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Research article

Spatial-temporal coupling coordination relationship between well-being and technological innovation: Panel evidence from China

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ABSTRACT

Since the dawn of the industrial era, the relationship between human well-being and technological in-novation has become increasingly close. This study explores this intricate relationship to understand how technological advancements can be harnessed to promote sustained and improved well-being for all. Focusing on China as a case study, this study considers both human well-being and technological innovation as key research objects. An evaluation index system for well-being is established by leveraging the spatial Durbin model and existing literature. This study empirically calculates well-being levels and conducts a classification analysis of the coupling and coordination between well-being and technological innovation across 31 provinces and cities. Additionally, the factors driving the coupling and coordination relationships are further clarified. The results reveal that (1) the coordination between well-being and technological innovation varies significantly between provinces but, overall, is gradually increasing; (2) a significant positive correlation exists between well-being and the coupling and coordination of scientific and technological innovation, and the spatial aggregation of the coupling and coordination development is gradually strengthening; and (3) several key factors influence this relationship. Rationalisation of the industrial structure, inclusive digital finance, talent concentration, and consumption rate all yield positive and significant impacts. Conversely, government intervention appears to negatively influence the coordination between these two crucial aspects. Based on this study's results, a series of policy recommendations are proposed to coordinate the development of well-being and technological innovation.

1. Introduction

As scientific and technological innovation aims to improve human production and life, its ultimate effectiveness should be reflected in human well-being [1]. With advancements in science and technology and the human subjective spirit's rediscovery, enhancing people's well-being and improving their quality of life have become the internal driving force and ultimate value goal for healthy societal development [1,2]. Technological innovation, as an important driving force for human society's development, changes the quality of human life and affects human well-being through factors such as production [2–5], life concepts [6–9], income distribution,

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and consumption patterns [10–14].

Numerous meaningful explorations have been conducted on the definition and evaluation criteria of happiness, measurement of happiness, and influence of scientific and technological innovation on human society (including income, environment, and lifestyle), which provide a useful reference for this study. However, few scholars have focused on the relationship between human happiness and scientific and technological innovation, and the empirical research on their mechanisms and interactions is insufficient. As an important force affecting human pro-duction and life, scientific and technological innovation started late in China compared to other countries, and its evaluation index system is being further enriched. Accordingly, this study quantitatively calculates the well-being level in various regions of China by constructing an evaluation index system of well-being, based on the panel data of 31 provinces and cities from 2014 to 2022; it empirically analyses the coupling relationship between well-being and scientific and technological innovation and the spatiotemporal distribution characteristics of the coupling and coordination of the two; further, it analyses the current situation and dynamic evolution law of the coupling and coordinated development of scientific and technological innovation and happiness, to provide experience and reference for the mutual promotion and coordinated development of the two. This study has certain innovative significance. This paper comprises six sections. The remaining five sections are as follows. Section 2 provides a review of relevant studies. Section 3 predominantly explains the data sources and re-search methods used herein. Section 4 presents the data analysis results. Section 5 discusses this study's findings in terms of the literature. Section 6 summarises the full text and presents a series of recommendations and research limitations based on this study's results.

2. Literature review

2.1. Well-being

Well-being—first systematically discussed by Wanner Wilson in 1976—can be divided in-to subjective, objective, and psychological happiness [15,16]. Subsequently, Richard Easterlin found no significant correlation between well-being and income growth—known as Easterlin's paradox—through his study of the theory of subjective well-being in humans [17,18]. The proposal of the 'Easterling paradox' has led an increasing number of economists to conduct extensive research on well-being under the framework of economic theoretical analysis. For example, Durayappah proposed the 'The 3P model' by suggesting that individual subjective well-being perception is rooted in time and is related to past comparisons, present evaluations, and future prospects; Cai used China as a case study and found that evidence supporting the paradox might be context-specific, appearing within specific timeframes and income ranges[19]; Grimes[20] studied the important relationship between subjective well-being and subjective well-being inequality from the perspectives of social and welfare inequality [21–24], resources [25–28], and environment [29–32]. Additionally, quantifying well-being has always been an important research topic and is a focus of this study. Kahneman postulated that objective well-being and its measurement standard provided a scientific method for the measurement of well-being and laid the foundation for the national well-being index [33,34,] and that the measures of happiness vary by region [35,36,]. Taira K (2024) calculated the Happiness Index to reflect people's happiness level through the dimensions of quality of life, life philosophy, governance, and living standards [37]. Hasan M.R. (2024) constructed a multidimension-al happiness index to measure the happiness level in Bangladesh using the following seven dimensions: health, finance, culture, security, governance, religion, and science and technology [38]. The ultimate goal of human development is happiness, which is influenced by numerous factors [39,40].

Traditional assessments of happiness have been based on common economic indicators [41]. In the global pursuit of GDP, economic growth has negatively impacted the improvement of happiness. For example, from the perspective of equity and efficiency, a large developmental gap exists between urban and rural areas [42], and income inequality is negatively correlated with happiness [43–46]. From the perspective of resources and the environment, air quality [47] and urban greening rate and quality [48] all affect well-being. Therefore, using only common economic indicators to measure happiness may fail to represent the actual situation [49], and more economic indicators need to be considered [50–52]. Along with economic indicators, non-economic indicators are important factors influencing well-being, such as demo-graphic variables [53–57], social security conditions [52,58], and quality of life [59–62]. In summary, this study introduces happiness measurement scales from foreign scholars [63–65] and innovatively constructs an evaluation system suitable for China's happiness based on six dimensions (namely, income and consumption, demographic variables, social security, resources and the environment, quality of life, and fairness and efficiency) according to China's national conditions.

2.2. Well-being and technological innovation

Well-being stems not only from people's subjective feelings but is also closely related to an objective material basis [66]. From the beginning of the Industrial Revolution in the United Kingdom to the Information Technology Revolution in the United States to Industry 4.0, with the rapid global development of science and technology, the relationship between hu-man happiness and technological innovation has become increasingly close [67]. Scientific and technological innovation plays a significant role in promoting the upgrading of industrial structure and high-quality economic development, and the improvement of happiness is reflected in the growth of economic consumption [68,69]. Studies have reported that promoting technological upgrading in Africa through technology transfer has contributed greatly to Africa's development and well-being [70]. Additionally, the new technologies brought about by current scientific and technological innovation—such as artificial intelligence, information and communication technology, digitalisation, and digital finance—are all related to happiness [71–74] and significantly impact economic [75], social [76], and ecological welfare [77,78]. As government intervention [79], industrial structure adjustment [70], digital economy development [80], innovative talent [81], and regional development status [65] affect scientific and technological innovation and happiness simultaneously, this study considers them as influencing factors driving the coordination between scientific and technological innovation and well-being.

3. Research design

3.1. Data sources

Based on the happiness evaluation index system proposed in this study, and to fulfil our re-search needs, we primarily collected raw data for various quantified indicators from 31 Chinese provinces (cities and autonomous regions) between 2014 and 2021. The data sources included publications from the National Bureau of Statistics and provincial statistical departments, such as the 'China Statistical Yearbook', 'China Education Statistical Yearbook', 'China Third Indus-try Statistical Yearbook', 'China Urban and Rural Construction Statistical Yearbook', 'China Health Statistical Yearbook', 'China Regional Science and Technology Innovation Evaluation Report', 'National Statistical Bulletin on Science and Technology Funding', and various local urban construction status bulletins. For the assessment of technological innovation, we employed each province's comprehensive technological innovation index, as compiled in the annual 'China Regional Technological Innovation Evaluation Report'. This index encompasses the following five dimensions: innovation environment, investment in technological activities, out-put of technological activities, high-tech industrialisation, and promotion of technological development in the economy and society.

3.2. Construction of the indicator system

Building on the theoretical analyses and empirical research on the concept of happiness, its measurement methods, and related influencing factors [20,82–84], this study proposes a well-being index system specifically tailored to residents. Drawing on the existing research on happiness determinants and index construction, this system prioritizes objectivity, rationality, indicator availability, and comprehensiveness. It comprises six first-level indicators, namely, income and consumption, demographic variables, social security, resources and environment, quality of life, and fairness and efficiency. These are further refined and supplemented by 31 s-level indicators, primarily expressed as relative per capita values, to control for potential regional differences in population size. Table 1 lists the well-being index's specific indicators.

Table 1
Construction of evaluation index system for well-being.

Target level	Quasi-testing layer	Indicator layer	Weights	Indicator properties
Indicator System for Evaluating the Happiness of Residents	Income and consumption	GDP per capita	0.0377	+
		Per capita disposable income	0.0345	+
		Proportion of property income	0.0348	+
		Value added of tertiary sector as a share of GDP	0.0306	+
		Consumption expenditure per capita	0.0318	+
		Consumption level index	0.0267	+
		House price-to-income ratio	0.0286	+
	Demographic variables	Mortality rate	0.0273	–
		Birth rate	0.0291	+
		Average years of education	0.0270	+
		Urbanization rate of resident population	0.0262	+
		Divorce rate	0.0279	–
	Social security	Unemployment insurance expenditure per capita	0.0489	+
		Per capita expenditure on old-age insurance	0.0398	+
		Per capita expenditure on health insurance	0.0301	+
		Unemployment rate	0.0240	–
		Percentage of expenditure on social security and employment	0.0371	+
	Resources and environment	Sulpfur dioxide emissions per capita	0.0238	–
		Water resources per capita	0.0231	+
		Investment in industrial pollution control completed	0.0237	–
		Forest cover	0.1250	+
	Quality of life	Per capita consumption expenditure on education, culture and recreation as a percentage	0.0252	+
		Health technicians per 10,000 population	0.0296	+
		Public transportation vehicles per 10,000 population	0.0271	+
		Average park green area per capita	0.0262	+
	Fairness and efficiency	Theil index of urban–rural incom	0.0270	–
		Theil index of urban–rural consumption	0.0247	–
		Theil index of urban–rural medical consumption expenditure	0.0231	–
		Gap of Engel's coefficient between urban and rural residents	0.0242	–
		Variance in per capita financial revenue	0.0288	–
		GDP per capita variance	0.0263	–

3.3. Research methods

3.3.1. Entropy value method

Considering the extensive number of indicators in the happiness evaluation system, the entropy value method is employed to objectively assign weights to both subsystems and individual indicators within the system. This objective approach helps minimise errors stemming from subjective biases. Widely applied in comprehensive multi-indicator evaluations, the entropy value method leverages complete data to allocate weights based on the correlation degree be-tween indicators [85]. Entropy, a concept originally introduced by the physicist Clausius in 1865, essentially serves as a measure of uncertainty and reflects the internal order within a system [86]. Here, we outline the steps involved in calculating indicator weights using the entropy method.

First, the indicators are standardised, and the polar transformation method is applied to eliminate the effects of different scales and orders of magnitude. The formulae for the positive and negative indicators are as follows:

Positive indicators:

$$\mathrm{x}_{\mathrm{ij}}' = \left(\mathrm{x}_{\mathrm{ij}} - \min \mathrm{x}_{\mathrm{ij}}\right) \Big/ \left(\max \mathrm{x}_{\mathrm{ij}} - \min \mathrm{x}_{\mathrm{ij}}\right) + 0.00001 \tag{1}$$

Negative indicators:

$$\mathrm{x}_{\mathrm{ij}}' = \left(\max \mathrm{x}_{\mathrm{ij}} - \mathrm{x}_{\mathrm{ij}}\right) \Big/ \left(\max \mathrm{x}_{\mathrm{ij}} - \min \mathrm{x}_{\mathrm{ij}}\right) + 0.00001 \tag{2}$$

$max\ x_{ij}$ and $min\ x_{ij}$ are the indicator's maximum and minimum values, respectively; to eliminate the outliers and zeros, the minimal values are added to the equation for coordinate translation.

Calculation of the weight of each indicator

$$P_{ij} = \frac{x_{ij}'}{\sum_{i=1}^{n} x_{ij}'} \tag{3}$$

Calculation of the information entropy of the jth indicator

$$e_j = -\frac{1}{\ln n} \sum_{j=1}^{n} x_{ij}' \ln x_{ij}' \tag{4}$$

Calculation of the weight of the jth indicator

$$w_j = \frac{1 - e_j}{\sum_{j=1}^{n} 1 - e_j} \tag{5}$$

Synthesized assessment.

$U = \sum_{j=1}^{n} w_j x_{ij}'$ (6)

3.3.2. Coupling coordination degree model

The coupling coordination degree model uses the coupling degree to assess the level of mutual influence between multiple systems. However, this metric reflects only the interaction and coupling degrees, failing to comprehensively capture the coordinated development between the two subsystems, such as scientific and technological innovation and well-being. Therefore, this study employs the coupling coordination degree model to calculate the comprehensive co-ordination degree between these two subsystems as follows:

$$C = \left[\frac{U_1 U_2}{\left(\frac{U_1 + U_2}{2}\right)^2} \right]^{\frac{1}{2}} \tag{7}$$

$$T = \alpha U_1 + \beta U_2 \tag{8}$$

$$D = \sqrt{CT} \tag{9}$$

where C is the degree of coupling between *STI* and happiness, U_1 is the science and technology innovation index, U_2 represents the evaluation of happiness, T is the comprehensive evaluation index, α and β are the weight coefficients to be determined, and satisfy$\alpha+\beta=1$. In the evaluation process, the degree of importance between the two is considered to be the same, and therefore taken as $\alpha = \beta = 0.5$; D is the coupling coordination degree.

According to the size of the coupling coordination degree, the degree of coupling coordination between science and technology innovation and happiness is classified into 10 levels. Table 2 presents the classification criteria.

3.3.3. Spatial autocorrelation research methods

Spatial autocorrelation analysis is used to identify whether elements within a region exhibit spatial dependence irrespective of spatial aggregation [87]. Building on existing methods, it employs both a global test (Global Moran's I index) and local test (Local Moran's I index) to verify the presence of a spatial correlation. The Global Moran's I index detects the tested variables' overall distribution characteristics. The global test formula is as follows:

$$I = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(x_i - \overline{x})(x_j - \overline{x})}{s^2 \sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}} \tag{10}$$

where I is the global Moran's index, $s^2 = \frac{\sum_{i=1}^{n}(x_i - \overline{x})^2}{n}$ is the sample variance, and w_{ij} is the spatial distance weight matrix used to measure the distance between regions i and j.

To study localized areas' atypical characteristics, the localized test formula is as follows:

$$I_i = \frac{(x_i - \overline{x})}{s^2} \sum_{j=1}^{n} w_{ij}\left(\left(x_j - \overline{x}\right)\right) \tag{11}$$

The value of Moran's index ranges from −1 to 1. Positive values indicate positive autocorrelation (that is, high values cluster together, as do low values). Negative values indicate negative autocorrelation that is, high values are surrounded by low values, and vice versa). Values close to 0 indicate a random spatial distribution with no autocorrelation [88].

3.3.4. Spatial panel econometric model

Spatial econometric models primarily fall into the following three categories: spatial lag, spatial error, and spatial Durbin. Among these, the spatial Durbin model (SDM) is unique because it incorporates both spatial lag and spatial error effects. This allows us to analyse the existence of spatial spillovers among explanatory variables as well as the influence of omitted variables (those not included in the model) and unobservable stochastic shocks on the dependent variable. The SDM's basic structure is as follows:

$$y_{it} = \rho \sum_{j=1}^{N} w_{ij} y_{jt} + x_{it}\beta + \sum_{j=1}^{N} w_{ij} x_{jt}\gamma + \mu_i + \delta_t + v_{it} \tag{12}$$

where y_{it} is the explanatory variable; ρ is the spatial lagged effect coefficients; w_{ij} is the spatial weight matrix; $\rho \sum_{j=1}^{N} w_{ij} y_{jt}$ is the spatial lag term of the explanatory variable; $\sum_{j=1}^{N} w_{ij} x_{jt}\gamma$ is the spatial lag term of the explanatory variable; μ_i and δ_t are the spatial and time fixed effects, respectively; and v_{it} is the random perturbation term.

Considering that the coupling and coordinated development of happiness and technological innovation are influenced by multiple factors, to clearly analyse the main driving factors, this study chooses *gov*, *ir*, *dfi*, *eh*, *gdp*, and *cir* as explanatory variables, which are elucidated below.

Government Intervention (gov): as an external institutional environment, local governments predominantly use investment, fiscal allocation, and administrative policies to guide technological and economic development, which significantly benefit resident security, living conditions, and the scientific and technological innovation environment. Brandt posited that moderate government intervention is beneficial for maximising well-being, arguing in favour of more limited and rational intervention; this study considers regional fiscal expenditure as a share of regional GDP as a measure of the level of government intervention [89].

Industrial structure adjustment: the adjustment of industrial structure significantly impacts resident income, urban employment, demand consumption, and the improvement of the gap be-tween urban and rural areas. Yin et al. argued that industrial restructuring not only helps balance environmental governance and economic development but also increases demand for scientific and technological innovation [90]. In this study, the rationalisation level (ir) of the industrial structure is used as a variable to study the factors influencing well-being and the coupling coordination degree of scientific and techno-logical innovation.

Table 2
Criteria for categoriszing and judging the degree of coordination degree.

Dysfunctional recession category		Harmonisation of development categories	
Interval of D-values for coupling coordination	Type of coupled coordination	Interval of D-values for coupling coordination	Type of coupled coordination
(0.0–0.1)	Extreme imbalance decline	(0.5–0.6)	Marginally coupling coordination
(0.1–0.2)	Serious imbalance decline	(0.6–0.7)	Primary coupling coordination
(0.2–0.3)	Moderate imbalance decline	(0.7–0.8)	Intermediate coupling coordination
(0.3–0.4)	Minor imbalance decline	(0.8–0.9)	Well-coupled coordination
(0.4–0.5)	On the verge of imbalance decline	(0.9–1.0)	Quality coupling coordination

The digital economy's development and regional talent flow play an important role in regional development and the change in people's production and life [91,92], Gagulina et al. identified the digital economy's role as a driving force in promoting innovation development and the population's quality of life, while Araki found a positive relationship be-tween educational attainment and life satisfaction through multilevel regression, especially the expansion of education at the societal level on well-being, therefore, this study uses the Digital Financial Inclusion Index (dfi) and proportion of higher education (eh) to measure these two levels.

Finally, in traditional economics studies, income, wealth, and consumption are used as important indicators that affect people's utility levels. As a means of evaluating the level of well-being, the regional development status is measured using the gross domestic product (gdp) and consumption-to-income ratio (cir) of residents, and the influence of economy and consumption on well-being and the coupling and coordination degrees of scientific and technological innovation are explored. Additionally, the above six indicators are logarithmically processed to effectively eliminate the adverse effects of the dimensions and units in the model.

4. Results

4.1. Spatial-temporal characteristics of well-being and scientific and technological innovation

Through data standardisation, the entropy method is used to calculate each index's weight, and the well-being index for each region is obtained. From the perspective of the time series, as Fig. 1 depicts, significant differences exist in each province's well-being index, but the overall trend is increasing. In the inter-provincial well-being index, Beijing, Shanghai, Zhejiang, and Jiangsu rank in the top four, whereas Gansu, Yunnan, Guizhou, and Heilongjiang rank in the bottom four. From 2014 to 2022, the well-being indices of all provinces exhibit a fluctuating upward trend. In 2018 and 2020, all provinces exhibit a significant decline—possibly owing to the increased downward pressure on the global economy in 2018 and the full-scale outbreak of global COVID-19 in 2020.

From the perspective of each region's spatial distribution, as Table 3 depicts, the extreme difference at the national level is 0.335 and the coefficient of variation is 0.154, which indicates that the degree of difference between some provinces and cities is larger and the data are more discrete, suggesting a two-level distribution. Only the eastern well-being index score is higher than the national average. Overall, well-being is found to follow a pattern of east > west and central > northeast. Notably, the east differs significantly from other regions. Cities in the east-ern region—such as Beijing, Shanghai, Jiangsu, Zhejiang, and Tianjin—exhibit significantly higher well-being indices than the other cities. In the western region, only Tibet and Inner Mongolia exceed the national average. Interestingly, both regions share the following common characteristics: sparse population, abundant resources, desirable environmental conditions, lower living costs compared with developed cities, and higher social security levels. Additionally, these regions exhibit smaller urban–rural gaps, contributing to their residents' higher well-being.

Fig. 2 presents a time-series diagram of the science and technology innovation index and well-being from the perspective of the integration of the science and technology innovation and well-being indices in various places. Both maintain a continuous growth process, and the provinces and cities exhibit a trend towards leading development in science and technology innovation. Only the well-being and scientific and technological innovation index in Tibet exhibits an opposite state, indicating that the scientific and technological innovation level in Tibet is significantly lower than that of other regions. However, owing to the national policy inclination, various subsidies have reduced the living pressure, the gap between the rich and the poor is not large, and the rich resources and

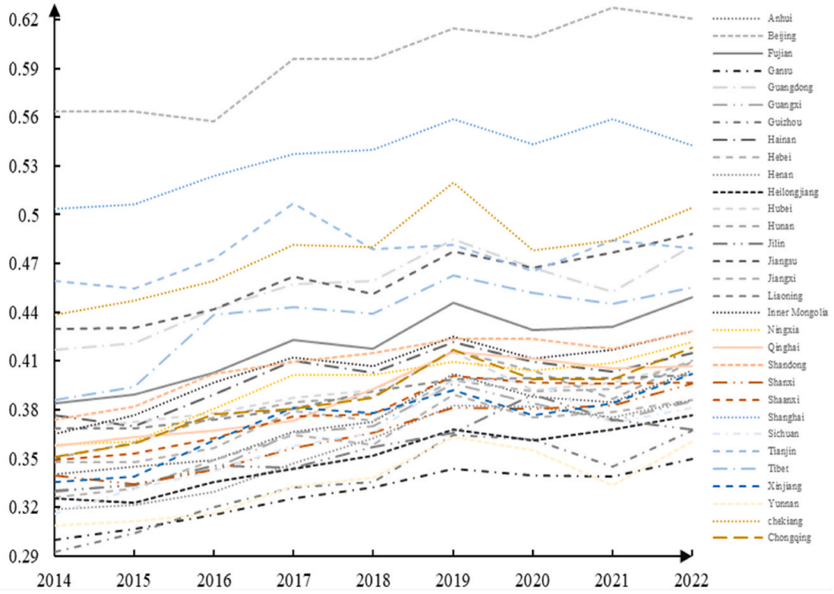

Fig. 1. Change of key technical parameters.

Table 3
Descriptive statistics of sample basic characteristics.

Shore	N	Mean	p50	sd	min	max	range	cv
National	279	0.400	0.387	0.062	0.292	0.628	0.335	0.154
East	90	0.458	0.452	0.068	0.326	0.628	0.302	0.149
Central	54	0.374	0.38	0.025	0.319	0.416	0.098	0.066
West	108	0.374	0.375	0.037	0.292	0.463	0.17	0.100
Northeast	27	0.364	0.368	0.024	0.323	0.401	0.078	0.065

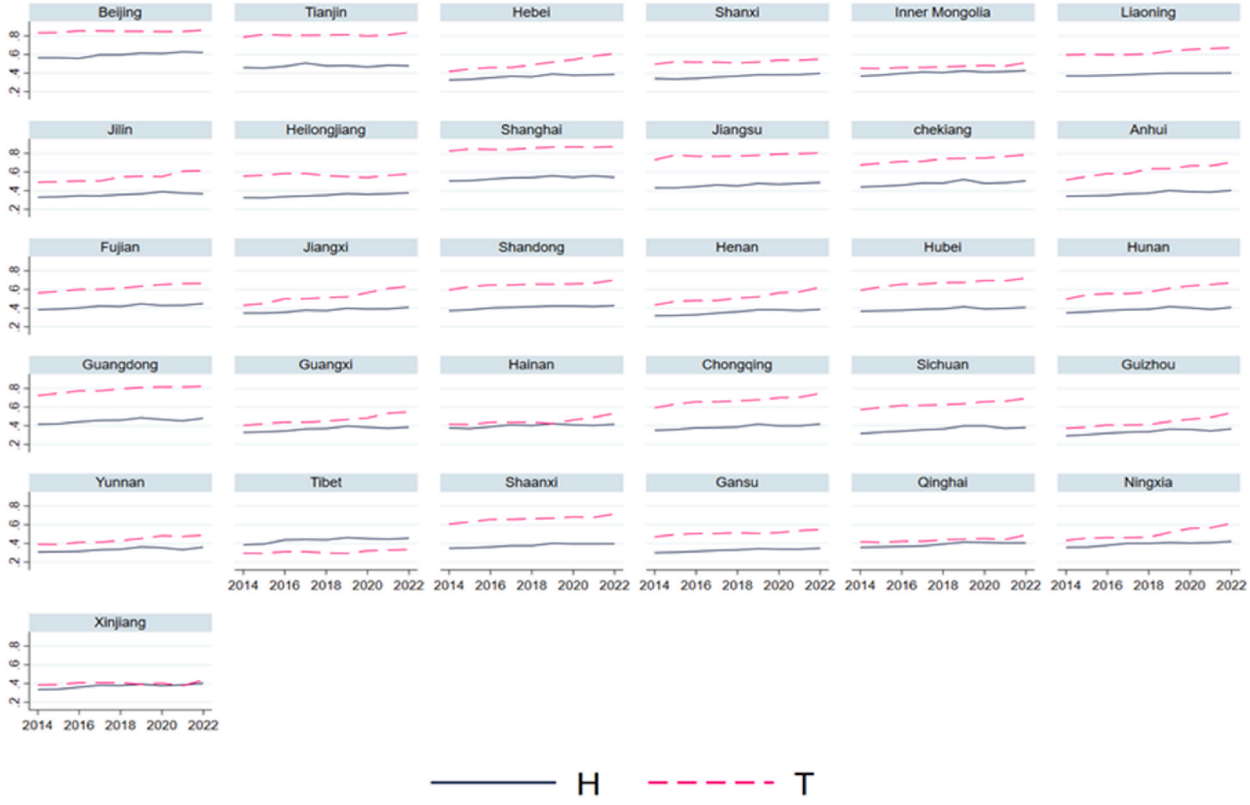

Fig. 2. Time series plot of STI index and resident well-being in sample area.

environmental/geographical advantages indicate a high well-being level.

4.2. Coupling and coordination relationship between well-being and scientific and technological innovation

Table 4 presents the coupling coordination degree between well-being and scientific and technological innovation. We analyse the coupling coordination degree across regions over time and across developmental statuses. In the time dimension, the coupling coordination degree for each region ranges between 0.575 and 0.855. Notably, both Beijing and Shanghai consistently maintain a satisfactory coupling state, indicating an increasingly closer relationship between well-being and science and technology innovation in these two cities. Considering the development status of different provinces and cities, an overall upward trend can be observed in their degrees of coupling coordination. In 2014, only 19.35 % of provinces and cities exhibited an intermediate level of coordination or above. By 2022, this proportion had significantly increased to 51.61 %. Among these, Beijing, Shanghai, Tianjin, Zhejiang, Jiangsu, and Guangdong had significantly higher coupling coordination than other cities. By contrast, Guizhou, Yunnan, Tibet, and Xinjiang lagged. However, by 2022, only Beijing (0.855) and Shanghai (0.829) achieved satisfactory coupling coordination. Most other provinces remained in the primary or intermediate stages. While Guizhou, Yunnan, Tibet, and Xinjiang improved from ‘barely coordinated’ status, they still only reached the level of primary coupling coordination.

Analysing regional differences, only the eastern region has consistently maintained intermediate coupling coordination, and cities achieving satisfactory coupling coordination are concentrated in this area. This suggests that development in other regions lags behind that in the east. Although the central region has exhibited progress in achieving intermediate coordination in recent years, the western and northeastern regions remain primarily at the basic coordination level. This creates an overall pattern of east > central > northeast

Table 4
Level of coupled and coordinated development in 31 provinces and cities, 2014–2022.

Region	provinces	2014	2015	2016	2017	2018	2019	2020	2021	2022
East	Beijing	0.827	0.828	0.831	0.844	0.843	0.850	0.847	0.854	0.855
	Tianjin	0.775	0.780	0.786	0.799	0.789	0.791	0.781	0.791	0.795
	Anhui	0.607	0.619	0.633	0.640	0.647	0.670	0.672	0.685	0.696
	Shanghai	0.803	0.809	0.815	0.820	0.825	0.834	0.829	0.833	0.829
	Jiangsu	0.749	0.762	0.763	0.772	0.768	0.781	0.780	0.785	0.791
	Zhejiang	0.738	0.746	0.757	0.766	0.773	0.789	0.774	0.781	0.793
	Fujian	0.682	0.689	0.702	0.710	0.712	0.729	0.727	0.731	0.739
	Shandong	0.687	0.701	0.715	0.718	0.723	0.726	0.727	0.727	0.740
	Guangdong	0.741	0.749	0.765	0.771	0.777	0.792	0.786	0.779	0.793
	Hainan	0.629	0.625	0.642	0.650	0.648	0.650	0.659	0.667	0.686
	average value	0.724	0.731	0.741	0.749	0.750	0.761	0.758	0.763	0.772
Central	Shanxi	0.640	0.646	0.649	0.655	0.657	0.667	0.673	0.674	0.684
	Anhui	0.647	0.660	0.671	0.680	0.697	0.711	0.713	0.712	0.730
	Jiangxi	0.622	0.629	0.650	0.660	0.661	0.675	0.686	0.700	0.714
	Henan	0.610	0.624	0.631	0.640	0.655	0.668	0.682	0.682	0.700
	Hubei	0.683	0.695	0.706	0.710	0.717	0.728	0.723	0.724	0.737
	Hunan	0.646	0.665	0.676	0.680	0.687	0.711	0.713	0.709	0.724
	average value	0.641	0.653	0.664	0.671	0.679	0.693	0.698	0.700	0.715
West	Inner Mongolia	0.637	0.641	0.654	0.660	0.660	0.670	0.668	0.668	0.684
	Guangxi	0.603	0.612	0.623	0.632	0.638	0.656	0.656	0.668	0.678
	Chongqing	0.675	0.690	0.706	0.707	0.713	0.729	0.727	0.728	0.748
	Sichuan	0.652	0.667	0.678	0.686	0.691	0.709	0.715	0.705	0.717
	Guizhou	0.575	0.585	0.601	0.607	0.610	0.634	0.642	0.641	0.667
	Yunnan	0.589	0.590	0.601	0.609	0.617	0.637	0.643	0.631	0.648
	Tibet	0.581	0.583	0.608	0.610	0.601	0.607	0.618	0.619	0.625
	Shaanxi	0.679	0.687	0.698	0.705	0.708	0.720	0.722	0.720	0.730
	Gansu	0.613	0.624	0.632	0.637	0.643	0.646	0.647	0.653	0.662
	Qinghai	0.622	0.622	0.628	0.630	0.645	0.656	0.657	0.651	0.668
	Ningxia Zhejiang	0.628	0.637	0.648	0.656	0.658	0.679	0.690	0.694	0.713
	Xinjiang	0.599	0.602	0.619	0.628	0.626	0.626	0.624	0.617	0.647
	average value	0.621	0.628	0.641	0.647	0.651	0.664	0.667	0.666	0.682
North-east	Liaoning	0.684	0.686	0.688	0.691	0.698	0.709	0.714	0.717	0.721
	Jilin	0.634	0.637	0.646	0.645	0.664	0.671	0.680	0.691	0.689
	Heilongjiang	0.652	0.653	0.665	0.669	0.666	0.671	0.665	0.675	0.683
	average value	0.657	0.659	0.666	0.668	0.676	0.684	0.686	0.694	0.698

> west. From a national perspective, the coupling coordination between well-being and science and technology innovation exhibits a clear 'high in the east, low in the west' characteristic, indicating significant room for improvement across the country.

4.3. Spatial correlation analysis

According to Table 5, the global Moran's I index for the 2014–2022 period is greater than 0, and all of them pass the significance test at the 1 % level. This indicates a significant positive spatial autocorrelation, implying that provinces and cities with similar levels of coupled coordination tend to cluster geographically. The index value also exhibits a gradual upward trend, in-creasing from 0.336 in 2014 to 0.358 in 2022, despite some minor fluctuations. This suggests a slow strengthening of the spatial clustering of coupled co-ordinated development.

Although the global Moran's I index identifies the overall presence and strength of spatial correlation, it lacks details regarding

Table 5
Global Moran's index of coupled harmonisation of well-being and science and technology innovation.

Year	Moran's I	Z	P
2014	0.336	4.053	0.000 1
2015	0.335	4.026	0.000 1
2016	0.338	4.050	0.000 1
2017	0.355	4.245	0.000 0
2018	0.348	4.165	0.000 0
2019	0.340	4.065	0.000 0
2020	0.328	3.949	0.000 1
2021	0.355	4.252	0.000 0
2022	0.358	4.263	0.000 0

specific locations. Four years (2014, 2016, 2018, and 2022) are selected for the local correlation test, and Fig. 3 presents the local Moran's I index scatter at the coupled coordination level.

The local Moran's I index of happiness and technological innovation coupling coordination in 31 provinces and cities are mainly concentrated in the first and third quadrants, with obvious H-H clustering and L-L clustering characteristics in space, which indicates a significant local spatial positive correlation and be consistent with the conclusion that the global spatial correlation are all positive.

From the spatial clustering distribution of specific provinces, high-high clustering is mostly distributed in eastern cities such as Beijing, Tianjin, Zhejiang, Jiangsu, and Shandong, such as Beijing, Tianjin, Zhejiang, Jiangsu, Shandong, etc., while low-low clustering is more mainly in cities in the western region, such as Qinghai, Gansu, Heilongjiang, Jilin, and other cities in the northeastern region.

Analysis shows that the proportion of high-high clustering and low-low clustering has increased from 64.2 % in 2014 to 74.2 % in 2022, demonstrating the increasing spatial clustering between the two systems and verifying the reliability of the global Moran's I index mentioned earlier.

4.4. *Analysis of drivers*

A significant spatial correlation is observed between the coupled coordination degree of well-being and science and technology innovation in 31 provinces and cities. To accurately de-scribe the relationship between the influence of explanatory variables on the coupling coordination degree between the two, selecting a suitable spatial measurement model is necessary [93]. Reasonable models are selected using LM, Hausman, LR, and Wald tests.

Table 6 suggests that the spatial error model (SEM) and spatial lag model (SAR) are applicable based on the LM test. The LM-lag, Robust LM-lag, and LM-error statistics are all significant at the 1 % level, indicating spatial autocorrelation and justifying the use of the spatial econometric model. The Hausman test results suggest that the model error term likely includes the fixed effects. The null hypothesis of 'the random effects model is the correct model' is rejected at the 1 % significance level, resulting in the selection of the fixed effects model for analysis. The LR test helps choose the appropriate fixed-effects structure. The results indicate that the two-way fixed effects model (spatial and time fixed effects) is significant at the 1 % level com-pared with the one-way fixed effects model. Therefore, this study adopts a two-way fixed spatial model. Finally, the LR and Wald tests are used to determine whether the SDM can be simplified to SEM or SAR. The results reveal that both the spatial lag and spatial error are present and significant. Additionally, the combined Wald and LR test confirms that the SDM cannot be reduced to SEM or SAR, thus validating the choice of the SDM.

In summary, the following two-way fixed-space Durbin model is proposed for detailed testing and analysis, which is modelled as follows:

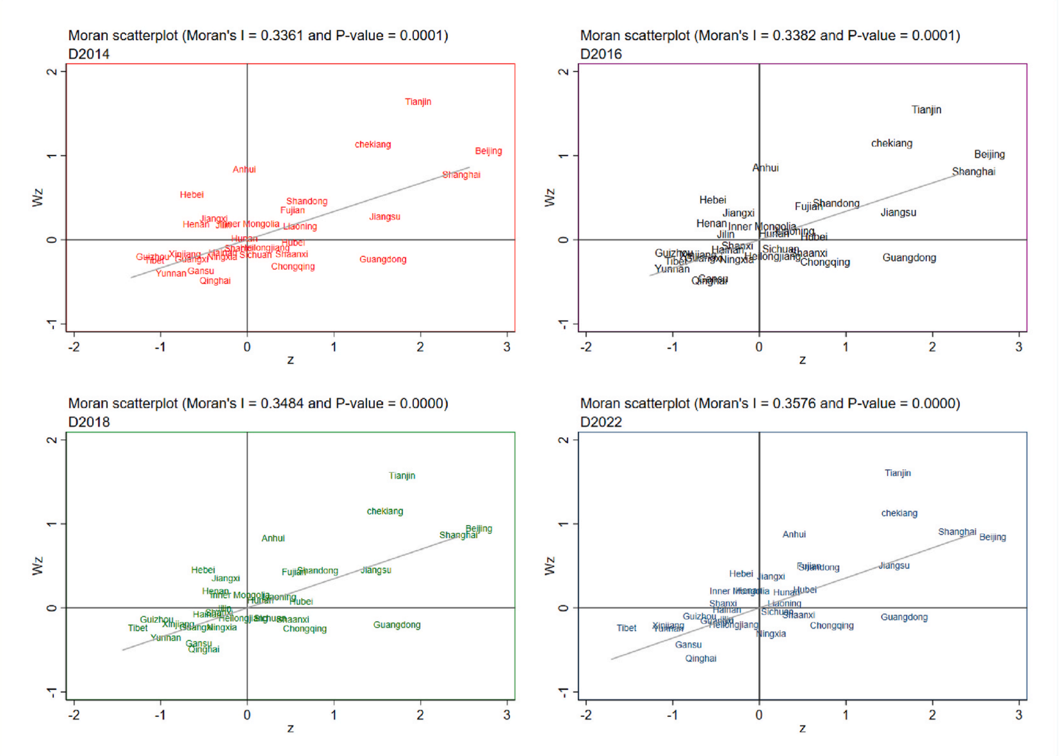

Fig. 3. Moran scatterplot of coupled harmonized development levels.

Table 6
Global Moran's index of coupled harmonisation of well-being and science and technology innovation.

Spatial panel model testing		Value	P-Value
LM test	Moran's I	6.655***	0.000
	LM-lag	37.394***	0.000
	Robust LM-lag	30.242***	0.000
	LM-error	9.688***	0.002
	Robust LM-error	2.536	0.111
LR test	LR-SDM/SEM	16.01**	0.013 7
	LR-SDM/SAR	19.60***	0.003 3
Space-Time Fixed Effects Tests	LR-both/time	590.98***	0.000
	LR-both/ind	66.90***	0.000
Wald test	Wald-SDM/SEM	18.85***	0.004 4
	Wald-SDM/SAR	14.45**	0.025 0
Hausman test	Test	29.62***	0.000 0

Note: *, * *, and * * * indicate significance at the 10 %, 5 %, and 1 % levels, respectively.

$$
\begin{aligned}
\ln D_{it} = {} & \beta_1 \ln gov + \beta_2 \ln ir + \beta_3 \ln DFI + \beta_4 \ln EH + \beta_5 \ln gdp + \beta_6 \ln cir \\
& + \beta_7 \sum_{j=1}^{n} W_{ij} \ln gov + \beta_8 \sum_{j=1}^{n} W_{ij} \ln ir + \beta_9 \sum_{j=1}^{n} W_{ij} \ln dfi \\
& + \beta_{10} \sum_{j=1}^{n} W_{ij} \ln eh + \beta_{11} \sum_{j=1}^{n} W_{ij} \ln gdp + \beta_{12} \sum_{j=1}^{n} W_{ij} \ln cir \\
& + \rho \sum_{j=1}^{n} W_{ij} \ln D_{it} + \mu_i + \delta_t + \nu_{it} \qquad (13)
\end{aligned}
$$

where D_{it} is the explanatory variables, indicating the coupled coordination degree of regional well-being and science and technology innovation; *gov*, *ir*, *dfi*, *eh*, *gdp*, and *cir* are the explanatory variables, indicating the degree of government intervention, rationalisation of industrial structure, digital financial inclusion, proportion of higher education, gross regional product, and consumption-to-income ratio, respectively; further, μ_i andδ_t are fixed effects in space and time, respectively, and ν_{it} is the randomised disturbance term.

The regressions are conducted using the SDM and a panel fixed-effects model (FEM). Table 7 presents the results, which reveal that in the FEM model, gdp exerts a certain influence on the coordination degree, but in the SDM model, after introducing the spatial dimension, a significant change occurs, and gdp no longer significantly influences the coordination degree. This may be because the feeling of happiness is also related to the comparison of neighbouring regions, and the change in the coordination degree caused by pure economic growth is gradually weakening, and, in fact, by testing the AIC criterion for the two, t the SDM model is, seemingly, superior to the FEM model, wherein the rho value is significant at the 1 % level, indicating a significant spatial dependence in the coupled coordination degree of happiness and scientific and technological innovation. The regression results of the two models reveal that the regression coefficients' size and sign are fundamentally the same, which also indicates that the other selected explanatory

Table 7
Empirical results of SDM and FEM models.

Variables	(1)SDM		(2)FEM
	Main	Wx	
lnir	−0.0059***	−0.0060	−0.0061***
	(0.0019)	(0.0042)	(0.0019)
lnDFI	0.1219***	−0.2044**	0.0979**
	(0.0378)	(0.0982)	(0.0382)
lnEH	0.0059*	−0.0049	0.0083**
	(0.0035)	(0.0080)	(0.0040)
lngov	−0.0228**	−0.00603	−0.0258***
	(0.0089)	(0.0219)	(0.0097)
lncir	0.0654***	0.1516***	0.0702***
	(0.0206)	(0.0450)	(0.0219)
lngdp	0.0214	0.0550*	0.0293*
	(0.0170)	(0.0331)	(0.0162)
rho	−0.3400***		0.9595
	(0.1150)		
sigma2_e	9.69e-05***		
	(8.28e-06)		
Spatia-fe	Yes	Yes	Yes
Time-fe	Yes	Yes	Yes
Observations	279	279	279
Number of id	31	31	31

Note: *, * *, * * * respectively indicate significance at 10 %, 5 %, 1 %.

variables significantly affect the coordination degree, and substantiates the results' robustness. Owing to the spatial lag term, the lag term's estimated coefficient size can-not represent the independent variables' impact on the dependent variable; therefore, the impact effect must be decomposed to further explain the marginal impact of the explanatory variables in the spatial panel model.

As documented by LeSage et al. [94], spatial effects can be decomposed into direct and indirect effects using partial differentiation methods. Table 8 presents the results.

The results for the direct effects reveal that, except for gdp, which is insignificant, both the rationalisation of the industrial structure and government intervention negatively influence the coordination degree. By contrast, digital financial inclusion, the proportion of higher education, and the consumption-to-income ratio exhibit significant positive effects. For indirect effects, digital financial inclusion and the consumption-to-income ratio exhibit significant spatial spill-over effects on neighbouring provinces.

Concerning indirect effects, digital financial inclusion and the consumption-to-income ratio exhibit significant spatial spillover effects on neighbouring provinces. Notably, the gross regional product did not exhibit a significant direct or indirect effect on the coordination degree. This finding aligns with the Easterlin paradox, suggesting that pure economic growth alone may be insufficient to enhance well-being and improve the coordination between happiness and in-novation.

Industrial structure rationalisation is measured using the Thiel index, where a smaller value indicates a higher degree of rationalisation. This higher level of rationalisation positively in-fluences the local coordination degree by optimising resource allocation. In developed regions, through the optimisation of resource allocation and promotion of new industries, more employment opportunities are created and the income and living standards of the population are raised, ultimately achieving a win-win situation in terms of scientific and techno-logical innovation and a sense of well-being. In developing countries, the rationalisation of industrial structure not only requires attention to scientific and technological innovation but also focuses on solving structural problems, such as the development of infrastructure and enhancement of human capital, to effectively promote economic growth and the improvement of people's livelihoods, which, in turn, contributes to the enhancement of people's sense of well-being. Interestingly, the analysis suggests that a city's own industrial structure adjustments do not significantly impact the coordination degree in neighbouring areas.

The development of digital inclusive finance significantly positively impacts the development of local coordination, has lowered the threshold for financial services through digital technology networks, and broadened the channels whereby rural residents can access financial resources. Rural low-income groups can obtain financial support through the low-cost advantages of digital inclusive financing, which eases the liquidity constraints of rural residents, improves the efficiency of resource allocation, promotes the economic development of rural areas, and narrows the income gap be-tween urban and rural areas. Additionally, it provides people with more convenient and efficient life services, fulfils the personalised needs of different groups, and promotes information transparency and social participation, which is conducive to the harmonious and stable development of society and enhances people's sense of well-being. Second, digitally inclusive finance can promote the ability of scientific and technological innovation by improving the allocation of credit resources and lowering innovation financing costs. Owing to the high investment in scientific and technological innovation, the ever-expanding demand for funds requires more efficient and low-cost financial services. Simultaneously, the region's digital inclusive finance may exhibit a dampening effect on the coordination degree in neighbouring regions owing to the siphon effect. This results in the excellent development of digitally inclusive finance in the province may create more employment to attract high-skilled labour in neighbouring regions, leading to a brain drain from neighbouring regions, intensified competition for talent, and rapid development of the central region but the slow development of neighbouring regions, which widens the income gap because of more opportunities and better conditions precipitating adverse effects on neighbouring provinces.

The proportion of higher education in a region significantly influences its coordination degree. Regions with a concentration of tertiary education talent can promote scientific and technological progress, raise living standards, and improve the quality of life, thus promoting social harmony and stability through the advantages of the talent pool, dynamism of innovative activities, and development

Table 8

Decomposition of the effects of the SDM model.

Variables	(1)	(2)	(3)
	LR_Direct	LR_Indirect	LR_Total
lnir	−0.005 64***	−0.003 17	−0.008 80***
	(0.002 14)	(0.003 66)	(0.002 84)
lnDFI	0.134***	−0.197**	−0.063 5
	(0.039 2)	(0.082 8)	(0.065 3)
lnEH	0.006 60*	−0.005 14	0.001 47
	(0.003 45)	(0.006 13)	(0.006 63)
lngov	−0.023 1**	0.002 47	−0.020 6
	(0.0091 6)	(0.018 1)	(0.016 0)
lncir	0.058 7***	0.101***	0.160***
	(0.020 7)	(0.035 9)	(0.031 9)
lngdp	0.019 5	0.039 2	0.058 7***
	(0.017 8)	(0.028 0)	(0.022 5)
Spatia-fe	Yes	Yes	Yes
Time-fe	Yes	Yes	Yes
Observations	279	279	279
Number of id	31	31	31

Note: *, * *, and * * * indicate significance at the 10 %, 5 %, and 1 % levels, respectively.

of scientific and technological industries. Talent gathering in a city attracts more information, knowledge, and technology resources for local scientific research, thereby providing raw materials for innovation and enriching the innovation environment. This can drive regional high-tech industries' development. Furthermore, a high concentration of talent contributes to local economies. Individuals with strong innovation abilities improve production efficiency, increase enterprise specialisation, and generate economies of scale, precipitating overall improvements in income, education, healthcare, transportation, housing, and environmental quality. However, the proportion of higher education in one region does not significantly impact the coordination degree of in other regions.

Government intervention significantly negatively impacts the coordination between the two, and its economic effect is not solely promoting or hindering. The negative effect on the co-ordination degree may stem from differing focuses on government expenditures. For a long time, local governments have primarily focused on economic development, potentially leading to heavy financial support for traditional, high-polluting, and high-energy-consuming enterprises. This prioritisation may negatively impact the living environment and quality of life of residents and neglect other necessary investments. Excessive government intervention may lead to the ineffective allocation of resources, bureaucratic bloat, and suppression of the spirit of innovation. Simultaneously, governments must be concerned about the possible unintended consequences of policy implementation, such as the inefficient allocation of resources or unnecessary restrictions on innovative activities.

A higher resident consumption-income ratio significantly positively affects both local and neighbouring regions. The increase in resident consumption drives up regional production demand, which promotes the transformation and application of scientific and technological achievements. Simultaneously, consumption is the purpose of production, source of the creation of new needs for new production, prerequisite and driving force for reproduction, and an important means to satisfy residents' material and spiritual needs. The expansion of residents' demand and circulation of consumer products among various places are the main reasons for the positive spatial spillover of the consumption rate of residents; consumption behaviour, through the regional spillover effect, results in the economic development of the surrounding areas and scientific and technological innovation, and promotes the region's synergistic development. Therefore, consumption is both a source of happiness and an important source of impetus for coordinated development between provinces, cities, and regions.

4.5. Robustness testing

To ensure the estimation results' reliability, a robustness test is performed by replacing the inverse distance-squared matrix with a spatial distance matrix. The results in Table 9 indicate that after re-placing the weight matrix, the regression coefficients, positive and negative signs, and significance of the explanatory variables are in satisfactory agreement with the regression above, indicating that the conclusions are robust and that the original results are reliable.

5. Discussions

Well-being is an important symbol of social progress, which can not only provide a basis for the government to formulate scientific and effective social policies, but also one of the important indicators to evaluate the level of social and economic development, reflecting the impact of economic development on the quality of life of residents. The sense of happiness in China shows a clear leading trend in the eastern region, far surpassing other regions, and the situation of the eastern coastal cities such as Beijing, Shanghai, Zhejiang. At the same time, we find that Tibet and Inner Mongolia are remote areas in the west, and their happiness level also exceeds the national average [95]. As Liang-Shun demonstrated, the degree of happiness is closely related to ecology, resources, and social well-being [22,96].

With an increasing emphasis on happiness, innovation should be based on objective standards of happiness—as argued by Tur-Sinai

Table 9
Robustness test.

Variables	(1)	(2)	(3)
	LR_Direct	LR_Indirect	LR_Total
lnir	−0.0056***	−0.0065	−0.0120**
	(0.0021)	(0.0060)	(0.0050)
lnDFI	0.1270***	−0.2822**	−0.1552
	(0.0386)	(0.1190)	(0.0988)
lnEH	0.0069**	−0.0117	−0.0048
	(0.0035)	(0.0108)	(0.0108)
lngov	−0.0240***	0.0192	−0.0048
	(0.0092)	(0.0281)	(0.0253)
lncir	0.0637***	0.1244**	0.1880***
	(0.0211)	(0.0575)	(0.0503)
lngdp	0.0194	0.0783	0.0977***
	(0.0178)	(0.0447)	(0.0368)
Spatia-fe	Yes	Yes	Yes
Time-fe	Yes	Yes	Yes
Observations	279	279	279
Number of id	31	31	31

[97]. Based on previous research on happiness, we add the level of technological innovation and evaluate the coupling and coordination between happiness and technological innovation. The results reveal that, in the more developed eastern region, the coordination between happiness and scientific and technological innovation is better. However, owing to limited development and low levels of scientific and technological innovation, some central and western regions cannot per-form their functions effectively. According to Aldieri's study [98], the dependence of innovation and development on the economy and resources may negatively impact happiness and affect the coordination between happiness and scientific and technological innovation. This is closely related to its own resources, location characteristics, and development status.

The adjustment of the industrial structure, development of digital finance, and continuous flow of talent are rapidly driving changes in the regional economic and social environments [99]. This study finds that a simple change in economic growth does not significantly affect the coordination degree between happiness and technological innovation, substantiating the existence of the Easterling paradox in a specific time and space. As Li posited, for economic growth to serve as a driving force, fully ensuring fairness, efficiency, and people's livelihoods is necessary [100]. The optimisation and adjustment of the industrial structure, development of digital inclusive finance, and proportion of talent with higher education will better promote the coordination of the cities' scientific and technological innovation ability and happiness, and it is expected to achieve a win-win situation in mutual promotion. Resident consumption is a significant driving force in development and coordination. Per Jiling's findings [101], CPI exhibits a significant mutual influence on happiness, which not only significantly influences the local area but also affects the surrounding cities through consumption radiation, driving their development and resource circulation. Simultaneously, the influence of government intervention cannot be neglected. Owing to the shift in the development focus and pursuit of government tasks and objectives, the degree of government intervention may become a major obstacle to coordination [102].

6. Conclusion, recommendations, and limitations

6.1. Conclusions

This study analyses well-being across 31 Chinese provinces (cities) by constructing a resident happiness evaluation index system. The analysis reveals that residents in the eastern region generally exhibit higher well-being levels than those in the other regions. This finding is aligned with the rapid economic and social development observed in the east. However, this study also identifies exceptions, such as Tibet and Inner Mongolia, where residents report high happiness despite disparities in economic growth. These instances suggest that factors beyond economic prosperity contribute to well-being, including elements such as low urban–rural disparity, rich natural resources, affordable living costs, and favourable living environments.

Second, this study employs a coupled coordination model to evaluate and analyse the relationship between regional well-being and scientific and technological innovations. The analysis reveals a steady increase in the degree of coordination between regions, with only minor fluctuations. Additionally, the results demonstrate a clear spatial correlation. This finding suggests that the levels of both scientific and technological innovation and well-being in China have gradually improved in recent years and that these two factors exhibit significant spatial correlation characteristics.

Finally, a spatial econometric model was used to analyse the driving factors behind the coupled coordination degree of regional well-being and science and technology innovation. The results reveal that several factors significantly promote the local coordination degree: rationalisation of the industrial structure, development of digital inclusive finance, mobility of talent aggregation, and higher consumption income ratio. Conversely, government intervention negatively impacts local coordination. Additionally, the siphoning effect of digital inclusive finance on neighbouring regions may exhibit a negative impact, while the residents' consumption ratio significantly promotes the coordination degree in neighbouring provinces (municipalities). Interestingly, the impact of gdp on the coordination degree is not significant, suggesting that pure economic growth no longer satisfies people's desires for a better life. This indicates a shift in residents' priorities, with greater emphasis on the living cost, living environment, and psycho-logical perception compared to others.

6.2. Policy recommendations

Based on the above analysis, the following recommendations are proposed.

First, the government should clarify the direction of industrial structure optimisation and actively promote the digital economy's development. The optimisation of industrial structure and development of the digital economy plays an inaccessible role in the co-development of the well-being of regional residents and scientific and technological innovation. The government can improve the technical level and competitiveness of traditional industries through the renew-al of equipment and management innovation in traditional industries; focus on new energy, the Internet of Things, blockchain, and other emerging industries in terms of policy; and encourage cross-fertilisation between emerging industries and traditional industries. The convenience and technology precipitated by digitalisation must be used to improve efficiency, and the optimisation of industrial structure and formation of a development model must be promoted for deeply integrating the digital and real economies. The synergistic development of industries between regions and complementary advantages of different regions must be promoted; further, industrial chains must be formed, and interregional cooperation and exchange must be strengthened. Noteworthily, in some economically underdeveloped regions should be based on provincial conditions, avoiding the pursuit of advanced industrial structure, as far as possible, to ensure that the resource endowment and transformation of factors is of high quality and efficiency, to achieve a better allocation of resources.

Second, we rationalise the degree of government intervention and improve talent training and introduction policies. The evaluation of the government's performance should not be limited to the economy itself, and the degree of government expenditure intervention should also consider people's livelihoods, environment, sustainable development, etc. Effective supervision and feedback mechanisms should be established to ensure that policy measures not only achieve the desired goals but also minimise the inhibition of innovation vitality. The quality of life and education in the region should be actively promoted, and the region should be enabled to develop local talent and retain foreign talent under sufficiently liveable conditions through talent ad-mission strategies. A sound evaluation mechanism for the dynamics of social ecology and talent development can effectively contribute to improving the relevant systems.

Finally, the phenomenon of high savings rates prevailing in China and other developing countries persists, and resident consumption is not only a driver to stimulate economic growth but also a direct source of residents' happiness. The government should actively optimise the consumption environment, improve financial services, enhance its credibility, and boost consumer confidence through media campaigns and policy propaganda to enable people to feel optimistic regarding future economic conditions, thus prompting the masses to more positively predict their life prospects and boost their confidence in consumption.

6.3. Limitations

Previous research has extensively explored and analysed the impact of science and technology innovation on material life and production capacity, refining its mechanisms of action. Scholars have extensively debated the definition of happiness, which has resulted in diverse interpretations and evolving evaluation criteria for subjective, objective, individual, and social happiness. However, domestic research on happiness remains limited. This study addresses this gap by measuring and analysing the happiness of residents in 31 Chinese provinces and cities. By dissecting the dynamic relationship between well-being and coordinated development of science and technology innovation and further examining the driving factors affecting their coordination degree, this study contributes to a more comprehensive understanding of the interplay between science, technology, innovation, and a sense of happiness. Noteworthily, despite con-structing an evaluation index system for residents' happiness and exploring their interactive processes with science and technology innovation, this study has some limitations. First, owing to the inherent subjectivity of happiness, future refinement of the evaluation index system might involve adjusting the weights of the subjective indicators. Second, the selected timeframe of nine years (2014–2022) may have introduced biases in terms of reliability and validity. Future research could address this issue by utilising longer time-series data for a more robust analysis.

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Data availability statement

The data used in this paper are all official public data of China. All datas used in this research can be provided upon request.

CRediT authorship contribution statement

Lingmei Han: Writing – review & editing, Project administration, Conceptualization. **Yulong Fu:** Writing – original draft, Data curation. **Hongtao Shen:** Investigation, Conceptualization.

Declaration of competing interest

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

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