

RESEARCH ON INNOVATION AND DEVELOPMENT OF INDUSTRIAL CLUSTERS UNDER LOW-CARBON ECONOMY

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ABSTRACT. *In recent years according to the country on low-carbon economy-related laws and regulations, it is clearly pointed out that the development of low-carbon economy is the development of China's future economic premier and it will also affect the development of industrial clusters layout. Therefore, how to apply low-carbon economy to the innovation and development of industrial clusters has become the focus of the focus. First this paper gives a theoretical review of the innovation and development of industrial clusters under the low-carbon economy, and then analyzes the problems in the current situation of innovation and development of industrial clusters under the environment of low-carbon economy in China. Finally, the countermeasures and suggestions on the innovation and development of industrial clusters in low-carbon economic environment are proposed.*

Keywords: Low-carbon economy, Industrial clusters, Innovation

1. **Introduction.** According to the proposal on the “thirteenth five plan of China”, low-carbon economy will be developed vigorously. The national energy structure will be optimized, and the consuming of fossil energy must be controlled in a reasonable range. Since 2014, the General Office of the State Council has issued a series of related policy documents concerned to implement the national strategy of new energy development and to change traditional energy model into new energy economic development model.

China's economic development pattern is unique and has its own graphical features. One demonstration of the graphical features is the various kinds of industry clusters all over China. Because of its low cost, the advantages of the scale effect, the effective information communication, the industry cluster has become an important part of regional economic development. Despite the type and aggregation degree of industrial cluster are different in different China's areas, on the whole, China's eastern coastal areas have become a relatively mature industry cluster area.

In recent years, with the implementation of western development strategy, the industrial clusters of China's central and western regions are gradually developed from point to plane, such as the coal industry cluster in Shanxi Province, the industry cluster of traditional Chinese medicine in Anhui Province, the industrial cluster of grain in Henan Province. The most intuitive benefits of industrial cluster that bring about the most intuitive benefits are the economic benefit. The characteristic of extensive economic development mode is pursuing excessively economic interests and ignoring the sustainable

development of energy. The plight of industrial cluster development in China is facing a shortage of resources. This kind of situation is particularly serious in the eastern coastal areas. In recent years, although the carbon intensity of some traditional industrial cluster is reduced under the low-carbon economy policy regulation, the total carbon emissions of China are rising because of the influence of economic structure. At present, China is in a period of rapid industrial development, and high carbon energy structure of industrial cluster could not have fundamental changes in the short term. Therefore, the innovation commercialization and industrialization of low carbon technology are the only way for industry cluster to develop low carbon economy. This paper focuses on industry cluster innovation's inadaptability to the low carbon economy environment and finding the solution.

2. A Review of Related Studies.

1) A review of studies on industrial cluster innovation

The research on technological innovation of industrial clusters originates from the transformation of technological innovation research from "linear paradigm" to "network paradigm". The innovation research perspective shifts from focusing on a single enterprise to the connection and interaction between the enterprise and the external environment, leading to the rise of "network paradigm" in technological innovation research. Asheim and Isaksen [1] suggested that regional innovation system is a regional cluster surrounded by supporting institutions, and he also classifies regional innovation system in categories. Other foreign scholars have done a lot of empirical research on industrial cluster technology innovation from different research perspectives as well. The research results of Capello [2], Baptista and Swann [3] empirically showed that the forming of industrial clusters is good for promoting the improvement of the innovation ability of enterprises within clusters and the diffusion of innovation results. Danish scholars Dalum et al. [4] studied the influence of technology life cycle on the development of industrial clusters by taking the wireless communication tool cluster in northern Europe as an example. Cooke and Schienstock [5] believed that innovation clusters and cooperative networks are efficient and effective tools to promote regional development, enhance innovation capabilities and regional competitive advantages, and reduce inconvenience caused by geographical distance and social imbalance. Chinese scholars have also carefully studied the technological innovation of industrial clusters, among which Zhu [6] found that the innovation advantage of forming industrial clusters is to improve the innovation ability of enterprises within the clusters through more interactive learning process and superior learning environment of enterprises in clusters.

2) A review of research on collaborative mechanism of industrial cluster innovation

Foreign scholars have done a lot of work on the collaborative mechanism of industrial cluster innovation. Arthur and Cooke [7] believed that industrial cluster is a complex adaptive system, and knowledge flows through various components within the system to enhance innovation of enterprises within the cluster. Freeman and Soete [8] first proposed the concept of innovation network, and proposed that the main link mechanism of innovation network is the cooperative relationship between innovation subjects. Pekkarinen and Harmaakorpi [9] both believed that collaborative networks mainly consist of enterprises themselves, upstream and downstream enterprises, competitors, marketing intermediaries, universities and research institutions. Based on empirical data, Nieto and Santamaria [10] believed that enterprise collaborative network has a significant positive effect on innovation performance. Whitley [11] believed that different cooperative partner choices have different effects on enterprise innovation. Domestic scholars have also done a lot of research in this field. For example, Liu [12] revealed the internal mechanism of cluster innovation network of regional international competitiveness, and built regional

international competitiveness analytical model based on the cluster innovation network theory.

The studies of industry cluster innovation and its coordination mechanism so far, mainly focus either on “cluster effect” analysis or on cooperation mechanism analysis. Most of the existing studies have severed the internal relationship between industrial cluster innovation and low-carbon economy by ignoring the positive influence of industrial cluster innovation on the structural transformation of low-carbon economy. Therefore, this paper focuses on the factors and obstacles that cause industrial cluster innovation fail to adapt to the low-carbon economic environment and solutions to these obstacles.

3. The Difficulties in the Innovation of Industrial Cluster in Low-Carbon Economic Environment. The innovation of industrial cluster refers to all kinds of various activities conducted by the correlative enterprises in a specific regional environment and their supporting mechanisms in cooperation in order to create knowledge, new technologies and products for the purpose of improving the core competitiveness of the industrial cluster. The social environment consists of various industrial clusters which can be viewed as small environments. Thus, to develop low-carbon industrial cluster, it is necessary to focus on the existence and development of each industrial cluster so as to improve the level of the whole low-carbon industrial cluster. However, at present, the high-consumption, high-investment and low-efficiency development pattern in China driven by economic growth completely goes against the innovative development of industrial cluster in low-carbon economic environment. In the current situation, there are following problems in the innovative development of industrial cluster in low-carbon economic environment.

1) Non-comprehensive understanding of the meaning

At present, China is still exploring the concept of the integration of industrial cluster into low-carbon economy. Thus, people’s understanding of this concept is superficial. Industrial cluster in low-carbon economy has not become a popular trend, which is always taken as an approach to accelerate development. As long as their economic benefit grows, entrepreneurs, who pay great attention to investment and output, will exploit resources continuously to meet the need of manufacturing and production instead of taking the negative influence on the environment brought by economic growth into consideration. People always think that to develop low-carbon economy is only a measure taken by the government, but neglecting the larger and sustainable benefit will be brought by the adjustment or restructuring of industrial cluster. Meanwhile, the concept of low carbon is not widely advertised in enterprises. And the government does not take any effective punishment measures to the negative influence on the environment brought by production.

2) Extensional economic growth mode

Extensional economy is also called extensive economy which refers to the extension of the factors of production input into enterprise like labor input, production facility and equipment input, which can increase enterprises’ scale of production and promote the economic growth of industrial cluster. In the international economic environment, goods with “Made in China” can be seen almost everywhere, which directly shows the low cost of acquiring resources and labor in Chinese industrial clusters. To maintain their stable economy, industrial clusters have to depend on resource and energy exploration. In production, almost all industrial clusters show “waste-centered” developing trend. And the extensive economic growth mode in the majority of industrial clusters dramatically increases carbon consumption in GDP.

If such high-consumption, high-emission, high-investment, unsustainable and low-efficiency industrial cluster growth mode continues developing, the Chinese economy will no longer increase or even decline after the exhaustion of resources. For example, coal industrial cluster is the most developed one in West China. However, based on its situation in the last decade, this industry will not change its industrial cluster structure. Thus, the

only way is to change the mode of economic development and the pattern of consumption. Meanwhile, rich coal and cement resources in Northwest China drive the development of local industrial economy. Carbon emission and pollution reduction will further improve the competitiveness of this region in sustainable development and develop its low carbon advantages.

3) Service to the end of global industrial chain

At present, in the whole international environment, the situation of the division of function is changing from producing the entire product to dividing functions based on the factors of production. However, located at the end of the global manufacturing industrial chain, the technical content of Chinese products is obviously lower than that of developed countries. Global industrial chain consists of several stages like product research and design and product manufacturing. At these stages, most industrial clusters are in the middle and lower parts or the end of the global industrial chain, which further reduces the additional value of Chinese products. The majority of Chinese industrial clusters provide service to the developed countries in Europe and America and seek economic development by meeting their needs. European and American countries grab the high-value parts of the finished product and components; while the energy-consuming development process and high-carbon-emission manufacturing process are conducted in China. In general, industrial clusters in China cannot get the high-value part but take the consequences of the crisis brought by environmental change. If most industrial clusters in China provide service to developed countries, it will cause not only severe contamination to the environment in China but also energy exhaustion.

4) Weak technical support and innovation capability

Currently, industrial clusters in China develop rapidly but have not unified completely. Different industrial clusters have different personnel and equipment at different management levels. And the integration of industrial cluster in the aspects like technology, organization and knowledge are still at a low level. Moreover, the facilities of the industrial cluster in various regions are different; for example, people are lack of the knowledge about industrial cluster; the facilities and equipment in regions are inadequate. Therefore, there is still not a mechanism of innovation in most industrial clusters and these clusters are also lack of high-tech technologies needed for innovation capability. Industrial clusters adhere to tradition instead of adjusting their management mode with changing times. Both imperfect technologies and weak innovation capability lead to the result that the pursuit of the innovation of low-carbon economic industrial cluster becomes a serious difficulty.

4. Strategies for Innovative Development of Industrial Cluster in Low-Carbon Economic Environment. Industrial cluster is the product of the integration of several enterprises; low-carbon environment refers to the high efficiency and low consumption in resource development and utilization. The most important thing is to change traditional view which is to realize the system of production responsibility in green-economy enterprise. To combine industrial cluster and low-carbon economy and to realize the mutual benefit of economy and environment will completely change the traditional mode of industrial cluster in China. To make the new low-carbon economic development mode adapt to the organizations like the government and enterprises, this paper proposes the following strategies.

1) Improve enterprises' understanding of low-carbon economy

Hold more activities to publicize low-carbon economy. Firstly, governments at all levels and enterprises in different scales should have a deep understanding of the important significance of industrial cluster in low-carbon economic environment and advertise and spread this concept continuously in the development of new-pattern industrial cluster. Policy support plays a significant role in the period of industrial cluster transformation.

A complete strategic planning and top-level system design are the crucial premise of the development of low-carbon environment. Secondly, technicians and administrative staff in enterprises should acquire the knowledge about the production and management of industrial cluster in low-carbon economy from foreign countries and enterprises should devote more energy to staff training. Finally, the concept should be permeated into various industries. The development of new-pattern industrial cluster needs the participation of several enterprises which should advertise the concept based on the characteristics and brand effect of each industry and help all enterprises to understand the benefits of the development of new-pattern industrial cluster so as to promote the persistent development of industrial cluster.

Spread the concept of low carbon from the leading enterprises. Leading enterprise plays the “leading” role in the development of industrial cluster innovation in low-carbon economic environment. To develop new-pattern industrial cluster innovation, it is necessary to actively establish influential and correlative large-scale enterprises to drive its development. By virtue of network technique, leading enterprises can build a distribution network and an information network to spread information in various aspects. To keep the effective communication among industrial clusters and to guarantee the integrity of the industrial chain can maintain the communication in the whole process of operation unobstructed. Leading enterprises’ new development pattern causes the change of core competitiveness of each enterprise; their great support to the recombination and restructuring of the enterprises in industrial cluster or the introduction and adoption of correlative enterprises enable leading enterprises to drive surrounding small and medium-sized enterprises to contribute to the innovative development of industrial cluster in low-carbon economic environment.

The following is a dynamic game of cooperative innovation among enterprises to illustrate the importance of the influence of industrial cluster cooperative innovation on the concept of low-carbon economy.

TABLE 1. Dynamic game model of cooperative innovation among enterprises in industrial clusters

Enterprise A	Enterprise B	
	participation in cooperation y	nonparticipation in cooperation $1 - y$
participation in cooperation x	$\pi_1 - C_1, \pi_1 - C_1$	$R_1 - C_1, R_2 - C_2$
nonparticipation in cooperation $1 - x$	$R_2 - C_2, R_1 - C_1$	$\pi_2 - C_2, \pi_2 - C_2$

When enterprise A chooses to participate in the innovation cooperation, the following benefits are obtained:

$$U_{A1} = y(\pi_1 - C_1) + (1 - y)(R_1 - C_1)$$

When enterprise A chooses not to participate in the innovation cooperation, the following benefits are obtained:

$$U_{A2} = y(R_2 - C_2) + (1 - y)(\pi_2 - C_2)$$

Therefore, the average return obtained by enterprise A for the two different choices is:

$$\begin{aligned} U_A &= xU_{A1} + (1 - x)U_{A2} \\ &= x[y(\pi_1 - C_1) + (1 - y)(R_1 - C_1)] + (1 - x)[y(R_2 - C_2) + (1 - y)(\pi_2 - C_2)] \end{aligned}$$

Similarly, when enterprise B chooses to participate in the innovation cooperation, the following benefits are obtained:

$$U_{B1} = x(\pi_1 - C_1) + (1 - x)(R_1 - C_1)$$

When enterprise B chooses not to participate in the innovation cooperation, the following benefits are obtained:

$$U_{B2} = x(R_2 - C_2) + (1 - x)(\pi_2 - C_2)$$

Therefore, the average return obtained by enterprise B for the two different choices is:

$$\begin{aligned} U_B &= yU_{B1} + (1 - y)U_{B2} \\ &= y[x(\pi_1 - C_1) + (1 - x)(R_1 - C_1)] + (1 - y)[x(R_2 - C_2) + (1 - x)(\pi_2 - C_2)] \end{aligned}$$

From the above derivation, we can obtain the dynamic equation of replication as follows:

$$F(x) = \frac{dx}{dt} = x(U_{A1} - \bar{U}_A) = x(1 - x)[(\pi_1 - R_2 + \pi_2 - R_1)y - (\pi_2 - C_2 - R_1 + C_1)]$$

$$F(y) = \frac{dy}{dt} = y(U_{B1} - \bar{U}_B) = y(1 - y)[x(\pi_1 - R_1 - R_2 + \pi_2) - (\pi_2 - C_2 - R_1 + C_1)]$$

$F(x) = \frac{dx}{dt} = 0$, $F(y) = \frac{dy}{dt} = 0$, it can be concluded that there may be five balance points in the dynamic system of asymmetric innovation cooperative game model between enterprise A and enterprise B: O(0, 0), N1(1, 1), N2(0, 1), N3(1, 0),

$$N4(x^*, y^*) = \left(\frac{\pi_2 - C_2 - R_1 + C_1}{\pi_1 - R_2 + \pi_2 - R_1}, \frac{\pi_2 - C_2 - R_1 + C_1}{\pi_1 - R_2 + \pi_2 - R_1} \right).$$

2) Seek new patterns of economic growth

To develop and innovate industrial cluster in low-carbon environment is the only way to realize economic model transform in China. When promoting economic growth and development, industrial cluster should also guarantee that the nature can keep providing resource and environmental services. Firstly, industrial cluster can change its mode of economic growth by energy saving and emission reduction. Industrial clusters based on coal, mineral products, electricity and steel should slow down the development of energy resources so as to live up to the international standard of carbon emission. The upstream and downstream of the industrial chain in industrial cluster change no longer pursue economic growth only, but industrial cluster development and innovation on the premise of low-carbon economy. Secondly, industrial clusters change their traditional pattern by ecological innovation. In brief, ecological innovation is beneficial to reduce natural resources consumption. Based on ecological innovation, industrial cluster does not pursue scale growth but high additional value, and changes its mode from large and comprehensive industrial chain into exclusive and refined one. Finally, industrial cluster introduces clean energy. To put it simply, clean energy refers to the energy without the discharge of pollutants. The use of clean energy in industrial cluster will dramatically reduce carbon emission.

According to the three suggestions about the development of industrial cluster in low-carbon economy given above, enterprises can establish and follow rules together and make the concept go deep into people's minds so as to guarantee the effective communication and information spreading inside industrial cluster. Resources in industry should be applied properly. If necessary, resources can be used for more than one time in order to improve utilization rate, which obviously promotes the economic development of industrial cluster.

3) Establish low-carbon industrial parks

Industrial cluster formed by enterprises can attract enterprises in surrounding areas by establishing low-carbon industrial parks, which lays a foundation for the development of industrial cluster and paves a road for revolutions. Industrial park refers to the industrial cluster formed by the enterprises with the same or similar characteristics. Enterprises should not only develop their strengths but also cooperate to meet the needs of the development of the cluster. It is suggested to develop low-carbon industrial park efficiently, keep the continuous connection and development among the enterprises inside industrial

cluster, take innovative development as the core goal, strictly manage and control the industrial chain of the park so as to adapt to the goal of the development of industrial park and support the development of the enterprises inside industrial cluster by reasonable construction planning. The establishment of professional industrial park can promote industrial cluster to realize low-carbon development. Meanwhile, it is also suggested to improve all supporting facilities in the industrial park, guarantee the effective implementation of low-carbon economy so as to completely change the development pattern of industrial cluster in the industrial chain.

4) Provide high-tech support

Industrial cluster provides high-tech support mainly from two aspects: technological innovation and the establishment of information service platform. Firstly, it is necessary to change entrepreneurs' understanding of traditional development pattern of industrial cluster, guarantee the accurate delivery of information and relevant strategic decision between upstream and downstream, reduce labor consumption and the error in information delivery. Staff should control carbon emission consciously. Industrial cluster should not only give attention to and reduce pollutant discharge but also improve management by science and technology. Secondly, enterprises should improve technological level based on the development of carbon at present. It is also crucial to focus on the trends of the development of low-carbon economic industrial cluster in the world, establish exclusive information platform inside industrial cluster, change development pattern timely based on the information about carbon emission and develop and realize low-carbon development and "win-win" strategic situation.

5. Conclusion. The innovative development of industrial cluster is a significant approach for enterprises to keep core competitiveness sustainable in the low-carbon economic environment in the future. In this paper, we find that the low carbon concept is not paid enough attention to in enterprises, and we also find out the major obstacles to industrial cluster innovation in the low carbon economic environment, including the extended economic development model, the accessory position of the global industrial chain, lack of high added value of production, and the lack of innovation mechanism of industrial clusters.

REFERENCES

- [1] B. T. Asheim and A. Isaksen, Regional innovation systems: The integration of local 'sticky' and global 'ubiquitous' knowledge, *The Journal of Technology Transfer*, vol.27, no.1, pp.77-86, 2002.
- [2] R. Capello, Spatial transfer of knowledge in high technology milieux: Learning versus collective learning progresses, *Regional Studies*, vol.33, no.4, pp.352-365, 1999.
- [3] R. Baptista and P. Swann, Do firms in clusters innovate more?, *Research Policy*, vol.27, pp.525-540, 1998.
- [4] B. Dalum, C. O. R. Pedersen and G. Villumsen, Techological life cycles: Regional clusters facing disruption, *Druid Working Papers*, vol.12, no.3, pp.229-246, 2002.
- [5] P. Cooke and G. Schienstock, Structural competitiveness and learning region, *Enterprise and Innovation Management Studies*, vol.1, no.3, pp.265-280, 2000.
- [6] Y. Zhu, On the innovative advantage of industrial clusters, *China Soft Science*, vol.7, pp.107-112, 2003.
- [7] Arthur and P. Cooke, *Knowledge Economics: Clusters, Learning and Cooperative Advantage*, Routledge, London, 2001.
- [8] C. Freeman and L. Soete, *The Economics of Industrial Innovation*, Pinter, London, 2002.
- [9] S. Pekkarinen and V. Harmaakorpi, Building regional innovation networks: The definition of an age business core process in a regional innovation system, *Regional Studies*, vol.40, no.4, pp.401-413, 2006.
- [10] M. J. Nieto and L. Santamaria, The importance of diverse collaborative networks for the novelty of product innovation, *Technovation*, vol.27, nos.6-7, pp.367-377, 2007.
- [11] R. Whitley, Developing innovative competences: The role of institutional frameworks, *Industrial and Corporate Change*, vol.11, no.3, pp.497-528, 2002.

- [12] Y.-J. Liu, Study on the conditions of the industrial cluster transferring, *Journal of Hunan Finance and Economics University*, vol.4, pp.32-36, 2011.
- [13] M. Bengtsson and O. Soelvell, Climate of competition, clusters and innovative performance, *Scandinavian Journal of Management*, vol.20, pp.225-244, 2004.
- [14] Institute of Directors, Environment Policy Comment, *The Business of the Environment: Policy and Opportunities*, IOD Seminar, 2006.
- [15] M. E. Porter, The Adam Smith address: Location, clusters, and the “new” microeconomics of competition, *The National Association of Business Economists*, vol.33, pp.7-17, 2013.
- [16] Y. Zheng and J. Xu, Research on emerging industry cluster development strategy in Hebei province, *Economic Research Guide*, vol.19, pp.32-33, 2016.
- [17] W. R. Morrow, A. Hasanbeigi, J. Sathaye et al., Assessment of energy efficiency improvement and CO₂ emission reduction potentials in India’s cement and iron & steel industries, *Journal of Cleaner Production*, p.65, 2014.
- [18] L. Yao, Promote the development of low-carbon economy in Gansu province based on industrial cluster, *Productivity Research*, pp.11-14, 2017.
- [19] H. Zhang, The analysis of dynamic mechanism of new energy industry cluster and evolutionary path under the background of low-carbon economy, *Journal of Industrial Technological Economic*, pp.155-159, 2016.