1.81)	(-1.37)	(-0.80)
OPEN				-0.1816***	-0.1270***
				(-4.22)	(-3.47)
RD					0.0957***
					(5.11)
Constant	0.1366***	0.1313***	0.1297***	0.2363***	0.1403***
	(3.79)	(3.65)	(3.61)	(5.98)	(3.85)
Fixed effects	Yes	Yes	Yes	Yes	Yes
N	360	360	360	360	360
R²	0.360	0.362	0.367	0.478	0.678

Note: Standard errors in parentheses; *** $p<0.01$, ** $p<0.05$, * $p<0.1$. The following tables are the same.

In columns (1) to (5), the estimated coefficients of FD are positive at the 1% significance level during the process, which fully indicates that financial driver can significantly improve RER and also proves that the regression results are robust. Financial institutions can provide diversified financing channels and innovative financing models for enterprises by expanding their scale, improving efficiency and deepening, and optimizing the financial resource allocation, thus ensuring stable economic growth and enhancing economic resilience.

In terms of control variables, the coefficient of CAP stays significantly positive, indicating that physical capital input can expand the production scale of enterprises, drive regional economic growth and enhance local economic resilience, while with the enhanced financial drive, excessive input of physical capital will bring diseconomies of scale and force economic resilience to decline. The coefficient of external openness is significantly negative, indicating that the higher the degree of regional external dependence, the closer its economic ties with the outside world, the more likely it is to cause a chain reaction in case of external shocks, resulting in lower economic resilience. The coefficient of innovation level is significant at 1% level, which indicates that the increase of innovation level can contribute to the rapid recovery of the economy after the setback, i.e., the regional economic resilience is significantly improved.

5.2 Analysis of non-linear relationship

To investigate the nonlinear characteristics, based on equations (2), regression results are shown in columns (2) and (3) of Table 4.

Table 4. Non-linear regression results.

Variables	(1)	(2)	(3)
	RER	RER	RER
FD	0.1532***	0.4193***	0.2169***
	(5.45)	(4.97)	(3.34)
FD²		-0.1196***	-0.0590**
		(-4.09)	(-2.55)
CAP		0.0006***	0.0005**
		(3.58)	(2.46)
INF		-0.0373	-0.0274
		(-1.02)	(-0.69)
OPEN		-0.2615***	-0.1717***

		(-5.68)	(-4.15)
RD			0.0864***
			(4.86)
Constant	0.1366***	0.0834	0.0743
	(3.79)	(1.49)	(1.60)
Fixed effects	Yes	Yes	Yes
N	360	360	360
R^2	0.360	0.548	0.693

In column (2), the squared term of FD is significantly negative at the 5% level, while financial driver is significantly positive at the 1% level, indicating that the impact of FD on RER has non-linear characteristic. Specifically, it shows an "inverted-U shape": its impact on RER shifts from promoting to inhibiting as the capacity of financial driver increases. After column (3) adds the variable of innovation level, the financial driver and its squared term are still significant at the 1% level, indicating that the non-linear regression results are robust. In the early stage of financial development, financial activities can effectively alleviate enterprise financing constraints, support the development of new industries and technological progress, which in turn is conducive to enhancing economic resilience.

However, when financial development reaches a certain level, especially in recent years, fintech, not only has the traditional credit risk and liquidity risk, but also brings new financial risks: technology risk, regulatory risk and systemic risk (Zhou Quan & Han He Yang, 2020). The sudden outbreak of external financial risk events is likely to form a "domino effect" among markets, which will trigger a series of financial risks, endangering the stability of financial markets. It has a significant impact on the normal operation of the macroeconomy, which is difficult to effectively resist and recover through its own mechanism in the short term, resulting in a dampening effect on economic resilience. The effect will be inhibited.

5.3 Staged heterogeneous analysis of RER

According to the previous hypothesis, to examine the different effects that financial drivers may play in different stages of regional economic resilience, two models without and with added control variables are set up for estimation in each stage of RER in this paper. The empirical results are in Table 5.

Table 5. Regression results of the staged heterogeneous analysis of RER.

Variables	Stage 1		Stage 2		Stage 3	
	(1)	(2)	(3)	(4)	(5)	(6)
FD	0.2058***	-0.0185	0.0871***	0.0289**	0.0215	0.0004
	(7.06)	(-0.38)	(4.66)	(2.05)	(0.88)	(0.60)
Control	NO	YES	NO	YES	NO	YES
Constant	0.0469	-0.3596***	0.2241***	0.2486***	0.3516***	0.1809
	(1.42)	(-4.78)	(9.52)	(9.81)	(9.77)	(1.43)
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
N	90	90	180	180	90	90
R^2	0.558	0.772	0.398	0.707	0.012	0.509

From columns (1) and (2), it can be seen that the coefficient of FD on RER at the "shock resistance stage" is significant at the 1% level without adding control variables, but it is not significant when control variables are added;

meanwhile, from columns (5) and (6), the effect of FD on RER at the "reconstruction stage" is not significant with or without control variables; finally, from columns (3) and (4), the coefficient of financial driver is more significant and robust with or without control variables, indicating that financial driver has a significant contribution only when economic resilience is at the "recovery stage".

In the "shock resistance stage", external shocks in international trade and serious losses in the foreign exchange reserves cause a serious blow to China's export-oriented economic growth model. In the short term, China's economic growth slowed down, unemployment increased, national income decreased, and consumption decreased, all of which made the economy less resilient. Meanwhile, domestic business banks suffered heavy losses in foreign financial business. Some domestic financial institutions were affected by the chain reaction, external loans could not be recovered, credit risks then increased, and social fixed asset investment fell. Further result is the supply of funds for innovative industries is difficult to ensure. Economic regulation and innovation capacity weakened.

During the "recovery stage", firms not only have credit support from the financial sector, but also are able to use diversified financial instruments for intertemporal resource allocation and risk diversification (Levine, 1991). At the same time, financial institutions use their information advantages to invest in promising enterprises, which rationalizes the allocation of limited resources in time and space and provides strong momentum for rapid economic recovery (Levine, 1999). In addition, the rapid development of financial technology during the recovery period promotes the improvement of financial efficiency and the reduction of financing costs, accelerates the innovation and transformation of enterprise products, increases economic growth rate, and enhances economic resilience.

During the "economic restructuring stage", financial development is rapid, but also prone to excessive credit and high leverage (Xu, 2020), resulting in the "de-realization" of financial funds. The large-scale application of new financial derivatives brought about by financial innovation, further expands the risk of the financial market. The transmission of risk will bring about great volatility in the overall financial market, leading to instability in the financial system, and its impact on the real economy is also highly uncertain, ultimately leading to a weakening of economic resilience.

6. Empirical Results and Analysis Robustness test

6.1. Endogeneity test

Considering that there may be a two-way causal relationship between FD and RER, which raises the issue of endogeneity and affects the accuracy and reliability of the regression results, the lagged one-period of the explanatory variable financial driver is used as an instrumental variable for endogeneity testing, and the results are in column (1) of Table 6. The sign and significance of the independent variables are the same, so it can be concluded that the results are robust.

6.2. Replacing core dependent variables

Referring to the study of Doran and Fingleton (2018), the unemployment rate (UNE) is chosen to replace RER. The results are shown in column (2) of Table 6. The coefficient of FD is significantly negative at the 1% level, indicating that the higher the FD, the lower the unemployment rate. Therefore, the regional economy is more resilient. The results are robust.

6.3. Replacing core independent variables

In addition, to further eliminate the influence on the conclusion due to the measurement error of the financial

driver index, this paper draws on Wen Kun(2017) and uses the ratio of deposit and loan balances of financial institutions to GDP (FIN) instead of the financial driver index (FD) for the robustness test. In column (3) of Table 6, the coefficient of FIN is significantly positive at the 5% level, proving the robustness of the regression model.

6.4. Winsorizing of the dependent variable

To control the influence of the outliers of the dependent variable RER on the benchmark regression results, the samples with the largest and the smallest 1% of regional economic toughness are subjected to winsorizing. In column (4) of Table 6, the coefficient of FD is still significantly positive, fully verifying the robustness of the results.

Table 6. Robustness test regression results.

Variables	(1)	(2)	(3)	(4)
	RER	*UNE*	*RER*	*RER_W*
FD		-0.8524***		0.0617***
		(-4.15)		(2.98)
L.FD	0.0721***			
	(3.80)			
FIN			0.0212**	
			（2.26）	
CAP	0.0002	-0.0041	0.0004*	0.0005**
	(1.32)	(-1.36)	(1.85)	(2.59)
INF	0.0016	0.4822	-0.0095	-0.0403
	(0.04)	(0.65)	(-0.22)	(-1.02)
OPEN	-0.1443***	-0.8377***	-0.1306***	0.1216***
	(-4.36)	(-2.48)	(-3.47)	(-3.30)
RD	0.0794***	-0.3964***	0.0995***	0.0941***
	(4.49)	(-3.08)	(5.25)	(5.07)
Constant	0.1626***	5.3179***	0.1496***	0.1413***
	(4.64)	(13.95)	(4.05)	(3.84)
Fixed effects	Yes	Yes	Yes	Yes
N	330	360	360	360
R^2	0.665	0.323	0.668	0.675

7. Further analysis

7.1. The analysis of impact pathway of FD on RER

Based on the model equations (3), (4) and (5), the financial driver (FD) is decomposed into financial scale (FS), financial efficiency (FE) and financial deepening (MG), and two models without and with added control variables are also set up to regress the regional economic resilience from different dimensions to further explore the impact pathway of FD on RER, and the regression results are in Table 7.

Table 7. Regression results of the sub-dimensionality test.

Variables	(1) RER	(2) RER	(3) RER	(4) RER	(5) RER	(6) RER
FS	1.8031***	0.8630***				
	(6.24)	(4.19)				
FE			0.2065***	0.0787***		
			(6.74)	(2.82)		
MG					0.0566***	0.0216**
					(5.43)	(2.54)
Control	NO	YES	NO	YES	NO	YES
Constant	0.2221***	0.1666***	0.1762***	0.1621***	0.1617***	0.1483***
	(12.53)	(5.85)	(7.58)	(3.31)	(5.13)	(4.15)
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
N	360	360	360	360	360	360
R^2	0.424	0.707	0.191	0.661	0.333	0.672

In Table 7, all three dimensions have a significant and robust contribution to RER, with or without adding control variables. With adding control variables, the regression coefficients of financial scale (FS) and financial efficiency (FE) are both significantly positive at the 1% level, while financial deepening (MG) is significantly positive at the 5% level. Comparing their marginal effects, FS (0.8630) > FE (0.0787) > MG (0.0216).

From the above results, it is clear that financial scale (FS) plays the largest role in the financial-driven impact on RER, and the economy of scale effect it exerts is the key factor. The expansion of financial scale implies an increase in the number of financial institutions and the volume of savings business. Especially, banks can take in more deposits and issue more loans, eventually leading to the expansion of bank credit scale, which will provide diverse financing channels for enterprises. While with the help of technology empowerment, financial institutions provide more convenient financing modes through innovative financial products and services, thus constructing a large-scale innovative technology platform for enterprises. This will provide more financial support for enterprises to construct large-scale innovation technology platforms to improve total factor productivity, further enhance the core competitiveness of the industrial chain, promote the growth of the economy and national income, and provide solid support for the normal operation of China's economy and resist external risks.

The improvement of financial efficiency (FE) is also an effective way to enhance economic resilience. Financial efficiency refers to the allocation efficiency of financial resources. Improving financial efficiency not only enhances the efficiency of capital use, but also helps to bring into play the effect of economies of scale. It is easy to transfer capital from inefficient industries to high-efficiency industries, thus promoting the rationalization and advanced industrial structure and boosting economic transformation and upgrading to cope with external shocks.

Financial deepening (MG) has the least contribution to regional economic resilience. Financial deepening, also known as financial liberalization, promotes the inflow of foreign capital and thus absorbs savings by deregulating the government's excessive control over financial markets, and various investment opportunities are adjusted accordingly according to sensitive interest rates. It is conducive to new industries and technological innovation projects, improving the overall investment efficiency of society and promoting overall economic development.

7.2. Heterogeneity Analysis

The level of financial driver in China is characterized by significant imbalance in spatial distribution, so the impact of FD on RER varies across regions. Therefore, the total sample is divided into eastern, central and western

regions to examine the regional heterogeneity of the impact of financial driver on regional economic resilience, and the results are shown in Table 8.

Table 8. Regional heterogeneity regression results.

Variables	Eastern region		Central region		Western region	
	(1)	(2)	(3)	(4)	(5)	(6)
FD	0.2010**	0.0139	0.1621**	0.1044***	0.1078***	0.0781***
	(2.97)	(0.31)	(3.30)	(7.35)	(4.31)	(3.76)
Control	NO	YES	NO	YES	NO	YES
Constant	0.0937	0.2823***	0.1608**	0.0281	0.1438***	0.0704*
	(0.95)	(3.29)	(3.12)	(1.25)	(4.49)	(1.99)
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
N	132	132	96	96	132	132
R²	0.363	0.771	0.440	0.746	0.393	0.574

From columns (1) and (2), the effect of FD on RER in the eastern region is not significant and unstable. Interestingly, the effects in the central region (in columns (3) and (4)) and the western region (in columns (5) and (6)) are more significant, and the effect in the central region is the strongest.

The faster pace of financial development in the eastern region is accompanied by numerous uncertainties in financial activities, which will exacerbate the disruptions in financial markets and the decline in economic growth rates. In addition, the eastern region has a high degree of economic openness and close ties with other economies. Therefore, external shocks have a relatively large impact on the region's economy, and the ability of economic regulation and recovery is constrained.

Although the financial development in the central region is slow, the growth state is more stable compared to other regions, and the allocation of financial resources is more efficient, which positively drives the regional development and economic resilience. Although the financial growth rate in the western region is faster, the degree of financial marketization and financial efficiency is not high compared to the central region, and it is also accompanied by certain financial risks, which has a weaker role in promoting economic resilience than the central region. It's necessary to speed up regional economic integration, increase spatial economic resilience, and ensure the smooth operation of industrial and supply chains.

7.3. Spatial agglomeration of regional economic resilience

Referring to the study of Östh et al. (2015), to some extent economic resilience have spatial characteristic. To explore the spatial agglomeration and distribution characteristics, this paper employs a global correlation and local correlation test on economic resilience of 30 provinces (municipalities and regions) in China.

7.3.1. Global correlation test

According to Formula (6) above, the global Moran's I during 2008-2019 is calculated, and the results are shown in Table 9.

Table 9. Global Moran's I of regional economic resilience.

year	Moran'I	E(I)	Sd(I)	z	p-value
2008	0.232**	-0..034	0.123	2.158	0.015
2009	0.238**	-0.034	0.124	2.197	0.014

2010	0.251**	-0.034	0.124	2.294	0.011
2011	0.241**	-0.034	0.124	2.214	0.013
2012	0.227**	-0.034	0.124	2.108	0.018
2013	0.240**	-0.034	0.124	2.215	0.013
2014	0.236**	-0.034	0.124	2.180	0.015
2015	0.248**	-0.034	0.124	2.279	0.011
2016	0.252**	-0.034	0.124	2.315	0.010
2017	0.245**	-0.034	0.124	2.264	0.012
2018	0.214**	-0.034	0.124	2.010	0.022
2019	0.237**	-0.034	0.124	2.190	0.014

In Table 9, during the study period, all the Moran's indexes are significantly positive, stable between 0.214 and 0.252, indicating that on the whole the economic resilience has an obvious spatial agglomeration feature in China.

7.3.2. Local correlation test

Compared with the global Moran's index, the local Moran scatter chart can directly reflect the spatial dependence of a specific region. Local autocorrelation has four quadrants: high-high agglomeration (the high-value region is adjacent to the high-value region); low-high agglomeration; low-low agglomeration; high-low agglomeration.

Local spatial correlation test of regional economic resilience in 2008, 2012, 2016 and 2019 is conducted, and the local scatter plot is shown in Figure 8.
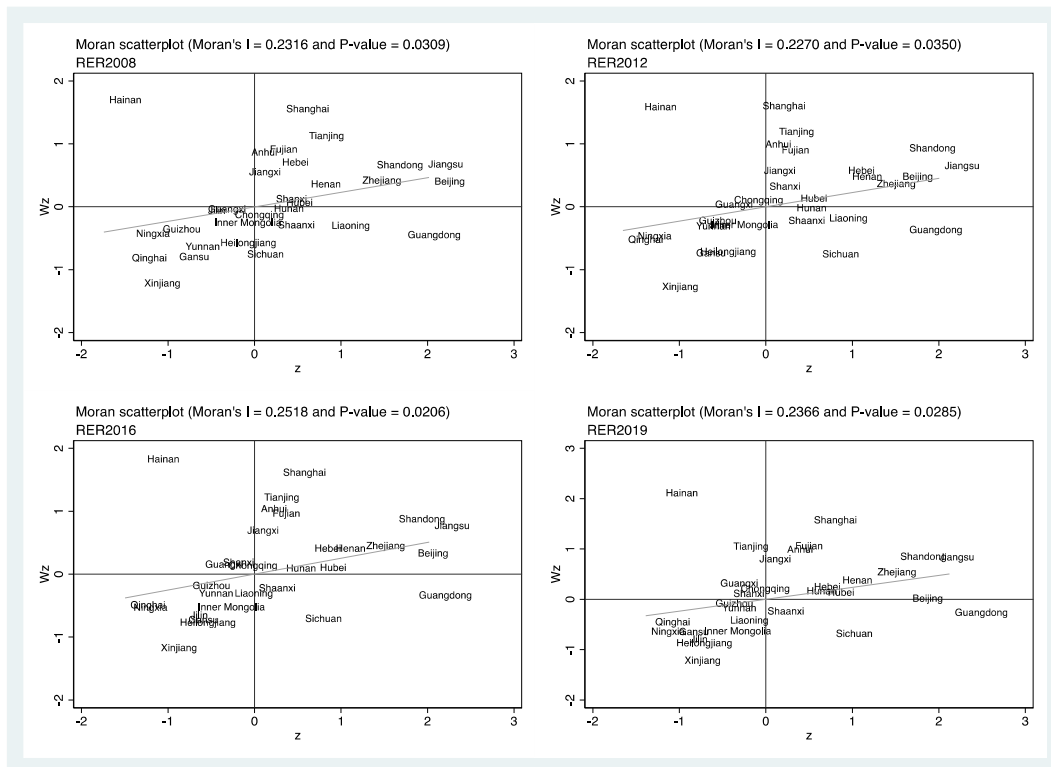

Figure 8. Moran'I scatter chart of RER in 2008, 2012, 2016 and 2019.

Fig. 8, most of the provinces of the Beijing-Tianjin-Hebei region and the Yangtze River Delta region are in the " high-high agglomeration area", which have a large economic aggregate, relatively balanced development, and

intensive innovation resources, and possess significant advantages of regional integration and high-quality development. Facing external shocks, these provinces can break down administrative barriers, fully leverage their strengths in resources, innovation and openness, and achieve coordinated development, demonstrating strong economic resilience.

The provinces in the "low and low concentration areas" are mostly in the northwest and northeast region. The economic development foundation of these provinces is weak, without surrounding region to play a guiding role. The outflow of innovative talents is serious, which makes them vulnerable to the chain reaction brought by external shocks.

Interestingly, Hainan with a moderate economic growth has been located in the "low and high agglomeration area" because its neighboring Pearl River Delta region has strong economic resilience, which is corresponding to the "high and low agglomeration area" of Guangdong Province. However, Sichuan and Shaanxi remain in the "high and low concentration areas", indicating that cities such as Chengdu and Xi 'an have broad economic development prospects in recent years, attracting more innovative talents and resources and achieving stable economic growth.

8. Conclusion and Policy Implications

This paper exploratively constructs an analytical framework for the impact of financial drivers on regional economic resilience. Based on provincial panel data in China from 2008-2019, a comprehensive indicator system is constructed to measure regional economic resilience (RER), and the impact of financial driver (FD) on RER from staged, pathway and non-linear perspectives is explored. The study shows that: (1) Both national and regional levels of FD and RER show an upward trend, and the impact of FD on RER has an "inverted-U" shape: as the capacity of FD increases, its impact on regional economic resilience shifts from promoting to inhibiting. The RER has significant spatial agglomeration characteristic. (2) Interestingly, staged analysis shows FD can significantly promote RER only when it is in the "recovery stage". (3) The pathway analysis of its effect on regional economic resilience shows the following characteristics: financial scale > financial efficiency > financial deepening. (4) From different regions, there are significant differences in the effect of FD on the promotion of regional economic resilience: central region > western region > eastern region. Accordingly, the following policy insights are proposed.

(1) Strengthen the construction of financial rule and improve the financial risk disposal mechanism. Focusing on the rectification of illegal arbitrage and other serious disruption of the financial market order, enhance the supervision of Internet finance and strictly regulate the integrated operation of finance and the combination of industry and finance. Strengthen the source of financial risk control and strict market access. Financial institutions fully shoulder the main responsibility to prevent risks, and strengthen the construction of social credit system. It is also necessary to cultivate scientific and technological financial regulatory personnel, improve the level of supervision, and reduce regulatory "blind spots". In addition, the government needs to reduce the leverage ratio of state-owned enterprises, and play the role of capital markets and various financial institutions in mergers and acquisitions, so as to strengthen economic resilience and ensure a safe and solid driving force.

(2) Vigorously promote financial market-oriented reform and coordinate financial macro-control. The scale of finance should be fully adapted to the development requirements of the social economy. It should serve the real economy as the fundamental, and put more funds in the development of social services, to increase the sustainability of economic development. In addition, the financial structure should be optimized, financial policies should be used rationally for regulation and control. The development of financial scale, financial efficiency and financial deepening should be coordinated, thereby creating a favorable financial environment and providing a stable and strong driving force for the economy to cope with internal and external shocks.

(3) Strengthen the construction of digital inclusive financial infrastructure and promote the coordinated development of regional digital inclusive finance. Accelerate the deep integration of digital technology and finance,

provide diversified financing channels, continuously enrich digital inclusive financial products and services, and improve the digital inclusive financial system in each region so as to expand its coverage and give full play to the economy of its scale effect. At the same time, to improve the productivity of other input factors and provide a strong driving force to promote regional economic resilience, it is significant to prevent overheating of digital inclusive finance, improve the digital regulatory system, and try to seek the optimal scale of financial development by promoting technological innovation.

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Conflict of interest

The authors claim that the manuscript is completely original. The authors also declare no conflict of interest.

Author contributions

XiaoLi Hao: Writing – original draft, supervision, validation, visualization. Junhong Qu: writing–review & editing, conceptualization, data curation, formal analysis.

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