Regional economic efficiency evaluation of economic zones in China: Analysis based on the DEA model with undesirable output

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2021.11.01

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Contents

Contents

1、Introduction

China’s development

- Since the reform and opening-up, China's economy has developed rapidly
- China's GDP has steadily ranked second in the world Since 2009

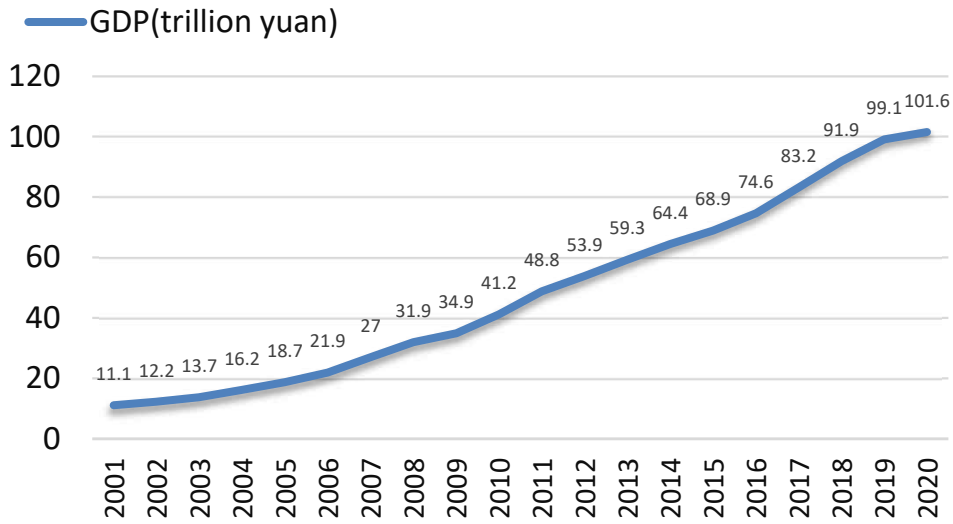
❖ Why?

- Rich human resources
- Establish economic development zones
- Abundant natural resources
- Complete industrial systems

GDP

- According to the statistics of the China Bureau of statistics and the data released by the National Bureau of Statistics, China's gross domestic product (GDP) exceeded the 100 trillion yuan mark for the first time in 2020, reaching 101.6 trillion yuan, an increase of 2.3% over last year

<China's GDP development in 20 years>



1、Introduction

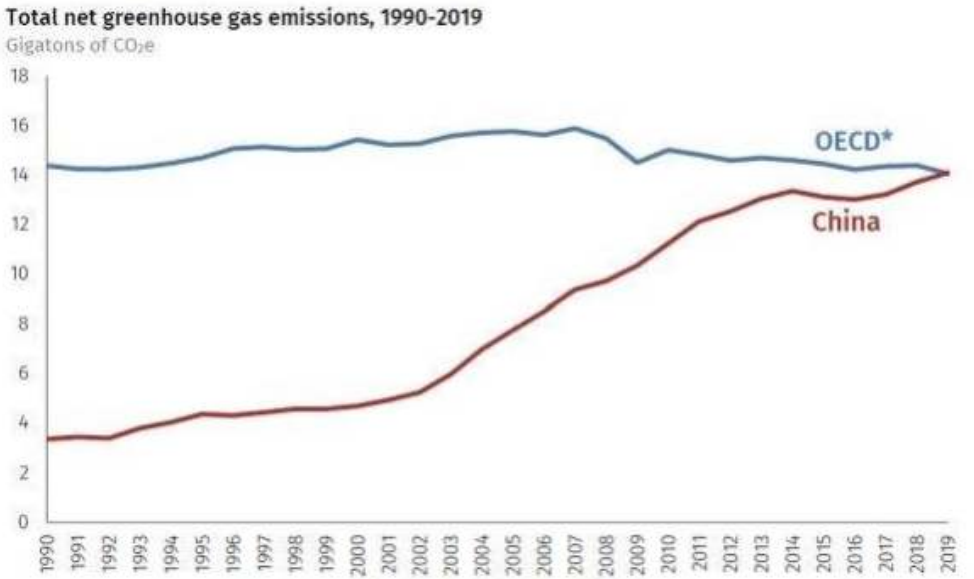
Environmental problems

- With global warming and the increasing pressure on resources and environment, carbon emission has become a major issue facing the world
- China's carbon emission ranks first in the world and grows rapidly, far exceeding that of other countries in the world
- China's carbon emission has been the first in the world since 2005

Carbon emission in China

- China's emissions accounted for 27% of the world's total emissions in 2019, far surpassing the second largest United States, which accounted for 11%
- In 2019, China's carbon emissions reached 14.093 billion metric tons, more than three times the 1990 emission level. In the past 10 years, China's carbon emissions have increased by 25%

<China's greenhouse gas emissions>



1、Introduction

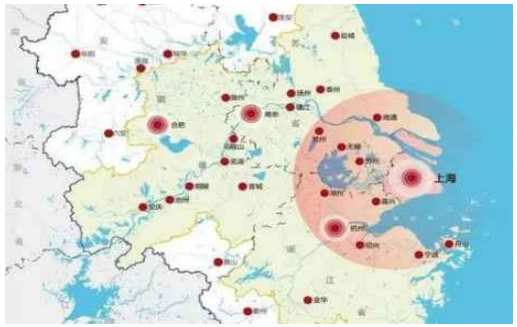
The Pearl River Delta

The Bohai economic zone is one of the key areas of national opening and development

[the Location of the Pearl River Delta]

The Yangtze River Delta

The Yangtze River Delta creates nearly a quarter of China's total economic output every year



[the Location of the Yangtze River delta]

The Beijing-Tianjin-Hebei Region

The Beijing Tianjin Hebei region is China's "capital economic circle", including Beijing, Tianjin and Hebei Province

[the Location of the Beijing-Tianjin-Hebei region]

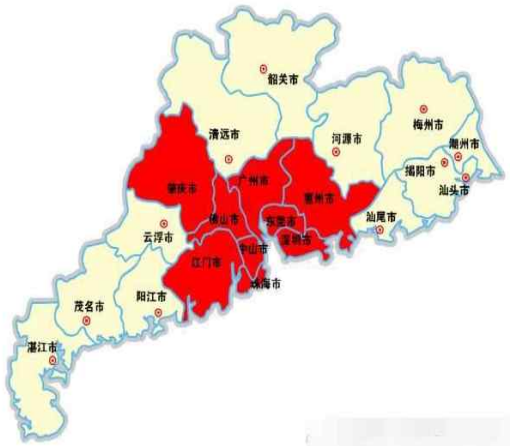
The Bohai Economic Rim

The Bohai economic zone is one of the key areas of national opening and development.

[the Location of the Bohai Economic Rim]

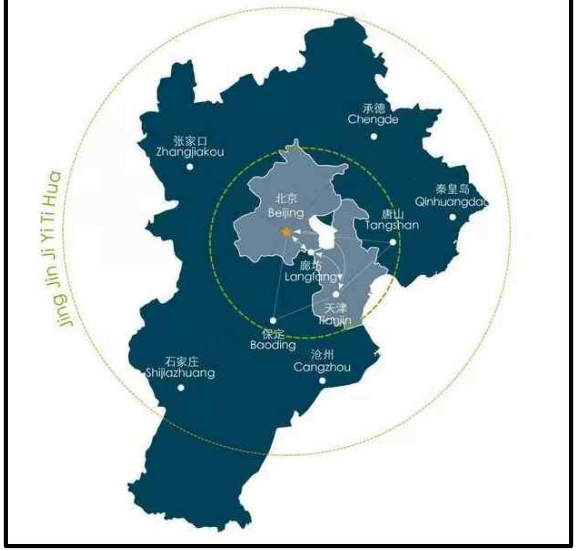
1、Introduction

The Pearl River Delta

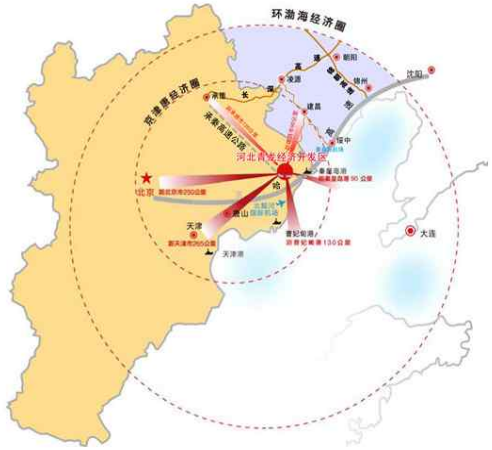


The Yangtze River Delta

The Beijing-Tianjin-Hebei Region

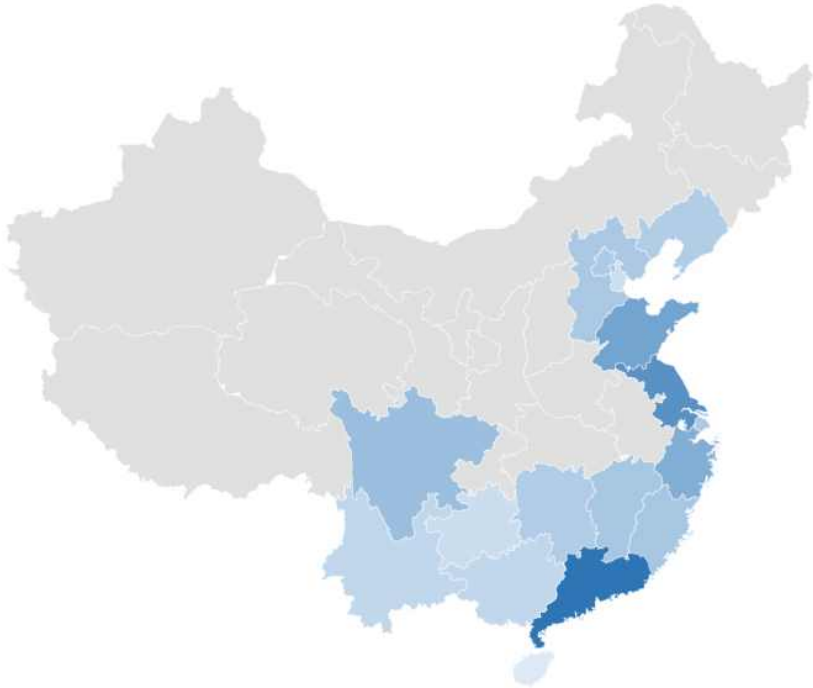


The Bohai Economic Rim



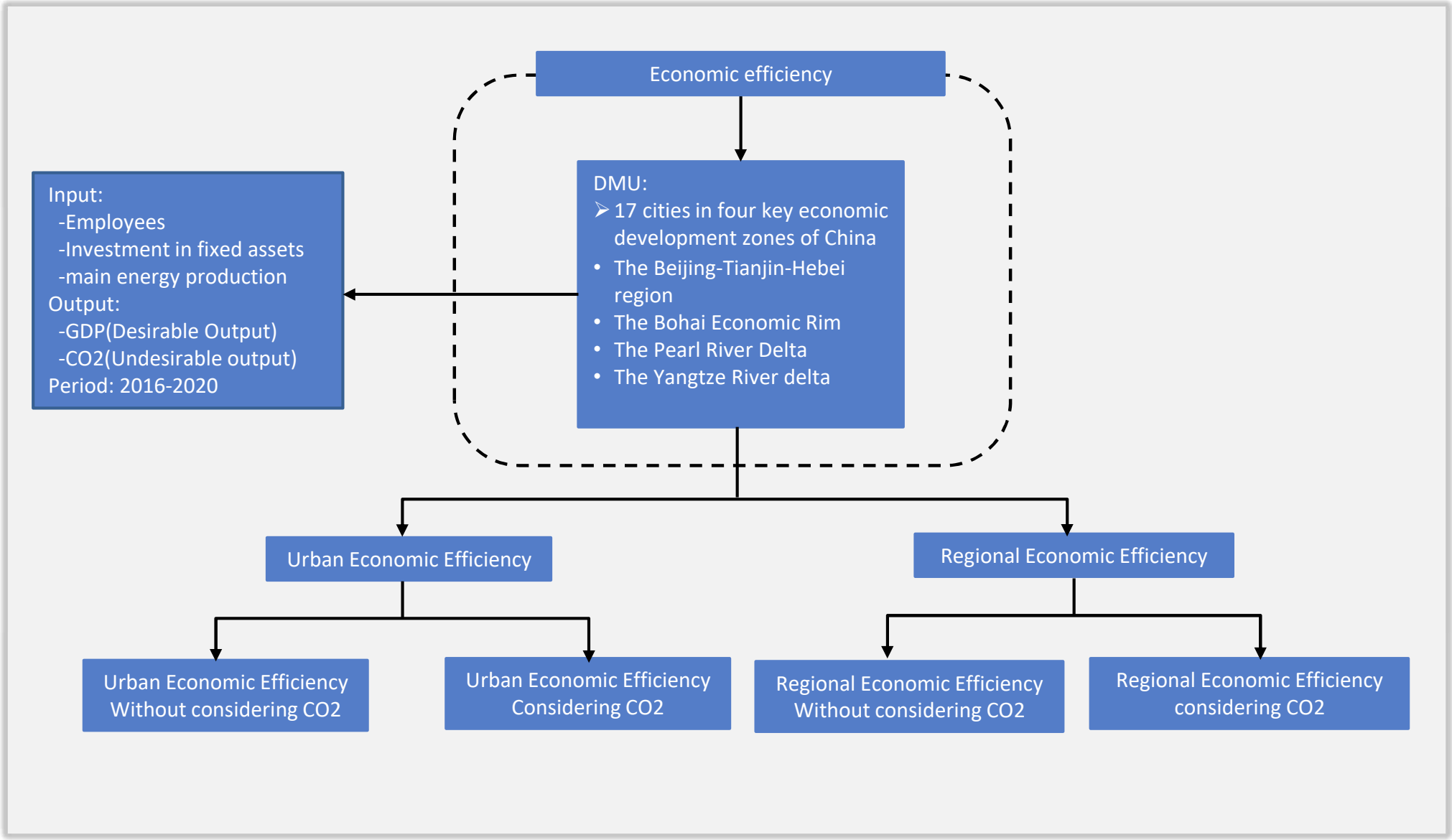
❖ Research objective

- To better understand the relationship between economic conditions and air pollutants
- To explore the relationship from the level of cities and economic zones
- To put forward corresponding policies under the background of economic transformation and upgrading in China



1、Introduction

❖ Organization of this research



Contents

2、Statistics

❖ Research objective

Research Regions

The Beijing-Tianjin-Hebei region

- BeiJing
- Tianjin
- Shanghai

The Bohai Economic Rim

- BeiJing
- Tianjin
- Hebei
- Liaoning
- Shandong

The Pearl River Delta

- Fujian
- Jiangxi
- Hunan
- Guangdong
- Guangxi
- Hainan
- Sichuan
- Guizhou
- Yunnan

The Yangtze River delta

- Shanghai
- Jiangsu
- Zhejiang

17 Cities

Beijing	Tianjin	Hebei	Liaoning	Shandong	Shanghai	Jiangsu	Zhejiang	
Fujian	Jiangxi	Hunan	Guangdong	Guangxi	Hainan	Sichuan	Guizhou	Yunnan

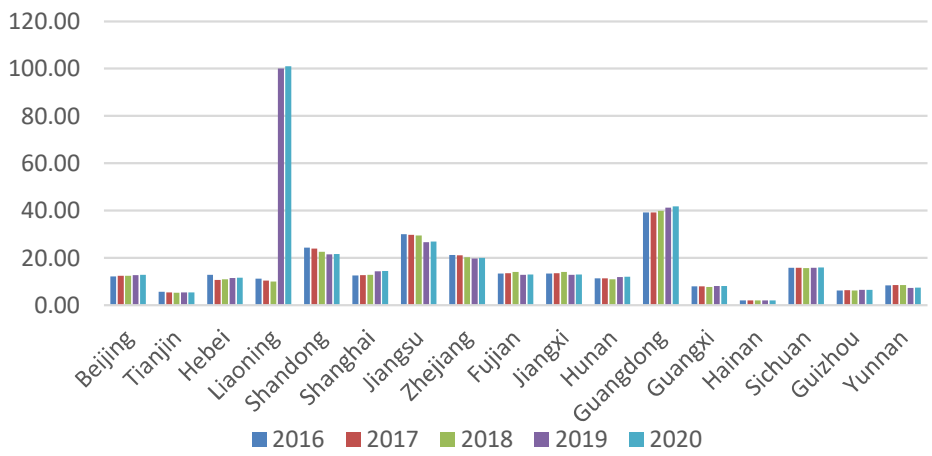
2、Statistics

The Data In 2020

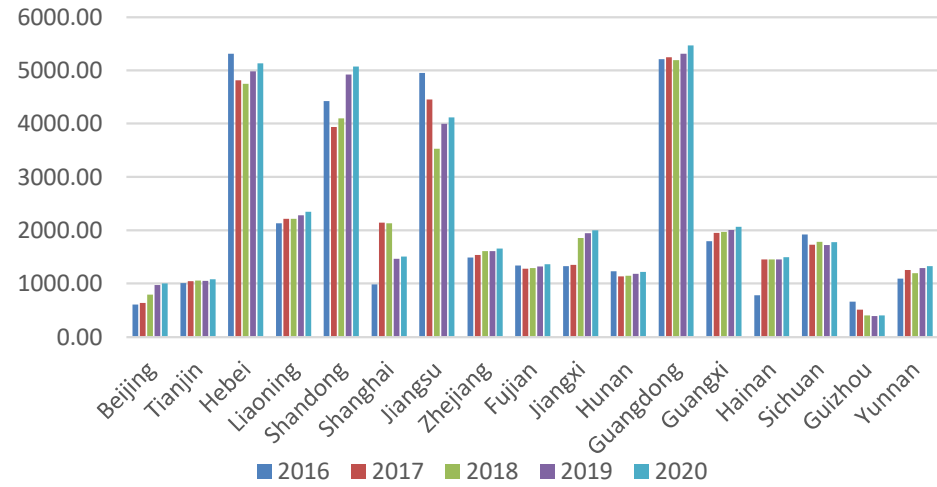
2020		Input			Desirable output	Undesirable output
		I(1)	I(2)	I(3)	O(1)	O(2)
No	City	Employees (million people)	Investment in fixed assets (billion)	Main energy production (10000 tons)	GDP (billion)	CO2 (10000 tons)
1	Beijing	12.86	20616.48	1002.55	36102.6	12008.9
2	Tianjin	5.44	11316.74	1081.28	14083.7	15117.8
3	Hebei	11.64	71020.16	5132.46	36206.9	59119.3
4	Liaoning	100.98	16100.35	2349.86	25115.0	39483.5
5	Shandong	21.65	118889.24	5068.53	73129.0	71263.6
6	Shanghai	14.46	19186.30	1508.38	38700.6	19753.5
7	Jiangsu	26.92	119448.51	4115.01	102719.0	58862.7
8	Zhejiang	19.95	74235.68	1656.93	64613.3	34238
9	Fujian	12.92	58553.42	1360.41	43903.9	17024.4
10	Jiangxi	12.92	46233.85	2001.76	25691.5	15648.9
11	Hunan	12.05	68167.75	1218.27	41781.5	26181.3
12	Guangdong	41.70	92478.40	5468.95	110760.9	55554.6
13	Guangxi	8.16	44253.00	2066.38	22156.7	15223.4
14	Hainan	2.06	9711.47	1493.82	5532.4	2906.2
15	Sichuan	15.94	70453.28	1774.09	48598.8	19202.7
16	Guizhou	6.48	34210.62	403.44	17826.6	15535.1
17	Yunnan	7.42	41916.07	1328.89	24521.9	6943.4

2、Statistics

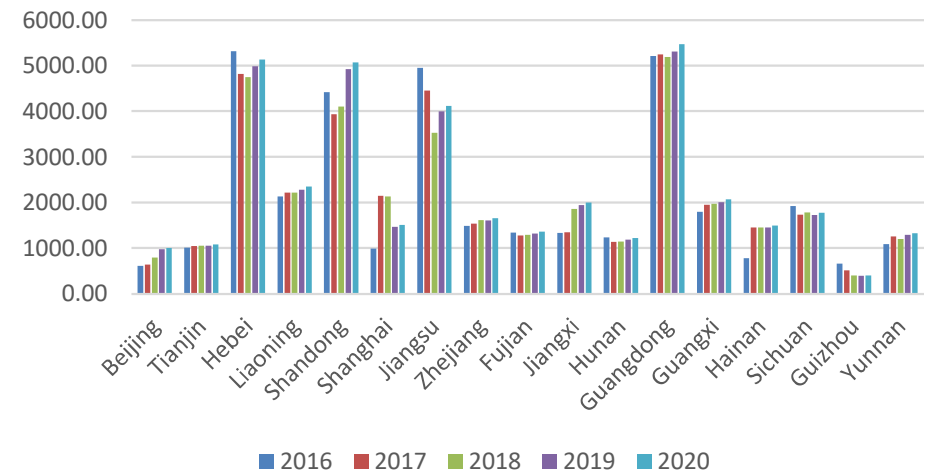
Employees between 2016-2020



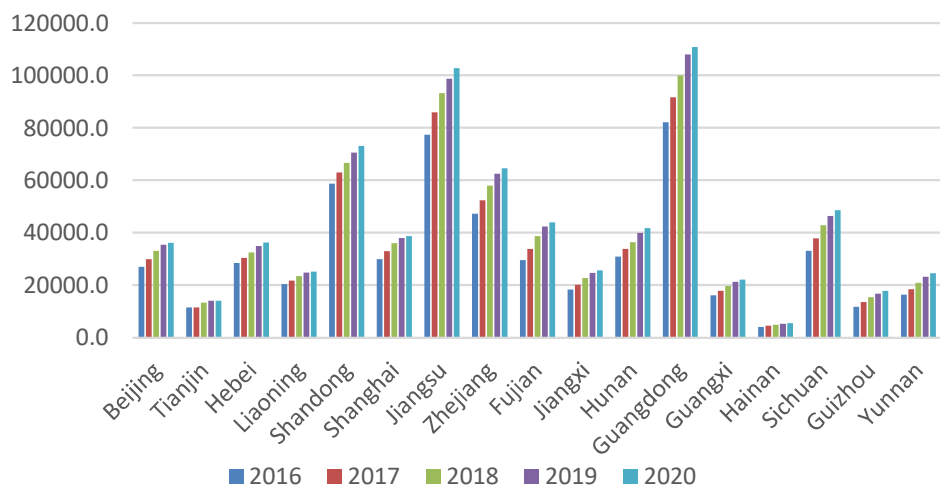
Investment between 2016-2020



Main energy production between 2016-2020



GDP between 2016-2020



Contents

3、 Literature review and Research Gap

Literature Review

Authors	Inputs	Desirable Outputs	Undesirable Outputs
Hu and Wang (2006)	Labor, Capital, Energy, Sown area of farm crops	GDP	
Hu and Kao (2007)	Labor, Capital, Energy	GDP	
Wei et al. (2007)	Fuel Oil, Coal, Coke	Pig iron, Crude & Finished steels	
Hu and Lee (2008)	Labor, Capital, Solid wastes, Waste water, Waste gas	GDP	
Zhou and Ang (2008)	Labor, Capital, Coal, Oil, Electricity, Other energy	GDP	CO2
Zhou et al. (2008)	Energy	GDP	CO2
Zhou et al. (2010)	Labor, Capital, Energy	GDP	CO2
Guo et al. (2011)	Labor, Capital, Energy	GDP	CO2
Zhang et al. (2013)	Labor, Capital, Energy Strong	GDP	
Choi et al. (2014)	Labor, Capital, Energy Strong	GDP	CO2
Wang et al. (2015)	Labor, Capital, Coal, Oil, Gas	GDP	CO2 and SO2
Wu et al. (2016)	Labor, Capital, Energy	Industrial added value	CO2
Li et al. (2016)	Labor, Capital, Energy	GDP	
Pan et al. (2017)	Labor, Capital, Energy Strong	Industrial added value	Wasted gas
Wang et al. (2017)	Labor, Capital, Energy Strong	GDP	CO2
Wang et al. (2018)	Population Total energy, CO2, Non-fossil energy	GDP	
Wang et al. (2019)	Labor, Capital, Coal, Oil, Gas	GDP	CO2

3、 Literature review and Research Gap

Research Significance

Previous study

- Some scholars set up the input and output, and analyzed the urban economic benefits by considering the undesired output
- Some scholars have used DEA to calculate the economic development of developing area or some city
- However, few scholars could take a comprehensive consideration of China's economic development and conduct a comparative study

Research Gap

- In general, there are scant papers combine undesirable output and use DEA method to compare the economic efficiency of China's economic development regions
- Furthermore, this paper presents some related suggestions regarding the results of the analysis with a view to providing more reliable data and as a reference for continuing research

Contents

4、Methodology

❖ DEA Model

CCR model

- The DEA-CCR model is presented by Charnes, A, Cooper, W. W., Rhodes, E. L. (1978)
- Constant Returns to Scale: CRS

$$\begin{aligned}\text{Max}\quad & E_0 = u_1 y_{1o} + u_2 y_{1o} + \cdots + u_a y_{ao} \\ \text{s.t}\quad & \textstyle\sum_{i=1}^{m} v_i x_{\dot{b}} = 1 \\ & \textstyle\sum_{r=1}^{s} u_r y_{rj} \le \sum_{i=1}^{m} v_i x_{\dot{y}} \ (j = 1, 2, \cdots, n) \\ \text{and}\quad & v_i \ge 0 (i = 1, 2, \cdots, m), u_r \ge 0 (r = 1, 2, \cdots, s)\end{aligned}$$

BCC model

- DEA-BCC model is presented by Bank, R. D., Charnes, A. and Cooper, W. W.(1984)
- Variable Returns to Scale: VRS
- Pure technology efficiency and Scale efficiency

$$\begin{aligned}\text{Max}\quad & E_0 = u_1 y_{1o} + u_2 y_{1o} + \cdots + u_s y_{so} + u_0 \\ \text{s.t}\quad & \textstyle\sum_{i=1}^{m} v_i x_{\dot{b}} = 1 \\ & \textstyle\sum_{r=1}^{s} u_r y_{rj} + u_0 \le \sum_{i=1}^{m} v_i x_{\dot{y}} \ (j = 1, 2, \cdots, n) \\ \text{and}\quad & v_i \ge 0 (i = 1, 2, \cdots, m), u_r \ge 0 (r = 1, 2, \cdots, s)\end{aligned}$$

DEA-SBM model

$$\theta^* = m\dot{n} \frac{1 - \frac{1}{m}\sum_{i=1}^{m} \frac{s_i^-}{x_{\dot{b}}}}{1 + \frac{1}{s_1 + s_2}\left(\sum_{r=1}^{s_2} \frac{s_r^b}{y_{r_0}^b} + \sum_{r=1}^{s_2} \frac{s_r^b}{y_{r_0}^b}\right)}$$

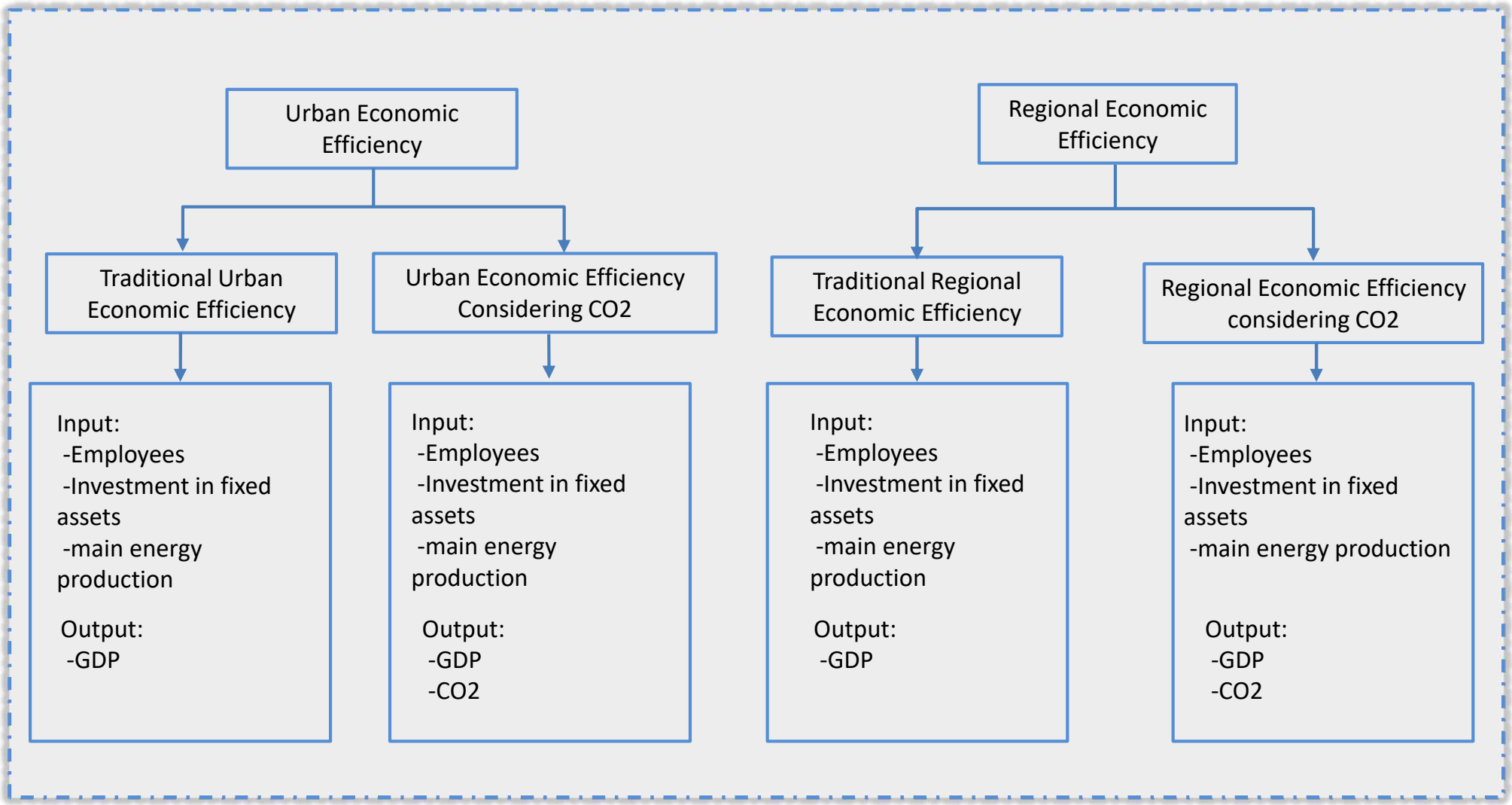
$$\begin{aligned}s.t\quad & \lambda X + s^- = x_0 \\ & \lambda Y^g - S^g = y_0^g \\ & \lambda Y^g + S^b = y_0^b \\ & S^- \ge 0, S^g \ge 0, S^b \ge 0, \lambda \ge 0\end{aligned}$$

- Where θ^* is the efficiency value of DMUo
- S^-, S^g, S^b are the slacks in inputs, desirable outputs and undesirable outputs.
- m, s_1, s_2 stand for the number of inputs, desirable outputs and undesirable outputs respectively
- λ is the intensity vector

Contents

5、Case study and Implication

❖ **The structure of case study**

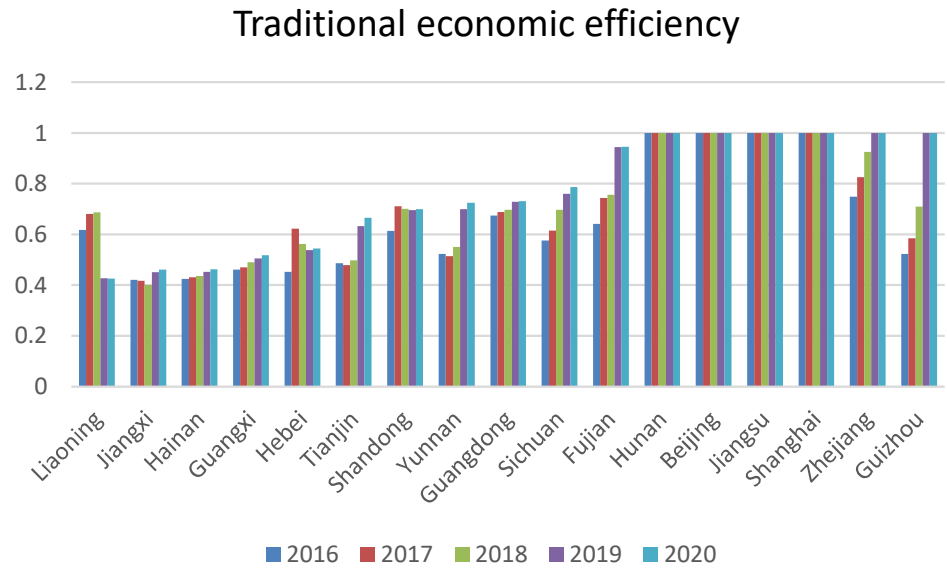


5、Case study and Implication

❖ Traditional Urban Economic Efficiency

The efficiency value of cities

Cities	2016	2017	2018	2019	2020
Liaoning	0.6173329	0.67996	0.686256	0.427112	0.425386
Jiangxi	0.4206348	0.415869	0.400292	0.450319	0.460673
Hainan	0.4245544	0.429804	0.435287	0.452446	0.461472
Guangxi	0.4609123	0.469599	0.489041	0.50421	0.51686
Hebei	0.4515098	0.622747	0.561685	0.537374	0.543534
Tianjin	0.4852593	0.478227	0.497828	0.63249	0.664569
Shandong	0.6138267	0.709929	0.700072	0.695068	0.699082
Yunnan	0.5226233	0.513807	0.549959	0.698748	0.723914
Guangdong	0.6736779	0.687855	0.696677	0.728169	0.730741
Sichuan	0.5759471	0.615029	0.69662	0.759356	0.78566
Fujian	0.6415428	0.742949	0.755374	0.943282	0.945577
Hunan	1	1	1	1	1
Beijing	1	1	1	1	1
Jiangsu	1	1	1	1	1
Shanghai	1	1	1	1	1
Zhejiang	0.7485871	0.825086	0.925176	1	1
Guizhou	0.5219945	0.583923	0.709803	1	1



- The efficiency value of Liaoning is decreasing year by year, which is mainly due to the rapid growth of employees every year, but the change of GDP is not obvious
- The obvious increase in the efficiency value of Zhejiang and Guizhou is due to the increased investment in these two regions in 2018 and 2019, resulting in a large increase in GDP

5、Case study and Implication

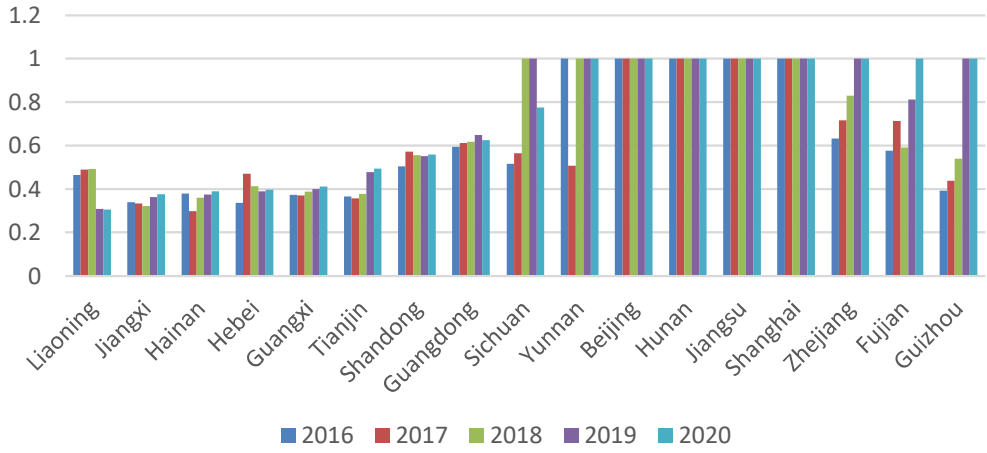
❖ Urban Economic Efficiency considering CO_2

The efficiency value of cities

CO_2

Cities	2016	2017	2018	2019	2020
Liaoning	0.4643981	0.4890166	0.4930616	0.3086777	0.3051094
Jiangxi	0.3394745	0.3329368	0.3214046	0.362626	0.3754612
Hainan	0.3788778	0.2982889	0.3591202	0.3745142	0.3899568
Hebei	0.3367383	0.4698232	0.4128132	0.389933	0.3964708
Guangxi	0.3733666	0.3696307	0.3872111	0.4000164	0.4108787
Tianjin	0.3664438	0.3575286	0.3771772	0.4780573	0.4940816
Shandong	0.5040844	0.5724805	0.5551644	0.5515802	0.5589768
Guangdong	0.5944936	0.6121548	0.6181232	0.6480271	0.6254149
Sichuan	0.5157086	0.5643386	1	1	0.7747675
Yunnan	1	0.5075929	1	1	1
Beijing	1	1	1	1	1
Hunan	1	1	1	1	1
Jiangsu	1	1	1	1	1
Shanghai	1	1	1	1	1
Zhejiang	0.6325906	0.716404	0.8303937	1	1
Fujian	0.5759916	0.7135482	0.5917089	0.8121644	1
Guizhou	0.3920504	0.4383659	0.5395072	1	1

Economic efficiency considering undesirable output



- Obviously, the economic efficiency of considering unexpected output is lower than that of the traditional economy without considering unexpected output
- The two cities of Sichuan and Yunnan stand out because they have large green areas and less carbon dioxide emissions than other cities

5、Case study and Implication

Traditional Urban Economic Efficiency

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Jiangsu	1	1	1	1	1
Shanghai	1	1	1	1	1
Zhejiang	0.7485871	0.825086	0.925176	1	1
Guizhou	0.5219945	0.583923	0.709803	1	1

Urban Economic Efficiency Considering CO2

CO_2

Cities	2016	2017	2018	2019	2020
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Jiangxi	0.3394745	0.3329368	0.3214046	0.362626	0.3754612
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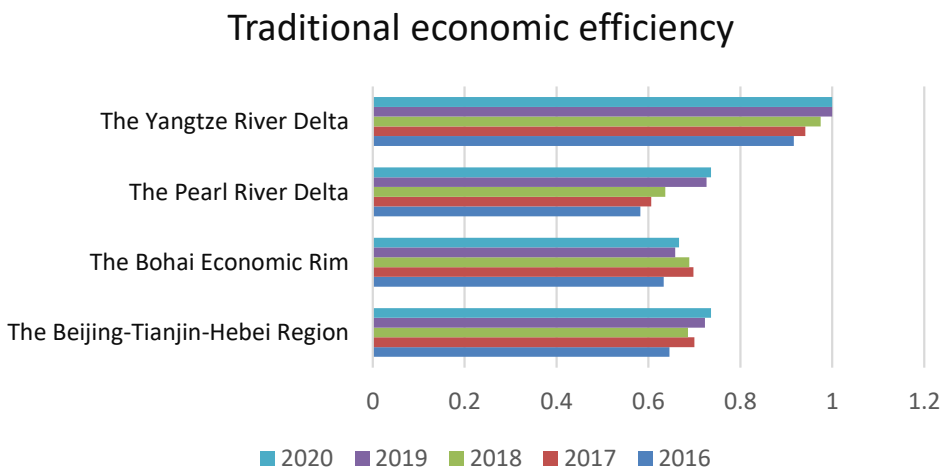
5、Case study and Implication

❖ Traditional Regional Economic Efficiency

The efficiency value of economic development zones

Economic Efficiency without considering undesirable output	2016	2017	2018	2019	2020
The Beijing-Tianjin-Hebei Region	0.64559	0.700325	0.686504	0.723288	0.736034
The Bohai Economic Rim	0.633586	0.698173	0.689168	0.658409	0.666514
The Pearl River Delta	0.582432	0.606537	0.637006	0.726281	0.736099
The Yangtze River Delta	0.916196	0.941695	0.975059	1	1



- In terms of the economic development zones, **the Yangtze River Delta** has the highest economic efficiency among these four economic belts
- The value of green economic efficiency from high to low is the Yangtze River Delta, the Beijing-Tianjin area, the Pearl River Delta, and the Bohai Bay Economic Belt

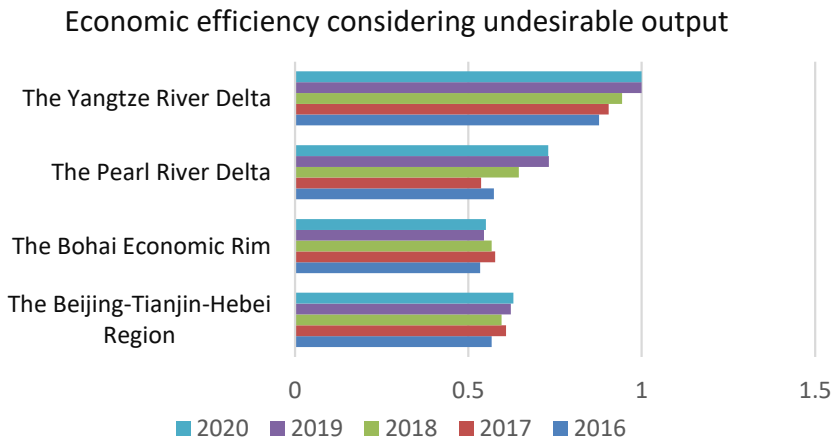
5、Case study and Implication

❖ Regional Economic Efficiency considering CO_2

CO_2

The efficiency value of economic development zones

Efficiency considering undesirable output	2016	2017	2018	2019	2020
The Beijing-Tianjin-Hebei Region	0.567727	0.609117	0.596663	0.622663	0.630184
The Bohai Economic Rim	0.534333	0.57777	0.567643	0.54565	0.550928
The Pearl River Delta	0.57444	0.537429	0.646342	0.733039	0.73072
The Yangtze River Delta	0.87753	0.905468	0.943465	1	1



- **The Yangtze River Delta** has the highest economic efficiency among these four economic belts, and the Bohai Economic Rim is still the last one
- Same as the urban economic efficiency, the efficiency considering unexpected output is obviously lower than that of the traditional economy without considering unexpected output

5、Case study and Implication

Compare with the efficiency

Economic efficiency without considering undesirable output	2016	2017	2018	2019	2020
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CO_2

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The Bohai Economic Rim	0.534333	0.57777	0.567643	0.54565	0.550928
The Pearl River Delta	0.57444	0.537429	0.646342	0.733039	0.73072
The Yangtze River Delta	0.87753	0.905468	0.943465	1	1

By the comparison:

- **The Yangtze River Delta** always has the highest efficiency value among these four economic belts
- The reason why Bohai economic Rim always ranks last is that the economic efficiency of Liaoning is always poor in the region and the carbon dioxide emissions are also high

Contents

6、Conclusion

Conclusion

Conclusion

- The economic efficiency considering the undesirable output is always lower than the traditional economic efficiency from 2016 to 2020
- It is found that the cities with effective economic efficiency are Beijing, Shanghai, Hunan and Jiangsu
- On the contrary, cities with poor economic efficiency include Liaoning, Jiangxi, Hainan and Hebei
- From the perspective of regional economic efficiency, these four economic zones are all in the stage of steady increase year by year, which shows that China's economic policy is effective

Limitation and future work

- Because of the huge area of China, this research does not select all of the economic regions as the research objects. The latter scholars could expand the scope of research objective for more comparative analysis
- Analysis of elements affecting economics efficiency is not comprehensive

Suggestion

- It is suggested that the government should allocate different emission targets to different regions depending on the industrial structure and economic development level of different economic zones, to promote the rapid economic development of the country

Thanks for your attention

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