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Competitiveness Evaluation of High-Quality Manufacturing Development in the Yangtze River Economic Belt

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ABSTRACT

This paper aims to construct the evaluation index system and model for the competitiveness of high-quality manufacturing development in China, and put forward pertinent suggestions. To this end, the evaluation index system was designed in reference to the input-process-output model of the systems theory; the entropy method was improved through analytic hierarchy process (AHP), and then combined with the technique for order preference by similarity to ideal solution (TOPSIS) into the improved entropy TOPSIS model. On this basis, the competitiveness of the Yangtze River Economic Belt (YREB) in high-quality manufacturing development (HQMD) was evaluated with the panel data of 2013-2018, in terms of overall competitiveness, spatial and temporal trends, industrial landscape, and national ranking. The results show that: The overall HQMD competitiveness improved steadily, under the strong boost from two factors and slight constraint from two factors. In terms of space, the HQMD competitiveness was stronger in the east, with widening regional gaps; in terms of time, the HQMD competitiveness was improving across the board, especially in the central region. Five provinces maintain steady growth of HQMD competitiveness, and six provinces witnessed fluctuating growth. In the final manufacturing landscape, there were one leader, two subleaders, three supporters, and five followers. The YREB is the demonstration zone of China's HQMD, with 80% of its provinces falling in medium and high levels. Finally, several suggestions were presented to improve the HQMD competitiveness in the YREB. The research findings provide a good reference for policymakers to promote manufacturing and pursue sustainable development.

1. INTRODUCTION

High-quality development (HQD) is synonymous with sustainable development in many respects. For China's manufacturing industry, HQD is the only path towards sustainable development. Facing immense pressures from within and without, Chinese manufacturers must complete the paradigm shift from fast growth to HQD, trying to acquire and maintain a competitive edge in the new round of global competition centered on intelligent manufacturing.

However, HQD is a relatively new concept. There is not yet a clear and unified definition of high-quality manufacturing development (HQMD), not to mention scientific evaluation indices. As a result, it is very difficult to evaluate the competitiveness or formulate industrial policies of HQMD. To effectively promote HQMD in China, the most urgent task is to establish a scientific evaluation index system and carry out accurate competitiveness evaluation.

Both HQD and HQMD are concepts with strong Chinese features. At present, foreign studies on HQD mainly focus on its core contents, such as technical innovation, green manufacturing, and structural upgrading. Some scholars highlighted the importance of technical innovation, and treated innovation indices as the core metrics of HQD [1-3]. Some characterized HQD as efficient resource allocation, and industrial transformation and upgrading [4-6]. Some pointed out the three key aspects of HQD: coordination between industrial growth and environment, green manufacturing, and green sustainable development [7-10].

In China, scholars mainly investigated the evaluation indices of HQMD, and put forward core indices like innovation, greenness, opening, structure, benefit, efficiency, quality, and integration [11-13]. Their findings provide useful references for the design of HQMD indices. However, the existing research has three common defects: the evaluation index system lacks a scientific basis, that is, clear understanding of HQMD; the current evaluation models are too theoretical to be directly applied; the policy suggestions are not very pertinent, due to the lack of empirical research on HQMD competitiveness.

In this background, this paper attempts to achieve the following objectives: First, clarify the connotation of HQMD based on the input-process-output model of the systems theory, and construct a scientific evaluation index for HQMD competitiveness; Second, improve the entropy method by analytic hierarchy process (AHP), and then create a novel evaluation model for HQMD competitiveness, called improved entropy technique for order preference by similarity to ideal solution (TOPSIS) model; Third, evaluate HQMD competitiveness empirically based on the panel data in the Yangtze River Economic Belt (YREB), and put forward some pertinent suggestions.

The remainder of this paper is organized as follows: Section 2 explains the connotation of HQMD, and set up an evaluation index system; Section 3 constructs the improved TOPSIS model; Section 4 empirically evaluates HQMD competitiveness in the YREB; Section 5 puts forward the conclusions and suggestions.

2. CONNOTATION OF HQMD AND EVALUATION INDEX SYSTEM

2.1 Connotation of HQMD

Before clarifying the connation of HQMD, it is necessary to understand some relevant concepts, namely, quality, product quality, quality of industrial development, quality of manufacturing development and HQD. In economics, quality is a value judgement about the level or degree of an object; product quality measures the value of a product by how much it meets social needs [14]. The quality of industrial development is the overall quality of various products, covering a static dimension (quantity of products/services) and a dynamic dimension (evolution of industrial structure). The quality of manufacturing development is the extension of the quality of industrial development in the manufacturing field. HQD is an advanced state of development, which is high-end, efficient, fair, green, and sustainable. HQD could be achieved through benefit improvement, innovation, structural optimization, intensive development, and comprehensive coordination [15]. Finally, HQMD is the extension of HQD in the manufacturing field.

Based on the above concepts, this paper defines HQMD as an advanced development mode of manufacturing with a certain scale, in which multiple outputs, namely, structural upgrading, benefit optimization, environmental coordination, and opening & freedom, are optimized by increasing the input of innovation elements and improving resource allocation. HQMD is the advanced state of the quality of manufacturing development, providing the material products that satisfy people's need for a better life. This definition emphasizes on the following aspects of HQMD: the innovation elements in the input system, intensive utilization in the process system, and economic benefits, environmental protection and opening in the output system.

2.2 Evaluation index system

According to the connotation of HQMD, this paper sets up an evaluation index system of HQMD competitiveness from six perspectives: innovation, intensive utilization, structural upgrading, benefit optimization, environmental coordination, and opening & freedom. The entire evaluation index system is displayed in Table 1.

Table 1. Evaluation index system for HQMD competitiveness

Primary index	Secondary index	Tertiary index	Calculation formula
Innovation (A)	Innovation inputs (A1)	Proportion of R&D talents (A11)	Number of manufacturing R&D employees / annual mean number of manufacturing employees
		Proportion of R&D expenditure (A12)	Manufacturing R&D expenditure / gross domestic product (GDP)
	Innovation outputs (A2)	Proportion of patents (A21)	Number of patents / number of patent applications
		Per-capita number of invention patents (A22)	Number of patents / mean number of manufacturing employees
		Proportion of new products (A23)	Main business income of new manufacturing products / main business income of manufacturing
Intensive utilization (B)	Capital allocation efficiency (B1)	Capital productivity (B11)	Manufacturing added value / total investment in manufacturing fixed assets
	Labor allocation efficiency (B2)	Labor productivity (B21)	Manufacturing added value / annual mean number of employees
	Energy allocation efficiency (B3)	Energy productivity (B31)	Manufacturing added value / total manufacturing energy consumption
	Land allocation efficiency (B4)	Land productivity (B41)	Manufacturing added value / urban built-up area
Structural upgrading (C)	Product structural upgrading (C1)	Qualified product rate (C11)	Batch of qualified products / batch of spot check products
		Superior product rate (C12)	Superior product rate in statistical yearbooks
	Enterprise structural upgrading (C2)	Proportion of high-tech enterprises (C21)	Number of high-tech enterprises / numbers of manufacturing enterprises
		Proportion of R&D enterprises (C22)	Number of enterprises with R&D activities / number of manufacturing enterprises
		Proportion of top-500 enterprises (C23)	Number of to-500 manufacturing enterprises / number of manufacturing enterprises
	Industry structural upgrading (C3)	Proportion of high-tech manufacturing (C31)	Main business income of high-tech manufacturing / main business income of manufacturing
Benefit optimization (D)	Economic benefit optimization (D1)	Profit margin (D11)	Total manufacturing profit / main business income of manufacturing
		Output contribution (D12)	Manufacturing added value / GDP
	Social benefit optimization (D2)	Tax contribution (D21)	Manufacturing tax / total tax
		Employment contribution (D22)	Annual mean number of manufacturing employees / total number of employees
	Ecological benefit optimization (D3)	Green cycle rate (D31)	Comprehensive utilization rate of manufacturing solid waste in statistical yearbooks

Environment coordination (E)	Wastewater emission (E1)	Wastewater emission per unit added value (E11)	Manufacturing wastewater emission / manufacturing added value
	Exhaust gas emission (E2)	Exhaust gas emission per unit added value (E21)	Manufacturing sulfur dioxide emission / manufacturing added value
	Solid waste emission (E3)	Solid waste emission per unit added value (E31)	Manufacturing solid waste emissions / manufacturing added value
Opening & freedom (F)	Freedom of foreign trade (F1)	Foreign trade dependence (F11)	Total manufacturing import and export / total manufacturing output
	Freedom of foreign investment (F2)	Foreign capital dependence (F21)	Total assets of foreign enterprises / total manufacturing assets

Among them, innovation is the primary driver of HQMD. Innovation requires inputs like talents and expenditure of research and development (R&D) [16], and outputs patents and new products [17].

Intensive utilization is the key for manufacturing to realize sustainable development under tight resource constraints. It is mainly reflected by the allocation efficiencies of manufacturing inputs, such as capital, labor, energy and land [18].

Hence, the primary index of intensive utilization was decomposed to the allocation efficiencies of capital, labor, energy and land, which can be measured by productivity.

Structural upgrading is the goal of HQMD in terms of industrial structure. Since the industrial structure is a hierarchy of product structure, enterprise structure and industry structure [19], the primary index of structural upgrading was split into the structural upgrading of product, enterprise, and industry.

Benefit optimization is the benefit goal of HQMD. The development of manufacturing generally brings three kinds of benefits: economic benefit, social benefit, and ecological benefit [20]. Hence, the primary index of benefit optimization was divided into economic benefit optimization, social benefit optimization, and ecological benefit optimization. Specifically, the optimization of economic benefit was measured by the contribution to manufacturing profit and added value, that of social benefit was measured by the contribution to tax and employment, and that of ecological benefit was measured by pollution control.

Environmental coordination, as the environmental goal of HQMD, aims to lower the emissions of wastewater, exhaust gas, and solid waste [21]. The emission of each pollutant was measured per unit of manufacturing added value.

Opening & freedom the desired degree of opening for HQMD, reflecting the integration of manufacturing in the global industrial chain. This primary index was decomposed into foreign trade freedom and foreign investment freedom [22], measured by foreign trade dependence and foreign capital dependence, respectively.

In total, our evaluation index system contains 6 primary indices, 17 secondary indices, and 25 tertiary indices. Only 3 of these indices, namely, wastewater emission, exhaust gas emission, and solid waste emission, are negative. The other indices all have positive correlations with HQMD competitiveness.

3. IMPROVED ENTROPY TOPSIS MODEL

3.1 Selection and improvement of evaluation model

In economics and management, competitiveness is commonly evaluated by fuzzy evaluation, delph approach, AHP, entropy method, and TOPSIS. Each of these methods has its strengths and weaknesses.

Fuzzy evaluation mainly deals with qualitative problems that cannot be accurately depicted by data. Delphi approach relies too much on the subjective scores rated by experts. AHP has difficulty in passing the consistency test, in the presence of too many indices. Entropy method and TOPSIS are more suitable than the above methods for our research.

Entropy method is a relatively objective weighting method. Each index is weighted based on its degree of variation. If the index value is highly dispersed, the weight assigned to the index might be inaccurate.

To overcome this defect, entropy method is often combined with TOPSIS for scientific research. TOPSIS provides a solution to multi-objective decision-making. Through TOPSIS, the competitiveness of the evaluation object is measured by its distance to the best or worst scheme. Drawing on the relevant literature, this paper improves the entropy method by the AHP, and then combines the improved entropy method with TOPSIS to evaluate the HQMD competitiveness.

3.2 Steps of model construction

The improved entropy TOPSIS model was constructed in the following steps:

Step 1. Data normalization

Let y_{ijt} be the value of index j of province i in year t; y_j^{max} and y_j^{min} be the maximum and minimum values of index j, respectively; $x_{ijt}\in[0.1,1]$ is the normalized value. Then, y_{ijt} can be normalized as follows:

If index j is a positive index:

$$x_{ijt} = \left(\frac{y_{ijt}-y_j^{min}}{y_j^{max}-y_j^{min}}\right) * 0.9 + 0.1 \quad (1)$$

If index j is a negative index:

$$x_{ijt} = \left(\frac{y_j^{max}-y_{ijt}}{y_j^{max}-y_j^{min}}\right) \times 0.9 + 0.1 \quad (2)$$

Step 2. Entropy calculation

The entropy of each index was calculated by the global entropy method. The n indices of province m in year t were arranged chronologically, forming a global judgment matrix $mt\times n$. Then, the entropy e_j of index j can be calculated by:

$$e_j = -\frac{1}{\ln(mT)}\sum_{i=1}^{m}\sum_{t=1}^{T}(f_{ijt} * lnf_{ijt}) \quad (3)$$

The f_{ijt} can be obtained by:

$$f_{ijt} = \frac{x_{ijt}}{\sum_{i=1}^{m}\sum_{t=1}^{T} x_{ijt}} \quad (4)$$

Step 3. AHP-based improvement

(1) The difference coefficient g_j, maximum difference coefficient D, and mapping ratio R of index j can be respectively calculated by:

$$g_j = 1 - e_j \quad (5)$$

$$D = \frac{maxg_j}{ming_j} \quad (6)$$

$$R = \sqrt[\partial-1]{\frac{D}{\partial}} \quad (7)$$

where, ∂ is the adjustment coefficient. If $D \leq 9$, ∂ is the integer closest to D; otherwise, ∂ equals 9. The first power of $(\partial-1)$ is to distribute D evenly on the mapping values of the 1-9 scale. Here, D/∂ is adopted to make the mapping values of the 1-9 scale consistent with the mapping structure of the AHP.

(2) The mapping values of the 1-9 scale were obtained, and multiplied with R^{n-1} to get the mapping values of the improved entropy method (Table 2).

(3) To construct the judgment matrix R, the difference coefficient ratio between every two indices was calculated by:

$$r_{jk} = \frac{g_j}{g_k} \quad (8)$$

If $r < 1$:

$$r_{kj} = \frac{g_k}{g_j} \quad (9)$$

The minimum difference between R and mapping value was taken as the relative importance of the two indices. Then, the judgment matrix of the improved entropy method was constructed based on the relative importance.

(4) The weight w_j of each index was calculated through the AHP, according to the judgement matrix.

Step 4. TOPSIS model construction

(1) The weighting matrix B can be created by:

$$B = (b_{ijt})mT \times n \quad (10)$$

$$b_{ijt} = w_j \times x_{ijt} \quad (11)$$

(2) The best scheme Q_j^+ and worst scheme Q_j^- can be respectively calculated by:

$$Q_j^+ = (maxb_{i1t}, maxb_{i2t}, \dots, maxb_{int}) \quad (12)$$

$$Q_j^- = (minb_{i1t}, minb_{i2t}, \dots, minb_{int}) \quad (13)$$

(3) The Euclidean distances d_i^+ and d_i^- from each index to the optimal and worst schemes can be respectively obtained by:

$$d_i^+ = \sqrt{\sum_{j=1}^{m}\left(Q_j^+ - b_{ijt}\right)^2} \quad (14)$$

$$d_i^- = \sqrt{\sum_{j=1}^{m}\left(Q_j^- - b_{ijt}\right)^2} \quad (15)$$

(4) The proximity between each index and the ideal scheme can be calculated by:

$$C_i = \frac{d_i^-}{d_i^+ + d_i^-} \quad (16)$$

where, C_i falls between 0 and 1. The closer the C_i value is to 1, the better is the result.

Table 2. The mapping values of the 1-9 scale

Level	1	2	3	4	5	6	7	8	9
Mapping value	$1 \times R^0$	$2 \times R^1$	$3 \times R^2$	$4 \times R^3$	$5 \times R^4$	$6 \times R^5$	$7 \times R^6$	$8 \times R^7$	$9 \times R^8$

4. EMPIRICAL ANALYSIS

4.1 Sample selection

The YREB was selected as the study area, for its representativeness of China's manufacturing development. As one of the three major economic regions in China, the YREB spans across 11 provincial administrative regions (hereinafter referred to as provinces) in eastern, central, and western China. The study area takes up over 40% of China's population and GDP. In addition, there are important manufacturing bases across the YREB, whether in the upper, middle, or lower reaches. The HQMD of the YREB not only bears on the overall HQMD of China, but also determines the strategic positioning of the YREB.

4.2 Data sources

For the consistency and completeness of various indices, the relevant data were selected from statistical yearbooks published in the sample period of 2013-2018, and downloaded from official websites of relevant authorities. Specifically, the data on R&D and patents are from *China Statistical Yearbooks on Science and Technology*, the data on high-tech enterprises are from *China Statistics Yearbooks on High Technology Industry*, the data on manufacturing enterprises above designated size are from the *China Industry Statistical Yearbooks*, the data on fixed asset investment are from the *Statistical Yearbook of the Chinese Investment in Fixed Assets*, the data on import and export are from the foreign trade database of the Development Research Center of the State Council, the tax data are from the Ministry of Finance and State Administration of Taxation, the data on top-500 enterprises are from the *List of Top 500 Manufacturing Enterprises in China*, and the data on GDP, environment, and other issues are from *China Statistical Yearbooks* and provincial statistical yearbooks.

4.3 Index weighting

The weight of each index was calculated by the improved entropy method. As shown in Table 3, all consistency ratios

(CRs) were smaller than 0.1, passing the consistency test. The weights reflect the relative importance of each index. The highest weight belongs to structural upgrading, indicating that structural upgrading has a great impact on China's manufacturing in recent years. The second highest weight belongs to innovation, which proves the driving effect of innovation on HQMD. The lowest weight belongs to environment coordination. Thus, it is an urgent task for China to mitigate the environmental impact of manufacturing development.

Table 3. The weights of evaluation indices

Primary index	Weight	CR	Secondary index	Weight	CR_i	Tertiary index	Weight
Innovation (A)	0.2592	0.0134	A1	0.1225	0.0079	A11	0.0601
						A12	0.0624
			A2	0.1367		A21	0.0276
						A22	0.0601
						A23	0.0491
Intensive utilization (B)	0.1588		B1	0.0613	0.0012	B11	0.0613
			B2	0.0341		B21	0.0341
			B3	0.0294		B31	0.0294
			B4	0.0341		B41	0.0341
Structural upgrading (C)	0.2757		C1	0.0467	0.0245	C11	0.0173
						C12	0.0294
			C2	0.1693		C21	0.0499
						C22	0.0597
						C23	0.0597
			C3	0.0597		C31	0.0597
Benefit optimization (D)	0.1293		D1	0.0323	0.0044	D11	0.0142
						D12	0.0181
			D2	0.0629		D21	0.0299
						D22	0.0330
			D3	0.0341		D31	0.0341
Environment coordination (E)	0.0314		E1	0.0126	0	E11	0.0126
			E2	0.0097		E21	0.0097
			E3	0.0091		E31	0.0091
Opening & freedom (F)	0.1456		F1	0.0750	0	F11	0.0750
			F2	0.0706		F21	0.0706

4.4 Results analysis

Tables 4-8 present the evaluation results on HQMD competitiveness of the YREB in 2013-2018. From different perspectives, the evaluation results were analyzed in details below.

(1) The overall HQMD competitiveness improved steadily, under the strong boost from two factors and slight constraint from two factors.

Table 4 provides the overall HQMD competitiveness of the YREB in 2013-2018. It can be seen that HQMD competitiveness of the YREB increased by 16.46% from 0.2917 to 0.3397 in the sample period.

To be specific, innovation and structural upgrading, as main drivers of HQMD, both grew substantially by over 42%. Environment coordination and intensive utilization, as important propellers of HQMD, increased by 22.68% and 15.64%, respectively. On the contrary, benefit optimization and opening & freedom, which restrict HQMD, plunged by 18.57% and 15.20%, respectively.

Overall, the HQMD competitiveness of the YREB increased substantially in the sample period: the innovation was significantly enhanced, the industrial structure was greatly optimized, the resource allocation was made much more efficient, and the environment was better coordinated; however, benefit optimization and opening & freedom became to major obstacles of HQMD.

The decline of benefit optimization is directly attributed to the dwindling contributions of manufacturing to GDP (-6.98%), tax (-6.56%), and employment (-7.59%). The dwindling is inevitable as the YREB undergoes the transform from real economy to fictitious economy. The dominance of manufacturing is being replaced by service industry, finance, and real estate, weakening the benefit contribution of manufacturing. The decline of opening & freedom comes from the diminishing freedom of foreign trade (-0.25%) and foreign investment (-0.02%). In recent years, China's manufacturing has become less attractive in the international market, as developed countries are promoting the return of high-end manufacturing, and other developing countries are gnawing away the shares in low- and mid-end markets.

Table 4. The overall HQMD competitiveness of the YREB in 2013-2018

Year	HQMD competitiveness	(A)	(B)	(C)	(D)	(E)	(F)
2013	0.2917	0.2151	0.2673	0.2712	0.5623	0.6935	0.2704
2014	0.2994	0.2279	0.2752	0.2958	0.5550	0.7393	0.2572
2015	0.3056	0.2414	0.2865	0.3065	0.5331	0.7722	0.2535
2016	0.3165	0.2635	0.2907	0.3274	0.5224	0.7910	0.2500
2017	0.3262	0.2828	0.2938	0.3553	0.5049	0.7910	0.2337
2018	0.3397	0.3057	0.3091	0.3860	0.4579	0.8508	0.2293
Cumulative growth	16.46%	42.12%	15.64%	42.33%	-18.57%	22.68%	-15.20%

Table 5. The HQMD competitiveness in the upper, middle, and lower reaches of HQMD in 2013-2018

Year	Lower reaches	Middle reaches	Upper reaches	Gap between lower and middle reaches	Gap between lower and upper reaches	Gap between middle and upper reaches
2013	0.4387	0.2418	0.2298	0.1969	0.2089	0.0120
2014	0.4467	0.2516	0.2368	0.1951	0.2099	0.0148
2015	0.4504	0.2637	0.2389	0.1867	0.2115	0.0248
2016	0.4641	0.2713	0.2511	0.1928	0.2130	0.0202
2017	0.4761	0.2817	0.2584	0.1944	0.2177	0.0233
2018	0.4945	0.2969	0.2665	0.1976	0.2280	0.0304
Cumulative growth	12.72%	22.79%	15.97%	0.0036	0.0914	1.5333

Table 6. The HQMD competitiveness in 11 YREB provinces in 2013-2018

Ranking	Province	2013	2014	2015	2016	2017	2018	Cumulative growth
1	Shanghai	0.5513	0.5570	0.5617	0.5834	0.5893	0.6100	10.65%
2	Jiangsu	0.4097	0.4192	0.4153	0.4245	0.4362	0.4545	10.93%
3	Zhejiang	0.3553	0.3638	0.3743	0.3844	0.4029	0.4189	17.90%
4	Chongqing	0.2947	0.3024	0.3172	0.3330	0.3478	0.3535	19.95%
5	Anhui	0.2403	0.2591	0.2693	0.2919	0.3160	0.3352	39.49%
6	Hunan	0.2487	0.2640	0.2728	0.2825	0.2955	0.3083	23.96%
7	Hubei	0.2626	0.2598	0.2643	0.2652	0.2775	0.2910	10.81%
8	Sichuan	0.2262	0.2337	0.2430	0.2587	0.2518	0.2554	12.91%
9	Jiangxi	0.2224	0.2236	0.2485	0.2454	0.2378	0.2532	13.85%
10	Yunnan	0.1920	0.1997	0.1970	0.2052	0.2322	0.2408	25.42%
11	Guizhou	0.2062	0.2114	0.1984	0.2074	0.2016	0.2164	4.95%

Table 7. The HQMD competitiveness of 30 Chinese provinces in 2018

Provinces	HQMD Competitiveness	(A)	(B)	(C)	(D)	(E)	(F)	Categories
Beijing	0.6580	0.8305	0.6418	0.8303	0.3829	0.9838	0.4126	
Shanghai	0.6100	0.5358	0.6643	0.5027	0.5460	0.9049	0.9269	
Tianjin	0.4899	0.4685	0.3793	0.5492	0.7054	0.9708	0.4099	
Guangdong	0.4889	0.4088	0.3411	0.5511	0.6405	0.9286	0.5292	High level
Jiangsu	0.4545	0.3814	0.3112	0.5417	0.6531	0.8733	0.4183	
Zhejiang	0.4189	0.4133	0.3162	0.4625	0.6103	0.8544	0.3282	
Hainan	0.3792	0.3020	0.3358	0.3924	0.2605	0.6364	0.5311	
Chongqing	0.3535	0.3106	0.2651	0.4612	0.4615	0.9160	0.2251	
Anhui	0.3352	0.4294	0.2471	0.3243	0.5401	0.8940	0.0939	
Shandong	0.3109	0.2824	0.2607	0.3177	0.6724	0.8694	0.1679	
Hunan	0.3083	0.3019	0.3227	0.3454	0.5465	0.9173	0.0604	
Fujian	0.3082	0.1917	0.3497	0.3206	0.5258	0.8737	0.2735	
Liaoning	0.2991	0.2639	0.2432	0.2792	0.3615	0.7651	0.3579	Medium level
Shaanxi	0.2939	0.2378	0.3373	0.3428	0.4751	0.9584	0.0950	
Hubei	0.2910	0.2874	0.2762	0.3184	0.4024	0.9290	0.1823	
Sichuan	0.2554	0.2220	0.2312	0.3432	0.2574	0.9012	0.0937	
Jiangxi	0.2532	0.1394	0.2411	0.3611	0.3482	0.7046	0.1229	
Jilin	0.2514	0.1835	0.2795	0.2618	0.4627	0.9480	0.1340	
Guangxi	0.2512	0.1750	0.2794	0.2686	0.3903	0.9001	0.2069	
Hebei	0.2462	0.1473	0.2911	0.2597	0.5028	0.8068	0.1258	
Henan	0.2435	0.1426	0.2762	0.2694	0.5347	0.8004	0.0582	
Yunnan	0.2408	0.1789	0.2717	0.3149	0.3342	0.6452	0.0563	
Ningxia	0.2251	0.2161	0.1548	0.2924	0.3472	0.6308	0.0358	
Inner Mongolia	0.2245	0.1341	0.3872	0.1946	0.2802	0.8703	0.1052	
Guizhou	0.2164	0.1626	0.2533	0.2702	0.3368	0.8187	0.0145	Low level
Gansu	0.2090	0.1367	0.1251	0.3006	0.3312	0.6765	0.0269	
Qinghai	0.2066	0.1337	0.2736	0.2836	0.2428	0.5185	0.0106	
Heilongjiang	0.1914	0.1721	0.1527	0.2093	0.2751	0.8418	0.1254	
Shanxi	0.1849	0.1360	0.1345	0.2405	0.2995	0.6135	0.0783	
Xinjiang	0.1694	0.1026	0.1825	0.1786	0.2546	0.6182	0.1539	
National average	0.3123	0.2676	0.2942	0.3529	0.4327	0.8190	0.2120	
YREB average	0.3397	0.3057	0.3091	0.3860	0.4579	0.8508	0.2293	

Table 8. The national ranking of the 11 YREB provinces by HQMD competitiveness and its primary indices

Province	Competitiveness	(A)	(B)	(C)	(D)	(E)	(F)
Shanghai	2	2	1	5	7	9	1
Jiangsu	5	7	11	4	3	14	4
Zhejiang	6	5	10	6	5	17	8
Chongqing	8	8	19	7	14	8	10

Anhui	9	4	22	13	8	12	21
Hunan	11	10	9	10	6	7	24
Hubei	15	11	16	15	15	5	12
Sichuan	16	15	25	11	28	10	22
Jiangxi	17	25	24	9	19	23	18
Yunnan	22	19	18	17	22	25	26
Guizhou	25	22	21	22	21	19	29

(2) In terms of space, the HQMD competitiveness was stronger in the east, with widening regional gaps; in terms of time, the HQMD competitiveness was improving across the board, especially in the central region.

Table 5 provides the HQMD competitiveness in the upper, middle, and lower reaches of the YREB in the sample period. In terms of space, the lower reaches had far stronger HQMD competitiveness than the middle and upper reaches; the middle reaches maintained a slight lead over the upper reaches. From 2013 to 2018, the gap of HQMD competitiveness between upper and lower reaches, and that between upper and middle reaches widened by 0.0914 and 1.5333, respectively. To sum up, the HQMD competitiveness was stronger in the east, with widening regional gaps.

In terms of time, the HQMD competitiveness was improving in all three regions of the YREB throughout the sample period. The cumulative growths in the upper, middle and lower reaches were 15.97%, 22.79%, and 12.72%, respectively. The growth rate of the middle reaches was significantly higher than that of the upper and lower reaches, indicating that the central region is making the fastest progress in HQMD.

The main reasons for the above trends are as follows: The provinces in the lower reaches (e.g. Shanghai, Jiangsu, and Zhejiang) are traditional manufacturing powerhouses. But the manufacturing growth in this region is affected, as industrial upgrading and transfer are picking up speed. The provinces in the middle reaches (e.g. Hubei and Hunan) have the geographical advantage and industrial foundation to undertake the industrial transfer from the east. In recent years, these provinces have attracted many high-quality projects, enhancing their HQMD potential. The provinces in the upper reaches (e.g. Sichuan and Guizhou) have a weak manufacturing foundation, and a relatively low attractiveness to manufacturers, owing to the pressure of environmental protection. Hence, the regional gaps in HQMD competitiveness are still expanding.

(3) Five provinces maintain steady growth of HQMD competitiveness, and six provinces witnessed fluctuating growth. In the final manufacturing landscape, there were one leader, two subleaders, three supporters, and five followers.

Table 6 shows the HQMD competitiveness in the 11 YREB provinces in 2013-2018. In terms of provincial ranking, Shanghai, Jiangsu, Zhejiang, and Chongqing steadily occupied the top four spots; Anhui and Hubei switched their positions (5^{th} and 7^{th}); Yunnan and Guizhou also swapped their places (10^{th} and 11^{th}); the other three provinces remained unchanged in the ranking.

In terms of growth pattern, the HQMD competitiveness of all 11 provinces had improved significantly. The growth was steady in Shanghai, Zhejiang, Chongqing, Anhui, and Hunan, whose cumulative growths were 0.0587, 0.0636, 0.0588, 0.0949, and 0.0596, respectively. These provinces ended up as the top five in the final ranking. The other six provinces went through fluctuating growth, and appeared on the lower half of the final ranking.

In terms of industrial landscape, the manufacturing industry in the YREB had one leader (Shanghai), two subleaders (Jiangsu and Zhejiang), and eight followers in 2013. During the sample period, this landscape was disrupted by the fast progress in Anhui, Hunan, and Chongqing. The HQMD competitiveness of the three provinces grew rapidly by 39.49%, 23.96% and 19.95%, respectively. In 2018, Anhui, Hunan, and Chongqing developed into three important supporters of HQMD in the study area.

Through the sample period, Chongqing has forged two pillar industries, namely, automobile and electronic information, thanks to its important political status: municipality directly under the central government, national central city, and the first city to implement the China Western Development strategy. In recent years, Anhui has been actively integrating into the Yangtze River Delta urban agglomeration. With a favorable geographical location, Anhui is now the best destination of industrial transfer from the Yangtze River Delta. Meanwhile, Hunan has extended its industrial chain and expanded the industrial clusters around construction machinery and rail transit equipment, making the two industries competitive on the world stage.

By contrast, Hubei dropped by 2 places in the provincial ranking, owing to the sluggish development of its superior industries: the iron and steel industry was busy with structural transformation and upgrading to cut capacity; the market competitiveness of the automobile industry has declined amidst intense competition at home and abroad. Similar to Hubei, Guizhou also performed poorly in HQMD. There are two reasons for the underperformance: the traditional pillar industries like liquor, coal, electricity, and tobacco are hard to transform or innovate; tourism and big data are the development focus of Guizhou, rather than manufacturing.

(4) The YREB is the demonstration zone of China's HQMD, with 80% of its provinces falling in medium and high levels.

The HQMD competitiveness of 30 Chinese provinces (excluding Tibet, Hong Kong, Macao, and Taiwan) in 2018 were evaluated by the improved entropy TOPSIS model. Then, the authors identified the positions of the HQMD competitiveness of the 11 YREB provinces in China. Inspired by Wei and Li (2018), all 30 provinces were allocated to three categories (high level, medium level, and low level) by HQMD competitiveness, according to the formula of mean score (M) and standard deviation (SD) (M±0.5SD). High level scores are greater than 0.3736 (M+0.5SD); Medium level scores are greater than 0.2510 but smaller than 0.3736 (M+0.5SD~M-0.5SD); Low level scores are smaller than 0.2510 (M-0.5SD). The HQMD competitiveness of 30 Chinese provinces in 2018 are displayed in Table 7. The national ranking of the 11 YREB provinces by HQMD competitiveness and its primary indices are exhibited in Table 8.

As shown in Tables 7 and 8, three (27%) YREB provinces belonged to the high level, six (55%) to the medium level, and two (18%) to the low level. The proportions (27%: 55%: 18%) in the YREB are obviously better than those (23%: 50%: 27%) across China. Overall, more than 80% of YREB provinces fell in high and medium levels.

On average, the HQMD competitiveness in the YREB was 0.3397, higher than the national average of 0.3123. Besides, the average scores of the YREB in innovation, intensive utilization, structural upgrading, benefit optimization, environment coordination, and opening & freedom were all higher than the national average scores.

Judging by primary indices, Shanghai, which had the second highest HQMD competitiveness in China, ranked first in intensive utilization, and opening & freedom, and second in innovation. Therefore, Shanghai is the benchmark of HQMD in China. In addition, Jiangsu (4th in structural upgrading, and opening & freedom), Zhejiang (5th in innovation, and benefit optimization), Hunan (6th in benefit optimization; 7th in environment coordination), and Hubei (5th in environment coordination) were in the forefront of the country in some of the primary indices. Therefore, the YREB is the demonstration zone of China's HQMD.

5. CONCLUSIONS

This paper firstly clarifies the connotation of HQMD, using the input-process-output model of the systems theory, and then constructs a scientific evaluation index system of HQMD competitiveness. After that, the entropy method was improved through the AHP, and combined with TOPSIS into an evaluation model of HQMD competitiveness. On this basis, the HQMD competitiveness of the YREB was empirically analyzed based on the panel data from 2013 to 2018. The main conclusions are drawn as follows:

(1) The overall HQMD competitiveness improved steadily, under the strong boost from two factors and slight constraint from two factors.

(2) In terms of space, the HQMD competitiveness was stronger in the east, with widening regional gaps; in terms of time, the HQMD competitiveness was improving across the board, especially in the central region.

(3) Five provinces maintain steady growth of HQMD competitiveness, and six provinces witnessed fluctuating growth. In the final manufacturing landscape, there were one leader, two subleaders, three supporters, and five followers.

(4) The YREB is the demonstration zone of China's HQMD, with 80% of its provinces falling in medium and high levels.

The HQD is a comprehensive, coordinated, and sustainable development model. Considering the main problems with the HQMD in the YREB, this paper presents the following policy recommendations:

(1) Make up for the weak links and enhance the overall HQMD competitiveness.

Benefit optimization and opening & freedom are the two weak links that restrict the HQMD competitiveness in the YREB. To improve benefit optimization, China should tone down the expansion of real estate and finance in the transform from real economy to fictitious economy, highlight the importance of real economy to national economy, and encourage the financial industry to divert more funds to manufacturing, such that manufacturing could contribute greater to economic growth and social progress.

To improve opening & freedom, China should speed up the supply-side reform of manufacturing, promote the structural reform towards intelligent manufacturing, and strengthen the competitive advantage of manufactured products in the global market. In the meantime, the domestic consumption pattern should be upgraded to unleash the potential of domestic consumption, and to offset the adverse impact from the grim prospect of the global market.

(2) Promote regional linkages and enhance regional coordination in HQMD.

In the YREB, the regional gaps in HQMD competitiveness are still expanding, that is, the imbalance of regional development is increasingly severe. To curb the imbalance, the upper reaches of the YREB should step up the implementation of China Western Development strategy, relying on their resource endowment and policy advantages. According to the principles of regional linkage and dislocation competition, this region should undertake some national manufacturing projects, accept project transfer from eastern and central regions, and introduce local incubation programs. Moreover, this region should promote the free circulation of innovative elements, and fully integrate into the industrial chain of manufacturing.

(3) Strengthen characteristic industries and upgrade the manufacturing structure.

Among the 11 YREB provinces, Chongqing, Anhui, and Hunan are the top three in the middle level, while Yunnan and Guizhou are in the top half in the low level. These provinces face the demand and have the capability to upgrade the manufacturing structure. Since the HQMD hinges on pillar industries, the five provinces should strengthen their characteristic industries (e.g. automobile manufacturing, electronic information, household appliances, equipment manufacturing, new materials, and biological medicine) by extending the industrial chain, expanding the industrial cluster, and digging into core technologies. In this way, these provinces could create industrial brands with national and global influence, and quickly improve their HQMD competitiveness.

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