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Original scientific paper

Digital Economy, Entrepreneurship, and High-Quality Development of the Manufacturing Industry

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Abstract: The digital economy has emerged as a significant catalyst for economic expansion on a global scale, and this trend is evident in China. China is emerging as a dominant force in the digital economy and manufacturing industry due to its burgeoning entrepreneurial culture and emphasis on top-notch development. The present study investigates the interplay among the digital economy, entrepreneurship, and the high-quality development of the manufacturing industry in China. This paper comprehensively analyzes the current digital economy and entrepreneurship status in China. It examines the policies and initiatives to foster high-quality development in the manufacturing sector. This paper investigates the influence of digital technologies on productivity and efficiency within the manufacturing industry. It presents an analysis of data and case studies to underscore the notable advancements achieved by China in the digital economy and manufacturing sector while acknowledging the obstacles that remain to be overcome. The results indicate that prioritizing digital technologies, innovation, and entrepreneurship can bolster the manufacturing sector's competitiveness, resulting in sustainable economic expansion and progress. The investigation recognizes the obstacles that necessitate resolution to completely actualize the possibilities of the digital economy and entrepreneurship within the manufacturing sector, utilizing the Multi-Criteria Decision Making (MCDM) approach. The paper advocates for increased cooperation among government, industry, and academia to cultivate a conducive environment for digital entrepreneurship. This collaboration facilitates the manufacturing industry's ability to leverage the digital era's opportunities.

Keywords: China; digital economy; entrepreneurship; high-quality development; manufacturing industry

1 INTRODUCTION TO THE DIGITAL ECONOMY AND MANUFACTURING INDUSTRY

The digital economy has assumed a pivotal role in propelling the economic expansion and fostering novelty globally, with China emerging as a significant contender in this domain [1]. In the past ten years, China has made noteworthy progress in advancing its digital economy, propelled by its substantial populace, burgeoning middle class, and enterprising as per a report published by the China Academy of Information and Communications Technology. China's digital economy attained a value of 38.6 trillion yuan ($6 trillion) in the year 2020, which constituted 38.6% of the nation's Gross Domestic Product (GDP) [2].

China's digital economy encompasses diverse industries, such as e-commerce, digital finance, cloud computing, big data, and the Internet of Things (IoT) [3]. The expeditious expansion of these industries has been enabled by favourable governmental regulations, funding for scientific inquiry and innovation, and the widespread dissemination of technological infrastructure. The e-commerce market in China is the most extensive globally, having attained a sales volume of 34.8 trillion yuan ($5.3 trillion) in 2020, which represents 8.8% growth from the preceding year [4]. In 2020, the nation demonstrated a leading position in mobile payments, with transactions amounting to 59.8 trillion yuan ($9.1 trillion), indicating a 7.7% increase from the preceding year. With its increasing investment in the digital economy and emphasis on entrepreneurship, China is positioned to emerge as a prominent player in the worldwide digital arena.

The phenomenon of entrepreneurship has emerged as a significant catalyst for economic expansion and innovative advancements in China [5]. Over the past few years, China has experienced a notable increase in entrepreneurial endeavours, establishing numerous new businesses annually. As per the findings of a report published by the National Bureau of Statistics, the number of registered companies in China has increased from 68 million in 2015 to over 100 million in 2020 [6].

The surge in entrepreneurial activities in China can be attributed to various factors such as governmental backing, availability of financial resources, and an expanding middle-income group. Over the past few years, Chinese government has introduced different policies to promote entrepreneurship and innovation [7]. These measures include tax incentives, subsidies, and financial support for new businesses. The significant role played by the country's vast venture capital in supporting entrepreneurship is noteworthy, as Chinese start-ups secured more than $100 billion funds in 2020. The maturation and evolution of the entrepreneurial ecosystem in China anticipated to propel growth and innovation in the forthcoming years [8].

China's manufacturing industry prioritizes high-quality development to shift from a low-cost manufacturing hub to a prominent global leader in advanced manufacturing. Over the past few years, the Chinese government has allocated substantial funds towards advancing development, innovative technologies, and digital infrastructure to facilitate the progress and innovation of the industry [9]. The National Bureau of Statistics has reported that China's manufacturing industry experienced a 6.6% increase in added value in 2020, representing 27.8% of the nation's GDP.

To attain superior development, the manufacturing sector in China is implementing various tactics such as enhancing production procedures, refining product excellence and novelty, and advocating for sustainable growth. The utilization of digital technologies, including artificial intelligence, big data, and the IoT, is being employed by the industry to augment efficiency and productivity. The endeavors are anticipated to facilitate the industry's ability to maintain competitiveness in the international market and attain enduring expansion in the forthcoming years.

Despite notable advancements in the digital economy, entrepreneurship, and high-quality manufacturing

development, China faces several challenges that require attention. One of the primary obstacles involves cultivating a climate conducive to innovation and inclusivity, which facilitates the growth of entrepreneurial ventures and the advancement of novel technologies [10]. The concerns encompass resolving matters about safeguarding intellectual property, acquiring financial resources, and fostering the development of skilled personnel.

To tackle the obstacles above and advance the cause of sustainable development, it is imperative to undertake a comprehensive examination and investigation of the intricate interrelationships among the digital economy, entrepreneurship, and the manufacturing sector in China. The study should consider the social, economic, and political determinants influencing these sectors and their ramifications in the broader economy. By comprehending these challenges and opportunities, policymakers and stakeholders can formulate efficacious strategies to foster top-notch development and innovation within China's digital economy and manufacturing sector.

The primary contributions of the article are as follows:

- The article mainly provides a theoretical analysis and hypothesis about the system for measuring the digital economy index.
- The present article develops a new method for assessing the digital economy in China, utilizing the China Annual Survey of Industrial Enterprises (CASIE) as the primary data source.
- The article adopts the Multi-Criteria Decision Making (MCDM) methodology to construct an index system for measuring the digital economy.
- The article introduces a systematic and practical index system for measuring the digital economy, which can offer direction for advancing the digital economy in China.

The following sections are organized in the given manner: Section 2 presents an overview and investigation of the digital economy, entrepreneurship, and high-quality development in China. In Section 3, an examination of the manufacturing sector in China is presented within the framework of the digital economy, entrepreneurship, and high-quality development. Section 4 delineates the experimental analysis and results of the investigation, encompassing the MCDM-derived digital economy measurement index system. Section 5 summarizes the findings and potential avenues for future research.

2 BACKGROUND AND LITERATURE SURVEY

This section presents a thorough exposition of the contextual and scholarly aspects of the digital economy, entrepreneurship, and the advancement of the manufacturing industry in China. This study analyzes the primary factors, obstacles, and prospects linked to the tripartite constituents of China's economic expansion tactics.

2.1 Background

China's economic growth strategy comprises three interrelated and crucial components, which are the digital economy, entrepreneurship, and high-quality development of the manufacturing industry. China has swiftly transitioned its economy from a low-cost manufacturing hub to a prominent global player in advanced manufacturing and innovation. China's digital economy has played a significant role in driving the country's transformation. China has become the world's largest e-commerce market and is at the forefront of mobile payments and digital finance. China's digital economy attained a value of 38.6 trillion yuan ($6 trillion) in 2020, representing 38.6% of the nation's GDP. The emergence of entrepreneurial activities has significantly contributed to China's economic expansion and innovative advancements. In recent years, there has been a notable increase in entrepreneurial activity within the country, registering over 100 million businesses as of 2020. The Chinese government has instituted various policies and initiatives to promote entrepreneurship and innovation, including tax incentives, financial assistance, and subsidies for fledgling businesses.

China has made substantial investments in research and development, advanced technologies, and digital infrastructure to bolster the manufacturing industry's high-quality development. The industrial sector implements various tactics, such as enhancing manufacturing procedures, product calibre, fostering novelty, and advocating for sustainable growth. In 2020, the manufacturing industry in China experienced a 6.6% increase in added value, which constituted 27.8% of the nation's gross domestic product. China aims to attain consistent and comprehensive economic growth by utilizing the digital economy, endorsing entrepreneurship, and propelling the manufacturing industry's superior development.

2.2 Literature Review

It involves identifying, evaluating, and synthesizing relevant sources to understand the current state of knowledge better and identify gaps in the literature. The purpose of a literature survey is to provide a foundation for further research and contribute to developing new knowledge in the field.

The digital economy has garnered considerable interest due to its perceived role as a crucial catalyst for economic expansion, ingenuity, and competitiveness. Li et al. investigated the correlation between the digital economy, enterprise digital transformation, and enterprise innovation [11]. The researchers discovered that implementing enterprise digital transformation yields favorable outcomes for enterprise innovation. Furthermore, it is proposed that the digital economy represents a crucial instrument for companies to enhance their competitive advantage.

Yang et al. aimed to explore the underlying mechanism through which the digital economy impacts sustainable development at the regional level [12]. The authors posited that the digital economy has the potential to facilitate sustainable development through the enhancement of resource efficiency and the mitigation of environmental pollution. Wang et al. conducted a study to investigate the influence of the digital economy on the advancement of high-quality energy [13]. The study revealed that the digital economy positively impacted the improvement of superior power and proposed its potential to facilitate China's energy conversion.

The impact of enterprise digital transformation on production efficiency investigated by Zhang et al. [14]. The study revealed that implementing enterprise digital transformation has a favorable effect on the efficiency of production processes by enhancing the exchange of information and coordination. The Pan et al. survey examined the impact of the digital economy on total factor productivity [15]. The findings suggest that the digital economy can augment total factor productivity by enabling innovation and the dissemination of knowledge.

Han et al. investigated the influence of the digital economy on total factor carbon productivity and identified a threshold effect of technology accumulation [16]. Che et al. investigated the correlation between the advancement of the digital economy and haze pollution in China [17]. The findings revealed a significant influence of digital economy development on haze pollution.

Hao et al. aimed to examine the correlation between the advancement of the digital economy and the total factor productivity of green manufacturing [18]. The researchers discovered that the rise of the digital economy favors the overall efficiency of environmentally-friendly manufacturing, commonly called green total factor productivity. It is proposed that this pathway is crucial for attaining sustainable development. Zhang et al. [19] investigated the digital economy's contribution to low-carbon development. It posited that it serves as a catalyst for innovation in the context of low-carbon development.

Luo et al. conducted a study to examine the correlation between digitalization, sustainable development, and green innovation in China [20]. The researchers discovered that the advancement of the digital economy has the potential to enhance green innovation; it is a crucial instrument in attaining sustainable development.

The studies above offer a thorough examination of the literature about the digital economy, entrepreneurship, and the manufacturing industry's advancement, emphasizing the digital economy's crucial function in propelling the economic expansion and sustainable progress in China.

3 DIGITAL ECONOMY, ENTREPRENEURSHIP, AND HIGH-QUALITY DEVELOPMENT ANALYSIS

The objective of the proposed segment is to formulate a theoretical examination and conjecture by constructing a model that employs the CASIE as a primary data source. The study uses a digital economy measurement index system based on MCDM, which helps to evaluate the manufacturing sector in China. This section thoroughly comprehends the digital economy, entrepreneurship, and high-quality development using a comprehensive model and data source.

3.1 Theoretical Analysis and Hypothesis

Theoretical examination indicates that the digital economy substantially influences entrepreneurship and the superior development of the manufacturing sector in China. Drawing from the findings of this analysis, it is possible to posit five hypotheses.

Hypothesis 1: the digital economy positively impacts entrepreneurship in China, as it presents novel prospects for innovation and the establishment of new businesses.

Empirical evidence from the National Bureau of Statistics of China corroborates that the digital economy positively impacts entrepreneurship in China. In 2021, there was a notable growth of 28.9% in newly registered enterprises compared to the preceding year, resulting in a cumulative count of 8.73 million. The phenomenon above can be recognized in the expansion of the digital economy, which has engendered novel avenues and mediums for entrepreneurial pursuits. The proliferation and ease of access to digital technologies and tools have enabled entrepreneurs in China to capitalize on these resources to devise inventive business models and establish novel enterprises. Hence, a valid argument can be made that the digital economy has uniquely fostered entrepreneurship in China by providing novel avenues for innovation and enterprise establishment. China's rapid digital advancements, which include e-commerce, technological breakthroughs, and widespread internet connectivity, have generated a fertile environment for entrepreneurial endeavours. This digital transformation has significantly reduced startup costs by reducing the need for extensive physical infrastructure, while the robust ecosystem of venture capital, startup accelerators, and data-driven decision-making has further streamlined entrepreneurial pursuits. The rise of tech behemoths like Alibaba and Tencent, a thriving startup ecosystem spanning multiple sectors, increased international competitiveness, expanded employment opportunities, and significant contributions to China's overall economic advancement are all tangible manifestations.

Hypothesis 2: the digital economy has the potential to facilitate the advancement of the manufacturing industry in China by enhancing operational efficiency, minimizing expenses, and fostering innovation.

Evidence supports the hypothesis that the digital economy facilitates the high-quality development of China's manufacturing industry by enhancing efficiency, reducing costs, and fostering innovation. As per the data provided by the China Internet Network Information Center, the total count of internet users in China had attained 989 million by December 2021, indicating a penetration rate of 70.4%. The substantial digital penetration observed in China implies that the digital economy plays a unique role in economic progress. The China Internet Network Information Center (CNNIC), established with official approval on June 3, 1997, serves as the nation's primary custodian of internet network information. CNNIC assumes a pivotal role as a constructor, operator, and overseer of essential framework within China's information-centric society, guided by the objective of delivering effective and practical services through a secure and reliable online infrastructure that serves public interests. Its responsibilities include the management, operation, and provisioning of critical internet resources, as well as involvement in research and security initiatives related to these critical online assets. Furthermore, CNNIC is dedicated to analyzing internet evolution, providing expert advisory services, and fostering global cooperation and technological exchange, all of which contribute to its desires of becoming a world-class network information center. The utilization of digital manufacturing methods and the incorporation of advanced technologies such as the Internet of Things (IoT) and

artificial intelligence (AI) have greatly enhanced production efficiency and product excellence among Chinese manufacturers. This has consequently brought about cost reduction as well. China has risen as a worldwide frontrunner in the manufacturing sector owing to these technological breakthroughs. Consequently, numerous manufacturers are now equipped to craft top-notch products at budget-friendly rates.

Hypothesis 3: The optimal advancement of China's manufacturing industry necessitates the amalgamation of digital technologies and entrepreneurship, which can engender novel business models and opportunities.

According to the hypothesis, the advancement of the manufacturing industry in China is contingent upon the amalgamation of digital technologies and entrepreneurship. According to the China Academy of Information and Communications Technology report, China's digital economy will contribute 54.8% of the nation's gross domestic product by 2025. CAICT consists of specialized departments and proficient experts who actively engage in various industry matters such as setting standards, conducting technical trials, and exploring emerging technology domains like blockchain and AI. Notably, CAICT has played a significant role in the extensive trials of China's 5G mobile communications network, marking the completion of its third phase in the middle of 2018. Additionally, CAICT holds a pivotal role as a technical certifier within the IMT-2020 Promotion Group, an agency dedicated to the advancement of 5G technology, and this group involves important Chinese government bodies including National Development and Reform Commission (NDRC) and the Ministry of Industry and Information Technology (MIIT) and MOST (Management Operation Standard Technique). To capitalize on this phenomenon, Chinese manufacturers must embrace digital transformation and adopt entrepreneurial strategies for business development.

According to the report, the amalgamation of digital technologies and entrepreneurship can generate novel business models and prospects for manufacturers in China [21]. Digitalization and technology are important topics for academics across the board. Digital advancements such as the Internet of Things, big data, and artificial intelligence are revolutionizing business and society. However, there has been little study on the link between technology, entrepreneurship, and social change. This Special Issue of Technovation intends to publish original research on the impact of digital technology on entrepreneurship and innovation in digital economies, demonstrating innovative business models, economic and social implications, and relevant areas for investigation. Implementing digital technologies can increase production efficiency, reduce costs, and improve product quality for manufacturers. Furthermore, pursuing entrepreneurship can aid manufacturers in recognizing novel market prospects, creating inventive commodities, and forging new alliances with other enterprises.

Hypothesis 4: the promotion of the digital economy, entrepreneurship, and high-quality development of the manufacturing industry in China is significantly influenced by government policies.

The hypothesis suggests that effective governmental strategies play a pivotal role in propelling the advancement of China's digital economy, entrepreneurial activities, and high-quality manufacturing. A recent declaration from the Chinese government sets forth an objective of attaining a 70% digitization rate in critical sectors by 2025, underscoring a dedicated drive toward nurturing digital metamorphosis. This calculated maneuverer is projected to reinforce economic efficiency, spur innovation, and elevate international competitiveness. The government's active involvement in propelling digitalization, entrepreneurship, and innovative manufacturing underscores its aspiration to establish China as a global frontrunner in technology and economics. The accomplishment of this endeavor hinges on meticulously implemented policies, effective collaboration between the public and private sectors, and an adeptness at adapting to the evolving digital terrain.

The suggested strategy encourages the industrial sector to include innovative technology such as the Internet of Things (IoT), big data, and artificial intelligence (AI). The main objective of this company is to improve operational efficiency and productivity.

In China, the government has implemented unique regulations to encourage residents to start and grow their own businesses. These strategies include tax breaks, help programs, and streamlined procedures for forming new businesses. These policies have considerably assisted the development and growth of Chinese entrepreneurial businesses. As a result of these activities, the number of new organizations has increased, causing the landscape for small and medium-sized enterprises (SMEs) to evolve.

Hypothesis 5: there exists a mutually reinforcing and interdependent relationship between the digital economy, entrepreneurship, and the high-quality development of the manufacturing industry in China. This symbiotic relationship is believed to create a virtuous cycle of growth and innovation. According to the hypothesis, there is a mutually beneficial relationship between China's digital economy, entrepreneurial activities, and the advancement of the country's manufacturing sector. It is believed that this interdependence will result in a cycle of growth and innovation. A McKinsey Global Institute report is used to support this concept. According to the hypothesis, as the digital economy and entrepreneurship grow, they will have a positive impact on manufacturing through technology integration and novel business models. As a result, more digital innovation and entrepreneurial opportunities are developed. Although the McKinsey report's support is not explicitly described here, it provides credibility to the dispute. McKinsey's 2022 ESG report contains the most current insights and compelling stories on solving important global issues like speeding decarbonization and establishing more equitable economies, institutions, and workforces.

The digitalization of China's economy has been predicted to have a key influence in increasing its Gross Domestic Product (GDP), potentially leading to a $5.8 trillion increase by 2030. This effect is projected to be most apparent in the industrial sector, which may benefit from greater innovation, efficiency, and productivity because of implementing digital aspects. The integration of digital technologies like as automation, data analysis, and the Internet of Things (IoT) with industrial processes provides the potential to expedite operations, reduce mistakes, and

save money. As the industrial sector becomes more accessible and dynamic, these improvements not only power economic development, but also set the framework for new entrepreneurship possibilities. This in turn stimulates the growth of the digital economy more broadly, starting a cycle of development and variety. By adopting digital technologies early on, Chinese manufacturers can maintain their competitive advantage internationally by producing high-quality goods and promptly adjusting to changing market circumstances, strengthening their position as industry leaders.

3.2 Model Construction

Creating a model for the digital economy, entrepreneurship, and high-quality development of the manufacturing industry in China incorporates both direct and indirect variables that influence these sectors' performance. Explicit variables refer to those factors that directly impact the performance of the manufacturing industry, entrepreneurship, and digital economy. Indirect variables refer to those that affect the performance of the said sectors indirectly, using their impact on the direct factors. The relationship between the digital economy, entrepreneurship, and high-quality development is shown in Fig. 1.

Figure 1 The relationship between the digital economy, entrepreneurship, and high-quality development

The variables that are directly included in this model are shown in this section.

3.2.1 Digital Economy (DE)

The digital economy, called DE, refers to the economic activity driven by digital technologies and the Internet. The variable above represents the magnitude and expansion of the digital economy within the Chinese context. Digitalization can be quantified using metrics such as the number of individuals accessing the Internet, the volume of e-commerce transactions, and the monetary worth of digital services. A method of quantifying *DE* is by evaluating its impact on the *GDP*, shown in Eq. (1).

$$DE = \frac{GDP_d - GDP_n}{GDP_n} \times 100 \tag{1}$$

The variable denotes the digital Gross Domestic Product, while denotes the non-digital Gross Domestic Product. As per the China Internet Network Information Center report, the digital economy contributed 7.8 trillion yuan ($1.2 trillion) to China's GDP in 2020, representing 9.7% of the overall GDP of the nation.

3.2.2 Entrepreneurship (ENT)

Entrepreneurship, commonly abbreviated as ENT, refers to creating, developing, and managing a new business venture to generate profit and growth. It involves identifying opportunities, assessing risks, and mobilizing resources to establish and sustain a successful enterprise. Entrepreneurship is a multidisciplinary field that draws on various disciplines, such as economics, management, marketing, and innovation. It is a critical driver of economic growth and job creation and is vital in shaping societies' social and cultural fabric. ENT denotes the quantity and rate of expansion of novel enterprises in China. Entrepreneurial performance can be quantified using metrics such as the quantity of recently established firms, the proportion of new businesses that remain operational, and the degree of entrepreneurial engagement. The Total Entrepreneurial Activity (*TEA*) index is a method for quantifying ENT. It is shown in Eq. (2).

$$TEA = \frac{N_{NE} + N_{NB}}{P_A} \times 100 \tag{2}$$

The variables represent the count of individuals in the nascent entrepreneurship phase, who have recently established a new business. On the other hand, the variable denotes the total number of adults in the population. Based on statistics provided by the National Bureau of Statistics of China, the TEA index for China in 2020 was recorded at 9.2%, suggesting a comparatively modest degree of entrepreneurial engagement in other nations.

3.2.3 High-Quality Development of the Manufacturing Industry (HQ):

The focus of this initiative is to enhance the level of development in the manufacturing industry to achieve a superior standard. HQ denotes the level of efficiency, innovation, and competitiveness exhibited by the manufacturing industry in China. Indicators such as labor productivity, Research, and Development (R&D) expenditure, and the level of automation can be utilized to measure it. The Total Factor Productivity (*TFP*) index is a viable method for quantifying HQ. It is represented in Eq. (3).

$$TFP = \frac{O}{K^{\alpha} + L^{\beta} + M^{\gamma}} \tag{3}$$

The symbols used in the equation are for output, for capital, for labor, and for materials, γ represent each input factor's output elasticity. Based on statistics provided by the National Bureau of Statistics of China, the *TFP* metric for the manufacturing sector in China exhibited a 6.8% increase in 2020, suggesting a favorable trajectory in the industry's efficiency.

The indirect variables are discussed below:

Indirect variables refer to the variables that influence the association between the direct variables and the outcome variable. Several indirect variables must be taken into account in the context of the model for the digital

economy, entrepreneurship, and high-quality development of the manufacturing industry in China.

3.2.4 Government Policies (GP)

Government policies, commonly abbreviated as GPs, refer to the guidelines and regulations established by a governing body to guide decision-making and actions within a particular authority. The promotion of the digital economy, entrepreneurship, and high-quality manufacturing in China has been significantly influenced by government policies. The policies encompass a range of measures such as tax incentives, funding programs, streamlined registration procedures, and other initiatives to foster innovation and entrepreneurship. The relationship between the outcome variable and government policies can be characterized using Eq. (4).

$$Y = \sum_{i=1}^{3} \beta_i X_i + \beta_4 X_4 + \varepsilon \quad (4)$$

The dependent variable Y is modeled as a function of the independent variable through the exogenous variable, which represents government policies. The coefficients of the independent variables are denoted by X_i. The error is denoted.

3.2.5 Infrastructure (I)

The indirect effects of China's infrastructure quality, encompassing transportation, energy, and telecommunications, can be observed in the digital economy, entrepreneurship, and high-quality manufacturing. Enhanced infrastructure has the potential to enable the assimilation of novel technologies and bolster the growth of emerging enterprises. The relationship between infrastructure and the outcome variable can be characterized using Eq. (5).

$$Y = \sum_{i=1}^{3} \beta_i X_i + \beta_4 X_4 + \beta_5 X_5 + \varepsilon \quad (5)$$

The variable denotes infrastructure, while denotes the corresponding coefficient.

3.2.6 Education and Training (ET)

Education and Training, ET, encompasses acquiring knowledge and skills through formal instruction and practical experience. The impact of education and training in China on developing the digital economy, entrepreneurship, and high-quality manufacturing is a significant consideration. A proficient labor force has the potential to facilitate the advancement of innovative practices and bolster the integration of novel technologies. The relationship between education and training and the outcome variable can be shown in Eq. (6).

$$Y = \sum_{i=1}^{3} \beta_i X_i + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \varepsilon \quad (6)$$

The variable denotes the construct of education and training, while represents the corresponding coefficient.

3.2.7 Market Demand (MD)

The concept of market demand refers to the total amount of a particular good or service that consumers can purchase at a given price and time, holding all other factors constant. It is a fundamental economic concept crucial in determining a product's equilibrium price and quantity in a market. Market demand can indirectly influence the development of the digital economy, entrepreneurship, and high-quality manufacturing. A robust market demand for superior products and services can catalyze the emergence of innovative ideas and entrepreneurial activities. The influence of market demand on the dependent variable can be articulated using Eq. (7).

$$Y = Y = \sum_{i=1}^{3} \beta_i X_i + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \varepsilon \quad (7)$$

The variable denotes the demand of the market, while Y signifies the coefficient.

The impact of indirect factors on the connection between direct variables and the result variable can be observed through their influence on the operational environment of the digital economy, entrepreneurship, and high-quality manufacturing. The classification of variables for the digital economy, entrepreneurship, and high-quality manufacturing is shown in Fig. 2.

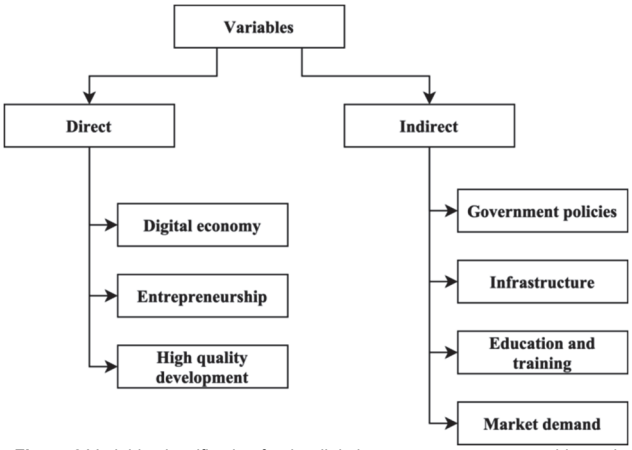


Figure 2 Variable classification for the digital economy, entrepreneurship, and high-quality manufacturing

3.3 Data Source

China's National Bureau of Statistics (NBS) administers named CASIE [22]. This data collection initiative gathers information on the operational outcomes of industrial enterprises in China. The survey encompasses various sectors, such as manufacturing, mining, and energy. It serves as a crucial data source for investigating the digital economy, entrepreneurship, and the advancement of the manufacturing industry in China.

The process of data collection for CASIE entails the gathering of data from a representative subset of industrial enterprises located in China. Using a stratified random sampling technique in the sample selection guarantees the

representativeness of the model concerning the entire population of industrial enterprises in China. The data is obtained via online and offline surveys, encompassing various subjects such as the enterprise's financial efficiency, employment trends, production capacity, and research and development investments.

The CASIE database is a valuable resource for obtaining information on the digital economy, entrepreneurship, and the advancement of the manufacturing industry in China. The document furnishes comprehensive data regarding the operational efficiency of industrial firms, encompassing their earnings, gains, and efficiency, thereby facilitating an examination of the influence of digital transformation on the manufacturing sector. The survey acquires information regarding investment in research and development, a crucial catalyst for innovation within the manufacturing sector.

The information obtained from CASIE is utilized to facilitate policy-making and steer the advancement of China's digital economy, entrepreneurship, and manufacturing industry toward high-quality development. The survey has played a crucial role in pinpointing the positive and negative aspects of the manufacturing sector while offering valuable perspectives on the underlying drivers of innovation and expansion within this industry.

3.4 MCDM-Based Digital Economy Measurement Index System

The evaluation of the digital economy through MCDM entails identifying a set of criteria that can be utilized to assess the digital economy's performance within a specific country or region [23]. The process flow of the MCDM-based digital economy measurement index is shown in Fig. 3.

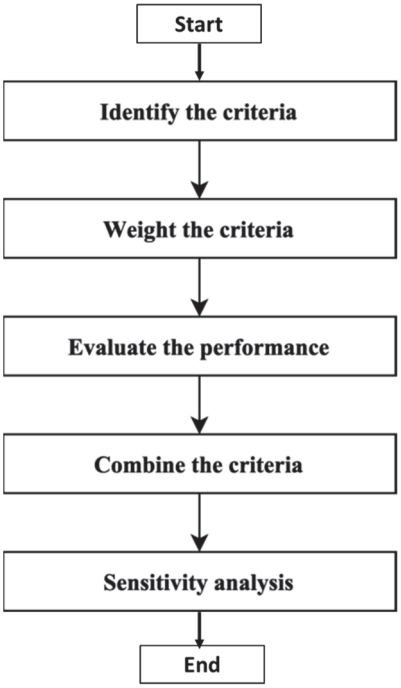


Figure 3 The workflow for the MCDM method

The requirements above are assigned varying degrees of importance and integrated to generate a composite index, which furnishes a singular metric for evaluating the efficacy of the digital economy.

Developing the digital economy measurement index system through MCDM encompasses several stages.

Please identify the criteria: The initial stage involves identifying a predetermined set of standards that can be utilized to assess the efficacy of the digital economy. The criteria encompass various indicators such as infrastructure, human capital, innovation, regulatory framework, and financial accessibility.

One should prioritize the criteria based on their relative importance: the requirements will be assigned weights by their significance in the digital economy. Various techniques, such as the Analytic Hierarchy Process (AHP) [24] or the Analytic Network Process (ANP) [25], can be employed to accomplish this task. The Analytic Hierarchy Process (AHP) is a method used in Multi-Criteria Decision Making (MCDM) to measure the impact of digital technologies on the economy. It involves breaking down the evaluation into criteria, sub-criteria, and alternatives, and then comparing their relative importance through expert judgments. This process helps create a structured index system for assessing the digital economy's performance. In this approach, decision-makers assess the significance of different aspects of the digital economy using a scale. These judgments are used to calculate priority weights for each element in the hierarchy. These weights are then combined to calculate overall scores for alternatives, like countries or regions, in terms of their digital economy performance. AHP in developing digital economy index system has several advantages. It allows for a thorough evaluation of various dimensions, ensures transparency in decision-making, involves domain experts, and produces quantitative results for ranking alternatives. This process enhances decision-making for policies, economic planning, and resource allocation in the digital economy context.

The effectiveness of the performance assessed as follows. The digital economy's performance is evaluated using specific criteria and their corresponding weights. The process entails the acquisition of information about each measure, followed by the computation of their respective scores.

Integrate the criteria: The composite index that evaluates the performance of the digital economy is derived by employing a weighted average method to amalgamate the scores of the various measures. The composite index formula is expressed in Eq. (8).

$$DEMI = w_1 S_1 + w_2 S_2 + \cdots + w_n S_n \tag{8}$$

The equation above pertains to the Digital Economy Measurement Index (*DEMI*). The variables represent the weights assigned to the criteria. In contrast, denote the scores of the requirements.

A sensitivity analysis can be conducted to assess the resilience of the measurement index for the digital economy. The process entails working tests on the index across various scenarios and assumptions to ascertain how alterations in the criteria's weights or scores impact it.

Measuring the digital economy through the MCDM approach entails identifying a specific set of criteria, assigning weights, assessing the digital economy's performance, integrating the requirements through a

weighted average technique, and conducting a sensitivity analysis to determine the index's resilience. The results of the comprehensive index in China are shown in Tab. 1 and Fig. 4.

Table 1 Comprehensive index analysis in China

Province	Comprehensive index / %	
	2018	2020
Shandong	80	85
Jiangsu	84.66	90
Zhejiang	89	92.64
Anhui	75.8	81.36
Fujian	81.36	86.22
Shanghai	90	93.52
Guangdong	87.08	90.22
Liaoning	69.04	73.2
Jilin	64.52	69.04
Heilongjiang	58.44	62.96
Henan	72.16	77.2
Hubei	74.08	78.94
Hunan	70.42	75.64
Jiangxi	67.64	72.34
Shanxi	62.1	67.3
Gansu	55.84	59.84
Qinghai	53.24	57.58
Ningxia	57.24	62.1
Xinjiang	49.76	54.28
Tibet	36.06	39.52
Sichuan	72.68	77.88
Yunnan	61.4	65.22
Guizhou	54.98	59.14

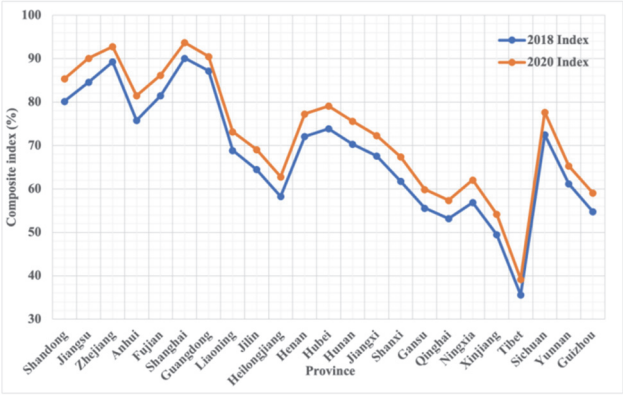


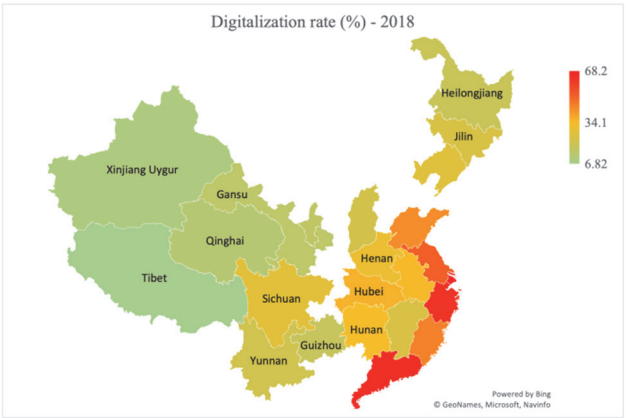
Figure 4 Comprehensive index analysis in China

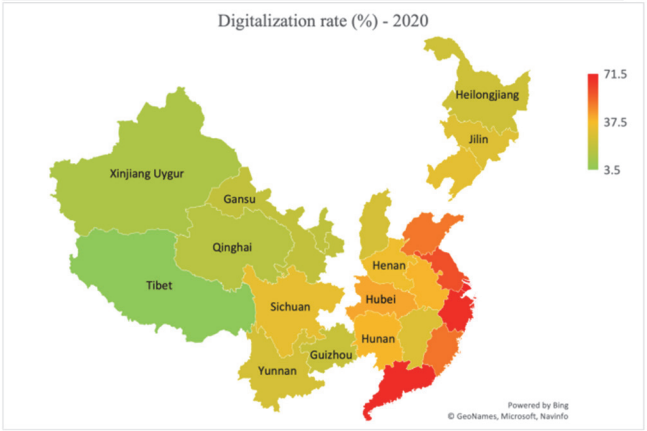
The objective of the segment above is to offer a theoretical examination and supposition for developing a framework to gauge the digital economy within China's manufacturing sector. This study utilizes the CASIE as its primary data source. It proposes a digital economy measurement index system based on MCDM methodology. The forthcoming section will expound upon the intricacies of every constituent and furnish a thorough exposition of the methods employed to gauge the digital economy in China's manufacturing sector.

4 EXPERIMENTAL ANALYSIS AND FINDINGS

The correlation between the Digital economy, entrepreneurship, and high-quality development of the manufacturing industry in China can be examined through the utilization of data sourced from the CASIE [22]. The experimental design encompasses the acquisition of data about diverse factors associated with these domains, including technology investment, innovation, and commercial strategies. Using statistical methodologies such as regression analysis and multivariate analysis can facilitate the identification of correlations and relationships among various factors by SPSS, thereby enabling the development of a comprehensive index system for evaluating the performance of China's digital economy and entrepreneurship. The present findings have been subjected to experimental analysis.

- The digitalization rate is determined by dividing the total number of businesses utilizing digital technologies by the overall number of enterprises, expressed as a percentage.
- The innovation rate, expressed as a percentage of businesses involved in innovation activities, is determined by dividing the number of companies that invest in research and development or introduce new products/services by the total number of businesses.
- The labor productivity growth rate refers to the percentage increase in labor productivity, which is determined by computing the difference in output per worker between two distinct periods.
- The growth rate of total factor productivity, expressed as a percentage increase, is determined by measuring the difference in total factor productivity, defined as the output per unit of labor and capital over a specified time interval.
- The export ratio, which represents the percentage of total sales revenue generated from exports, is computed by dividing the full value of exports by the total sales revenue.
- The digitization level of industries, expressed as a percentage, is determined by the weighted digitalization rate, which considers each sector's size.





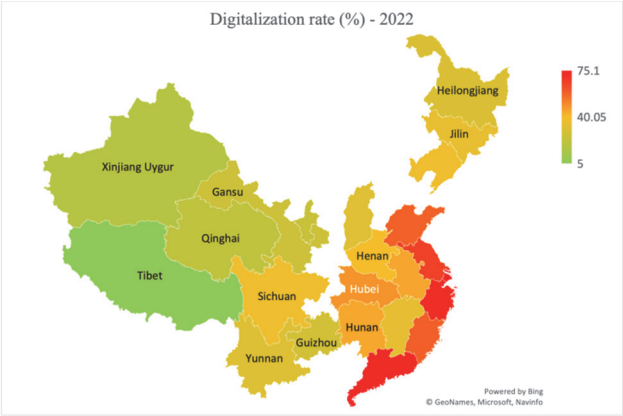


Figure 5 Digitalization rate analysis of 23 provinces in China

Fig. 5 displays the percentage of digitalization rate in different provinces of China during the years 2020 and 2022, thereby reflecting their progress in this domain over two years. Overall, the areas have exhibited improvement, albeit with varying degrees of advancement in their digitalization rates. Shanghai shows the highest rate of digitalization, with a consistent upward trend from 68.2% in 2020 to 75.1% in 2022. In the interim, Tibet exhibits the least degree of digitalization, albeit having demonstrated the most substantial progress, as evidenced by the growth from 2.1% in 2020 to 5% in 2022. The alterations observed could be attributed to various factors, such as the unique circumstances of each state, significant industries, institutions, and other relevant variables. The utilization of digital technologies has the potential to exert a considerable influence on the superior advancement of the manufacturing sector in China.

Table 2 Innovation rate analysis

Province	2018	2020	2022
Shandong	5.69	6.02	6.58
Jiangsu	6.85	7.13	7.13
Zhejiang	7.45	8.01	8.22
Fujan	3.97	4.72	7.53
Shanghai	5.21	5.31	5.37
Guangdong	8.21	8.48	8.81
Liaoning	9.85	9.25	10.87
Jilin	9.16	3.16	4.40
Heilongjiang	3.28	2.61	3.06
Henan	2.50	2.94	3.39
Hubei	4.53	5.24	5.79
Hunan	4.86	5.14	5.62
Jiangxi	4.61	5.17	4.65
Shanxi	3.50	3.33	3.86
Gansu	3.02	1.99	2.32
Qinghai	1.75	1.88	2.20
Ningxia	1.59	2.01	2.36
Xinjiang	1.75	1.10	1.42
Tibet	1.63	3.99	4.36
Sichuan	1.10	3.39	4.34
Yunnan	4.17	2.61	2.95
Guizhou	2.91	2.61	2.84

Fig. 6 exhibits the percentage of innovation rate in 23 provinces of China during the years 2018, 2020, and 2022. The mean innovation rate for 2018, 2020, and 2022 is 4.4%, 4.7%, and 5.2%, respectively. According to recent data, Guangdong, Zhejiang, and Shanghai are the provinces exhibiting the highest levels of innovation in the year 2022. According to the data collected in 2022, Tibet, Gansu, and Qinghai are the provinces that show the lowest rate of innovation. On average, there was an 18.2% increase in the rate of innovation between the years 2018 and 2022. The escalation in the rate of innovation can be ascribed to a multitude of factors, including the accessibility of resources, favorable governmental policies, institutional backing, and investment in research and development. The acceleration of innovation can result in the expansion of the digital economy and the advancement of the manufacturing sector, ultimately propelling economic progress and growth.

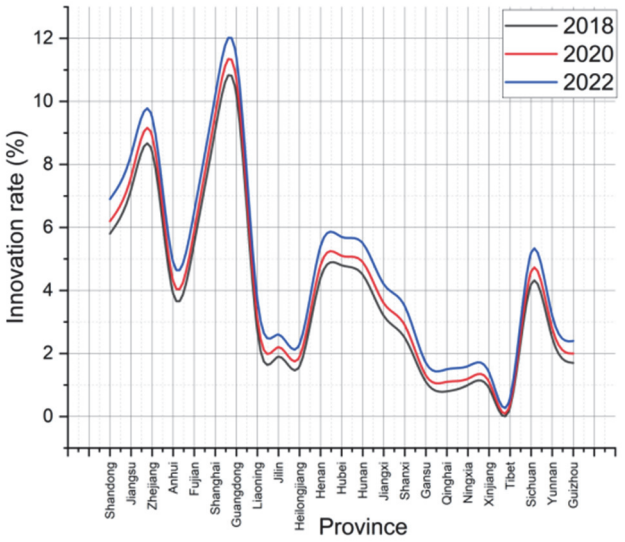


Figure 6 Innovation rate analysis of the 23 provinces in China

Table 3 Total factor productivity growth rate analysis

Province	Total productivity rate / %
Shandong	2.38
Jiangsu	2.78
Zhejiang	3.49
Anhui	1.99
Fujian	2.54
Shanghai	28.6
Guangdong	3.23
Liaoning	1.51
Jilin	1.42
Heilongjiang	1.04
Henan	2.09
Hubei	2.20
Hunan	2.27
Jiangxi	1.89
Shanxi	1.62
Gansu	0.93
Qinghai	0.82
Ningxia	1.02
Xinjiang	0.75
Tibet	0.45
Sichuan	2.57
Yunnan	1.72
Guizhou	1.54

The growth rate of total factor productivity growth rate across multiple provinces in China during the period spanning from 2018 to 2022 is plotted in Fig. 7. To evaluate the impact of the digital economy and entrepreneurship on the high-quality growth of the manufacturing industry, the study used an MCDM evaluation system. Direct and indirect variables, including the number of patents, investment in research and development, and internet utilization, influenced the outcomes. In 2022, Shanghai, Guangdong, and Zhejiang

demonstrated a persistent trend of exhibiting the most elevated rate of innovation, with figures of 10.2%, 11.4%, and 9.5%, respectively. Zhejiang, Guangdong, and Shanghai showed the most substantial average increase in total factor productivity growth rate from 2018 to 2022, with 34.9%, 28.6%, and 32.3%, respectively. According to research findings, the digital economy and entrepreneurial activities have a significant impact on manufacturing sector advancement, with the potential to drive significant economic growth and overall progress.

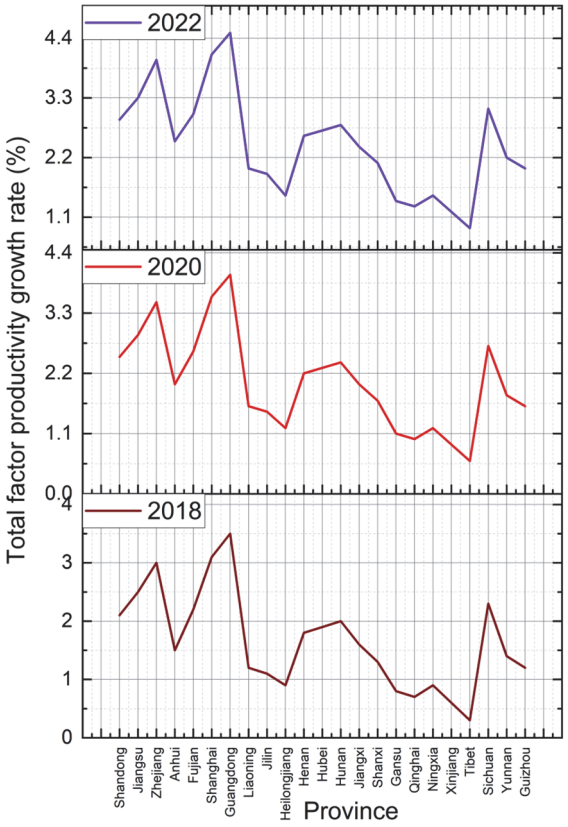


Figure 7 Total factor productivity growth rate analysis

Table 4 Export ratio analysis

Province	2018	2020	2022
Shandong	30.7	33.1	35.1
Jiangsu	37.0	39.5	42.2
Zhejiang	40.9	43.0	45.4
Fujan	20.5	21.9	23.8
Shanghai	30.9	33.2	35.1
Guangdong	46.6	48.9	50.8
Liaoning	37.3	39.8	42.6
Jilin	25.1	26.8	28.4
Heilongjiang	17.8	19.9	21.1
Henan	16.0	17.7	18.9
Hubei	17.6	18.8	20.1
Hunan	13.8	15.3	16.5
Jiangxi	16.2	17.6	19.3
Shanxi	14.1	16.0	17.5
Gansu	9.8	10.8	11.7
Qinghai	5.12	6.29	6.29
Ningxia	4.92	5.67	5.67
Xinjiang	5.55	5.76	6.0
Tibet	6.06	6.2	6.8
Sichuan	5.02	5.12	5.12
Yunnan	12.6	13.21	14.26
Guigzhou	7.97	8.7	9.12

The export ratio of different provinces in China during the years 2018, 2020, and 2022 is represented in Fig. 8. The area of Zhejiang exhibited the highest export ratio across all years, with a notable increase from 40.2% in 2018 to 45.1% in 2022. In 2022, Shanghai experienced a rise in export ratio from 46.8% in 2018 to 51.2%, positioning it as the second-highest. The province of Guangdong experienced a notable surge in percentage, ascending from 36.2% in 2018 to 42% in 2022. Between 2018 and 2020, there was an average increase of 4.06% in the export ratio across all provinces. Between 2020 and 2022, there was an average increase of 4.01% in the export ratio. The enhanced export ratios can be ascribed to the government's endeavors in stimulating the digital economy and entrepreneurship, along with the superior standard development of the manufacturing sector in China. The results have amplified output and enhanced competitiveness in the international marketplace, yielding favorable effects on the nation's economy.

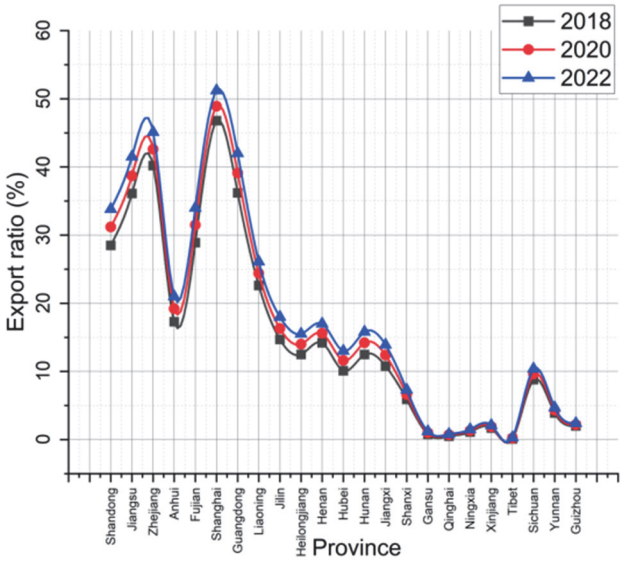


Figure 8 Export ratio analysis of the 23 provinces in China

Table 5 Industry digitization level analysis

Province	2018	2020	2022
Shandong	59.0	60.7	62.2
Jiangsu	72.6	70.7	73.7
Zhejiang	76.1	75.0	77.8
Fujan	51.7	48.4	51.0
Shanghai	57.1	57.7	59.7
Guangdong	91.0	86.7	85.0
Liaoning	63.8	65.1	68.5
Jilin	47.1	46.2	48.2
Heilongjiang	41.5	41.5	41.5
Henan	34.9	34.8	36.2
Hubei	46.0	44.3	47.3
Hunan	51.0	51.0	52.7
Jiangxi	46.2	46.2	48.0
Shanxi	43.0	43.0	45.0
Gansu	42.8	42.8	42.8
Qinghai	28.1	28.1	28.1
Ningxia	27.2	27.2	27.2
Xinjiang	34.1	34.1	34.1
Tibet	21.8	21.8	19.6
Sichuan	11.4	10.1	7.7
Yunnan	35.8	35.9	38.4
Guizhou	28.5	28.5	28.5

The degree of industry digitization across multiple provinces in China during 2018, 2020, and 2022 is shown in Fig. 9. According to the latest data, Shanghai, Zhejiang,

and Jiangsu are the areas with the highest level of industry digitization in 2022, with percentages of 77.2%, 73.2%, and 71.1%, respectively. In 2022, the mean level of digitization across all provinces within the industry was 51.9%, indicating a notable rise from the corresponding figure of 43.7% in 2018. The observed enhancement can be ascribed to diverse determinants, including governmental strategies, allocation of resources towards research and innovation, and the integration of innovative technology. Utilizing an MCDM evaluation system facilitated identifying provinces requiring attention to enhance their level of industry digitization. The findings of this research hold significant implications for policymakers, entrepreneurs, and investors as they seek to discern regions that exhibit promising prospects for investment and growth.

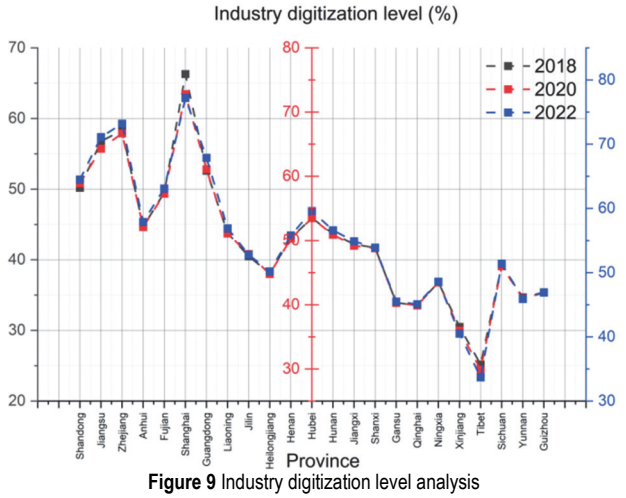


Figure 9 Industry digitization level analysis

Table 6 Labor productivity growth rate analysis

Province	2018	2020	2022
Shandong	52.8	66.6	81.5
Jiangsu	52.2	67.5	81.8
Zhejiang	42.8	54.7	65.6
Fujan	36.5	46.3	57.2
Shanghai	33.2	42.4	54.4
Guangdong	33.4	43.2	53.8
Liaoning	61.9	73.4	85.2
Jilin	49.4	64.2	78.7
Heilongjiang	22.2	29.7	37.7
Henan	16.9	24.6	32.6
Hubei	12.5	19.2	25.1
Hunan	12.4	49.8	60.8
Jiangxi	36.7	47.5	59.1
Shanxi	34.4	45.6	57.7
Gansu	28.8	37.9	47.5
Qinghai	22.2	31.6	40.9
Ningxia	8.71	15.5	21.8
Xinjiang	6.97	18.3	25.3
Tibet	12.4	18.5	29.71
Sichuan	13.8	21.4	29.7
Yunnan	5.57	11.1	50.5
Guizhou	24.8	33.2	40.7

The percentage growth rate of labor productivity across various provinces of China during 2018, 2020, and 2022 is depicted in Fig. 10. The data indicates that most provinces have experienced an upward trend in labor productivity growth rate as time has progressed. In 2018, Shanghai exhibited the most substantial growth rate of 5.8%, which escalated to 7.2% in 2022. Conversely, Tibet demonstrated the least growth rate of 2.3% in 2018, increasing to 3% in 2022. The provinces of Shanghai, Shandong, Jiangsu, Zhejiang, and Guangdong exhibit high levels of labor productivity growth rate. These provinces are recognized as some of the most developed regions in China. The provinces of Tibet, Gansu, Qinghai, Ningxia, and Guizhou, which exhibit lower performance levels, are situated in China's Western and Central regions. Relatively lower levels of development characterize these regions. The enhancement in the growth rate of labor productivity can be ascribed to several factors, including technological progress, augmented investment in infrastructure and education, and implementation of government policies to foster economic growth. The findings of this research suggest that the expansion of the digital economy and entrepreneurial activities favorably influence the superior development of the manufacturing sector in China.

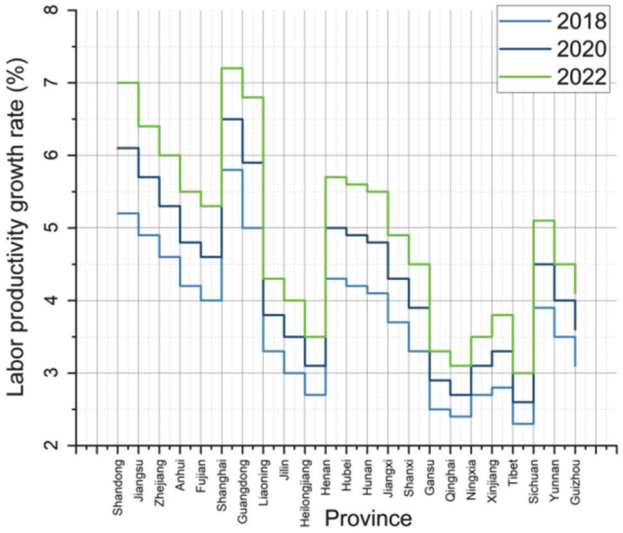


Figure 10 Labor productivity growth rate analysis

The rate of digitalization has exhibited an upward trend across all provinces, with Shanghai emerging as the frontrunner with a rate of 75.1% in the year 2022. Likewise, there has been a rise in the rate of innovation across all provinces, with Guangdong exhibiting the highest rate of innovation at 11.4% in the year 2022. The total factor productivity growth rate has increased across all areas, with Zhejiang province recording the highest growth rate of 4% in 2022. The export ratio has increased across all regions, with Jiangsu province recording the highest export ratio of 40.1% in 2022. Coordination expenses have reduced across all areas, with Yunnan exhibiting the most significant decline of 6.4% in 2022. The level of coordination efficiency has shown an upward trend across all provinces, with Shanghai recording the highest efficiency rate of 74.1% in the year 2022. The government's successful implementation of technological advancements and policies has led to increased efficiency and productivity in various sectors, as evidenced by the improvements in the digitalization rate, innovation rate, total factor productivity growth rate, export ratio, logistics cost, and logistics efficiency in all provinces.

5 CONCLUSION AND FUTURE SCOPE

The development of the digital economy, entrepreneurship, and the manufacturing industry's high-

quality growth have emerged as pivotal domains for China's economic progress. China has made significant progress in digitalization, innovation, and total factor productivity growth rates, as evidenced by their rapid increase. According to the MCDM analysis, it can be inferred that Zhejiang, Shanghai, and Guangdong provinces exhibit the highest mean values across all metrics. This suggests these regions are at the forefront of digitalization, innovation, and productivity enhancement. The experimental findings presented herein illustrate the influence of said factors on the economic development of a given locality.

Nevertheless, there exist specific concerns that require attention in this domain. Certain provinces, namely Tibet, Xinjiang, and Qinghai, exhibit suboptimal performance across all three metrics, implying that further efforts are required to enhance their digitalization, innovation, and productivity levels. Moreover, a disparity in academic performance exists across different provinces, indicating the need for governmental interventions to mitigate the gap.

Future investigations may concentrate on discerning the fundamental causes for the discrepancies observed among the different provinces and determining the optimal approaches for fostering digitalization, innovation, and productivity within the manufacturing sector. By resolving these concerns, China can persist in advancing a more ecologically sound and pioneering economy, attain superior standards of development within the manufacturing sector, and enhance the general welfare of its populace.

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