Comparison of Digital Economy Efficiency and Input Redundancy in China Based on DEA Model

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Abstract: Based on identifying the scope of industries of the digital economy, the article constructs a digital economy efficiency evaluation index system with reference to the theory of three factors of production and the “Classifications of Statistics of Digital Economy and Its Core(2021)”, selects the CCR-DEA, BBC-DEA and Malmquist-DEA models to measure the digital economy efficiency of 30 provinces and cities in China from 2013 to 2020 in two dimensions, static and dynamic, respectively; and the input redundancy of 30 provinces and cities are classified and compared. The study finds that: first, most of the 30 provinces and cities in China are inefficient during the study period, so there is still much room for improvement. Second, total factor productivity (TFP), in general, is increasing in an "M" shape, and it is mainly due to the increase of the technological progress index. Third, only 8 provinces and municipalities are zero redundancy areas, so the remaining provinces and municipalities still need to make corresponding policy adjustments according to their own conditions to guide the quality allocation of regional resources.

Keywords: Digital Economy Efficiency, Malmquist-DEA, DEA model, Input redundancy.

1 Introduction

In recent years, the rapid development of a new generation of information technology, represented by the Internet, big data, and cloud computing, has given birth to the digital economy and opened the digital era. According to the "White Paper on the Development of China's Digital Economy" released by China ICT, the scale of China's digital economy has expanded from 2.6 trillion yuan in 2005 to 39.2 trillion yuan in 2020, and the proportion of the digital economy in GDP has also increased from 14.2% to 38.6%, and in 2020, the growth rate of the digital economy is more than 3.2 times the nominal growth rate of GDP in the same period1. As the new round of technological revolution and industrial change continues to

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advance, coupled with the impact of epidemic factors, the digital economy has become a powerful support to promote China's economic "double cycle" development pattern, which has become one of the most core growth poles in the entire national economy.

With the role of the digital economy highlighted, scholars, politicians, research institutions and other people from all walks of life at home and abroad have started to interpret the digital economy from different perspectives. The author divides the domestic and foreign research on digital economy into the following three major parts. One is to study the development of regional digital economy: Sumit Kumar Maji (2020) studied the digital economy development in 43 Asia-Pacific countries from 2012 to 2017, and the findings show that there are significant differences in the use, access and overall digital economy in Asia-Pacific countries, confirming the prevalence of digital inequality [1]; Second, to explore the impact of the digital economy: Yongmin Chen (2020) points out that the digital economy has greatly reduced market frictions, but also poses new challenges to the effective operation of the market [3]; Third, to explore the measurement of digital economy:

Jingfei Wu and Xiaoyue Wang (2022) used the entropy weight method to construct digital economy development evaluation indicators with 18 indicators in four dimensions: digital product manufacturing industry, digital product service industry, digital technology application industry and digital factor-driven industry, and measured the digital economy development of 30 provinces in China [5].

Studies on the digital economy measure can be seen that whether it is the direct method of delineating the scope of digital economy and counting or estimating the total value added of digital industry sectors within the scope, or the comparative method of constructing an indicator system and evaluating the relative situation of the development level of digital economy through multi-dimensional indicators, the attention of many scholars is more on the measurement of the output level of digital economy. Research on the output efficiency of digital economy is rare. Therefore, the author starts from the perspective of efficiency and chooses the input-oriented DEA model to measure the development level of digital economy in China's provinces and cities, analyzes the efficiency of digital economy, the change of the year and explores whether the digital economy is input redundant, in the hope of contributing to the healthy development of digital economy.

2 Study design1.research methodology

2.1 Research Methodology

The DEA model is often used to measure efficiency because it does not need to specify the form of production function and distribution hypothesis; it does not need to assign weights to indicators and also does not need dimensionless processing of data. Therefore, this paper selects CCR-DEA, BC-DEA and Malmquist-DEA models to measure the digital economy efficiency of 30 provinces and cities in China during 2013-2020 from static and dynamic dimensions respectively; and selects a two-dimensional matrix analysis method to construct the combination of “capital redundancy ratio-labor redundancy ratio”.

2.2 Indicators and data

Selection of indicators: Based on say's theory of three factors of production, the author determines the core industry selection index of digital economy. First, according to the characteristics of digital economy, the "land" dimension of the three elements is merged into the "capital" dimension. Therefore, there are two input dimensions of capital and labor. Then, the core industries of "Classifications of Statistics of Digital Economy and Its Core (2021)" are studied, including Manufacture of Communication Equipment, Computers and Other Electronic Equipment, Telecommunications, Broadcasting Television and Satellite Transmission Services, Internet and related Services, Software and Information Technology Services. Therefore, in this paper, the fixed asset inputs of these four categories of industries are designated as capital inputs; their employed persons are selected as labor inputs; then the output level of the digital economy is selected as the output variable. However, because there are artificial and subjective factors in defining the added value of digital economy in each province and city, which lacks objectivity. The article draws on the method of Chang Cai, that is, the real GDP, which is strongly correlated with the development level of digital economy in each province and city, is chosen as the output indicator [6].

Data processing: In order to eliminate the influence factor of price, 2013 is set as the base year, and then the nominal GDP of each province is deflated; and the amount of capital investment in fixed assets is processed at comparable prices according to the GDP deflator. So we can use 2003 as the base year to obtain the real GDP and investment amount of each fixed asset of each province. In addition, due to the availability of data, Tibet, Hong Kong, Macau, and Taiwan are not included in the scope of this article, and the research object of this article is 30 provinces and cities in China except the above-mentioned provinces and cities.

3 Results and analysis

3.1 Descriptive statistics of digital economy inputs and outputs in 30 provinces and cities

Table 1 shows the descriptive statistics of the indicators in 30 provinces and cities, and Figures 1 and 2 show the trends of the digital economy inputs and outputs of 30 provinces and cities in China from 2013 to 2020, taking 2013 as the base period. As can be seen from Figures 1 and 2, the most significant upward movement in the input of the digital economy is in the fixed asset investment in Internet and related services; the fluctuating growth in Telecommunications, Broadcasting Television and Satellite Transmission Services; the slight decrease in fixed asset investment in Manufacture of Communication Equipment, Computers and Other Electronic Equipment; and the steady growth in the rest. It is obvious from Figure 3 that the growth of capital input is significantly higher than the growth of labor input. From Table 1, we can also see that the digital economy input and output of 30 provinces and cities in China vary greatly. Meanwhile, the research results of many scholars such as Jun Liu [2], Fang Liu [4], and Yan Li [7] also tell us that the level of digital economy development among provinces and cities in China is uneven. The above chart is only a simple statistic at the national, provincial and municipal levels for each index of digital economy evaluation. And the following is a specific analysis of the differences and input redundancy (slack) through the panel data of 30 provinces and cities in China from 2013 to 2020.

Table 1 Descriptive statistics of evaluation indicators.

Indicator Name	Indicator Unit	Average value	Standard deviation	Maximum value	Minimum value
Real GDP	billion yuan	26745.25	21552.19	111151.60	1713.30
Capital Investment	million yuan	4563265.55	4678233.17	28073775.10	139352.00
Labor input	10,000 people	40.64	71.51	401.68	0.80

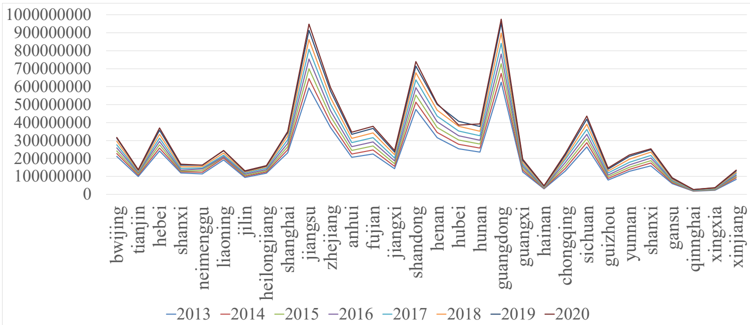

Figure 1 Real GDP of 30 Chinese provinces and cities from 2013 to 2020.

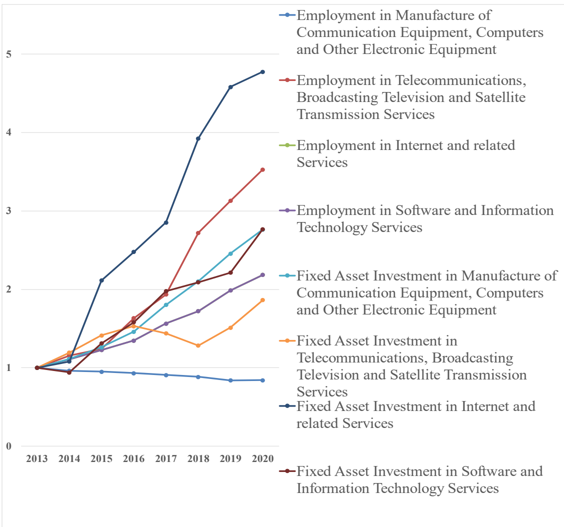

Figure 2 National Digital Economy Inputs from 2013 to 2020 – Classification.

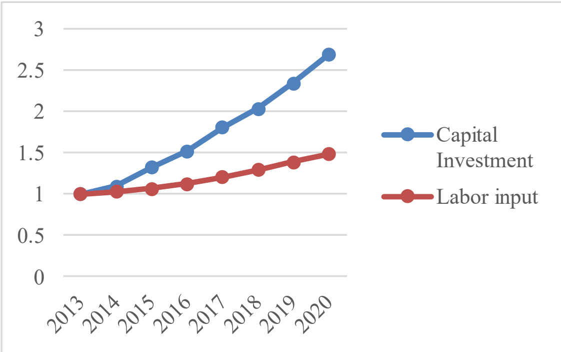

Figure 3 National Digital Economy Inputs from 2013 to 2020 – Total.

3.2 BCC-DEA and Malmquist-DEA model results

BCC-DEA model results and analysis: The BCC model of DEAP software will have four items: comprehensive technical efficiency (TE), pure technical efficiency (PTE), scale efficiency (SE) and scale gain change. TE is divided into two parts, PTE and SE, which integrally reflect the allocation ability and use efficiency of digital economy resources in 30 Chinese provinces and cities. Tables 2, 3 and 4 show the combined TE, PTE and SE of the digital economy in 30 Chinese provinces and cities from 2013 to 2020. From the three tables, it can be seen that Guizhou has a constant TE, PTE and SE of 1 during 2013-2020, i.e., the digital economy inputs are fully utilized in Guizhou province.

Table 2 Technical efficiency of the digital economy in 30 Chinese provinces and cities from 2013 to 2020.

Year / Region	2013	2014	2015	2016	2017	2018	2019	2020
Beijing	0.364	0.364	0.364	0.364	0.364	0.364	0.364	0.364
Tianjin	0.214	0.214	0.23	0.27	0.271	0.273	0.28	0.272
Hebei	0.629	0.557	0.604	0.629	0.633	0.701	0.721	0.699
Shanxi	0.497	0.497	0.497	0.497	0.5	0.497	0.507	0.497
Neimenggu	0.699	0.812	0.727	0.811	0.753	0.799	0.993	0.925
Liaoning	0.419	0.407	0.414	0.426	0.438	0.455	0.448	0.434
Jilin	0.531	0.521	0.526	0.546	0.551	0.597	0.686	0.817
Heilongjiang	0.606	0.537	0.51	0.544	0.501	0.537	0.591	0.575
Shanghai	0.375	0.375	0.375	0.375	0.375	0.375	0.375	0.375
Jiangsu	0.164	0.164	0.173	0.191	0.198	0.202	0.209	0.188
Zhejiang	0.462	0.462	0.462	0.489	0.509	0.473	0.494	0.462
Anhui	0.593	0.451	0.414	0.447	0.407	0.391	0.464	0.397
Fujian	0.256	0.255	0.277	0.297	0.304	0.307	0.329	0.331
Jiangxi	0.271	0.225	0.213	0.219	0.211	0.216	0.2	0.191
Shandong	0.448	0.448	0.462	0.496	0.533	0.543	0.586	0.562
Henan	0.282	0.266	0.267	0.273	0.277	0.307	0.293	0.281
Hubei	0.426	0.378	0.343	0.352	0.356	0.356	0.38	0.338
Hunan	0.421	0.415	0.427	0.464	0.405	0.485	0.535	0.482
Guangdong	0.308	0.308	0.308	0.308	0.308	0.308	0.308	0.308
Guangxi	0.397	0.385	0.38	0.396	0.393	0.401	0.434	0.389
Hainan	0.743	0.666	0.653	0.705	0.593	0.582	0.698	0.622

Chongqing	0.27	0.254	0.249	0.251	0.25	0.256	0.25	0.235
Sichuan	0.259	0.25	0.258	0.286	0.288	0.29	0.288	0.256
Guizhou	1	1	1	1	1	1	1	1
Yunnan	0.821	0.93	0.996	1	1	0.98	1	1
Shanxi	0.422	0.442	0.381	0.382	0.374	0.387	0.413	0.371
Gansu	0.58	0.611	0.597	0.628	0.605	0.617	0.609	0.61
Qinghai	0.716	0.767	0.82	0.803	0.809	0.797	0.902	0.787
Ningxia	0.813	0.813	0.861	0.912	0.973	0.922	0.923	0.813
Xinjiang	1	1	1	1	1	1	0.953	1

Table 3 Pure technical efficiency of the digital economy in 30 Chinese provinces and cities from 2013 to 2020.

Year / Region	2013	2014	2015	2016	2017	2018	2019	2020
Beijing	0.731	0.73	0.728	0.726	0.723	0.722	0.72	0.716
Tianjin	0.406	0.406	0.404	0.424	0.416	0.399	0.39	0.388
Hebei	1	1	1	1	1	1	1	1
Shanxi	0.759	0.75	0.733	0.72	0.712	0.705	0.7	0.699
Neimenggu	0.944	0.959	0.895	0.929	0.9	0.948	0.997	0.942
Liaoning	0.725	0.766	0.716	0.69	0.698	0.671	0.645	0.64
Jilin	0.7	0.655	0.621	0.627	0.622	0.694	0.687	0.827
Heilongjiang	0.872	0.784	0.751	0.74	0.698	0.716	0.659	0.653
Shanghai	0.764	0.762	0.76	0.758	0.756	0.755	0.753	0.75
Jiangsu	1	1	1	1	1	1	1	1
Zhejiang	0.991	0.989	0.989	0.989	0.989	0.989	0.99	0.99
Anhui	0.996	0.917	0.889	0.874	0.857	0.74	0.714	0.672
Fujian	0.561	0.593	0.591	0.61	0.584	0.557	0.553	0.587
Jiangxi	0.532	0.524	0.5	0.496	0.469	0.428	0.339	0.339
Shandong	1	1	1	1	1	1	1	1
Henan	0.714	0.701	0.673	0.675	0.672	0.688	0.672	0.664
Hubei	0.889	0.902	0.851	0.834	0.854	0.75	0.634	0.605
Hunan	0.852	0.924	0.965	0.949	0.9	0.881	0.819	0.8
Guangdong	1	1	1	1	1	1	1	1
Guangxi	0.624	0.655	0.618	0.62	0.615	0.563	0.579	0.551
Hainan	0.895	0.736	0.708	0.782	0.64	0.631	0.722	0.662
Chongqing	0.495	0.519	0.496	0.487	0.475	0.435	0.411	0.412
Sichuan	0.603	0.612	0.574	0.62	0.566	0.571	0.577	0.576
Guizhou	1	1	1	1	1	1	1	1
Yunnan	1	1	1	1	1	1	1	1
Shanxi	0.721	0.823	0.764	0.71	0.707	0.649	0.607	0.583
Gansu	0.634	0.643	0.617	0.652	0.618	0.641	0.613	0.614
Qinghai	1	1	1	1	1	1	1	1
Ningxia	1	1	1	1	1	1	1	1
Xinjiang	1	1	1	1	1	1	0.962	1

Table 4 Scale efficiency of the digital economy in 30 Chinese provinces and cities from 2013 to 2020.

Year / Region	2013	2014	2015	2016	2017	2018	2019	2020
Beijing	0.498	0.499	0.501	0.502	0.504	0.505	0.506	0.509
Tianjin	0.526	0.527	0.57	0.638	0.65	0.685	0.718	0.701

Hebei	0.629	0.557	0.604	0.629	0.633	0.701	0.721	0.699
Shanxi	0.655	0.663	0.678	0.691	0.702	0.705	0.724	0.712
Neimenggu	0.741	0.847	0.812	0.873	0.836	0.843	0.995	0.982
Liaoning	0.577	0.531	0.578	0.618	0.628	0.677	0.695	0.678
Jilin	0.759	0.795	0.847	0.87	0.886	0.861	0.998	0.988
Heilongjiang	0.695	0.686	0.679	0.736	0.717	0.751	0.898	0.88
Shanghai	0.491	0.492	0.494	0.495	0.496	0.497	0.498	0.5
Jiangsu	0.164	0.164	0.173	0.191	0.198	0.202	0.209	0.188
Zhejiang	0.467	0.467	0.467	0.495	0.515	0.478	0.499	0.467
Anhui	0.595	0.493	0.466	0.511	0.475	0.528	0.65	0.591
Fujian	0.457	0.43	0.468	0.487	0.521	0.552	0.595	0.564
Jiangxi	0.508	0.429	0.426	0.443	0.45	0.504	0.589	0.564
Shandong	0.448	0.448	0.462	0.496	0.533	0.543	0.586	0.562
Henan	0.396	0.379	0.397	0.405	0.411	0.447	0.436	0.423
Hubei	0.479	0.419	0.403	0.422	0.417	0.475	0.599	0.56
Hunan	0.494	0.45	0.443	0.489	0.45	0.55	0.653	0.602
Guangdong	0.308	0.308	0.308	0.308	0.308	0.308	0.308	0.308
Guangxi	0.636	0.588	0.615	0.639	0.638	0.712	0.75	0.705
Hainan	0.83	0.904	0.922	0.902	0.927	0.922	0.966	0.941
Chongqing	0.546	0.49	0.503	0.514	0.527	0.59	0.609	0.57
Sichuan	0.429	0.408	0.45	0.461	0.508	0.508	0.499	0.445
Guizhou	1	1	1	1	1	1	1	1
Yunnan	0.821	0.93	0.996	1	1	0.98	1	1
Shanxi	0.585	0.537	0.499	0.539	0.529	0.597	0.68	0.637
Gansu	0.915	0.95	0.968	0.963	0.978	0.962	0.993	0.995
Qinghai	0.716	0.767	0.82	0.803	0.809	0.797	0.902	0.787
Ningxia	0.813	0.813	0.861	0.912	0.973	0.922	0.923	0.813
Xinjiang	1	1	1	1	1	1	0.991	1

The TE of Jiangsu, Shandong, Guangdong, Yunnan, Qinghai and Ningxia is less than 1 during 2013-2020, but their PTE is 1, which means that these six provinces are constrained by scale efficiency. Namely, these six provinces have achieved effective management level and technology but their existing scale is not fully utilized so that their TE is less than 1. The other provinces where TE, PTE and SE are not 1 indicate that the TE value is not high because of the dual constraints of PTE and SE.

Taking Guangdong province as an example for specific analysis. Guangdong has a sound market system and a strong industrial base. In addition, the government has joined with enterprises to build a unified government cloud and big data platform, which greatly improves the level and efficiency of government processing. So Guangdong province in terms of management and technical level has excellent performance. Nevertheless, the SE value of Guangdong Province is slightly lower, mainly because of two reasons: first, its self-sufficiency rate of high-end chips is less than 20%. Second, the digital level of traditional industries is low. Therefore, Guangdong Province can start by guiding enterprises to establish high-end digital industries with key core technologies, and promoting traditional industries to digital grid-based intelligent transformation and upgrading in two aspects, so as to promote the growth of SE, thereby promoting the growth of the digital economy.

The digital economy size has a strong correlation with the economic base of provinces and cities. As we can see from the above example, however, this does not mean that the digital economy of large economic provinces has a high resource allocation and utilization rate. So provinces and cities with a small digital economy can learn from and study the development experience of Guangdong and other provinces and cities. They can actively explore replicable experiences, and develop a digital economy development method suitable for their own provinces and cities. Provinces with low digital economic output efficiency can first dig into their own provincial and municipal constraints according to the above table, whether they are PTE constraints or SE constraints, or both. Then, according to the constraints combined with the actual situation of each province and city further propose methods for resource optimization and efficiency improvement. The above is a static analysis of each province and city, and the relative efficiency values are not reflective of their dynamic changes. Therefore, the following is a dynamic measurement of the digital economy of 30 provinces and cities from 2013 to 2020 using the Malmquist-DEA model.

Malmquist-DEA model results and analysis: From Table 5, we can see that the TFP of China's 30 provinces and cities in the development of the digital economy from 2013 to 2020 is in an "M" shaped oscillating rise. Except for a 0.9% decline in the period 2019-2020, the TFPCH has maintained positive growth in the rest of the years, with an overall average annual growth of 1.7%. A detailed analysis of the decline in TFPCH from 2019 to 2020 shows that TECHCH increased by 3.9% and EFFCH decreased by 4.6%. This indicates that the decrease of TFPCH is due to the influence of EFFCH, which can be further divided into PECH and SECH. While in the period 2019-2020 PECH decreases by 0.4% and SECH decreases by 4.2%. So it is said that it is the joint decrease of PECH and SECH that leads to the decrease of EFFCH, which in turn leads to the decrease of TFPCH. From the last row of Table 5, it can be seen that the TFPCH of China's digital economy increased by 12.4%, the EFFCH increased by 2.3%, and the TECHCH increased by 9.8% from 2013 to 2020. Thus it can be seen that the improvement of China's digital economy output efficiency is due to the double growth of EFFCH and TECHCH, especially the contribution of TECHCH.

Table 5 Change in decomposition and mean value of the national Malmquist productivity index from 2013 to 2020.

Year	EFFCH	TECHCH	PECH	SECH	TFPCH
2013-2014	0.976	1.061	0.999	0.976	1.036
2014-2015	0.999	1.044	0.976	1.024	1.043
2015-2016	1.044	0.982	1.005	1.040	1.026
2016-2017	0.988	1.019	0.978	1.010	1.007
2017-2018	1.020	0.988	0.982	1.039	1.008
2018-2019	1.045	0.965	0.977	1.069	1.008
2019-2020	0.954	1.039	0.996	0.958	0.991
Average	1.003	1.014	0.988	1.016	1.017
Cumulative multiplication	1.023	1.098	0.916	1.117	1.124

Table 6 shows the changes of total factor productivity index of digital economy in 30 provinces and cities in China from 2013 to 2020. As can be seen from Table 6, except for Anhui, Jiangxi and Hubei provinces, all the remaining 27 provinces and cities have achieved positive growth in TFPCH of digital economy development, among which five provinces, Jilin, Inner Mongolia, Yunnan, Fujian and Hunan, have increased their TFPCH by more than 30% between 2013 and 2020. And all of them are the result of the joint growth of EFFCH and TECHCH.

Table 6 Malmquist Index of Digital Economy and its Decomposition in 30 Chinese Provinces.

Region \ Type	EFFCH	TECHCH	PECH	SECH	TFPCH
Beijing	1	1	0.977	1.023	1
Tianjin	1.276	1.013	0.955	1.334	1.291
Hebei	1.111	1.064	1	1.111	1.185
Shanxi	1.000	1.026	0.921	1.089	1.025
Neimenggu	1.323	1.214	0.998	1.322	1.604
Liaoning	1.037	1.112	0.884	1.174	1.154
Jilin	1.536	1.063	1.183	1.301	1.639
Heilongjiang	0.948	1.149	0.749	1.266	1.090
Shanghai	1	1	0.981	1.019	1
Jiangsu	1.141	1.004	1	1.141	1.145
Zhejiang	1	1	1	1	1
Anhui	0.670	1.214	0.674	0.991	0.813
Fujian	1.295	1.056	1.047	1.236	1.365
Jiangxi	0.706	1.193	0.636	1.109	0.841
Shandong	1.255	0.981	1	1.255	1.231
Henan	0.994	1.082	0.930	1.070	1.075
Hubei	0.795	1.178	0.680	1.168	0.935
Hunan	1.144	1.187	0.939	1.219	1.356
Guangdong	1	1	1	1	1
Guangxi	0.981	1.122	0.883	1.108	1.100
Hainan	0.839	1.214	0.740	1.134	1.018
Chongqing	0.867	1.155	0.831	1.044	1.003
Sichuan	0.991	1.105	0.956	1.036	1.093
Guizhou	1	1.037	1	1	1.037
Yunnan	1.218	1.138	1	1.218	1.388
Shanxi	0.881	1.216	0.808	1.090	1.073
Gansu	1.051	1.158	0.967	1.089	1.216
Qinghai	1.100	1.140	1	1.100	1.253
Ningxia	0.999	1.033	1	0.999	1.033
Xinjiang	1	1.184	1	1	1.182

3.3 Redundancy analysis of digital economy inputs in 30 Chinese provinces and cities

Based on the BCC-DEA model, the article analyzes the input redundancy of each decision unit in both capital and labor directions. The ratio of the input redundancy of the decision unit to the input of the decision unit is defined as the input redundancy ratio. From Table 7, we can see that the capital redundancy ratio of China's overall digital economy is greater than the labor redundancy ratio. It can be seen from Figure 4 that except for Hebei, Jiangsu, Shandong, Guangdong, Guizhou, Yunnan, Qinghai and Ningxia, which are zero-redundancy areas, the remaining 22 provinces and cities have capital redundancy or labor redundancy. Specifically, Beijing, Shanghai, Shanxi and Zhejiang are low-capital redundancy and high-labor redundancy areas; Tianjin, Xinjiang, Liaoning, Gansu, Fujian, Sichuan, Guangxi, Chongqing and Jilin are low-capital redundancy and low-labor redundancy areas; Henan, Shaanxi, Jiangxi, Heilongjiang, Hubei, Hainan, Hunan, Inner Mongolia, and Anhui belong to high capital redundancy and low labor redundancy areas.

Table 7 Average redundancy of digital economy inputs in 30 provinces and cities from 2013 to 2020.

Capital Redundancy	Redundancy ratio≥12.628%	Neimenggu	Heilongjiang	Anhui	Jiangxi	Henan	
		Hubei	Hunan	Hainan	Shanxi		
	Redundancy ratio＜12.628%	Beijing	Tianjin	Hebei	Shanxi	Liaoning	
		Jilin	Shanghai	Jiangsu	Fujian	Shandong	
		Guangdong	Guangxi	Chongqing	Sichuan	Guzhou	
		Yunnan	Gansu	Qinghai	Ningxia	Xinjiang	
Labor Redundancy	Redundancy ratio≥6.575%	Beijing	Shanxi	Shanghai	Zhejiang		
	Redundancy ratio＜6.575%	Tianjin	Hebei	Neimenggu	Liaoning	Jilin	
		Heilongjiang	Jiangsu	Anhui	Fujian	Jiangxi	
		Shandong	Henan	Hubei	Hunan	Guangdong	
		Guangxi	Hainan	Chongqing	Sichuan	Guizhou	
		Yunnan	Shanxi	Gansu	Qinghai	Ningxia	Xinjiang

Low capital redundancy and low labor redundancy areas, especially zero redundancy areas indicate better resource allocation. Governments in low capital redundancy and high labor redundancy areas can reduce labor redundancy by increasing the input of digital economy and trying to drive more people to engage in digital economy and its related industries. For example, the government can set up special assistance funds, programs or preferential policies in the field of digital economy to provide incentives for redundant labor, consciously guide enterprises or research institutions to carry out basic research, applied research and industrial innovation, develop and break through the "neck" constraints, and enhance independent innovation capabilities.

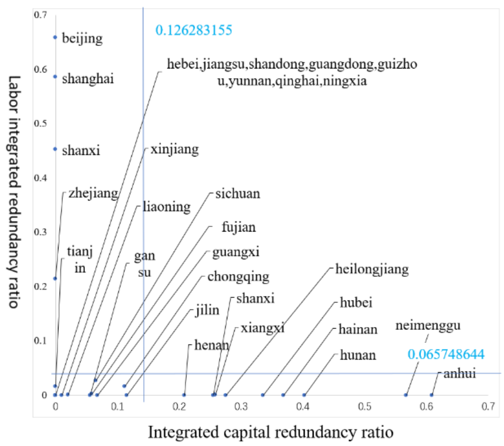

Figure 4 Average input redundancy in the digital economy in 30 provinces and cities from 2013 to 2020.

The focus of the regions with high capital and low labor redundancy should be to rationalize the allocation of capital, which can be used to introduce composite and high-end digital economy talents, thus promoting the rapid development of digital economy. In terms of business environment, the government's financial and taxation policies will be increased to support science and technology parks and enterprises, and research sites, support funds and experimental equipment will be provided for cutting-edge research to support the development of digital economy. In terms of talent introduction, we should expand the introduction of compound talents in digital segmentation verticals through headhunting, social recruitment and internal promotion in a variety of ways, based on the principle of unlimited positions, sources and salaries, and the promotion of industrial development. In addition, regular forums, summits and events with international influence can be held to bring in and retain "high precision" talents continuously.

4 Conclusions

This paper selects the CCR and BCC models from a static perspective and the Malmquist index model from a dynamic perspective to calculate the output efficiency of the digital economy of 30 Chinese provinces and cities from 2013 to 2020, and uses a two-dimensional matrix analysis to classify the digital economy of 30 Chinese provinces and cities according to the level of capital redundancy and labor redundancy.

The static measurement results show that the digital economy in most of the 30 provinces and cities in China during 2013-2020 is located in an inefficient state. Among the provinces and cities in inefficiency six provinces and cities in Hebei, Jiangsu, Shandong, Guangdong, Qinghai, and Ningxia in 2013-2020 and Yunnan in 2013-2015, 2018, and Xinjiang in 2013-2018, 2020 are affected by digital PTE of the digital economy, while the inefficiency of other provinces and cities during the study period is affected by both the PTE of the digital economy and the effect of the SE of the digital economy. There is still more room for improving the efficiency of the digital economy in Chinese provinces and cities. The dynamic results show that the TFP of China's digital economy is in an "M"-shaped oscillatory rise, with the efficiency of China's digital economy increasing by 12.4%, the TECHCH increasing by 9.8%, and the EFFCH increasing by 2.3% between 2013 and 2020. The double effect of the TECHCH and the EFFCH promotes the improvement of digital economy efficiency, and is mainly due to the rise of the TECHCH.

Analyzing the capital and labor redundancy in 30 Chinese provinces and cities during 2013-2020, it is found that the overall capital redundancy in China's digital economy is greater than labor redundancy, which may be caused by the fact that the state has attached great importance to the development and growth of the digital economy in recent years, and provinces and cities have been bent on increasing the investment injection in digital economy-related projects. According to the measurement results: Hebei, Jiangsu, Shandong, Guangdong, Guizhou, Yunnan, Qinghai and Ningxia 8 provinces are zero redundancy areas; Tianjin, Xinjiang, Liaoning, Gansu, Fujian, Sichuan, Guangxi, Chongqing and Jilin 9 provinces and cities are low capital redundancy and low labor redundancy areas, indicating that these 17 provinces and cities have better resource utilization; Beijing, Shanghai, Shanxi and Zhejiang 4 provinces and cities are low capital redundancy and high labor redundancy areas, these regions need to take measures such as attracting more people to the digital economy industry to reduce labor redundancy; 9 provinces and cities in Henan, Shaanxi, Jiangxi, Heilongjiang, Hubei, Hainan, Hunan, Inner Mongolia, and Anhui are high capital redundancy low labor redundancy regions, and these regions can increase the support for digital economy talents, especially composite talents and digital economy projects, to optimize capital redundancy.

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