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Industrial agglomeration and effective energy service: Panel threshold analysis for China's iron and steel industry

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ABSTRACT

From the perspective of industrial agglomeration, this paper attempts to explore how much energy used is transformed into effective work affecting steel production and consumption. Using panel data of Chinese provinces from 1997 to 2016, we measure industrial agglomeration and effective energy service of the iron and steel industry. The panel threshold model is utilized with GDP per capita as the threshold variable, and a nonlinear framework is constructed to identify the relationship between agglomeration and effective energy service. The results show that the iron and steel industry exhibit agglomeration characteristics, with the average location entropy index exceeding 1. The effective energy service experiences a rise from 1997 to 2013, but declines from 2014 to 2016. The effective energy service in central and western regions lag behind that in eastern region. And with the economic growth, the influence of agglomeration on effective energy service is increasing. Finally, the paper suggests some policy priorities to improve the effective energy service of the iron and steel industry.

Keywords: Iron and steel industry, Industrial agglomeration, Effective energy service, Panel threshold model

NONMENCLATURE

Abbreviations	
ISI	Iron and steel industry

1. INTRODUCTION

Energy is considered as the basic production factor in iron and steel industry (ISI). Primary energy turns into an effective energy service and is put into work in a way that is different from energy use itself [1]. Sorrell et al. [2] believed that energy service comprises useful energy, an essential feature of which is access to useful work. In fact, the effective energy service is closely linked to energy efficiency. Higher energy efficiency means that more energy services are available for the same inputs.

The ISI's production is mainly concentrated in the eastern region. The ISI's output value in the eastern region accounted for 60.95% in 2016 [1]. Industrial agglomeration, as the distinctive geographical feature of economic activities, is an important factor affecting effective energy service [3]. For China's ISI, can industrial agglomeration promote effective energy service? Due to the large variations in different regions of China, does agglomeration exhibit a threshold effect on effective energy service under the condition of economic heterogeneity? Solving these problems is the main motivation of the study.

The innovation of the study mainly includes three aspects: (1) Few articles discuss the effective energy service of ISI. This paper quantitatively measures the effective energy service. It could help us have a better understanding as to how much energy is converted into useful work. (2) This paper discusses the interaction between agglomeration and effective energy service of ISI under the condition of economic heterogeneity. It is conducive to improving the effective energy service from

1 Source: China industry economy yearbook, 2017.

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the perspective of industrial agglomeration. (3) Based on the results, this paper proposes suggestions to improve the energy efficiency service of ISI.

2. LITERATURE REVIEW

There are a lot of in-depth studies on energy service, which focus on qualitative [4] and quantitative aspects [5, 6]. However, there is no agreed term of effective energy service. In this study, we prefer to use the concept that energy service is defined as useful work obtained from energy consumption [7]. The first reason is that the notion that energy service constitutes useful work is more often studied by researchers. The concept and measurement are more explicit. Second, energy service is the driving force of energy consumption. The effective energy service is a more important topic than energy consumption.

A considerable amount of literature focus on the influence of agglomeration on productivity, economic growth and energy efficiency [8]. But to our knowledge, there is little literature on the correlation of agglomeration and effective energy service of ISI. Given the huge production and energy consumption of China's ISI, it is urgent to explore how the agglomeration affects the useful energy work of ISI.

3. METHODOLOGY AND DATA

3.1 Estimation method of industrial agglomeration

Based on Morrissey [9], the formula for calculating location entropy can be written as follows:

$$LE_{ij} = \frac{S_{ij} / \sum_{i}^{m} S_{ij}}{\sum_{j}^{n} S_{ij} / \sum_{i}^{m} \sum_{j}^{n} S_{ij}} \qquad (1)$$

Where, LE_{ij} represents the location entropy of ISI. S_{ij} refers to industry j in i^{th} province. It is generally believed that if $LE_{ij} > 1$, the agglomeration of industry j in i^{th} province is relatively strong.

3.2 Estimation method of effective energy service

We first have to calculate energy efficiency. This paper assumes that there are N decision-making units (DMUs), which takes capital (K), labor (L), energy (E) as input and output (Y) as output. According to the definition of Hu and Wang [10], total factor energy efficiency is obtained by the following formula:

$$EF = 1 / D_E^T (K, L, E, Y) \qquad (2)$$

Following the idea of Sorrell and Dimitropoulos [2], effective energy service is defined as the product of energy consumption (E) and energy efficiency (EF).

$$ES = E * EF \qquad (3)$$

3.3 The regression model

The study adopts threshold model to explore the impact of agglomeration on effective energy service. Based on Hansen [11], the panel threshold model can be constructed as:

$$\ln ES_{jt} = \alpha_j + \beta_1 \ln LE_{jt} + \beta_2 \ln ED_{jt} + \beta_3 \ln RD_{jt} + \beta_4 \ln FS_{jt} + \beta_5 \ln EP_{jt} + \varepsilon_{jt},\ \mathrm{r}_{i-1} \le \theta_{jt} < r_i \qquad (4)$$

Where, θ_{jt} denotes the threshold variable. ES_{jt}, LE_{jt}, ED_{jt}, RD_{jt}, FS_{jt}, and EP_{jt} represent effective energy service, industrial agglomeration, economic development, R&D investment, firm size and energy price in province j at time t, respectively. α_j and ε_{jt} represent individual effects and random error terms that do not change over time, respectively.

3.4 Variables selection and data source

This paper uses data of 30 Chinese provinces between 1997 and 2016. The data are mainly from China Statistical Yearbook, China Science and Technology Statistical Yearbook and China industry economy yearbook.

Except for effective energy service and industrial agglomeration, the main control variables are explained as follows. (1) Economic development. GDP growth is positively correlated with an increase in effective energy service [12]. (2) R&D investment. Technological progress is the driver of growth in effective energy service [12, 13]. (3) Firm size. Firm size may affect effective energy service. Large firms can adopt more efficient equipment for mass production. Large firms also have more sufficient financial support in R&D investment and pollutant reduction. (4) Energy price. A higher price will encourage producers to adopt advanced technologies to improve productivity, leading to a rise in effective energy service.

4. RESULTS AND DISCUSSION

4.1 Industrial agglomeration of ISI

According to table 1. The annual average location entropy index of ISI in the eastern, central, and western

regions is 1.1300, 1.2290, and 1.1205, respectively. The location entropy index of three regions exceeds 1, which indicates that China's ISI has agglomeration characteristics.

Table 1 Average location entropy index of China's ISI during 1997-2016

Year	Eastern region	Central region	Western region
1997	1.1590	1.3870	1.2212
1998	1.1428	1.4142	1.1713
1999	1.1268	1.4558	1.1336
2000	1.1256	1.4837	1.1323
2001	1.1400	1.4760	1.0892
2002	1.1448	1.4763	1.0975
2003	1.1584	1.4340	1.0881
2004	1.1363	1.3421	1.0549
2005	1.1267	1.3015	1.0418
2006	1.1247	1.2564	1.0374
2007	1.1160	1.2170	1.0942
2008	1.1061	1.1686	1.0876
2009	1.1504	1.0985	1.1039
2010	1.1202	1.0545	1.1489
2011	1.0918	1.0131	1.1458
2012	1.0683	0.9836	1.1183
2013	1.0744	0.9871	1.1795
2014	1.1137	0.9988	1.1458
2015	1.1670	1.0279	1.1724
2016	1.2072	1.0046	1.1457
Average	1.1300	1.2290	1.1205

It can be found that the location entropy index of ISI has been on the rise since 2013. It may be mainly due to a series of policies adopted by the government to optimize the spatial distribution of ISI. On January 22, 2013, the Ministry of Industry and Information Technology issued the "Guidance on accelerating enterprise mergers and reorganizations in key industries". Furthermore, on October 6, 2013, China State Council issued “Guidance on resolving the serious overcapacity problem”, offering more specific guidance for iron and steel firms’ merger and reorganization. Merger and reorganization can enhance its position in industrial chains, which makes the location entropy improvement after 2013.

4.2 Effective energy service of ISI

Figure 1 presents the effective energy service changes from 1997 to 2006. At the national level, the effective energy service of ISI increased between 1997 to 2013 (except 2001), which was consistent with the rapid development of China's ISI during this period. According to the world steel yearbook, the annual growth rate of China's crude steel production between 1997 and 2013 was 9.62%[2]. It is apparent from figure 1 that the effective energy service of ISI declined in 2001. The decline may be attributed briefly to China’s accession to the World Trade Organization during that year. With further opening of the domestic market in 2001, China was under pressure on the product price and quality. Another important finding was that the effective energy service of ISI decreased from 2014 to 2016. There are two likely causes for this phenomenon. One is that the "new normal" of China's economy leads to a contraction in products demand. The decline in iron and steel production capacity reduces the supply of energy services. The other is that China put more emphasis on high-quality development and promoted the industrial upgrade. The application of new technologies leads to energy conservation.

At the regional level, the effective energy service of ISI in the eastern region is much higher than that in central and western regions. What stands out is that the gap in the effective energy service of ISI among regions is growing larger. This suggests that ISI should take a series of measures to improve effective energy service in the central and western regions, such as updating their equipment and technologies.

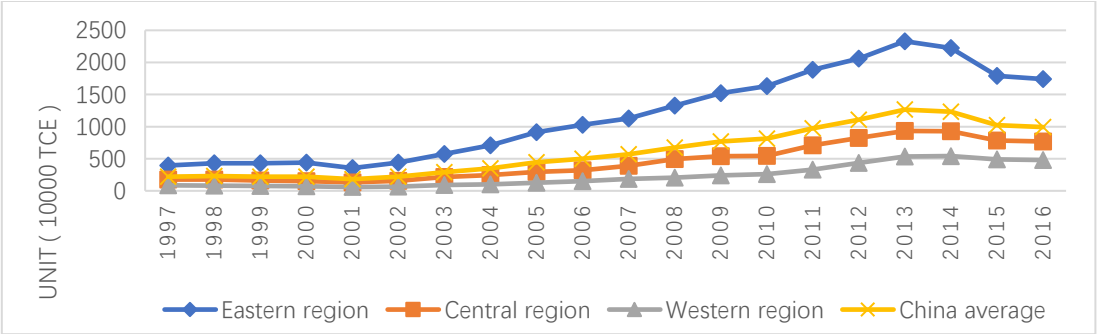

Figure 1 The effective energy service change of China’s ISI from 1997 to 2016

2 Source: Steel statistical yearbook, 1998-2014.

4.3 Impact of industrial agglomeration on effective energy service

4.3.1 Linear regression model estimation

It can be seen from the Model (1) and Model (2) in table 2 that industrial agglomeration significantly promotes the effective energy service of ISI. Specifically, as for the fixed effect model, 1% increase of industrial agglomeration will cause 1.252% increase in effective energy service. The industrial agglomeration may promote effective energy service of ISI through three aspects. Firstly, the iron and steel firms can share the convenient transportation and infrastructures, which helps to reduce transportation cost and improve the flow of energy. Shared infrastructures improve the effective energy service of ISI. Secondly, industrial agglomeration brings together technologies and other resources. It is conducive to accelerating knowledge diffusion and technology innovation. The improvement of the technical efficiency of resource utilization leads to an increase in the effective energy service of ISI. Thirdly, agglomeration can strengthen the competition among different iron and steel firms. This will encourage firms to improve productivity and effective energy service.

For control variables, both economic development and R&D investment have significant positive effects on the effective energy service of ISI. In other words, economic growth and technical progress facilitate the provision of effective energy service. The influence coefficient of firm size and energy price on effective energy service are not significant.

Table 2 The impact of industrial agglomeration on effective energy service

Variables	Model (1) Fixed effect	Model (2) Random effect	Model (3) IV-GMM
lnLE	1.252***	1.244***	1.327***
	(0.048)	(0.048)	(0.058)
lnED	2.097***	2.046***	2.089***
	(0.088)	(0.087)	(0.098)
lnRD	0.118***	0.119***	0.141***
	(0.028)	(0.029)	(0.031)
lnES	0.039	0.047	0.002
	(0.042)	(0.042)	(0.046)
lnEP	0.114	0.135	0.252**
	(0.109)	(0.108)	(0.119)
Constant	-13.76***	-13.49***	\
	(0.749)	(0.770)	
Hausman Test	0.0022		\
Observations	600	600	540
R^2	0.897	0.897	0.897

Note: "*", "**" and "***" are represented at 10%, 5%, and 1% respectively.

To overcome the endogenous problem, we select the first and second order of lag of agglomeration as tool variables. Model (3) in table 2 shows the IV-GMM estimation results. The influence of agglomeration on effective energy service is still significant. This indicates that without considering endogeneity, the promotion effect of industrial agglomeration on effective energy service is underestimated. Also, the impact of energy price on effective energy service becomes significant (at p=0.05 level) with consideration of endogeneity.

4.3.2 Nonlinear regression model estimation

Considering the economic heterogeneity, the estimation of three regions' samples will help us better understand the relationship between agglomeration and effective energy service. Therefore, we take GDP per capita as the threshold variable and construct the threshold model based on Hansen [11]. As can be seen from table 3, we set the model as the single threshold model. The relationship between industrial agglomeration and effective energy service of ISI is nonlinear.

Table 4 Estimation results of the threshold model

Variables	Model (1) Fixed effect	Model (2) Threshold model
lnLE	1.252***	\
	(0.048)	
$lnLE_1$	\	1.062***
		(0.053)
$lnLE_2$	\	1.642***
		(0.072)
lnED	2.097***	1.934***
	(0.088)	(0.088)
lnRD	0.118***	0.097***
	(0.028)	(0.027)
lnES	0.039	0.058
	(0.042)	(0.040)
lnEP	0.114	0.254**
	(0.109)	(0.106)
Constant	-13.760***	-13.40***
	(0.749)	(0.719)
Observations	600	600
R^2	0.897	0.906

Note: "*", "**" and "***" are represented at 10%, 5%, and 1% respectively.

The estimated results of the single threshold model are presented as Model (2) in table 4. It shows that there is a significant positive relationship between industrial agglomeration and effective energy service at two threshold intervals. The influence coefficient of agglomeration on effective energy service is 1.062 and 1.642, respectively. It shows that with economic improvement, agglomeration exerts a greater influence on the effective energy service of ISI. A possible explanation for this may be that the higher the economic development, the more mature the market is. The energy and other resources used in the ISI are efficient, which helps the firms provide more effective energy service. Compared with Model (1) in table 4, the impact of energy price on effective energy service becomes significant (at p=0.05 level) after considering economic heterogeneity.

The threshold value of GDP per capita is estimated to be 23601.100 Yuan RMB. We find that most provinces are in the first threshold interval (GDP per capita<23601.100 Yuan RMB). From the previous analysis, we know that the effective energy service of ISI in the central and western regions are lower than that in the eastern region. Therefore, to plug this gap, the role of industrial agglomeration in the effective energy service of ISI must be considered.

4.3.3 Robustness test

To improve the accuracy of the empirical results, we use two methods to test the robustness of threshold model. The first method is to shorten the time window. To eliminate other factors' interference, the sample from the past two five-year plans of China (2006-2015) is re-examined. The second method is to delete control variables one by one for re-estimation. The test results are summarized as Model (1)-(5) in table 5. It is apparent from this table that there is little difference for the core explanatory variable, which proves the robustness of results.

Table 3 Threshold effect test of GDP per capita (bootstrap=1000)

H0	H1	RSS	MSE	F	P	Reject or Accept H0
None threshold	Single threshold	34.2254	0.059	52.67**	0.037	Reject
Single threshold	Double thresholds	33.0426	0.057	20.76	0.302	Accept

Note: "*", "**" and "***" are represented at 10%, 5%, and 1% respectively.

Table 5 The robustness test of threshold model

Variables	Model (1) 2006-2015	Model (2) Drop lnED	Model (3) Drop lnRD	Model (4) Drop lnES	Model (5) Drop lnEP
$lnLE_1$	0.735***	0.566***	1.076***	1.103***	1.040***
	(-0.114)	(0.071)	(-0.054)	(-0.045)	(-0.053)
$lnLE_2$	2.214***	1.636***	1.688***	1.675***	1.585***
	(-0.114)	(0.087)	(-0.071)	(-0.068)	(-0.068)
lnED	1.017***	\	1.896***	1.992***	2.018***
	(-0.193)		(-0.088)	(-0.078)	(-0.081)
lnRD	0.083	0.006	\	0.090***	0.146***
	(-0.069)	(0.037)		(-0.027)	(-0.018)
lnES	0.381***	0.455***	0.034	\	0.097***
	(-0.073)	(0.048)	(-0.040)		(-0.037)
lnEP	0.663***	1.274***	0.540***	0.315***	\
	(-0.212)	(0.132)	(-0.070)	(-0.098)	
Constant	-9.668***	-5.241***	-15.150***	-14.030***	-12.530***
	(-1.317)	(0.815)	(-0.528)	(-0.573)	(-0.621)
Observations	300	600	600	600	600
R^2	0.835	0.829	0.904	0.905	0.905

Note: "*", "**" and "***" are represented at 10%, 5%, and 1% respectively.

5. CONCLUSIONS AND RECOMMENDATIONS

The conclusions of the study can be summarized into three points. Firstly, the location entropy index exceeds 1, which indicates that China's ISI has obvious agglomeration characteristics. Secondly, the effective energy service of ISI shows an upward trend from 1997 to 2013 (except 2000). The effective energy service of ISI

in the central and western regions is lower than that in the eastern region. Thirdly, the industrial agglomeration can promote the effective energy service of ISI. For control variables, economic development and R&D investment have significantly positive effects on effective energy service. The influence of agglomeration on effective energy service has a threshold effect. It indicates that industrial agglomeration exerts a greater influence on effective energy service with economic improvement.

This paper proposes suggestions for the sustainable development of China's ISI.

(1) When formulating industrial policies, the government should take into consideration the balanced development of ISI in different regions. The empirical results show that effective energy service in the central and western regions gradually lags behind that of the eastern region. Therefore, the government needs to make efforts to promote the economic development of backward regions and enhance the positive impact of agglomeration on effective energy service in central and western regions. Moreover, the government should actively break down regional barriers and encourage regional cooperation. In this way, the iron and steel firms in the agglomeration area can provide more effective energy service across the country.

(2) The government should focus on guidance and give full play to firms' initiative in the merger and reorganization. This study demonstrates that the iron and steel firms' size have no significant influence on the effective energy service. The government need provide appropriate guidance to merger and reorganization of ISI. However, the government, as the public services provider, should fully respect the independent decision-making rights of iron and steel firms. When iron and steel firms expand their production through mergers and reorganizations, they need to improve their management ability to make energy converted into more useful work.

(3) The ISI needs to increase R&D investment to promote industrial technology progress. The study illustrates that technological progress is conducive to improving the effective energy service of ISI. Production technology directly affects industrial energy utilization. Based on in-depth research on the processes and equipment of steel production, ISI should encourage the elimination of outdated equipment and carry out technological innovation. Moreover, ISI needs to increase investment in areas such as frontier metallurgical processes and key products. It will ultimately improve energy efficiency and increase effective energy service.

CONFLICTS OF INTEREST

We declare no conflict of interest.

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REFERENCES

[1] Patterson, M. G., 1996. What is energy efficiency? Concepts, issues and methodological issues. Energy Policy 24, 377– 390.

[2] Sorrell, S., Dimitropoulos, J., Sommerville, M., 2009. Empirical estimates of the direct rebound effect: A review. Energy Policy 37(4), 1356-1371.

[3] Krugman, P., 1991. Increasing returns and economic geography. J. Political Econ. 99 (3), 483-499.

[4] Kaygusuz, K., 2012. Energy for sustainable development. Renewable and Sustainable Energy Reviews 16(2), 1116-1126.

[5] Fujimori, S., Kainuma, M., Masui, T., 2014. The effectiveness of energy service demand reduction: A scenario analysis of global climate change mitigation. Energy Policy 75, 379-391.

[6] Hunt, L.C., Ryan, D.L., 2015. Economic modelling of energy services: Rectifying misspecified energy demand functions. Energy Economics 50, 273-285.

[7] Jonsson, D.K., Gustafsson, S., Wangel, J., 2011. Energy at your service: highlighting energy usage systems. Energy Efficiency 4, 355-369.

[8] Hu, C., Xu, Z., Yashiro, N., 2015. Agglomeration and productivity in China: Firm level evidence. China Economic Review 33, 50-66.

[9] Morrissey, K., 2014. Producing regional production multipliers for Irish marine sector policy: a location. Ocean Coast Manag. 91, 58-64.

[10] Hu, J.-L., Wang, S.-C., 2006. Total-factor energy efficiency of regions in China. Energy Policy 34 (17), 3206-3217.

[11] Hansen, B. E., 2000. Sample splitting and threshold estimation. Econometrica 68(3), 575-603.

[12] Haas, R., Nakicenovic, N., Ajanovic, A., Faber, T., Kranzl, L., 2008. Towards sustainability of energy systems: A primer on how to apply the concept of energy services to identify necessary trends and policies. Energy Policy 36(11), 4012-4021.

[13] Haas R, Wirl F. 1992. Market penetration of natural gas in Europe: prospects and impediments. Energy sources 14(1): 21-32.