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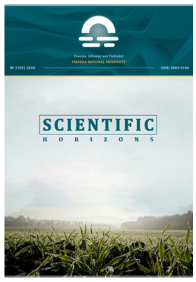

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Key Drivers of Urban Digital Economy Sustainable Development: The China Case

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Abstract. Digitalisation is a modern social and economic reality. The search for efficient pathways to move towards high-quality digital communities' sustainable development constitutes the scope of current urban research worldwide. Given the need to move towards sustainable urban digitalisation, investigation of its critical influencing factors deserves special attention. However, quantitative empirical studies that avoid subjective judgement on the drivers of sustainable urban digitalisation are lacking. The purpose of this study is to fill this knowledge gap by outlining and quantifying the key factors affecting the sustainable development of the urban digital economy through entropy-TOPSIS modelling. The study takes China's provinces and cities as an example due to China's success in digital economy development. It is proposed to use the complex four-dimensional (scientific and technological innovation, economic growth, social development, information infrastructure) system involving 16 sub-indices to measure urban digital economy sustainability. Applying data from 31 Chinese provinces and cities for 2016-2019 and the entropy-TOPSIS model, the development of the technological innovations was found to be the most impacting factor on the urban digital economy sustainability path. The R&D staff engagement and expenditures, goods export and import, and e-commerce sales fuel the urban digital economy sustainability the most, while the number of students, public financial expenditures, and unemployment are the least significant. Results show that the urban digital economy is more a business-driven process than pushed by authorities. The gap between Chinese regions' digital economy development was identified. This could be explained by the prevalence of conventional industries in several areas and the low level of their digitalisation and indicates the need to enhance interregional cooperation and partnership to promote sustainable development of the country under the digital economy paradigm. Despite China's context, this research contributes to further science and policy development in this field globally, covering the role of talents, innovations, business R&D investments, interregional cooperation, and multiscale partnership in the promotion of urban digitalisation conducive to sustainability ideas

Keywords: digitalisation, entropy method, sustainability, TOPSIS model, urban development

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INTRODUCTION

The digital economy is a more advanced economic stage following the agricultural and industrial economies. It takes digital information and knowledge as the key production factors, modern information networks as the primary carrier, the integration and application of information and communication technology, the digital transformation of all aspects as important driving forces to promote a new economic form that is inclusive, innovative, efficient, and sustainable (Chen *et al.*, 2020; Purnomo *et al.*, 2022). The digital economy comprehensively utilises information technology such as the Internet, computer, space technology, and communication – the comprehensive integration of contemporary high-tech reflecting the most advanced productive forces in the 21st century – and is conducive to the sustainable development of the urban economy and society (Gautier & Lamesh, 2021). To this end, the Chinese government attaches foremost importance to the sustainable development of an urban digital economy. It puts forward "implementing the national big data strategy, building a digital economy with data as the key element, accelerating the construction of "digital China" to promote the high-quality and sustainable development of digital economy from the aspects of technical support, market supply and demand, industrial development, and policy guarantee (Yin *et al.*, 2019). China's digital economy has achieved remarkable results in recent years. By 2020, the scale of China's digital economy has reached 5.4 trillion US dollars accounting for 34.8% of GDP and ranking second only to the US (13.6 trillion US dollars) (Chen *et al.*, 2020), which has become a driver for high-quality economic development and enhanced international digital competitiveness.

The rapid development of the Chinese digital economy has also revealed the following problems: the insufficient digital-driven innovation capability, the backward core innovation field of the digital economic basis, and weak R&D investments. Secondly, the construction of digital economic infrastructure is biased towards the construction of network communication resources. In contrast, the infrastructure development for new generation artificial intelligence and high-end equipment manufacturing is insufficient. Thirdly, a small proportion of knowledge-based talents engagement in a digital economy causes an imbalanced structure of the supply and demand for knowledge-based labour. Despite the achieved results, China's digital economy is still far from the sustainable path, especially in urban systems (Cao *et al.*, 2021). This is due to a lack of understanding of the entire digital economy development system and its drivers and a lack of measurement models to evaluate the performance and sustainability of digital economic development (Sturgeon, 2021). Elaboration of policy and promotion of sustainable conducive development of digital economy in urban agglomerations need drivers and incentives to be clearly defined through comprehensive studies and explorations. Therefore, the purpose of this paper is to outline the key factors affecting the sustainable development of the urban digital economy: build a scientific evaluation index system and quantitatively describe the impact of each key factor, supporting the science-based and justified decisions concerning the promotion of a sustainable path of urban digitalisation.

LITERATURE REVIEW

In recent years, different institutions have constructed various index systems to assess various aspects of digital economy development. The EU Digital Economy and Society Index measures the development of the digital economy in EU countries concerning five main elements: broadband access, human capital, Internet application, digital technology application, and digital public services (Curran, 2018). The International Telecommunication Union has set up 11 indicators to evaluate access, use, and skills concerning information and communication technologies (ICT). "White Paper on China's Digital Economy Development (2017)", issued by the China Academy of Information and Communications, suggests a direct method to estimate the digital economy expansion (includes seven leading indicators, ten consistent indicators, and four lagging indicators) (Yin *et al.*, 2019). Saidi Research Institute divides the digital economy into primary, resource-based, technology-based, integrated, and service-oriented and designs 34 secondary indicators like the scale of the information transmission industry and the number of data trading centres (Shaikh *et al.*, 2020; Zhao & Zhou, 2022).

Scholars continue to explore the development of the digital economy and evaluate it from different perspectives. X. Wan *et al.* (2019) propose a system of 71 four-level indicators assessing a digital economy's inputs and outputs. Zhang and Chen (2018) develop a system of 20 indicators to measure economic efficiency, social progress, structural optimisation, and resource environment for the digital economy by applying the analytic hierarchy process (AHP). Existing research also focuses on concrete geographical areas. Q. Lin and H. Lv (2019) suggest eight indicators, such as key applications, government affairs platform investment, and scientific research platform investment, to evaluate the digital economy industrial integration in Hefei through a fuzzy comprehensive evaluation method. J. Xin *et al.* (2019) propose the evaluation index system of digital economy development for Zhejiang province based on the complete index method. X. Ning (2018) designs the evaluation indices for Hubei Province based on the technological and economic paradigms.

The available literature provides a good reference for further research and can guide the urban digital economy sustainable development measurement process in general. However, the following issues are questionable: 1) the available approaches to measure the sustainability of urban digital economic development rarely include scientific (and technological) innovation capacity and digital infrastructure construction in the index system; 2) the most common methods used (a fuzzy comprehensive evaluation method, AHP, comprehensive index method) utilise expert scoring, which is too subjective; 3) there are few quantitative empirical studies on the macro-level factors affecting the sustainable development of the urban digital economy. To fill this knowledge gap, this study explores the core elements intertwined in the urban digital sustainable development and constructs the evaluation index system integrating four dimensions: information infrastructure, innovation, economic growth, and social development.

MATERIALS AND METHODS

The sustainable development of the urban digital economy is a complex system problem affected by many factors (Pan *et al.*, 2022). The multi-index comprehensive evaluation method could be more beneficial in assessing the urban digital economy sustainability. In this regard, an entropy weights-TOPSIS model (Technique for Order Preference by Similarity to an Ideal Solution) fits well to quantify a complex of impacts and ensure the factual accuracy of evaluation results.

The entropy method is an objective method to determine the weights. It deals with the original data variability: the smaller the degree of index variation, the lower will be the corresponding weight. This weighting method effectively avoids the interference of human factors, better reflects the evaluation index's objectivity and authenticity, and is widely used in social and economic sciences (Ding *et al.*, 2016). TOPSIS model is a common approach for multiple attribute decision making. It evaluates the existing object's attributes (Yang *et al.*, 2018). Evaluated things are not restricted to time, space, and sample size; the TOPSIS approach follows a simple calculation procedure, making it desirable. This study applies a combination of entropy-weight and TOPSIS to quantify factors affecting the urban digital economy of China regions' sustainable development. The entropy weight method is used the first to identify the weights of each indicator. Then the impact of each factor on the regional sustainable development is measured through the TOPSIS approach. The following steps specify the procedure of entropy weight-TOPSIS model application:

1. *Construction of the original data matrix*. To evaluate the sustainable development of m cities via n indicators, the initial X matrix of $m \times n$ is composed of the original data characterising cities' parameters (Eq. 1):

$$X = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ \dots & \dots & \dots & .. \\ \dots & \dots & \dots & .. \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix} \tag{1}$$

where m is the number of objects to be evaluated; n is the number of assessment criteria; x_{ij} is the element of matrix X, the value of the j ($j = 1, 2, \dots, n$) indicator of the i ($i = 1, 2, \dots, m$) object.

2. *Data normalisation*. To make the original data of different dimensions and different data sources comparable, this study follows the normalisation procedures. Evaluation results are classified according to the index content: in the case of a higher index value causing higher evaluation results, the impact will be judged positive (and negative – otherwise). For the positive effects of indicator x_{ij}, the normalised value S_{ij} can be calculated as follows (2):

$$S_{ij} = \frac{x_{ij} - \min x_{ij}}{\max x_{ij} - \min x_{ij}} \tag{2}$$

For the negative impact of x_{ij}, the normalised value S_{ij} is calculated in the following way (3):

$$S_{ij} = \frac{\max x_{ij} - x_{ij}}{\max x_{ij} - \min x_{ij}} \tag{3}$$

where S_{ij} is the normalised value; $max x_{ij}$ is the maximum value of the j^{th} indicator of the i^{th} object;
$min\ x_{ij}$ is the minimum value of the j^{th} indicator of the i^{th} object.

3. *Use of the entropy method* to quantify indicators' weights presupposes calculation of the standardised value p_{ij} of indicator j for object i following the Eq. 4 and an entropy value of the indicator – e_j (Eq. 5) used then to assess an information utility d_j value of the indicator (Eq. 6). Finally, the weighting value – w_j – of the j indicator is quantified in line with Eq. 7:

$$P_{ij} = \frac{S_{ij}}{\sum_{i=1}^{m} S_{ij}} \tag{4}$$

$$e_j = -\frac{1}{Inm} \sum_{i=1}^{m} p_{ij} Inp_{ij} \tag{5}$$

$$d_j = 1 - e_j \tag{6}$$

$$w_j = \frac{d_j}{\sum_{j=1}^{n} d_j} \tag{7}$$

where P_{ij} is the standardised value of indicator j for object i; e_j is the entropy value for j indicator; d_j is the information utility value of indicator j; w_j= is the weighting value for j indicator.

4. Use of TOPSIS model to quantify factors' impact. The first step is to compose the weighted assessment matrix (Eq. 8). The matrix elements are then classified as the best A^+ and the worst A^- solutions (Eq. 9, Eq. 10).

$$a_{ij} = w_j p_{ij} (i = 1,2, \dots, m; j = 1,2, \dots, n) \tag{8}$$

$$A^+ \{\max A_{ij} | i = 1,2, \dots, m\} = \{A_1^+ A_2^+, \dots, A_n^+\} \tag{9}$$

$$A^- \{\max A_{ij} | i = 1,2, \dots, m\} = \{A_1^- A_2^-, \dots, A_n^-\} \tag{10}$$

where a_{ij}=the weighted standardised matrix element; A^+=the positive ideal solution; A^-=the negative ideal solution.

The next step is to calculate the Euclidean distance $D_i^{+/-}$ between the evaluation value and the best solution A_j^+ (Eq. 11), the evaluation value and the worst solution A_j^- (Eq. 12):

$$D_i^+ \sqrt{\sum_{j=1}^{n} (A_j^+ - A_{ij})^2} (i = 1,2, \dots, m) \tag{11}$$

$$D_i^- \sqrt{\sum_{j=1}^{n}(A_j^- - A_{ij})^2}(i = 1,2,\dots,m) \quad (12)$$

The relative proximity C_i of the object i allows quantifying the distance between the evaluation value and two ideal solutions:

$$C_i = \frac{D_i^-}{D_i^+ - D_i^-}(i = 1,2,\dots,m) \quad (13)$$

where D_i^+ is the Euclidean distance between the evaluation value and the best solution; D_i^- is the Euclidean distance between the evaluation value and the worst solution; C_i is the relative closeness of the object i.

Finally, schemes are sorted according to the relative proximity: the larger the relative proximity is, the better the system is.

This research utilises the entropy-TOPSIS model to select and quantify the key factors influencing urban digital sustainable development and its performance among Chinese cities. This study utilises the data of 16 essential indicators of 31 provinces and cities in China for 2016-2019 from "China Statistical Yearbook", "China Urban Statistical Yearbook", and "China Regional Economic Statistical Yearbook". Provinces serve as primary statistical units in China – this determined the data selection approach. To grasp the overall state of China's digital economy sustainable development, this study explored regions under China's Central Government control (except for Hong Kong, Macao, and Taiwan). The vigorous growth of China's digital economy began with the "G20 Digital Economy Development and Cooperation Initiative" released at the G20 Hangzhou Summit in 2016. In this regard, the earlier data (before 2016) was judged as of little significance to this study. Following principles of data representativeness, regularity, and availability (the last complete statistical records are available only for 2020), 2016-2019 were selected to do this research.

RESULTS AND DISCUSSION

Construction of an urban digital economy sustainable development complex evaluation system

Accounting for the role of technology and innovations for digital transformation and based on the connotation of the sustainable development of the urban digital economy (Hongyue & Koblianska, 2022; Hongyue *et al.*, 2022), this study proposes the four-criteria complex system of indicators to measure the sustainability of urban digital economy development (Table 1). The proposed system embraces 16 sub-indices selected due to principles of scientificity, systematicity, practical significance, and data availability. Some comments on the proposed measurement system are given below.

Table 1. *System of factors influencing sustainable development of urban digital economy*

Criterion Layer	Index Layer	Index Unit	Index attribute
Information Infrastructure(A)	Mobile phone penetration (A1)	%	Positive
	Internet broadband access users (A2)	Thousands of families	Positive
	Length of optical cable line per unit area (A3)	Km/sq.	Positive
	Number of computers used per 100 population (A4)	Pieces	Positive
Science and Technology Innovation(B)	R&D project expenditure (B1)	Ten thousand yuan	Positive
	R&D personnel full-time equivalent (B2)	Man-year	Positive
	Number of patents granted (B3)	Item	Positive
	Number of students enrolled in institutions of higher learning (B4)	Ten thousand people	Positive
Economic growth(C)	E-Commerce Sales (C1)	Billion yuan	Positive
	Added value of tertiary industry (C2)	Billion yuan	Positive
	Industrial added value (C3)	Billion yuan	Positive
	Revenue from software business (C4)	Ten thousand yuan	Positive
Social development(D)	Urban registered unemployment rate (D1)	%	Negative
	Expenditure of urban public finance (D2)	Billion yuan	Positive
	Total imports and exports of goods (D3)	Thousands of US dollars	Negative
	Employed persons in software and information technology services (D4)	Ten thousand people	Positive

Source: *authors' development*

Information infrastructure (A) is the foundation for urban digital economy development and drives sustainability (Demestichas & Daskalakis, 2020; Wahome & Graham, 2020). Based on the digital economy networking nature, infrastructure mainly refers to Internet facilities and broadband networks: the penetration rate of mobile phones (A1), the number of Internet broadband access users (A2), the length of optical cable lines per unit area (A3), and the number of computers used per 100 people (A4). The mobile phone penetration rate (A1) reflects the potential driving force for developing a digital economy, while Internet broadband access users (A2) reflect the communication network quality in a particular area. The length of the optical cable line per unit area (A3) reflects the region's completeness of the Internet infrastructure. The number of computers per 100 people (A4) measures the degree of digital development.

The scientific and technological innovation development reflects the potential of a region's digital economy development and sustainability (Yi *et al*., 2021). R&D project expenditure (B1) measures enterprises' innovation, and digital investment activity, the full-time equivalent of R&D personnel (B2) reflects the current labour potential for innovations. Patent authorisation (B3) indicates the region's leadership in scientific and technological innovations, while the number of college students (B4) reflects the region's long-term potential to innovate. Economic growth is closely related to the development of the digital economy (Li *et al*., 2020). Given this, urban digital economy sustainability can be measured via proper economic growth indicators, namely: e-commerce sales (C1), the tertiary industry added value (C2), industrial added value (C3), and software business income (C4). Commenting on these sub-indices, one should mention the sales volume of e-commerce (C1) significance in measuring the scale of economic activities carried out by digital and network region's assets. Value-added of the tertiary industry (C2) reflects the degree of the region's economic transformations. Industrial added value (C3) reflects the contribution of the secondary sector to economic development. Software business income (C4) measures the digital industry development. Social development (D) affects the urban digital economy's sustainable development in a multifaceted way. A higher social development level better promotes the development of the digital economy (Sutherland & Jarrahi, 2018). In particular, the total import and export of goods (D3), indicating the level of the economy's openness, directly affects the urban digital economy caused by globalisation. The number of employees in the software and information service industry (D4) reflects the potential to drive the development of the urban digital economy and society.

Identification of factors' influence on urban digital economy sustainability via entropy method

Following the proposed measurement system (Table 1), the original data was collected and processed. Table 2 summarises the results of initial data normalisation and weighting (via entropy-weight method) for 31 Chinese cities.

Table 2*. Factors influencing the urban digital economy sustainability in China: Weights' dynamics for 2016-2019*

Primary index	Primary weight, %				Average weight of primary index, %	Secondary weight, %				Average weight of secondary index, %	Secondary index
	2016	2017	2018	2019		2016	2017	2018	2019		
A	14.02	13.71	13.01	14.05	13.7	2.20	1.94	2.36	2.63	2.28	A1
						4.49	4.67	3.96	4.18	4.33	A2
						4.65	4.64	4.02	4.21	4.38	A3
						2.68	2.46	2.67	3.03	2.71	A4
B	31.28	34.12	33.35	36.9	33.91	9.21	9.99	9.30	10.05	9.64	B1
						9.64	10.55	11.22	12.62	11.01	B2
						9.40	10.37	9.85	10.96	10.15	B3
						3.03	3.21	2.98	3.27	3.12	B4
C	28.22	30.43	27.7	30.95	29.33	9.66	10.81	9.68	11.00	10.29	C1
						5.01	5.27	4.82	5.42	5.13	C2
						5.80	6.13	5.64	6.23	5.95	C3
						7.75	8.22	7.56	8.30	7.96	C4
D	26.48	21.75	25.92	18.1	23.06	2.30	1.90	1.85	1.13	1.80	D1
						1.91	2.18	2.06	2.55	2.18	D2
						14.12	8.53	13.08	8.20	10.98	D3
						8.15	9.13	8.95	6.22	8.11	D4

Source*: authors' development*

Table 2 shows the highest average weight (33.91%) of scientific and technological innovation (B) among selected groups of factors influencing the urban digital economy's sustainable development. This is due to the policies issued at different scales to support the digital economy development via investments in scientific and technological innovation. Economic growth (C), accounting for 29.33% of significance, fuels the sustainable development of a digital economy and its rapid expansion. Social development (D) creates a favourable urban digitalisation and sustainability environment. Information infrastructure (A) has the lowest weight (13.7%), but it is no less vital for urban digital economy sustainability.

Scientific and technological innovation (B) significance increases year by year, reaching 36.9% in 2019. This aligns with earlier research on the crucial role of technological innovation and infrastructure construction in promoting sustainable urban development (Zhu & Chen, 2022). Among the group's secondary indicators, the weight of R&D personnel full-time equivalent (B2) is the highest, indicating the high relevance of the number of research and innovation personnel for sustainable urban digital economy development. The amount of patent authorisation (B3) and R&D project expenditure (B1) have minor difference in the influence on technological innovation, with an average weight of 10.15% and 9.64%, respectively. The average number of students in colleges and universities (B4) is the least impacting urban digital economy sustainability among the scientific and technological factors (3.12%).

The weight of e-commerce sales (C1) is the highest (10.29%) among the economic growth group of factors. Although the added value of tertiary industry (C2) has the lowest weight among economic factors, it is upward.

Although the overall weight of social development (D) has not changed much, it is declining. The most weighting index — the total import and export of goods (D3) — decreases significantly. The registered urban unemployment rate (D1) and urban public financial expenditure (D2) weights (1.80% and 2.18%, respectively) impact urban digital sustainability the least among all secondary indices. The impact of unemployment marks further "dis-embeddedness" of the digital employment sector from conventional social regulations that was found by B. Chen *et al.* (2020), and the need of transforming social institutions to support sustainable urban digitalisation (Curran, 2018).

Information infrastructure (A) weight is the most stable among all groups. The length of optical cable lines per unit area (A3) and the number of computers used per 100 people (A4) weights are slightly larger than those of mobile phone penetration (A1) and Internet broadband access users (A2). However, impacts of the mobile phone penetration rate (A1) and the number of computers per 100 people (A4) have a clear upward trend, indicating their high significance for urban digital economy sustainability.

To summarise, the following factors influence the urban digital economy sustainability the most (by average weights, top-five): the R&D personnel full-time equivalent; the total import and export of goods; the e-commerce sales; the amount of patent authorisation; the R&D project expenditure. The least significant are as follows: registered urban unemployment rate; public financial expenditure; mobile phone penetration; the number of computers per 100 people; the number of students in colleges and universities. This shows the fundamental driving forces of urban digital economy sustainability: talents, research, and economic activity. The urban digital economy is more a business-driven process than pushed by authorities.

Assessment of digital economy sustainable development performance in Chinese provinces and cities

The entropy-TOPSIS calculation results (Table 3) allow comparing the sustainable development of the digital economy in 31 Chinese provinces and cities. The relative proximity Ci [0; 1] serves the evaluation standard: Ci value closer to one attests to the better digital economy sustainability performance in the city and opposite. Figure 1 visualises obtained results.

***Table 3**. Digital economy sustainable development performance in Chinese provinces and cities in 2019*

Region	Relative proximity Ci	Ranking	Province	Relative proximity Ci	Ranking
The eastern coastal region	0.333	1	Guangdong	0.733	1
			Beijing	0.534	2
			Jiangsu	0.522	3
			Zhejiang	0.421	4
			Shanghai	0.358	5
			Shandong	0.305	6
			Fujian	0.166	10
			Hebei	0.119	14
			Tianjin	0.118	15
			Hainan	0.049	26
The central region	0.132	2	Hubei	0.192	7
			Henan	0.168	9
			Anhui	0.147	12
			Hunan	0.133	13
			Jiangxi	0.096	17
			Shanxi	0.055	24
The north-eastern region	0.079	3	Liaoning	0.117	16
			Heilongjiang	0.062	21
			Jilin	0.059	22

Table 3, Continued

Region	Relative proximity *Ci*	Ranking	Province	Relative proximity *Ci*	Ranking
The western region	0.071	4	Sichuan	0.185	8
			Shaanxi	0.152	11
			Chongqing	0.094	18
			Yunnan	0.066	19
			Guangxi	0.065	20
			Inner Mongolia	0.055	23
			Guizhou	0.054	25
			Xinjiang	0.042	27
			Qinghai	0.042	28
			Gansu	0.037	29
			Ningxia	0.031	30
			Tibet	0.026	31

***Source**: authors' development*

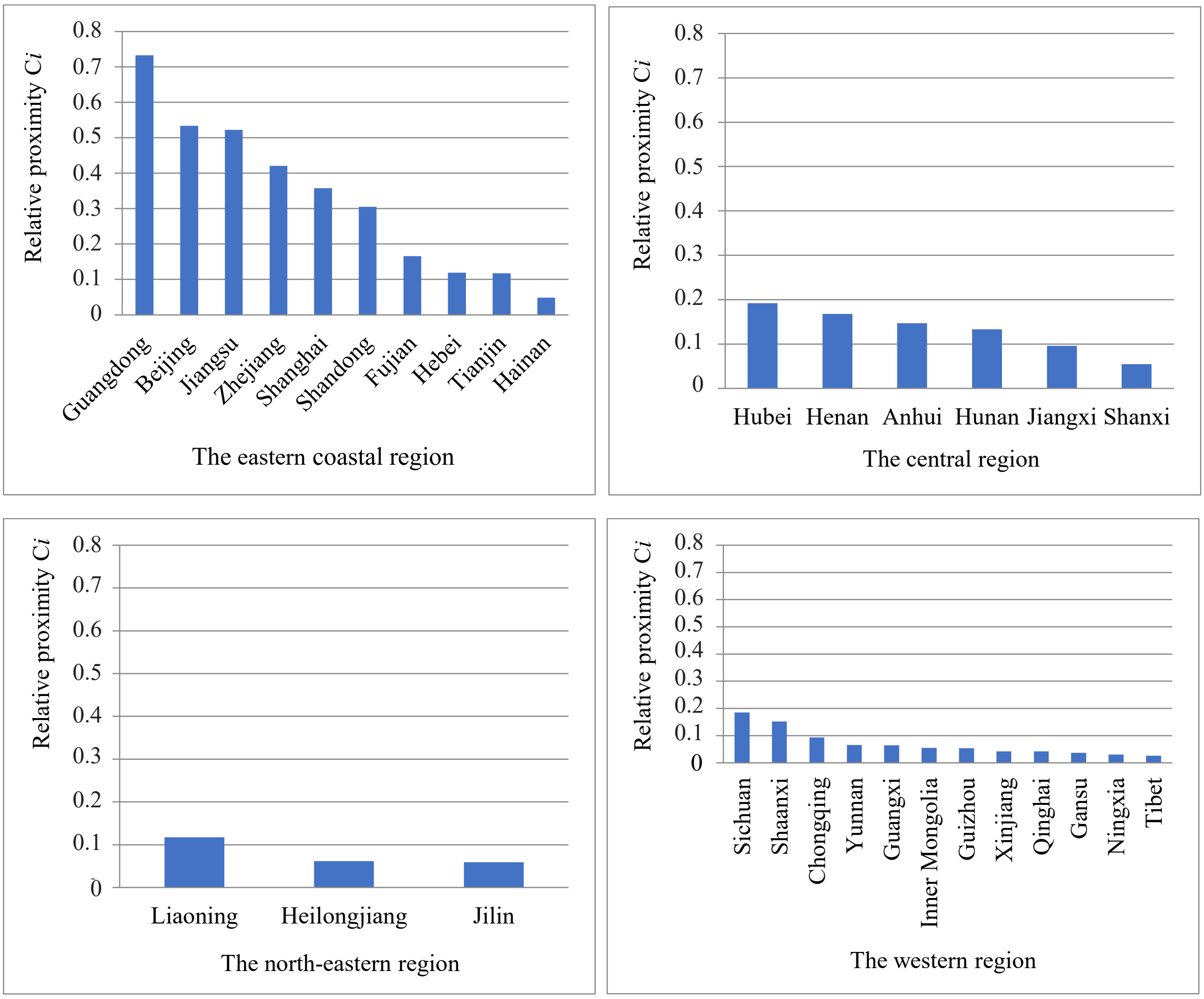

***Figure 1**. Range of Chinese provinces and cities' digital economy sustainable development performance in 2019*

***Source:** authors' development*

Chinese regions differ in the urban digital economy sustainability performance. Guangdong, Beijing, Jiangsu, Zhejiang, and Shanghai have the highest performance values and represent the eastern coastal region. Cities with the lowest performance value are concentrated mainly in the western part (Tibet, Ningxia, Gansu, Qinghai, Xinjiang). This is due to the weak development of digital industries like digital literary and content creation and lagging traditional industries' digital transformation. Many central and western provinces are still dominated by conventional industries: tourism in Tibet and Hainan, heavy industry in Heilongjiang and Liaoning, etc. Urban digitalisation in the central, western, and north-eastern regions is still in its infancy, resulting in a gap between the east and these regions. Complementing results of the available studies (Li *et al.*, 2020; Xin *et al.*, 2019; Zhu & Chen, 2022), the use of the entropy-TOPSIS model allows quantifying the level of urban digital economy performance in Chinese regions to identify leaders and prominent strategies.

CONCLUSIONS

This study constructs the four-level evaluation index system with 16 secondary indicators to quantify the influence of varied factors on the sustainability performance of the digital economy in Chinese regions. The results obtained via the entropy weighting method show the highest relevance of technological innovations followed by economic growth, social development, and urban information infrastructure development to promote sustainable urban digitalisation. Staff R&D engagement and R&D project expenditure, together with economic transparency and e-commerce development, were the most significant for the sustainable development of the urban digital economy. It was unexpected that the number of college and university students is a minor principal factor for urban digital sustainability. In this context, a new problem arises regarding the content of training programmes and the need to adapt it for society's digitalisation and innovation needs. The low significance of public financial expenditure attests to the small role of authorities' investments in digital economy growth. However, the legal and institutional environment favouring science and innovative business activity should not be underestimated. The same is true for the "physical foundation" of the digital economy – an information infrastructure.

This study uses the entropy-TOPSIS approach to evaluate the performance of Chinese provinces and cities in digital economy sustainable development. The eastern coastal areas of China demonstrate the highest level of sustainable digital development, followed by central and north-eastern towns, while the digital economy in western territories is underdeveloped. The gap in provinces' performance could be explained by the prevalence of conventional industries, their slow digitalisation, and the weak development of digital initiatives in China's west. The need to intensify regional opening-up and cooperation is prominent to avoid the marginalisation in the regions and ensure China's sustainable development path.

Although this study addresses China's practices, it is undoubtedly relevant in a broader context, covering the role of talents, innovations, business R&D investments, interregional cooperation, and multiscale partnership in promoting digitalisation conducive to the idea of sustainability. Whereas a lot of factors are difficult to quantify directly (for instance, public perception of a digital economy, responsibility, and enthusiasm) and thus were left out of this paper, further studies in this area could take obtained results as a starting point to measure the sustainable development of urban digital economy comprehensively and world-wide.

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Основні фактори сталого розвитку цифрової економіки в містах: приклад Китаю

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Анотація. Цифровізація є сучасною соціальною та економічною реальністю, і пошук ефективних шляхів для забезпечення високоякісного сталого розвитку, побудованих на цифрових рішеннях спільнот, є предметом сучасних досліджень щодо розвитку міст у всьому світі. На шляху до забезпечення сталості цифрової економіки міст на особливу увагу заслуговує вивчення ключових факторів, що впливають на ці процеси. Водночас, сьогодні бракує кількісних емпіричних досліджень, які б дозволяли уникнути суб'єктивних суджень щодо рушіїв сталої цифровізації міських поселень. Це дослідження має на меті заповнити цю прогалину шляхом визначення та кількісної оцінки ключових факторів, які впливають на сталий розвиток міської цифрової економіки, через застосування моделі ентропії-TOPSIS. Дане дослідження проведено на прикладі провінцій і міст Китаю, зважаючи на успіхи Китаю в питаннях розвитку цифрової економіки. У цьому дослідженні запропоновано використовувати комплексну чотиривимірну (науково-технічні інновації, економічне зростання, соціальний розвиток, інформаційна інфраструктура) систему показників, що містить 16 суб-індексів для вимірювання сталого розвитку цифрової економіки міських поселень. Використовуючи дані щодо 31 китайської провінції та міст за 2016-2019 роки та модель ентропії-TOPSIS, було встановлено, що розвиток науково-технічних інновацій має найбільший вплив на забезпечення сталості міської цифрової економіки. Залучений до досліджень персонал та витрати на дослідження та розробки, експорт та імпорт товарів, продажі через електронну комерцію найбільшою мірою сприяють сталому розвитку міської цифрової економіки, тоді як кількість студентів, публічні фінансові витрати та безробіття мають найменший вплив на цей процес. Отримані результати свідчать про те, що міська цифрова економіка, більшою мірою, є процесом, який стимулюється з боку бізнесу, а не влади. Визначений розрив у розвитку цифрової економіки регіонів Китаю пояснюється поширеністю традиційних галузей і низьким рівнем їх цифровізації. Останнє свідчить про необхідність посилення міжрегіонального співробітництва та розвитку партнерств для сприяння сталому розвитку країни в умовах парадигми цифрової економіки. Незважаючи на те, що дослідження побудоване на даних провінцій Китаю, отримані результати сприяють подальшому розвитку науки та політики у цій галузі в усьому світі, розкриваючи значення розвитку талантів, інновацій, бізнес-інвестицій у дослідження та розробки, міжрегіонального співробітництва та різносторонніх партнерств у сприянні процесам цифровізації урбанізованих територій відповідно до ідеї сталого розвитку

Ключові слова: цифровізація, метод ентропії, сталість, модель TOPSIS, міський розвиток