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regional distribution and layout evolution of technological innovation in the new energy electric vehicles industry of China

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Abstract: Based on the initial stage situation of new energy electric vehicles (electric vehicles) industry in China, this paper uses patents retrieval and literatures polymerization methods to analyze the technological innovation status quo and the regional distribution features in the electric vehicles industry at home and abroad. Then, the data envelopment analysis (DEA) method is applied to quantifiably evaluate technological innovation efficiency of the 17 major producing areas of electric vehicles. Furthermore, the layout trend of technological innovation is summarized; the regional distribution strategy of technological innovation in the domestic electric vehicles industry is also explored.

Keywords: New energy electric vehicles; Technological innovation; Regional distribution

1. Introduction

Technological innovation is the driving force of economic development, while enterprise is the carrier of economic development and the subject of technological innovation. Meanwhile, the technological innovation capability of enterprises directly determines the size of its core competencies, and plays an important role in the whole industry. Wang et al. (2009) studied the technological innovation level of automobile industry in China, and drew a

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conclusion that the increasingly annual level of technological innovation may enhance the automobile output by about 25 percent. In addition, the lack of the core technology and the capability of technological innovation have seriously hindered the development of the domestic automobile industry.

At present, the core technology of electric vehicles (short for new energy electric vehicles, similarly hereinafter) has been basically mastered. For instance, power batteries, electronic control system, drive motor and other key components. Automobile systems integration and application have also made a breakthrough in China. However, from the perspective of geographical layout of the industry, the gap of automobile industry between China and some developed countries remains large. By 2009, more than 160 Chinese automobile manufacturers are located in China's 20 provinces, municipalities or autonomous regions. Among them, the production of cars in Beijing was the highest. However, the share of the production of Beijing only accounted for 9.23% of the total production in China. Moreover, the output share of the top three production regions together occupied only 26.93% of the total production. On the contrary, the production of a region under the Municipality Detroit accounted for 27% share of the whole United States. At the same time, the layout of automobile industry in China is fragmented and unbalanced, which has increasingly affected the overall competitiveness of Chinese automobile industry. In this sense, as a combination of traditional and emerging product, researchers would like to know whether the layout of electric vehicles industry is same as the traditional automobile industry, and what are these characteristics of the regional distribution of technological innovation in the domestic electric vehicles industry.

Based on the status of technological innovation in the domestic electric vehicles industry,

some scholars formulated many proposals of regional technological innovation to promote it. Zhu (2006) summarized the technological innovation status of well-known Anhui Chery, JAC and Xingma auto manufacturers. He summed up the role model under the success of these enterprises in Anhui automobile industry. Zhu and Zhang (2009) analyzed the basic situation of the technological innovation in the Chongqing automobile industry, pointed out its weakness and proposed the choice pattern of the technological innovation of the industry. Tong et al. (2009) made a diagnosis of the independent innovation ability of Liaoning's automobile industry by building a quantified evaluation model, pointed out the existing problems and offered some theoretical references for further decision-making. Chen (2009) analyzed typical cases of Liaoning automobile industry in detail, including the experience in failure and in success for some auto enterprises, then summed up four effective ways to improve technological innovation ability.

However, the study of technological innovation in the electric vehicles industry mainly limits in the perspective of region. Although a combination of qualitative and quantitative evaluation methods are used, researches on regional distribution of technological innovation in the electric vehicles industry, studies of the overall trends and other issues are still not enough. This paper reviews development quo of technological innovation in the electric vehicles industry at home and abroad, summarizes regional distribution and layout trend of electric vehicles industry, eventually, explores the layout strategy of electric vehicles industry in China.

2. Regional distribution characteristics of technological innovation in the electric vehicles industry

At present, the structure of the global automotive industry is experiencing the fourth

round of reconstruction trend. The product must be qualified for the standard of "new energy electric vehicles", which means safer, more energy-saving and environmental-friendly. In order to seize the commanding point in this emerging market, Japan, the United States, Europe and other developed countries begin with technological research and development of electric vehicles, place great emphasis on technological innovation and industrial upgrading, also grant many concessions. Under the strong support from the governments, electric vehicles industry soon achieves the breakthrough and flourishes in China.



Fig.1. Global distribution of major technological innovation in the electric vehicles industry.

2.1 The status of technological innovation in the electric vehicle industry for foreign countries

Japan, the United States, Europe and other developed countries pay great attention to the strategy of technological innovation, technological improvement and industrial upgrading in order to promote electric vehicles industry. According to incomplete statistics, before the international financial crisis, developed countries have paid more than 1 billion dollars per year in research and development (R&D) in the electric vehicles field, and the total investment may have reached 10 billion dollars up to now.

Japan is one of the leading countries in technological innovation of electric vehicles, especially in hybrid electric vehicles (HEVs). In December 1997, Toyota launched the world's first mass-produced PRIUS HEV in the Japanese market. In order to develop the key technique of battery, Japan built the largest "Alliance of high-performance electric vehicles battery development industry". Among 7 years, Japanese government plans to invest 21 billion yen in this project, through the development of high-performance electric vehicles batteries, trying to realize the goal that driving range could be increased more than 3 times within a charge in 2020. Meanwhile, as one of the largest new energy countries, Japan is playing a leading role in the field of solar energy usage, and lays a solid foundation for the technological innovation of electric vehicles.

The United States started to develop electric vehicles relatively early, and launched a variety of mature models. As for the development of new energy, the United States mastered the most mature new energy technology. U.S. government encourages HEVs as the representative of the promotion of electric vehicles. Now, the country has become the largest HEVs owning country all over the world. In December 2008, with the support of the Argonne laboratory, 14 U.S. battery and high-tech materials companies set up a "Alliance of advanced transportation batteries ", so as to improve the technological innovation capabilities of Li-ion battery. In the following year, the U.S. government set up a R&D and manufacturing center in Kentucky, aiming at providing high-performance lithium batteries for plug-in hybrid electric vehicles.

The EU is the world's development center of new energy technology. In 2003, the EU issued a "European blueprint of hydrogen energy", and developed a "European Hydrogen Energy Roadmap". Both were strong impetuses to the development of electric vehicles and

new energy industry, enhancing the technical competitiveness of the automotive industry, too. The French power company EDF led to provide more than 110 million francs financial support per year for long-term technological innovation of electric vehicles and their components. Moreover, Germany has achieved the development and promotion of energy vehicles through the establishment of urban “Electric Vehicles Transport Company”. Meanwhile, the German government also implemented a 5-year tax-free policy for R&D departments to encourage innovation of energy vehicle by enterprises.

2.2 Domestic status quo of technological innovation in the electric vehicles industry

In 1992, the research of electric vehicles was included in the Eighth Five-Year national research programs for the first time and then in the Ninth Five-Year major national science and technology industrial projects. In 2001, the electric vehicles research projects were included in the Tenth Five-Year 863 major scientific and technological issues, planning to start manufacturing hydrogen-powered vehicles to advance the strategic goals based on gasoline cars. In 2006-2007, the domestic electric vehicles industry has made significant progress in pure electric vehicles (BEVs) and HEVs, wherein, BEVs achieved volume export. Meanwhile, fuel cell electric vehicles (FCEVs) products came out; its R&D was also advanced all over the world. In 2009, intensive supporting policies were introduced in the domestic electric vehicles industry and technological innovation management of the industry went into a rapid developing track.

At present, the electric vehicles industry mainly depends on the capital, technical strength and R&D base of previous automakers. To sum up, that could be divided into the following six clusters:



Fig.2. Distribution of mainly electric vehicles industry technological innovation in China.

(1) Northeast area of technological innovation cluster in the electric vehicles industry

Northeast area of electric vehicles industry technological innovation cluster mainly refers to the three core electric vehicles layouts of Liaoning, Jilin and Heilongjiang provinces. FAW Group stationed in Changchun, Hafei Automobile Group sited in Harbin, and Brilliance Auto and Jinbei General Automotive sited in Shenyang. These auto manufacturers run into the electric vehicles boom. Furthermore, there are a large number of famous universities here, which lay the technical foundation on the electric vehicles industry.

(2) Beijing-Tianjin area of technological innovation cluster in the electric vehicles industry

Beijing-Tianjin area of electric vehicles industry technological innovation cluster consists of two municipalities. In Beijing, electric vehicles industry is mainly guided by the Foton,

while Tianjin Toyota, Tianjin FAW are located in Tianjin. Moreover, there are lots of powerful new energy auto parts manufactures in the Beijing-Tianjin cluster, such as Beijing ASIMCO Tianwei, Tianjin Spartak Crane cars, and also convenient transportation network.

(3) Yangtze River Delta area of technological innovation cluster in the electric vehicles industry

Yangtze River Delta area of electric vehicles industry technological innovation cluster consists of Shanghai, Jiangsu and Zhejiang provinces. Among them, Shanghai has more than fifty world-class auto parts joint ventures and the broadest industrial base of auto parts all over the country; Zhejiang has a large number of powerful enterprises and small-scale auto parts manufacturers; Jiangsu also has many well-known auto components suppliers, such as Nanjing Fiat, KIA and others. The region has formed a dense automobile industry base, preparing to create an electric vehicles industry belt.

(4) Pearl River Delta area of technological innovation cluster in the electric vehicles industry

Pearl River Delta area of electric vehicles industry technological innovation cluster locates in the central and southern area of Guangdong province, which is the most economically developed province with the largest population. As the center, Guangzhou get ready for constructing three major automobile producing bases in Huangpu, Huadu and Nansha Development Zone. With Japan's Honda, Nissan, Toyota and other auto groups settling in and promoting a number of supporting parts here, the increasingly scale of auto components shaped.

(5) Central District area of technological innovation cluster in the electric vehicles industry

Wuhan is the center of the Central District area of technological innovation cluster in the electric vehicles industry, which occupies an important geographical location, has a strong market distribution capabilities and a wide range of economic radiation. Xiangfan Dongfeng Peugeot Citroen Automobile parts factory, Valeo automotive air conditioning and many other powerful auto parts enterprises are sited in the cluster. In the meantime, Wuhan University, Huazhong University of Science and other well-known universities are also located in this area, which providing qualified personnel and technology for electric vehicles industry.

(6) Southwest area of technological innovation cluster in the electric vehicles industry

The center of Southwest area of electric vehicles industry technological innovation cluster is Chongqing. There are many well-known auto manufacturers, such as the largest mini-car manufacturer Chang'an Group, and the representative of private manufacturer BYD. In addition, there are a large number of auto parts enterprises.

3. The status of scientific research achievements in the electric vehicles industry at home and abroad

3.1 The statistical analysis of scientific research achievements in the electric vehicles industry at home and abroad

Intellectual property is a main method of protecting technological innovation achievements. In law level, it can also defend one's leadership from the fierce competition of its industry. Through searching the patents of electric vehicles, we find that Japan has the largest numbers of these patents, which grabs 72% of the worldwide patents relating to electric vehicles. South Korea is following and United State is in the third position. In addition, China and German share the fourth position both hold 3 percent of the global electric vehicles patents.

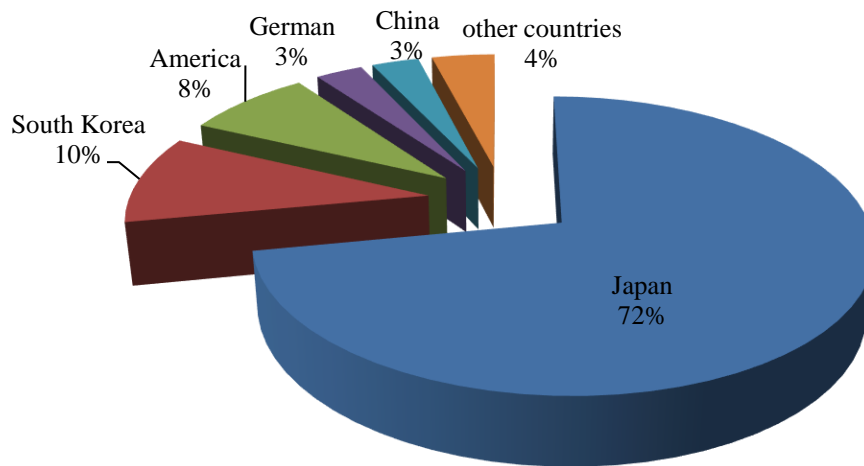


Fig.3. The status of scientific research achievements in the electric vehicles industry in the world.

Source: Tang and Zheng (2011).

In addition, among the 10 auto manufactures which obtained the largest numbers of electric vehicles patents, there are six enterprises coming from Japan, the other four coming from South Korea, German and United State separately. It means that Occident and Japan & Korea have strong ability of technological innovation in the electric vehicles field, and emphasize on protection of the Intellectual property. In contrast, domestic electric vehicles manufacturers are weak in the ability of technological innovation; the quality of patents is poor in this field, too. Shortages of technological innovation ability lead Chinese electric vehicles manufacturers to have little rights in intellectual property protection, while multinational corporations take control of the co-partnership companies .Meanwhile, foreign brand automobiles enjoy market dominance in China.

At the same time, the independent innovation abilities of domestic electric vehicles manufacturers of different ownership are quite different. Chery, Geely, BYD Auto and other private auto enterprises have highly innovative enthusiasm and strong R&D capabilities, providing a comfortable R&D environment and comprehensive support for the technological innovation. Their technological innovation abilities are far more than SAIC, FAW and other state-owned auto manufacturers.

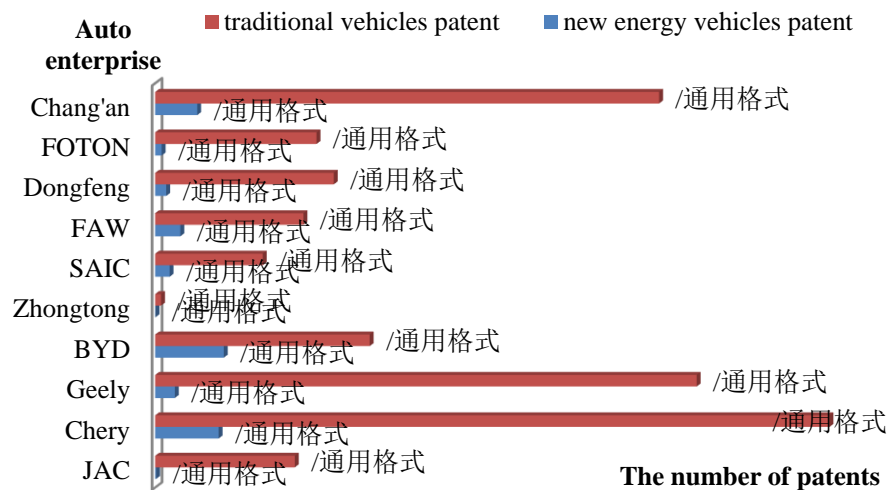


Fig.4. Patents of the traditional vehicles and electric vehicles of the domestic 10 major auto manufacturers. Source: State Intellectual Property Office of the People's Republic of China.

According to three categories of the electric vehicles, HEV obtains 555 related patents, which is the highest of all. Related patents of FCEV reach 99, are in the second position. In addition, related patents of domestic BEV are even fewer, only 78 authorized. The pace of technological innovation is relatively slower in the field of FCEVs and BEVs.

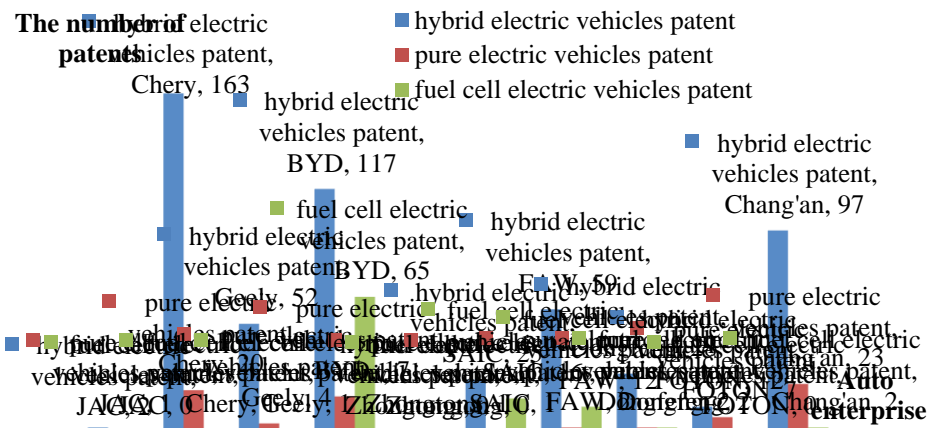


Fig.5. Patents statistics of ten major electric vehicles manufacturers in China. Source: State Intellectual Property Office of the People's Republic of China.

3.2 Efficiency evaluation of technological innovation of main electric vehicles producing areas in China

Table 1

The meanings of specific indicators.

Indicator categories	Specific indicators
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X : input indicators	X_1 : investment intensity of R&D
	X_2 : personnel of R&D
Y : output indicators	Y : related patents ownership of electric vehicles

Based on the above studies and focusing on the affecting factors of technological innovation, we choose investment intensity of R&D, personnel of R&D and related patents ownership of electric vehicles 3 factors for further study. Meanwhile , data envelopment analysis (DEA) approach is used to evaluate technological innovation efficiency of the following 17 major sample provinces: Shanghai, Beijing, Tianjin, Anhui, Chongqing, Guangdong, Sichuan, Jilin, Liaoning, Heilongjiang, Jiangsu, Hubei, Henan, Fujian, Shandong, Zhejiang and Shanxi.

Table 2

DEA fitting results and ordering.

Province	DMU	DEA value (%)	Rank
Shanghai	1	31.78	9
Beijing	2	24.30	10
Tianjin	3	23.31	11
Anhui	4	67.91	3
Chongqing	5	47.89	6
Guangdong	6	100.00	1
Sichuan	7	16.87	15
Jilin	8	19.88	14
Liaoning	9	22.25	12
Heilongjiang	10	14.65	16
Jiangsu	11	53.49	4
Hubei	12	41.68	7
Henan	13	50.63	5
Fujian	14	21.14	13
Shandong	15	39.59	8
Zhejiang	16	100.00	1
Shanxi	17	9.36	17

Sorting by the values of the DEA model, empirical research shows that, among 17 major producing areas, the technological innovation efficiency of Zhejiang and Guangdong provinces is the highest. That is to say, the technological innovation management of other 15 sample provinces is less efficient.

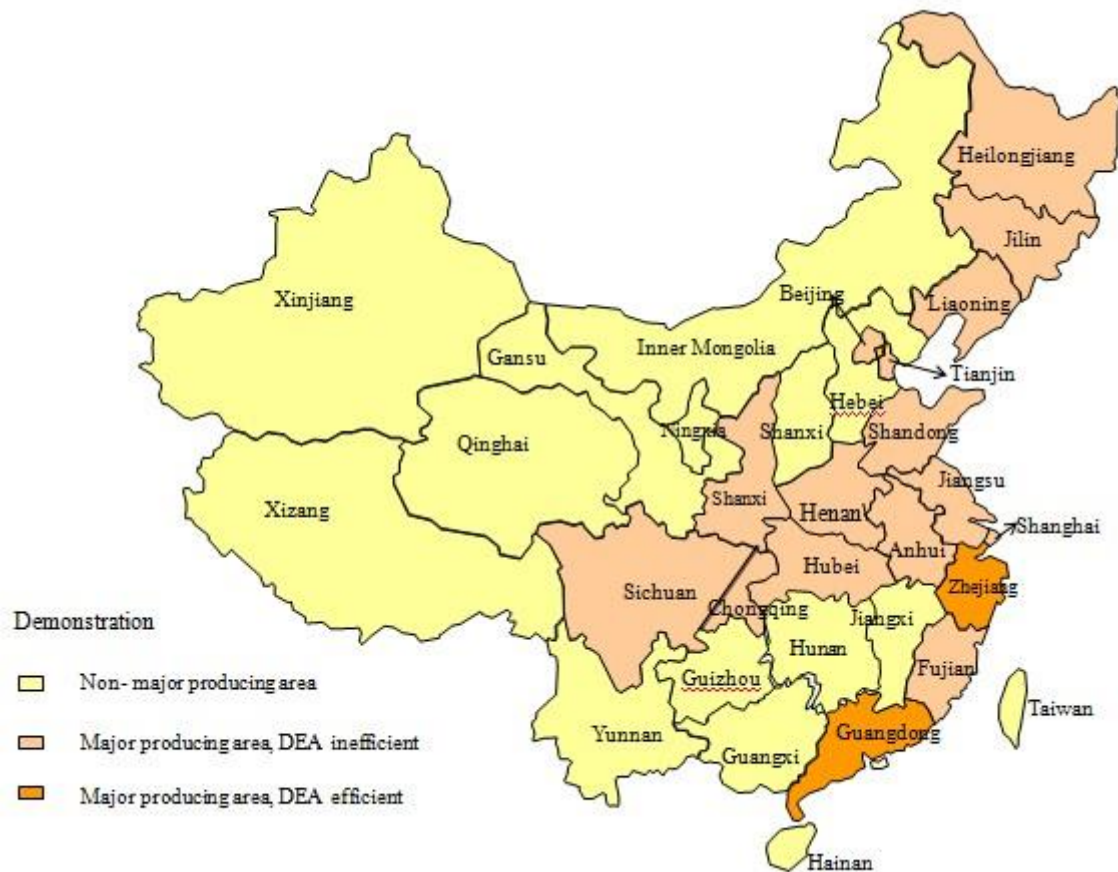


Fig.6. The results of technological innovation efficiency of 17 sample provinces.

3.3 The status quo of technological innovation of main electric vehicles producing areas in China

Considering the results of DEA analysis, extensive researches of literatures, investment conditions of R&D, electric vehicles ownership, supporting policies and other factors, we select the following 4 provinces or cities highlighted eventually.

(1) Guangdong: excellent location and many brands

Guangdong is different from other regions in the customs, language, history and culture. It is also a unique aspect of China, which has a good investment environment. As a provincial capital of Guangdong, Guangzhou owns the relatively best conditions of heavy industry in the Pearl River Delta area. The well-known European and American auto manufacturers came to Guangzhou before the Japanese auto enterprises arriving, their industrial supporting capacity and technological innovation ability were always strong. Furthermore, the local government

has committed to create a good software and hardware environment for electric vehicles industry.

(2) Zhejiang: appropriate roadmap and high R & D investment

Economy grows quickly in Zhejiang. Meanwhile, there are plenty of talents and resources. The past two years, the development of new energy industry in Zhejiang province is pretty rapid. In the future, the province will focus on the development of the solar photovoltaic and offshore wind power, which could meet the huge electricity demand of the electric vehicles industry. Moreover, from science and technology investment point of view, the research investment of Zhejiang is high; the transformation of R&D achievements is efficient, too.

(3) Beijing: thorough policy and solid R & D background

As the capital, Beijing is not only one of the most intensive science & technology, intelligence, personnel, policy and information resources areas, but also increasingly becomes a large electric vehicles cluster for manufacturers. Currently, Beijing owns the most universities all over the country, and also nearly 1/4 science & technology resources of the new energy field. Among them, there are several famous research institutes for electric vehicles here, including Electric vehicles Engineering Center of Tsinghua University, Electric Vehicles Engineering and Technology Center of Beijing Institute of Technology. Meanwhile, the Beijing municipal government attaches great importance to the development of electric vehicles, such as making a series of development plans, giving full support on the operational level, also leading the establishment of the first producing base of electric vehicles in China.

(4) Anhui: colony development and strong innovative ability

Anhui is located in the Yangtze River, which has well-developed transport, rich water and coal resources. After thirty years of development, Anhui automobile industry has played an

important part in the domestic automobile industry. Anhui province gathers large numbers of automobile manufacturers and components suppliers, forms a complete electric vehicles supply chain, and lays the material foundation on its technological innovation.

4. The layout trend of technological innovation in the electric vehicles industry in China

Based on studies of the regional distribution of technological innovation in the electric vehicles industry and current status of intellectual property, we could observe three trends as follows:

4.1 The whole electric vehicles industry inclines towards policies-intensive and resources-intensive regions

In the initial phase of its development, electric vehicles industry, like other high-tech industry, will first take into account the national and local industrial policies in the course of its layout and development, which corresponds to its feature that it always clusters around such large cities as Beijing and Shanghai. Meanwhile, natural resources, mineral resources, new energy and electricity power are all indispensable factors in the development of the electric vehicles industry. Those regions where above resources are abundant, therefore, should be given priority to.

4.2 R&D and marketing incline towards regions of intensive capital and rich human resources

Electric vehicles, a high-end technical production, integrating vehicle technology, electrochemical technology, new material, energy technology and modern intelligent technology, needs excellent human resources, advanced manufacturing equipment and large numbers of capital investments as support to research and manufacture. As important

economic provinces, Guangdong and Zhejiang attract lots of automobile companies at home and abroad with abundant research fund and financial strength. Meanwhile, the standard of electronization becomes higher and higher as vehicle technology developing, which indirectly presents more requests for IT human resources. To improve their innovation abilities, many electric vehicles manufacturers have already set their research centers in such regions with intensive resource and well planned infrastructure as Beijing Zhongguancun Science Park and Anhui Wuhui Industrial Park.

4.3 Diverging based on the traditional automobile industry layout

An emerging industry as electric vehicles industry is, it closely interrelated with traditional vehicle's development and research. In the initial step, the layout of electric vehicles will always rely on the existing six industrial clusters. Then, the industry will not expend and spread to other first or second tier cities, until auto manufacturers have enough ability to bring about independent innovation. At present, Changchun, Hefei, Kunming, Chengdu, Shenzhen and Yantai are building or planning to set up a group of automobile parks to boost the electric vehicles industry. For example, BYD, an individually-run enterprise, after developing steadily in Pearl River Delta, radiates its production base to Beijing-Tianjin area and southwest cluster, also extends its technological innovation to Changsha, which is a non-major producing area.

5. The layout strategy of technological innovation in the domestic electric vehicles industry

Based on the multiple angles of analyses above, four policies were put forward for the possible layout of technological innovation in the domestic electric vehicles industry:

5.1 Strengthening policy support and planning regional development

The automotive industry enjoys the highest concentration and internationalized operation in the modern society, while the electric vehicles industry, which is a new economic pillar, may be more likely to grab a priority and high ground. A typical case is just Beijing, where the electric vehicles industry rises to a new level under the wings of supporting policies and follow-up programming of the municipal government. Those who meet the demands of developing capital-intensive industries should co-ordinate the layout of the area, develop attracting and feasible supporting policies and encourage technological innovation to meet consumers' critical vision.

5.2 Optimizing allocation of resources and enhancing regional appeal

The resource endowments have a key influence on industrial layout all the time, and the electric vehicles industry is no exception. The technological innovation of the industry relies on advanced technology, professional personnel, adequate raw materials and accessories and also efficient supply chain. The area should do a comprehensive survey to find out their location advantages, attracting electric vehicles manufacturers. For example, the electric vehicles industry in Zhejiang province displays a sound momentum with developed local economic and solid scientific research strength, on the basis of which an Auto Park could be set up, taking full use of the existing auto parts and other resources to support the development of electric vehicles industry chain, thus making some breakthrough from the image of "petty commodities manufacturing province".

5.3 Enhancing win-win cooperation and centralizing innovative regions

Electric vehicles industry needs not only strong financial strength as a support, but also many suppliers' support and cooperation. However, the scattered layout of traditional auto industry in China has seriously hampered its development. Thus, we cannot set up electric

vehicles projects blindly and make the same mistakes for the traditional automobiles again, such as setting up everywhere, scattering capacity and investing repeatedly. Instead, the paper concentrates on human resources, financial and material resources to innovate on the basis of current six industrial clusters. Nowadays, Beijing has exported the largest number of automobiles in China, which should be encouraged to attract more electric vehicles manufacturers gathering here to research and develop, thus improving the concentration of production.

5.4 Improving infrastructure and boosting technological innovation

Without supporting infrastructures, electric vehicles cannot be promoted. For instance, pure electric vehicles need special charging stations, while fuel cell electric vehicles need refueling stations. Currently, the special charging stations for electric vehicles have been put into use in Beijing, Shenzhen, Hangzhou and some other big cities. The convenient charging facilities will give relief to the users' worry, opening up a market for the electric vehicles industry. So, qualified areas should first complete the infrastructures of electric vehicles to improve the local attraction.

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