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Measurement and Evaluation of Digital Technology Development Levels in the Three Northeastern Provinces

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Abstract: This paper constructs a comprehensive evaluation index system including three dimensions of digital infrastructure construction, digital technology industry development and digital technology innovation ability. It uses the entropy weight method to measure and evaluate the digital technology development level of the three northeastern provinces from 2015 to 2022. It is found that Liaoning Province has a relatively higher level of digital technology development, and Heilongjiang and Jilin Provinces are relatively backward, but also show a slow growth trend. The differences among the three provinces reveal their unique paths and challenges in digital technology development, and there is also a large gap between the overall level of digital technology development in the Northeast and that of other regions in China, based on which recommendations are made with the aim of promoting the balanced development of digital technology and economic revitalization in the Northeast.

1. Introduction

Technological innovation, especially the development of digital technology, is an important pillar for the comprehensive revitalization and development of industry. Driven by the wave of digitalization, the three northeastern provinces, as important old industrial bases in China, are in a critical period of industrial transformation. In recent years, the three northeastern provinces have been committed to realizing the transformation and upgrading of traditional industries and economic revitalization through the development of digital technology. Due to the differences in history, geography and economic structure, the development of their digital technology has shown different characteristics and trends, but the three provinces are still facing a lot of challenges in terms of the degree of integration between digital technology and the real economy, and the ability to innovate key core technologies [1]. This paper will measure the level of digital technology development in the three provinces and analyze their performance and problems in the digitization process, with a view to providing suggestions for digital technology development and regional economic revitalization in the Northeast.

2. Measurement and Evaluation of the Level of Digital Technology Development in the Three Northeastern Provinces

2.1 Data Sources and Measurement Methods

The datas are from the Statistical Yearbook of Liaoning Province, Statistical Yearbook of Jilin Province, Statistical Yearbook of Heilongjiang Province as well as the EPS database from 2015 to 2022, and entropy weigh method is used to determine the weights of the evaluation indexes, in order to objectively reflect the importance of the indexes in the comprehensive evaluation, to effectively reduce the impact of the subjective judgments on the evaluation results. Its core lies in the utilization of the principle of information entropy, which determines the weights of the indicators through their own data distribution, ensuring the scientific and rational nature of the evaluation process.

(1) The indicators selected in this paper are all positive indicators, and the normalization process for the whole indicator is as follows:

$$x'_{ij} = \frac{X_{ij} - \min(X_{ij})}{\max(X_{ij}) - \min(Xij)} \tag{1}$$

where i represents the province and j represents the selected indicator.

(2) Calculate the weight of the value of the ith indicator under the jth indicator:

$$p_{ij} = \frac{x'_{ij}}{\sum_{i=1}^{m} x'_{ij}(x'_{ij} > 0)} \tag{2}$$

where m stands for the number of provinces.

(3) Calculate the entropy value of the jth indicator:

$$e_j = -k\sum_{i=1}^{n} p_{ij}\ln(p_{ij}),\ j = 1,...,m \tag{3}$$

where k is the adjustment factor, $k = \frac{1}{\ln(m)}$, e_j is the information entropy value, $0 \leq e_j \leq 1$.

(4) Calculate the information entropy redundancy (variance):

$$e_j = 1 - e_j,\ j = 1,...,m \tag{4}$$

where the greater the variability, the lower the entropy value and the greater the impact on the evaluation object.

(5) Calculate the composite score for each sample:

$$s_i = \sum_{j=1}^{m} w_j x_{ij}, i = 1,...,n \tag{5}$$

2.2 Indicator System Construction

This paper selects three dimensions of digital infrastructure construction, digital technology industry development and digital technology innovation ability to construct the evaluation index system of digital technology development level [2]. The weights of the measured indicators are shown in Table 1.

Table 1: Indicator system for evaluating the level of digital technology development

Level 1 Indicators	Secondary indicators	Unit	Secondary indicator weights
Digital infrastructure construction	Length of long distance fiber optic cable lines	Million kilometers	0.024
	Number of Internet broadband access ports	Million	0.037
	Number of Internet domain names	Million	0.084
	Number of IPv4 addresses	Million	0.087
	Mobile Phone Penetration Rate	Departments/Hundred	0.016
Digital technology industry development	Number of employees in information technology services	Ten thousand people	0.073
	Total telecommunications business per capita	Yuan/person	0.080
	Total postal business per capita	Yuan/person	0.039
	Software business revenue as a share of GDP	%	0.086
	Enterprise e-commerce turnover	Billions of dollars	0.078
	Digital Inclusive Finance Index	Million	0.015
Digital technology innovation ability	R&D Expenditures of Industrial Enterprises Above Scale	Ten thousand yuan	0.078
	Number of R&D projects of industrial enterprises above designated size	Item	0.093
	Total amount of technology contracts	Million	0.119
	Number of Patent Applications Authorized	Item	0.091

2.3 Analysis and Evaluation of Measurement Results

The measured value of digital technology development and the trend of the data are shown in Figure 1.

From the comprehensive evaluation value of the development level of digital technology in the three northeastern provinces from 2015 to 2022 in the figure, it can be seen that the development level of digital technology in the three northeastern provinces in the past eight years has been improved, and the gap in the development of digital technology has shown a trend of narrowing. Among them, Liaoning Province has the highest development level of digital technology, followed by Heilongjiang Province and Jilin Province. In the past eight years, the annual average of the comprehensive value of the level of digital technology development in Liaoning Province was 0.119, showing a steady improvement, which has been in the leading position, and the comprehensive evaluation index in 2019 and 2020 exceeded the average level. Jilin and Heilongjiang provinces have similar levels of digital technology development, both of which have almost doubled from 2015 to 2020, and the average of the comprehensive value of the level of digital technology development is 0.068 and 0.069, respectively, but there is still a large gap compared with Liaoning province, indicating that Liaoning province has a relatively higher level of

economic development, and the government has invested relatively more in and paid more attention to the development of digital technology.

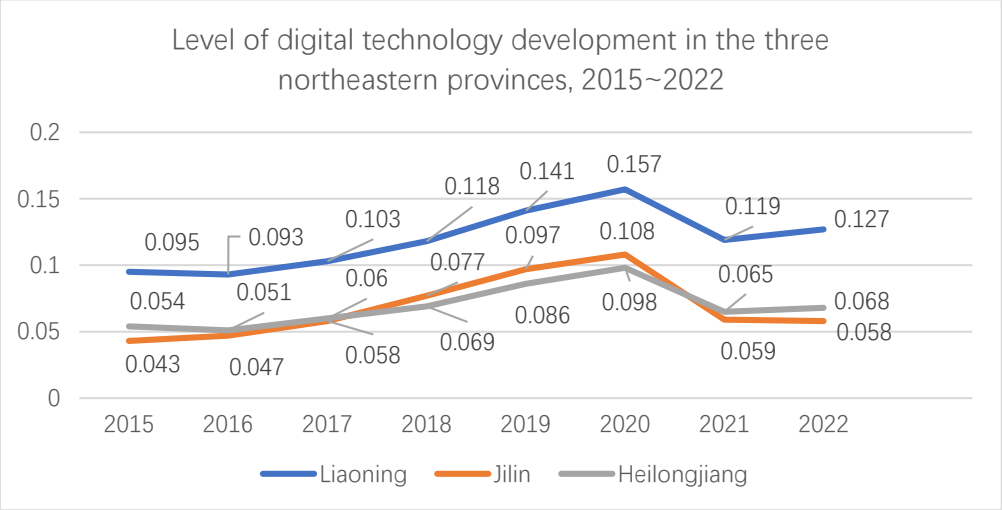

Figure 1: Level of digital technology development in the three northeastern provinces, 2015~2022

Jilin and Heilongjiang provinces also attach great importance to the development of digital technology. Jilin province is focusing on accelerating the development process of digital technology, although it has been in a lagging situation from 2015 to 2017, but through continuous development, it surpassed Heilongjiang province in 2018.The level of digital technology development in the three provinces in 2021 and 2022 declined relative to the previous years because of the economic downturn after the epidemic, and the economic recovery of the three provinces still needs time, but the Jilin province and Heilongjiang province's digital technology development level rebounded in 2022, and it can be predicted that after the adjustment in Jilin Province, the digital technology development level of the three provinces will still steadily increase in the future with the economic development.

2.4 Comparative Analysis with Control Cities

This section selects cities with similar economic development levels to the three northeastern provinces in recent years to compare the level of digital technology development with the three provinces. The cities are selected based on the total annual GDP [3]. Through data comparison, Tianjin is selected for comparison with the three provinces, and eight of them are also selected. The annual digital technology development level and average estimates are shown in Table 2.

Table 2: Comparison of the Development Level of Digital Technology between the Three Northeastern Provinces and Tianjin City

Area	2015	2016	2017	2018	2019	2020	2021	2022	Average
Tianjin	0.073	0.075	0.081	0.107	0.142	0.173	0.126	0.132	0.114
Liaoning	0.095	0.093	0.103	0.118	0.141	0.157	0.119	0.127	0.119
Jilin	0.043	0.047	0.058	0.077	0.097	0.108	0.059	0.058	0.068
Heilongjiang	0.054	0.051	0.060	0.069	0.086	0.098	0.065	0.068	0.069

Before 2019, the level of digital technology development in Tianjin was lower than that of Liaoning Province, and the average development level mean in recent years was also slightly lower than that of Liaoning, but its development level after 2019 was higher than that of the three northeastern provinces, and the starting value of the data was not low, and the growth rate was fast.

Even in the period of economic downturn after the epidemic in 2020, its development level has been higher than that of the three provinces, indicating that the development level of digital technology in Tianjin has great strength and potential. In recent years, Tianjin has gradually developed into a new first-tier city, and compared with the three northeastern provinces, there is a large gap in the level of digital technology development. Jilin and Heilongjiang provinces, in particular, still have much room for development and urgently need to adjust their policies and emphasize the development of digital technology to narrow the gap with the more developed cities, while Liaoning province should continue to increase its investment to consolidate and expand its leading position in the development of digital technology.

3. Current Status and Existing Problems of Digital Technology Development in the Three Northeastern Provinces

The development of digital technology in the three northeastern provinces has its own characteristics, reflecting the different strategies and advantages of the three provinces in promoting economic revitalization and industrial transformation and upgrading.

3.1 Current Status and Existing Problems of Digital Technology Development in Liaoning Province

Liaoning Province performs outstandingly in digital infrastructure construction. Liaoning Province has vigorously promoted the construction of 5G networks. As of the end of 2022, the number of 5G base stations has increased to 71,000. At the same time, it has made remarkable achievements in the industrial Internet identification analysis system and achieved province-wide coverage. In 2022, the province's industrial added value growth will pick up, and the gap with the country will narrow. Industrial investment will increase by 6.1% year-on-year, and investment in industrial technological transformation will increase by 18.3%, which is 9.2 percentage points higher than the national average. Liaoning Province has also launched a series of policies, such as providing financial support to enterprises in core industries of the digital economy and encouraging the development of market entities. Especially in terms of the penetration rate of digital R&D and design tools, it has reached 77.2%, exceeding the national average. These measures not only improve the digital infrastructure of Liaoning Province, but also lay a solid foundation for the development of industrial digitalization. However, from a national perspective, Liaoning Province's overall technological innovation capabilities are at the mid- to downstream level, the digital industry has not formed a complete industrial chain, and the digital industry integration capabilities need to be strengthened [4]. At the same time, there is a serious shortage of digital technology R&D investment compared to big cities, and the attraction to digital talents is decreasing year by year.

3.2 Current Status and Existing Problems of Digital Technology Development in Jilin Province

Jilin Province has performed outstandingly in promoting the deep integration of digital technology and the real economy. Jilin Province has released relevant policy plans aimed at promoting the deep integration of digital technology and the real economy through digital government construction. In order to realize agricultural modernization, Jilin Province has strengthened the application of digital technology in the agricultural field through platforms such as "Jinong Cloud" and "Jinong Ma", promoted integrated solutions, and promoted the construction of a beef cattle big data breeding system. A national-level livestock breeding source gene bank has been created; for industrial transformation and upgrading, Jilin Province has implemented an

intelligent manufacturing demonstration project to promote the automobile industry to comprehensively improve the digitalization level of the industrial chain; in the field of medical services, Jilin Province has established a four-level network covering provinces, cities, counties and townships. A new telemedicine network has formed a new service pattern with accessible services, standardized management, and people's satisfaction. The integration of digital technology and the real economy is a powerful driving force for the economic revitalization of Jilin Province. Nonetheless, the province faces several challenges, including an incomplete digital infrastructure layout, a scarcity of digital transformation services catering to small, medium, and micro enterprises, as well as inadequate scenarios for the sharing and utilization of the province's governmental, public, and social data.

3.3 Current Status and Existing Problems of Digital Technology Development in Heilongjiang Province

Heilongjiang Province has abundant data resources and has outstanding performance in exploring the open sharing of data resources. The Heilongjiang Provincial Government has issued a series of policy documents called the "Heilongjiang Province's "14th Five-Year Plan" Digital Economy Development Plan", which provides legal and policy support for the open sharing of data resources and clarifies the guiding ideology, and proposes to stimulate the value of data elements, release the potential of data elements [5]. Suihua City Big Data Center is the first digital base in Heilongjiang Province with the core of data resource aggregation and sharing. By strengthening data aggregation and integration, it forms an integrated data system, realizes data sharing, flow, openness and utilization, and improves government efficiency, administrative effectiveness and public service levels. Heilongjiang Province actively promotes data sharing and deepens the collection, management and sharing of public data. It has released 3,975 provincial data catalogs and 18,000 municipal (prefecture) data catalogs, basically forming a "one ledger" for the province's government data resources. The open sharing of data resources and business collaboration have laid the foundation. However, most of the digital industries in Heilongjiang Province are stuck in the data storage stage, and the amount of data storage is very small. They are relatively weak in data collection and processing. Also, they are at the end of the added value of the industrial chain and lack high-end technology enterprises for data analysis and processing.

4. Conclusion

This study comprehensively measures and evaluates the digital technology development level of the three northeastern provinces, revealing the advantages and existing problems of each province in digital technology development. The digital technology development level of Liaoning Province is higher than that of Jilin Province and Heilongjiang Province. And overall, the level of digital technology development in the three northeastern provinces still lags far behind regions with higher levels of economic development. Therefore, the three northeastern provinces still need to pay attention to the construction of digital infrastructure, accelerate the construction of big data centers for the industrial chain, realize the collection and sharing of important information in various industries, and lay a solid foundation for the digital innovation and integrated development of the industry; and continue to increase investment in scientific and technological innovation, cultivate high-quality talents; coordinate the balanced development of production factors through policy guidance, optimize the regional industrial structure, and promote the development of industrial digitalization. In summary, it is hoped that the above measures can provide certain reference value for the development of digital technology in the three northeastern provinces and help the development of digital technology in the Northeast region.

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