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Interaction Correlation Analysis between Scientific Technological Innovation and High-quality Development of New-type Urbanization: Panel Vector Autoregressive (PVAR) Approach

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Abstract:

Scientific-technological innovation (STI) plays a key role in urbanization. Previous studies have examined the relationship between STI and urban economy, but the relationship between STI and high-quality development of new-type urbanization (HQU) is still insufficient. By constructing two systematic evaluation index systems, this paper empirically analyzed the interaction correlation of the panel data of 11 cities in Zhejiang Province from 2006 to 2018. The results show that: (1) the comprehensive scores of STI and HQU in Zhejiang Province are increasing steadily in general. (2) There is a certain lag and difference in the interaction effect between STI and HQU in Zhejiang Province. The impact coefficient of HQU that lags behind the 1st stage on STI is 0.176, indicating that the HQU is conducive to the improvement of STI. However, the impact coefficient of STI on HQU is -0.117, indicating that STI has a slightly hindering effect on HQU and a “Crowding Out” effect of resources. (3) The results of variance decomposition show that the STI and HQU in Zhejiang Province mainly depends on its own development, and the promotion effect between them is weak. Finally, coordinated countermeasures and suggestions to promote STI and HQU are put forward.

Keywords*: Population urbanization, Scientific innovation, Sustainable development, Zhejiang Province.*

I. BACKGROUND

1.1 Research Background and Question

Urbanization is the process of transferring rural labor forces to cities during industrialization, which is the inevitable result of social and economic development. Over the past four decades of reform and opening-up, China’s urbanization rate has increased from 17.92% in 1978 to 58.58% in 2018. People,

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resources and many other factors have gradually concentrated in cities and towns, promoting the rapid development of regional economy [1]. However, with the rapid growth of urbanization, extensive and low-quality development patterns have exposed many problems. The excessive consumption of resources and arbitrary destruction of the environment have reduced the carrying capacity of cities, which is hindering cities' long-term development. Therefore, it is a focus topic of current society and academia to pursue and realize the sustainable and high-quality development of urbanization (HQU).

On 19 May, 2020, the International Institute for Sustainable Development (IISD) released "UN Secretary-General Releases 2020 Sustainable Development Goals Progress Report". In the report, 17 sustainable development goals related to the urbanization and technological innovations, including economic growth, poverty and hunger eradication, sustainable environmental sanitation, industrialization and innovation, and urban sustainability, etc. [2] As China is in the new developing era currently, the economic growth pattern is eager to be shifted from the traditional production factor-driven and investment-driven to innovation-driven, which would further promote urbanization development mode to transform into a new mode featuring people-oriented, intensive and efficient, urban-rural integrative and developing sustainable. Hence, how to scientifically and accurately confirm the relationship between urbanization development and scientific-technological innovation (STI) is a realistic issue that needs to be answered urgently.

Promoting HQU is the essential way for China to achieve basic modernization. It not only determines the future of China's urbanization development, but also affects the developing prospect and quality of the global urbanization [3]. Therefore, it is of great theoretical significance to explore the interaction between STI and HQU, which is helpful to analyse the characteristics of regional sustainable and high-quality development [4].

1.2 Literature Review

The relationship between STI and urbanization development has become an important content of urban sustainable development theoretical system. Existing researches mainly focus on the follows.

(1). Researches on the relationship between STI and sustainable development. For instance, some scholars claimed that innovation was an important means for enterprises to achieve sustainable development, the organization and management capabilities of enterprises played vital roles in the process of sustainable innovation. Some scholars believed that sustainable innovation was STI related to ecological environment, and there was an intimate relationship between technological innovation and ecological environment [5].

(2) The relationship between STI and urbanization development. These researches mainly contain three aspects: 1) Researches on the effect of STI on urbanization. Some scholars thought that STI was the basis for promoting the development of industrialization, and the acceleration of industrialization lead to the continuous agglomeration of population into cities, thus driving the development of urbanization [6]. STI

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also changes and upgrades technical tools, promotes the transformation and upgrading of industrial structure, and boosts the development of urban economy [7]. 2) Researches on the impact of urbanization on STI. Many scholars have confirmed that urbanization was a significant factor on STI that could not be ignored, which could bring positive externalities to technological progress [8]. On one hand, urbanization leads to the improvement of production efficiency, and then promote the generation of STI [9]. On the other hand, in the process of urbanization, a large number of surplus labour forces bring about because of population transfer, which provides objective conditions of labour resources for STI [10]. 3) Researches on Exploration of the bidirectional interaction between STI and urbanization. Some studies indicated that there was a close relationship between the level of urbanization and the number of patent applications from one single indicator [11]. Some scholars used the Vector Autoregression model (VAR) to analyses the relationship between urbanization and STI, and found that there was a strong positive correlation and a causal relationship between them [12]. Besides, based on the Coupling Coordination model, some studies pointed out that STI provided a driving force for the continuous development of urbanization, and urbanization provided element supports and diffusion platforms for STI simultaneously. There was a positive relationship between the coordination degree of the two and regional economic development [13].

(3) Research on high-quality development and driving force of new-type urbanization. The HQU is the intrinsic demand and foundation of new-type urbanization construction and urban sustainable development. So far, several scholars studied the main-line from measuring urbanization comprehensive developing degree, new-type urbanization level, urbanization development quality, new-type urbanization development quality to measuring HQU. For instance, starting from one initial single evaluation index, part researches focused on four aspect indexes—urban population, economic, human modernization, and urban-rural integration—to construct the urbanization quality measurement index system [14]. With the deepening understanding of the intrinsic rules of urbanization, the indexes of population, economy, society, resources, and environment were widely used to construct the quality index system of urbanization [15]. Around the five development concepts of innovation, coordination, green, openness and sharing, scholars have firmly realized that new-type urbanization was the amendment and optimization of traditional urbanization, which embodies the scientific concept of human centred, comprehensive, coordinated and sustainable development, and lays emphasis on quality and connotation development.

II. SUBJECTS AND METHODS

2.1 The Interaction Mechanism between STI and HQU System

STI and HQU have a natural interaction coupling relationship, which are mutual conditions, constraints, and promotion. Thus, the HQU system depends on STI system. Besides, STI can maintain a positive interaction with society and obtain recognition and support through the guidance of a new-type urbanization concept. Both of them are derived from human needs and social practice.

Firstly, the HQU needs the joint participation of politics, economy, culture, society, environment, education, science, and technology, among which STI is in a crucial position. STI is not only the vital

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foundation of urban construction but also the primary means of high-quality development of the city. Urbanization development system covers different levels of population, economy, society, and ecological environment, and the realization of high-quality development goals at each level is inseparable from STI. From the economic level, STI is the fundamental driving force of regional economic development and plays a significant role in the transformation of regional development mode. For example, STI has a spillover, which can not only replace the traditional resource elements, but also improve the efficiency of resource utilization, reorganize urban production factors, production organization, and realize the optimization and upgrading of industrial structure. For the ecological environment level, the prevention and control of environmental pollution and ecological protection are inseparable from the STI and application. Relying on STI can improve the technical level of urban ecological restoration and pollution control, improve the urban environmental capacity and resource utilization efficiency, reduce and eliminate pollutant emissions, and then achieve the ultimate goal of STI to support urban ecological environment protection and beautiful home construction [16].

Secondly, STI needs more theoretical guidance and practical support for the development of new-type urbanization. The negative effects of technology and ecological environment crises force people to reflect on the development process and make a choice of high quality and sustainable development of urbanization. HQU should not only solve the ecological environment damage caused by the economic and social development, but also shape the correct scientific and technological development concept, standardize and restrict the direction and mission of STI. It also shows that the HQU will become the guide of technological activities, and various problems encountered in the process of implementing sustainable development also constitute the main task and goal of STI [17].

2.2 Data Sources and Pre-processing

Based on the existing research conditions and availability of data, the data for our sample is from 2006 to 2018, among them, 2006 is the beginning year of the 12th Five-Year Plan. The indicator data of the HQU system were mainly obtained from the Zhejiang Statistical Yearbook (2007–2019), Zhejiang Natural Resources and Environment Statistical Yearbook (2007–2019) and Zhejiang 11 cities' Statistical Yearbook (2007–2019). The index data of STI system were gained from Zhejiang Science and Technology Statistical Yearbook (2007-2019). Individual data were got from the national economic and social development bulletins of Zhejiang and 11 cities, Zhejiang Provincial Government Work Report (2000-2020).

To eliminate the influence of the magnitude, dimension and sign of different indicators, Formulas (1) and (2) are adopted to normalize the original data [3,18].

For positive indicators:

$$X_{\mathrm{ij}}=(\mathrm{x}_{\mathrm{ij}}-\min\left\{x_j\right\})/(\max\left\{x_j\right\}-\min\left\{x_j\right\}) \qquad (1)$$

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For negative indicators:

$$X_{ij} = (\max\{x_j\} - x_{ij}) / (\max\{x_j\} - \min\{x_j\}) \quad (2)$$

Where x_{ij} represents the value of indicator variable x, indexed by j, in year i; $\max\{x_j\}$ and $\min\{x_j\}$ denote the maximum and minimum values of indicator x_j over all years, respectively. Thus, the value of all indicators x_j were normalized in the range of [0,1].

2.3 Evaluation Indicator System Construction

2.3.1 Indicator system selection

Through the review of relevant research results [19], this paper will follow the basic principles of index system construction, that is, comprehensive, scientific, systematic, comparable, relevant, operable, and dynamic. Meanwhile, considering the current development of Zhejiang Province, an integrated indicator evaluation system is built to reflect the high-quality development of STI activities and new-type urbanization in Zhejiang Province.

STI is a complex process of interdependence and interaction among scientific discovery, technological invention, and market application. Meanwhile, the existing research showed that STI is a complete process, which includes input, output, and market benefits, as well as the support of talents, education, and information. Based on these results, STI is conducive to the spatial agglomeration of these production factors, improve the industrial production efficiency, and then boost the high-quality development of urbanization. Referring to the results of references [4] and [9], a comprehensive index evaluation system of STI is finally constructed from four dimensions of STI's basis, input, output, and benefits. The specific indicators selection is shown in Table I, including 4 subsystems and 14 indicators

TABLE I. Indicator system of scientific and technological innovation (STI).

Subsystem	Indicator layer	Indicator description	effect	weight
T1 Basis of STI	T11 Basis of population	Number of students in colleges	+	0.0709
	T12 Basis of education	Financial education expenditure (10 thousand yuan)	+	0.0545
	T13 Basis of information	Scale of Internet users (10 thousand people)	+	0.0587
T2 Input of STI	T21 R&D personnel input	Number of R&D activity personnel (10 thousand people)	+	0.0716
	T22 R&D investment	R&D expenditure (100 million yuan)	+	0.0536
	T23 Fiscal expenditure on SciTech	Financial technology allocation (10 thousand yuan)	+	0.0485
	T24 R&D project input	Number of R&D projects of industrial enterprises above designated size	+	0.0623
T3 Output of STI	T31 Patent output	Number of patent applications granted	+	0.0959
	T32 Output of high-tech	Number of High-tech Enterprises	+	0.0625

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	enterprises			
	T33 Technology market output	Technical contract turnover amount (100 million yuan)	+	0.0551
	T34 Awards for SciTech achievements	Awards for SciTech achievements above prefecture-level city	+	0.0875
T4 Benefits of STI	T41 New product benefits	New product output rate (%)	+	0.0999
	T42 New technology benefits	High-tech added value accounted for the proportion of above-scale industrial added value (%)	+	0.0983
	T43 Energy consumption	Energy consumption per 10,000-yuan GDP of industrial enterprises above designated size (tons of standard coal)	-	0.0807

Compared with the traditional population urbanization, the new-type urbanization pays more attention to the quality and connotation of urbanization. The new-type urbanization adheres to the new development concept, adheres to the principles of people-oriented, fair sharing and inclusive development, takes people's livelihood, sustainable development and quality as the connotation, and pursues equality, happiness, transformation, intensive, green and ecological civilization in the process of high-quality urbanization development. Finally, a comprehensive index evaluation system of HQU is constructed, as shown in Table II, including 4 subsystems and 22 indicators.

TABLE II. Indicator system of high-quality development of new-type urbanization (HQU)

Subsystem	Indicator layer	Indicator description	effect	weight
U1 High quality development of urban population	U11Population concentration level	Resident Population Urbanization rate (%)	+	0.0391
	U12 Population space quality	Urban population density (km2/person)	-	0.0447
	U13Population living quality	Urban housing area per capita (m^2)	+	0.0379
	U14 Population employment quality	Proportion of employment in the tertiary industry (%)	+	0.0328
	U15 Infrastructure level	Urban road area per capita (m^2)	+	0.0395
U2 High quality development of urban economy	U21 Industrial structure quality	Proportion of secondary and tertiary industries (%)	+	0.0510
	U22 Resident income level	Per capita disposable income of urban residents (yuan)	+	0.0534
	U23 Capital investment level	Social investment in fixed assets (100 million yuan)	+	0.0451
	U24 Resident consumption level	Total retail sales of consumer goods (100 million yuan)	+	0.0383
	U25Urban-rural consumption gap	Per capita consumption expenditure ratio between urban and rural areas (%)	-	0.0452
U3 High quality development of urban society	U31 Health service level	Health technical personnel per 10,000 (%)	+	0.0464
	U32 Medical insurance	Basic medical insurance total	+	0.0624

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	level	participation rate (%)		
	U33 Urban employment level	Urban registered unemployment rate (%)	-	0.0620
	U34 Urban traffic level	Urban car ownership per 10,000 people (vehicles)	+	0.0568
	U35 Safety production level	Number of deaths due to production accidents of 100 million-yuan GDP	-	0.0474
U4 High quality development of urban environment	U41 Urban greening level	Green coverage rate in built-up area (%)	+	0.0392
	U42 Pollution control level	Total investment in environmental pollution control (10 thousand yuan)	+	0.0335
	U43 Wastewater treatment level	Wastewater discharge (10,000 tons)	-	0.0551
	U44 Air treatment level	Urban air quality good rate (%)	+	0.0539
	U45 Solid waste treatment level	Comprehensive utilization rate of industrial solid waste (%)	+	0.0381
	U46 Hazardous waste treatment level	Production of industrial hazardous waste (tons)	-	0.0346
	U47 Noise control level	Urban noise average (db)	-	0.0436

2.3.2 Indicator weight evaluation

At present, quantitative weighting methods mainly consists of subjective weighting methods (such as Analytic Hierarchy Process, Deiphi method, Structural Entropy Weight method) and objective weighting methods (such as Principal Component Analysis method, Mean Square Error decision method, Entropy method, etc.). Subjective weighting methods have strong subjectivity, which is based on the experts' experience that the index has a greater influence on the system. The greater the degree is, the greater the weight will be. The objective weighting method does not depend on people's subjective judgment, but is based on strong theoretical method. In contrast, the indexes used for horizontal comparison by Mean Square Error (MSE) decision method are more suitable for this study, because this method can make full use of the mean value and MSE of data to obtain the weighted coefficient and avoid the interference of subjective scoring method. Therefore, it is superior to the Analytic Hierarchy Process and Principal Component Analysis method [19].

The MSE decision method is an objective weighting method to determine the weight coefficient, which reflects the degree of dispersion of random variables. The greater the degree of dispersion, the greater the weight coefficient [20]. The MSE decision method takes a single indicator in two large systems as a random variable, takes out the mean square error of a single indicator, and normalizes the mean square error, then the final result is the weight coefficient of a single indicator [18, 21].

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The detail calculation steps of this method are as follows:

Step 1: Calculate the mean value $E(x_j)$ of each variable:

$$E(x_j)=\frac{1}{n}\sum_{i=1}^{n}X_{ij} \tag{3}$$

Step 2: Estimate the mean squared error $\sigma(x_j)$ of each variable:

$$\sigma(x_j)=\sqrt{\sum_{i=1}^{n}(X_{ij}-E(x_j))^2} \tag{4}$$

Step 3: Calculate the indicator weight w_j according to mean squared error $\sigma(x_j)$:

$$w_j=\sigma(x_j)/\sum_{j=1}^{m}\sigma(x_j) \tag{5}$$

Step 4: Estimate the comprehensive level of each subsystem S_k:

$$S_k=\sum_{j=1}^{m}X_{ij}*w_j \tag{6}$$

Where n is the number of years, m is the number of indicators, k represents the subsystem number of indicator layer, among them $k = 4$ in the comprehensive indicator system of STI and HQU.

2.4 Panel Vector Autoregressive Model

In order to investigate the bidirectional correlation between STI and HQU, a PVAR with the lagged variable is established. Compared with the traditional linear panel regression model, the PVAR model has several unique advantages. Firstly, based on the statistical properties and regular trends of data, the PVAR model takes the lag period of each endogenous variable of the system as the explanatory variable to construct the model. It is closer to reality than the traditional linear panel model and greatly reduces the risk of model mis-determination [22]. Then, the PVAR model is an economic system equation, which takes all economic variables as endogenous variables for mathematical modelling. Thus, it can effectively avoid the problem of finding tool variables in the traditional linear panel model and overcome the model's endogeneity.

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A generalized moment estimation (GMM) is carried out in the main steps of applying the PVAR model to estimate the regression fitting results between variables. Then the impact response function analysis is carried out to investigate how the influence of the disturbance term is propagated to each variable. Finally, variance analysis is used to measure the contribution degree of variables. The PVAR model is constructed as follows:

$$Y_{it} = \beta_0 + \sum_{j=1}^{k} \beta_j Y_{i,j-t} + \alpha_i + \gamma_t + \mu_{it} \quad (7)$$

Where, Y_{it} is a column variable that contains two endogenous variables, which are respectively the comprehensive score of STI and HQU system. $Y_{i,-jt}$ is the order lag term of Y_{it}, namely the lag term of endogenous variable as explanatory variable. i represents the number of cities, j is the lag order; β_0 represents the intercept term, β_j represents the estimated matrix of the lag order. α_i is the individual effect vector, γ_t is the time effect vector, and μ_{it} is a random error term.

Besides, to investigate the regional differences of the dynamic relationship between STI and HQU, we further divided the cities into the urban agglomeration around Hangzhou Bay (UAHB) and the non-Hangzhou Bay urban agglomeration (non-UAHB). The construction of UAHB is a new-type urbanization development strategy proposed by Zhejiang Province government in 2012, to make it a significant part of the south wing of the world-level city cluster in the Yangtze River Delta.

III. RESULTS

3.1 Spatio-temporal Evolution of STI and HQU System Comprehensive Scores

According to the above Formula (2), we obtain the score variation of the STI and HQU in the 11 cities in Zhejiang from 2006 to 2018, as shown in Figure 3 and Figure 4. Meanwhile, the scores of each subsystem of each city in 2006, 2012 and 2018 are displayed, respectively.

The comprehensive scores of STI and its four subsystems in the 11 cities generally reveal a trend of steady growth in Figure 1. The score of STI's basis and input subsystem is lower than that of STI's output and benefit subsystem. Hangzhou, the capital of Zhejiang Province, scores the highest in technological innovation, rising from 0.278 in 2006 to 0.922 in 2018, with an average annual growth rate of 10.5%; its scores of three subsystems—technological innovation foundation, input and output were all the highest in the 11 cities. In recent years, led by the digital economy, Hangzhou has increased investment in scientific research. The expenditure on research and experimental development accounts for about 3.4% of the total social expenditure. Hangzhou is continuously improving the supply quality and ability of STI. Relying on many scientific research platforms such as Zhejiang University, Alibaba Group, Westlake University and Zhejiang Laboratory, Hangzhou has promoted the gathering of technology talents to break through the core technologies of various industries, so as to generate more primitive innovative achievements [3]. Lishui, a

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city in the southwest mountain region of Zhejiang, scores the lowest in STI, rising from 0.053 in 2006 to 0.258 in 2018, with an average annual score of 0.152. The average scores of the 11 cities from 2006 to 2018 rank from highest to lowest as follows: Hangzhou > Ningbo > Wenzhou > Jiaxing > Shaoxing > Taizhou > Jinhua > Huzhou > Zhoushan > Quzhou > Lishui. The overall relative order of these cities has not changed during different years. However, the standard deviations among the 11 cities have extended from 0.061 in 2006 to 0.198 in 2018, indicating that the comprehensive strength gaps of STI in different cities are increasing distinctly.

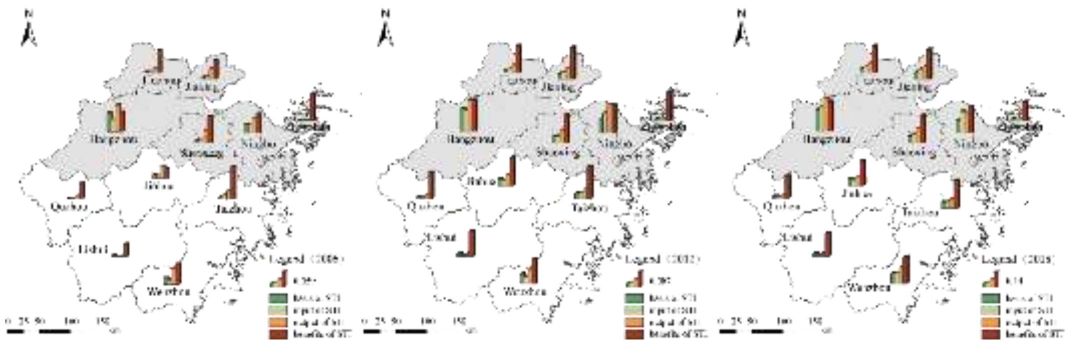

Fig 1: Comprehensive score of STI system of Zhejiang Province's 11 cities from 2006 to 2018(The gray cities on the map are UAHB and the rest are non-UAHB).

Similarly, as shown in Fig 2, the comprehensive scores of the HQU and its four subsystems in 11 cities also display a general tendency of steady growth. The score of high-quality development of population urbanization is lower than other subsystems. Hangzhou receives the highest score of HQU, with an average annual growth rate of 4.86% from 0.420 in 2006 to 0.743 in 2018. The growth rate is lower than that of the STI. Ningbo, a pilot city for China's new-type urbanization, reaches the second-highest score of HQU, rising from 0.430 in 2006 to 0.683 in 2018, with an average annual growth rate of 3.92%. Lishui gets the lowest score of HQU, changing from 0.268 in 2006 to 0.598 in 2018. Although Lishui possessed a fairly good ecological environment, it lags behind in economic development, urban and rural public infrastructure construction. The average scores of the 11 cities during the 13 years decrease as Hangzhou > Ningbo > Jinhua > Zhoushan >Shaoxing > Wenzhou > Huzhou >Taizhou > Jiaxing > Quzhou > Lishui. The sequence represents a certain extent of similarity (the ranking cities at the beginning and the end are the same) and difference (the ranking cities among the sequence is different) with the ranking of the STI. In addition, the overall pattern of the relative ranking of the11 cities has also varied to a certain extent. For example, the score of HQU in Ningbo is higher than that in Hangzhou from 2006 to 2008; while after 2009, Hangzhou begins to surpass Ningbo and maintains the leading position of the whole province. And Taizhou, ranked 6th in 2006, falls to 8th in 2018, with a certain decline. Otherwise, in general, the standard deviations among the 11 cities have been basically maintained between 0.04 and 0.05 over 13 years, manifesting that the gaps of the HQU in different cities have not widened significantly.

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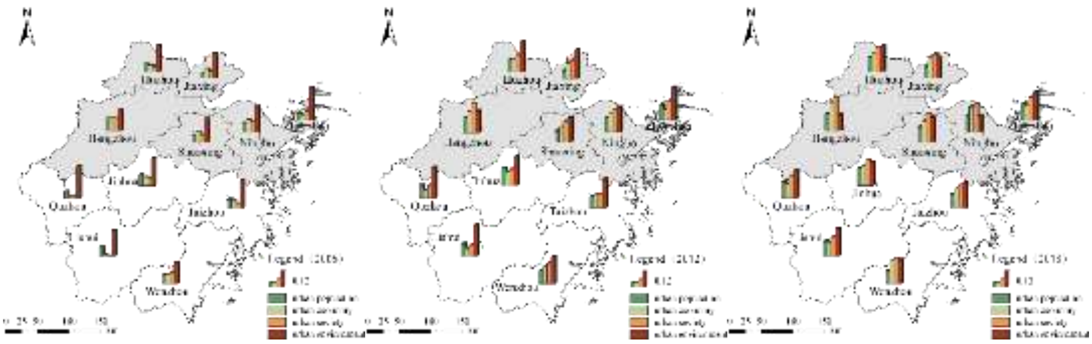

Fig 2: Comprehensive score of HQU system of Zhejiang Province's 11 cities from 2006 to 2018(The gray cities on the map are UAHB and the rest are non-UAHB).

3.2 Estimation Results of the PVAR Model

3.2.1 Estimation results of different regions

The System-GMM method is used to estimate the influence coefficients between STI and HQU by Equation (7), and the optimal lag order 1 is selected here. The results are shown in Table III.

TABLE III. Panel Vector Auto-Regression: System-GMM Results (lag 1)

Region	Variables		Coefficient	Z-statistics	P-value	95% confidence interval	
						Lower	Higher
Whole Province	STI	L1- STI	0.699***	12.420	0.000	0.589	0.809
		L1-HQU	0.176***	2.880	0.004	0.056	0.295
	HQU	L1- STI	-0.117*	-1.750	0.080	-0.247	0.014
		L1-HQU	0.975***	14.170	0.000	0.840	1.110
UAHB	STI	L1- STI	0.693***	10.230	0.000	0.561	0.826
		L1-HQU	0.209***	2.370	0.018	0.036	0.382
	HQU	L1- STI	-0.099	-1.280	0.201	-0.252	0.053
		L1-HQU	0.968***	10.560	0.000	0.788	1.148
Non-UAHB	STI	L1- STI	0.544***	4.100	0.000	0.284	0.805
		L1-HQU	0.292***	2.450	0.014	0.058	0.525
	HQU	L1- STI	-0.338*	-1.650	0.100	-0.739	0.064
		L1-HQU	1.167*	6.430	0.000	0.811	1.523

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

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Seen from the sample of the whole province, when STI is taken as the dependent variable, the influence coefficient of the HQU is 0.176, and it is significant at the 1% level, indicating that the HQU is conducive to the improvement of STI levels. At the same time, the deepening and expanding of STI will also contribute to the sustainable development of itself. When the HQU is taken as the dependent variable, the influence coefficient of the lagging STI on the HQU is -0.117 (significant at the 10% level). It reveals that STI has slightly hindered the HQU. It might be because in the process of factor-driven and investment-driven urbanization development, the attraction of capital, manpower and other elements of STI brings a certain "Crowding Out" effect on the urbanization construction and development, which will impede the improvement of urbanization development level to some extent. This also discloses the contradiction on emphasizing the expansion of land, population and infrastructure while neglecting the R&D investment in science and technology during the traditional urbanization process. Furthermore, at the current period, disconnection and conflict occurs between STI and HQU at the provincial level. The two systems are not well integrated. STI has not indeed been transformed into a powerful driving force to promote the construction of new-type urbanization.

According to the Estimation results of different regions, the influence coefficients of HQU on STI are 0.209 in the UAHB and 0.292 in the non-UAHB respectively, which are both significant at the 1% level. It illustrates the current HQU is stably conducive to the improvement of regional STI levels. In the UAHB, the influence coefficient of STI on the HQU is -0.099, while it has not passed the significant level test, indicating that the negative effect of STI on the HQU is not significant. Compared with the overall level of the whole province, the influence coefficient of the negative value is closer to 0, which has the potential to converse to the positive effect first.

3.2.2 Panel impulse response function

The impulse response reveals the result of the interaction between variables within the PVAR model and the dynamic interaction process between variables. To describe the dynamic interaction effect between STI and HQU intuitively, the impulse response graphs of STI and HQU in Zhejiang Province and other areas with different economic development levels are obtained through 500 Monte Carlo simulation (Fig 3). The horizontal axis is the number of impulse response periods, set as 12 periods; the vertical axis is the influence degree of variables; the middle curve represents the impulse response function, and the upper and lower curves represent the estimated values of 95% and 5% loci respectively.

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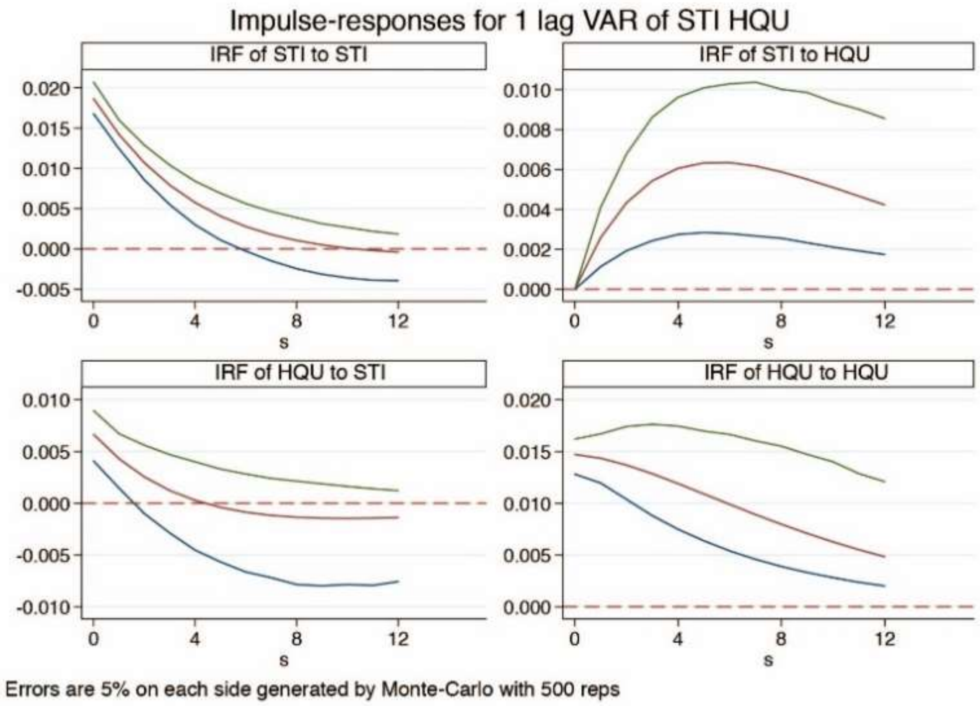

Fig 3: Impulse response function results of whole Zhejiang Province.

It can be clearly seen that:

(1) The impulse response of HQU on STI is various in different regions. The impulse response of the HQU on STI in the whole province and the UAHB is not obvious at the current period, but presents a strong positive impact later on and reaches the maximum in the fifth period, and then gradually weakens. The impulse response of HQU on STI in the non-UAHB has a long-term weak positive impact. From the response value, the positive response of the HQU on STI in the UAHB is obviously stronger than that in the non-UAHB. It manifests that the HQU of the UAHB has a more significant positive driving effect on STI.

(2) Similarly, the impact of STI on HQU is also different in different regions. The impulse response of STI on HQU in the whole province has a positive impact at the current period, and the impact intensity is decreasing and has experienced a process from positive to negative. But the trajectory of impulse response function is different in different regions. The impulse response of the STI on HQU in the whole province, the UAHB, and the non-UAHB turns to negative in the fifth phase, in the sixth phase, and in the second phase, respectively. The results manifest that STI has a slight hindrance on HQU and "Crowding Out" effect of resources, but the effects are various in different regions.

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3.3.3 Panel variance decomposition analysis

Variance decomposition decomposes the changes in endogenous variables into impulses on the components of the PVAR model [18], and evaluates the contribution degree of each impulse to the changes of endogenous variables, which will further explain the interaction degree between STI and HQU. The results of variance decomposition are shown in Table IV.

TABLE IV. Variance decomposition of variable prediction error

Variables	Lag	Whole province		UAHB		non-UAHB	
		STI	HQU	STI	HQU	STI	HQU
STI	1	1.000	0.000	1.000	0.000	1.000	0.000
HQU	1	0.169	0.831	0.206	0.794	0.218	0.782
STI	2	0.988	0.012	0.985	0.015	0.954	0.046
HQU	2	0.129	0.871	0.167	0.833	0.126	0.874
STI	3	0.963	0.037	0.956	0.044	0.857	0.143
HQU	3	0.102	0.898	0.138	0.862	0.079	0.921
STI	4	0.930	0.070	0.918	0.082	0.737	0.263
HQU	4	0.084	0.916	0.118	0.882	0.059	0.941
STI	5	0.892	0.108	0.877	0.123	0.621	0.379
HQU	5	0.072	0.928	0.104	0.896	0.053	0.947
STI	6	0.855	0.145	0.837	0.163	0.526	0.474
HQU	6	0.064	0.936	0.094	0.906	0.054	0.946
STI	7	0.820	0.180	0.801	0.199	0.455	0.545
HQU	7	0.059	0.941	0.087	0.913	0.058	0.942
STI	8	0.789	0.211	0.770	0.230	0.403	0.597
HQU	8	0.057	0.943	0.082	0.918	0.063	0.937
STI	9	0.763	0.237	0.744	0.256	0.367	0.633
HQU	9	0.055	0.945	0.079	0.921	0.069	0.931
STI	10	0.741	0.259	0.723	0.277	0.341	0.659
HQU	10	0.055	0.945	0.077	0.923	0.074	0.926

(1) To the whole province, the explanation degree of HQU on its own fluctuations reaches 83.1% in the first prediction period, 92.8% in the fifth prediction period, and 94.5% in the tenth prediction period. On the contrary, the explanation degree of STI on the fluctuation of HQU has decreased from 16.9% to 7.2% and then to 5.5% respectively. This demonstrates that HQU in Zhejiang Province mainly depends on its own development in the past decade, while the impact of the change of STI level on HQU is relatively weak. The explanation degree of STI on its own fluctuation was 100% in the first prediction period, and

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gradually decreased to 89.2% in the fifth prediction period and 74.1% in the tenth prediction period. However, the explanation degree of HQU on the fluctuation of STI increased to 10.8% and 25.9% respectively. It indicates that the level of STI also depends on its own development, but the impact of HQU on STI is gradually increasing with the time goes by.

(2) To the six UAHB cities, the explanation degree of HQU on its own fluctuations reaches 79.4%, 89.6% and 92.3% in the first prediction period, the fifth prediction period and the tenth prediction period, respectively. Correspondingly, the explanation degree of STI on the fluctuation of HQU gradually decreased from 20.6% (the first prediction period) to 10.4% (the fifth prediction period) and 7.7% (the tenth prediction period) respectively. HQU in the UAHB mainly depends on its own development in the past decade. The impact of STI level's change on HQU is relatively weak. But the impact in the UAHB is stronger than that in the whole province, implying the STI of the UAHB has more prominent impact on the HQU. The innovative cities represented by Hangzhou and Ningbo have played the leading roles. The variance decomposition results of STI in the UAHB are similar to that in the whole province. The level of STI in the UAHB mainly depends on its own development. Over time, however, the impact of HQU on STI has gradually increased.

(3) To the five non-UAHB cities, the explanation degree of HQU on its own fluctuations reaches 78.2%, 94.7% and 92.6% in the first prediction period, the fifth prediction period and the tenth prediction period, respectively, representing a trend of increasing first and then decreasing. Correspondingly, the explanation degree of STI on the fluctuation of HQU gradually decreased from 21.8% (the first prediction period) to 5.3% (the fifth prediction period) and 7.4% (the tenth prediction period) respectively. STI level's change on HQU in the non-UAHB has a weaker impact. While the impact is gradually improving in the long run. The explanation degree of STI on its own fluctuation was 100% in the first prediction period, then decreased to 62.1% in the fifth prediction period and 34.1% in the tenth prediction period; while the explanation degree of HQU on the fluctuation of STI increased from 0 first to 37.9% and 65.9% respectively. In the non-UAHB cities, HQU and STI both play crucial roles in improving the level of STI in the future.

3.4 Policy Implications

According to the analysis and results above, following countermeasures and suggestions are put forward:

(1) Emphasize on coordinated development and reduce the gap in technological innovation among regions. From the analysis in Section 4.1, the gap of STI level among different cities in Zhejiang is widening, and the technological development of the UAHB cities is better than that of the non-UAHB cities. Therefore, in addition to playing the leading roles of the UAHB cities in technological innovation in the future, it is necessary to increase pairing assistance and technical assistance to the non-UAHB cities, increase their technological capital and education investment, and strengthen the cultivation of technological talents.

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(2) Take advantage of the positive driving effect of the HQU on STI actively. The UAHB have favourable conditions of geographical location, economic development, resource factors, and policy environment. Relying on the "Accelerating the Implementation of New-type urbanization Action Plan in Zhejiang Province" issued and implemented by Zhejiang Provincial Government, it will be useful to take the UAHB cities as the sample region, and accelerate the establishment of a regional innovation system integrated the construction of innovation platforms, technology development, and the cultivation of high-tech enterprises and technical talents. We could accelerate the construction of major platforms and projects, for instance, the Yongjiang Science and Technology Innovation Corridor, the Yongjiang Laboratory, to create a cradle of technological innovation in advantageous fields.

(3) Deal with the obstructive effect of STI on the HQU and the "Crowding Out" effect of resources correctly and properly. The main crux lies in the input efficiency and achievement transferring efficiency of STI. Therefore, it is necessary to rationally allocate the factor input of STI and HQU, and further optimize the proportion of capital investment between the two systems to ensure the maximum output efficiency of capital investment. Meanwhile, we need to improve the transferring system and the pricing mechanism of STI achievements, enhance the market transferring efficiency, and promote STI achievements to transform into the authentic driving force for HQU.

(4) Make up for weakness and promote HQU continuously. High-quality development is the development that meets people's ever-growing needs for a better life. For example, it is necessary to continuously improve the basic public service facilities, and improve the high-quality development level of social urbanization. So that the elderly can be cared for, and the sick can have access to medical treatment. We also should optimize urban ecology, production and living space, build ecological and low-carbon cities that are livable and workable, comprehensively control urban environmental pollution, and raise the high-quality developing level of environmental urbanization.

IV. CONCLUSIONS

Using the PVAR model, this study conducts an empirical analysis of the dynamic correlation between STI and HQU in 11 cities in Zhejiang Province. The comprehensive scores of STI and HQU in the 11 cities present a steady growth in general. Hangzhou and Ningbo both have superior performance in the two systems. The standard deviation test manifests the gap of the overall levels of STI among cities is widening, while the gap of HQU has no significant expansion.

There is certain lag and difference in the interactive effect between STI and HQU in Zhejiang Province. The influence coefficient of HQU lagged behind the 1st stage on STI is 0.176 (significant at the 1% level), indicating that HQU is conducive to the improvement of STI. The lagging feature is more prominent in the UAHB. However, influence coefficient of STI lagged behind the 1st stage on HQU is -0.117 (significant at the 10% level), revealing that STI has a slightly hindering effect on HQU and a "Crowding Out" effect of resources. The results of variance decomposition demonstrate that STI and HQU in Zhejiang mainly depends on its own development (the contribution in the 10 forecasting periods is about

80% to 90%), and the promotion effect of each other is weak, meaning there is no good resultant force. This characteristic presents a certain regional difference. The promotion of STI in the UAHB is more prominent; while with time goes by, the impact of HQU on STI is gradually increasing.

Limited by the availability and continuity of the index data, the evaluation index system constructed in the study might be inadequate and still needs to be improved continuously. In the future, with the improvement of statistical data, we need to further optimize the evaluation index system and conduct in-depth tracking investigation and research on the change of dynamic relationship between STI and HQU.

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