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Research on the Policy Evolution of China's New Energy Vehicles Industry

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Abstract: China has formulated a series of industrial policies dedicated to the sustainable development of new energy vehicles (NEVs). Researching China's NEVs industry policy system, particularly its staged evolution characteristics and internal logic, is essential for future optimization of NEVs supporting policy system. In this paper, we use the co-word analysis method and social network analysis method to investigate the policy evaluation of China's NEVs industry. In total, 154 documents issued by the Chinese central government from 1991 to 2019 are chosen to describe the policy characteristics in four dimensions: policy themes, objects, key process along industry chain, and related measures. We explore policy evolution according to high-frequency words clustering. Results analyzing the policy development history showed that Chinese NEVs industry policy system has incurred the following stages: starting, initial formation, rapid expansion, and now strategic deepening. During the policy evolution in China, policy themes have emphasized the role of technology in NEV development. The industry process involved in policies has covered NEVs production, after-sales service, infrastructure, and battery management. Based on this analysis, we put forward relevant suggestions for improving China's NEVs industry policy.

Keywords: new energy vehicles; policy evolution; co-word analysis; social network analysis

1. Introduction

Carbon emission has become a global concern [1,2] and the transport sector is the main source of urban air pollution, accounting for 23% of global carbon emissions [3]. Since the implementation of the economic reform and open up policy, China's economy has developed rapidly, with increasing energy consumption and carbon emissions [4]. China surpassed the United States and became the world's largest greenhouse gas emitter economy in 2009 and the world's largest oil importer in 2013 [5,6]. The transport sector takes the main responsibility for deterioration of air quality and energy security. Over 70% of China's total oil products and 8% of terminal energy consumption are consumed in the transport sector [7]. Carbon emissions have increased from 8.5% in 2012 and plan to rise to 30% by 2050 [8]. The birth of new energy vehicles (NEVs) as an inevitable choice for low-carbon and green development in the transport sector provides an effective way to achieve carbon reduction and oil protection in the transport sector [9,10]. Wu et al. (2012) [11] showed that compared to internal combustion vehicles, pure electric vehicles (PEVs), plug-in hybrid electric vehicles (PHEVs), and hybrid electric vehicles (HEVs) consume only 1%, 50%, and 71%, respectively, of oil in the wheel-to-wheel process (ICEVs). Under the dual pressure of energy security and carbon reduction, China's NEV industry is growing under the continuous support from the government [12]. In 2018, China's NEV production reached 1,270,400 vehicles, a 151-fold increase compared to 2011, and the sales of NEVs

increased significantly. In 2013, NEVs sales in China were only 19,100, which accounted for 1% of the world's total. By 2018, it reached 4.0759 million, making it the world's largest NEV market (Figure 1). The development of China's NEV industry is inseparable from a series of industrial policies issued by the Chinese government [10,12]. Based to the characteristics and requirements of industrial development, the Chinese government progressively adjusts policy priorities so that policies are in the process of continuous development [2,4,5]. In-depth study of the evolution characteristics of China's NEV industry policy system is of great significance not only for grasping its staged priorities and development trends accurately but for exploring the internal logic of policy evolution, as well as improving the policy system.

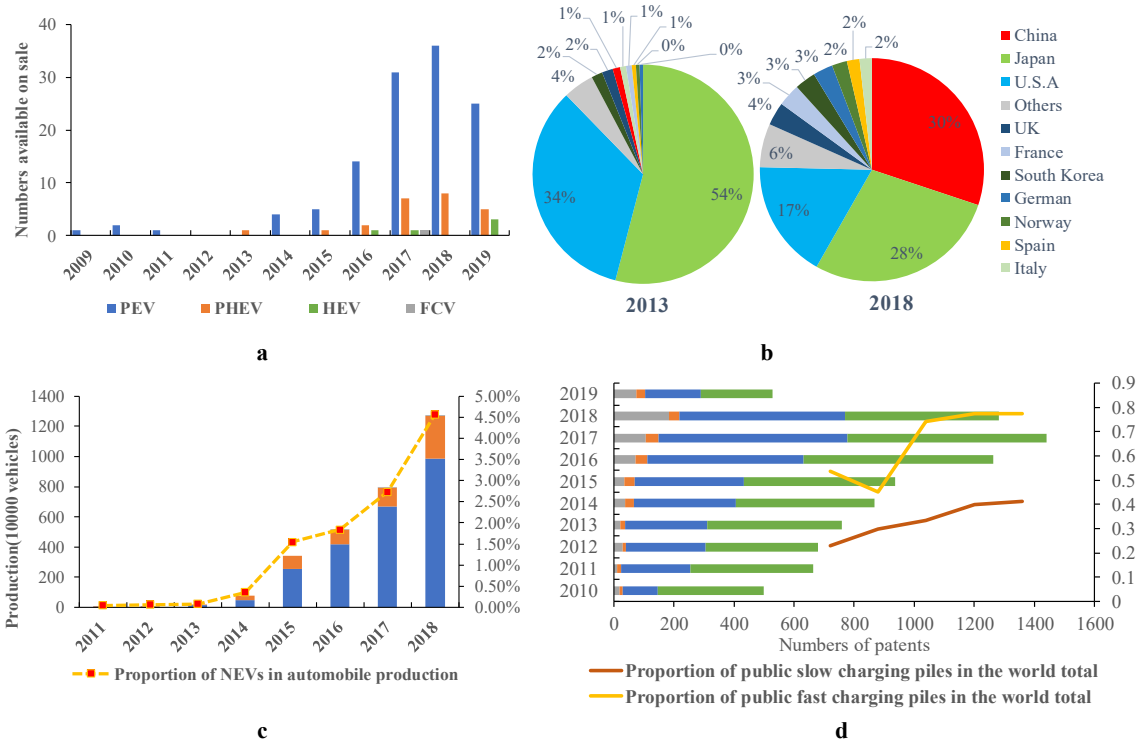

Figure 1. China's new energy vehicle (NEV) industry outlook: (**a**) The number of different types of NEVs available on sale from 2009 to 2019 in China. Source from Marklines [13]. (**b**) Comparison of global NEV sales market share in 2013 and 2018 [14]. (**c**) Production of three main types of NEVs in China and the ratio of NEVs production to world total from 2011 to 2018. The left vertical axis represents the output of NEVs and the right vertical axis represents the ratio of China's NEV production to global [15–22]. (**d**) Numbers of patents for major NEV products and charging piles construction. The horizontal axis represents the number of patents and the right vertical axis is the proportion of China's charging piles in the world. NEV-related patents are collected from National Intellectual Property Administration (NIPA) [23]. Data about charging piles are from iimedia [24].

Taking China's central supporting policies related to the NEV industry as the research object and sorting out the changes in existing documents, in this paper we analyze policy evolution and grasp its development pathway. The conceptual framework of this study is shown on Figure 2. The rest of this article is arranged as follows. Section 2 is the literature review, followed by methods and data in the third part. Main results are presented in Section 4. Section 5 is conclusions and discussion of the study.

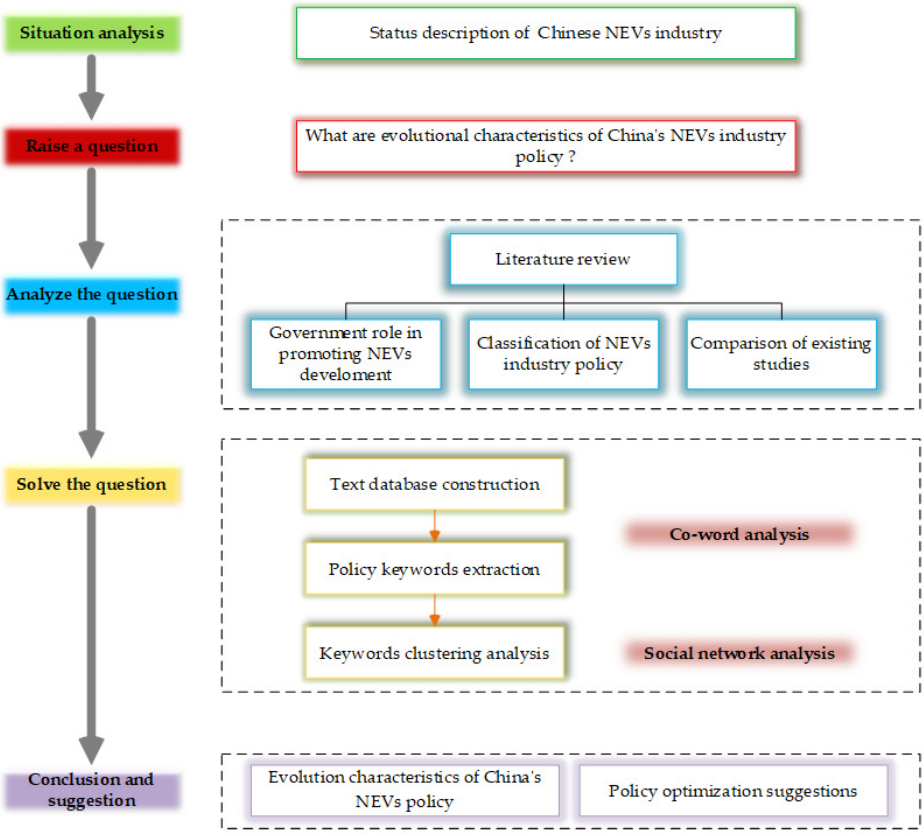

Figure 2. Conceptual framework of this work.

2. Literature Review

Due to the imperfect market mechanism, the government's role in promoting the NEV industrial development has been previously emphasized [10]. For instance, Åhman (2006) and McLellan et al. (2013) analyzed the importance of the Japanese government's plan to the technological flexibility of Japanese NEV technologies [25,26]. Gass et al. (2014) compared different supporting policies instruments for electric vehicles (EVs) in Austria, showing that fiscal supporting policies on up-front price do better than taxation policies [9]. Zhou et al. (2015) compared the PEV market and government policies in China, European countries, and the United States, revealing that PEV-related incentives issued by governments play a positive role in promoting the PEV market [27]. However, Jin et al. (2014) emphasized that not all types of government incentives have the same impact on the PEV market and that policy implementation needs to be adapted to the evolution of the NEV industry [28].

Some scholars categorized existing NEV policies into different types. For example, Taylor (2008) divided NEV incentive policies into upstream investment, market creation, and interface improvement starting from the industrial chain [29]. Other scholars categorized policies into producer-orientation versus consumer-orientation [4,30,31]. Xu and Su (2016) have the perspective of stakeholders involved in policies and further grouped policies into supply-side, environmental-side, and demand-side, considering environmental impact [32]. While Wachtmeister (2013), Bergek and Berggren (2014), Nemet (2009), and Di Stefano et al. (2012) thought policies were either government-controlled or market-motivated [33–36]. Li et al.(2016) further subdivided policies into macroscopic, demonstration, subsidization, preferential tax, technical support, industry management, and infrastructure [37].

Research related to China's NEV policy system is mainly focused on a qualitative analysis of the policy evolution process and policy evaluation based on patent quantity, production, and sales data [4,28,37]. Other researchers believed that China's NEV policies have gradually shifted from government and producer orientation to consumer orientation, emphasing more on environment [32,38]. Li et al. (2016) evaluated China's NEV policy system based on technical patents, production, and sales

data and business model [37]. Yu et al. (2019) constructed technology-market-policy framework to analyze the evolution of China's NEV industry, pointing out that policy as an indirect intervention only affected the behavior of the subject by influencing technology or capital and did not directly affect the subject. Therefore, it can offset shortcomings [2]. Jiang et al. (2018) focused on subsidies effectiveness towards manufacturing innovation of the NEV industry in China [39].

We compared previous literature on China's NEV policies to clarify the innovation of our study (Table 1). Existing research on China's NEV policies mostly applied qualitative analysis methods to classify policies into different types or analyze policies according to the stage of industrial development. For example, Zhang and Bai (2017) used PSM to visualize the links between key policies [10]. They collected 34 policies at the national level from 2006 to 2016 and focused on analyzing the policy linkages. These research gave us the inspiration to conduct our quantitative analysis. In this paper, we took a large amount of policies as research objects and applied co-word analysis and social network analysis to mine knowledge, law, and political meanings hidden behind policies.

Table 1. Comparison of literature published and related to the same topic.

Reference	Objectives	Duration	Policy Number	Method(s)
[4]	Evolution of China's NEVs policies	2010–2016	126 national policies and 423 provincial policies	Qualitative analysis
[5]	Electric vehicles policies	Not mentioned	Not mentioned	Quantify China's electric vehicles policies into financial policies, infrastructure promotion, and research and development (RD)
[10]	Links among policies to regulate changes	2006–2016	175 NEVs policies from national and Jing-Jin-Ji region	policy system map (PSM) method is used to visualize the links among policies
[32]	Policy transition within China's NEVs industry	1991–2015	70	Constructed a coordinate system evaluation policy evolution from two dimensions: government choice and market choice, and producer-oriented and consumer-oriented.
[37]	National NEV polices	2001–2015	less than 100	Qualitative analysis
[40]	Evolution in China's NEVs industry	Not mentioned	14 national level policies	Qualitative analysis
[41]	National NEV polices	2001–2016	13	Qualitative analysis
[42]	Subsidy scheme	2009–2013	Not mentioned	Qualitative analysis and cost analysis
[43]	Impact of preferential policies on citizens' intention to buy NEVs	2001–2016	7	Structural equation model is used to test the impact of factors to citizen intention

3. Methods and Data

3.1. Methods

Co-word analysis is a method that was first proposed by Callon et al. (1983) [44] to find out the relationship between a set of keywords by counting the numbers of appearances in the same document [45]. To find out representative keywords in each policy text, we used the words with high frequency as proxy [46], referring to research methods of bibliometrics for keywords. In combination with the definition and characteristics of the NEVs, we used "new energy vehicles", "electric vehicles", "clean energy vehicles", and "energy saving vehicles" as keywords when collecting relevant policy texts. In order to ensure the authoritativeness, representativeness, and effectiveness of the collected policies, the following principles were used to select the searched texts: firstly, the selected policies

were closely related to the development of NEVs industry; secondly, all selected texts were national policies and distributed by the central government and its affiliated institutions; thirdly, the types of selected policies referred mainly to laws and regulations, plans, notices, announcements, measures, opinions, methods, excluding catalogues, supervision documents, inspection documents, declaration guides, standards, and other policy documents reflected in above texts.

Moreover, we explored the characteristics of policy evolution through co-word analysis and social network analysis. The keyword-extraction process of each policy text was carried out in three steps. Firstly, we used the text mining software *ROSTCM6* [47] to automatically capture high frequency keywords in the policy text [40]. However, many words with no practical meaning might be extracted, while other proprietary words were not recognized. In the second step, we manually standardized the results identified in the first step. Finally, we merged the synonyms that existed in the first two steps, so that each policy text contained only three to five keywords. Based on the identified keywords, the co-word matrix was then constructed.

On the basis of above analysis, we used the social network analysis method [48,49] with the *Gephi* software [50] to further explore the characteristics and evolution of NEV policy. The social network analysis method is derived from graph theory and is a method used to visually analyze social relations to highlight the dynamic relationship between nodes [51]. We drew keyword networks and clustered them automatically and manually. According to the clustering result and the characteristics of the NEV industry, the groups clustered were named separately.

3.2. Data

China's NEV policy can be traced back to 1991 [32,52]. We took the text of the NEV industry policies promulgated by the Chinese central government from 1991 to 2019. Documents selected in this paper were all from public data on government websites. In this study, data was mainly collected from the websites of relevant central ministries of China, such as the State Council Information Office [53], GOV [54–62], National Development and Reform Commission (NDRC) [63–68], Ministry of Industry and Information Technology (MIIT) [69–73], Ministry of Science and Technology(MOST) [74–77], State Administration for Market Regulation (SAMR) [78], and China Associate Automobile Manufacturers (CAAM) [79].

In total, 154 valid texts were sorted out to establish a policy texts database. The number distribution of policies was demonstrated in Figure 3.

4. Main Results

4.1. Stage Division of China's NEVs Industry Policy

Due to the differences in study period, scholars have not yet reached a unified conclusion on the policy evolution stage of China's NEV industry and its time nodes. For example, Xu and Su (2016) traced China's NEV industry development back to 1991 [29] and divided the development of NEVs into four stages. Yu et al. (2019), Li and Zhan (2017), and Liu and Kokko (2013) took 2001 as the initial time point and thought China's NEV industry went through three periods [2,41,80]. Hao et al. (2014) divided industrial development stage of China's NEV industry according to the release time of the electric vehicle subsidy scheme (EVSS) in 2009 and 2013 [42].

Combined with the key events of China's NEV industry development and the release time of policies, we divided China's NEV policy system into four evolution stages: the starting stage, the initial formation stage, the rapid expansion settlement, and the strategic deepening stage (Figure 3). The starting stage of NEV industry policy was from 1991 to 2006, with the "Notice on the Adjustment of the Structure of the Automobile Industry" (Fagai Industry [2006] No.2882) as the representative policy, which embarked the development of energy-saving and environmentally-friendly vehicles [53]. This phase began with electric vehicles officially included in the eighth five-year national science and technology research plan. Electric vehicles and its components started to be researched and developed [79]. While the concept of new energy vehicles was not proposed [32].

From 2007 to 2009, NEV-related policies entered an initial formation stage. The landmark policy at this stage was the "Rules on the Production Admission Administration of New Energy Automobiles" (Guofa [2007] No.72 [55]). At this stage, the definition of the NEV industry was formally proposed. Moreover, the development goals and accessing rules for NEVs industry were proposed for the first time [41]. The demonstration project named "10 cities, each with one thousand NEVs" of energy-saving. Thus, NEVs was officially launched [10,74].

Along with the expansion of the second-round promotion of energy-saving and NEVs, and the expansion of demonstration projects into the private car sector [42], the evolution of NEV industry policies entered a period of rapid development from 2010 to 2014. At this stage, a decision was issued by the State Council to accelerate the cultivation and development of strategic emerging industries (Guofa [2010] No.32). GOV [57] was adopted as the landmark policy, in which the NEV industry was identified as strategic industries together with six other six industries [37]. During this period, the relevant supporting policies and measures for the NEV industry was continuously being issued, and the policy system was gradually established. Finally, policy was transitioned from a government-selection to a market-selection concept and from a producer-orientated to a consumer-orientated system [4,43].

In 2015, the State Council issued the Notice of Made in China 2025 (Guofa [2015] No.28) [59], marking the development of NEV industry policy into a new stage of strategic deepening [38]; China became the fastest growing country of NEVs in the world [5]. Industrial policies at this stage were expanded from a framework-based industrial policy to a specific implementation method for sub-sectors, such as charging infrastructure construction [60,64,67], power battery industry [71,72,78], and transportation investment [66,68].

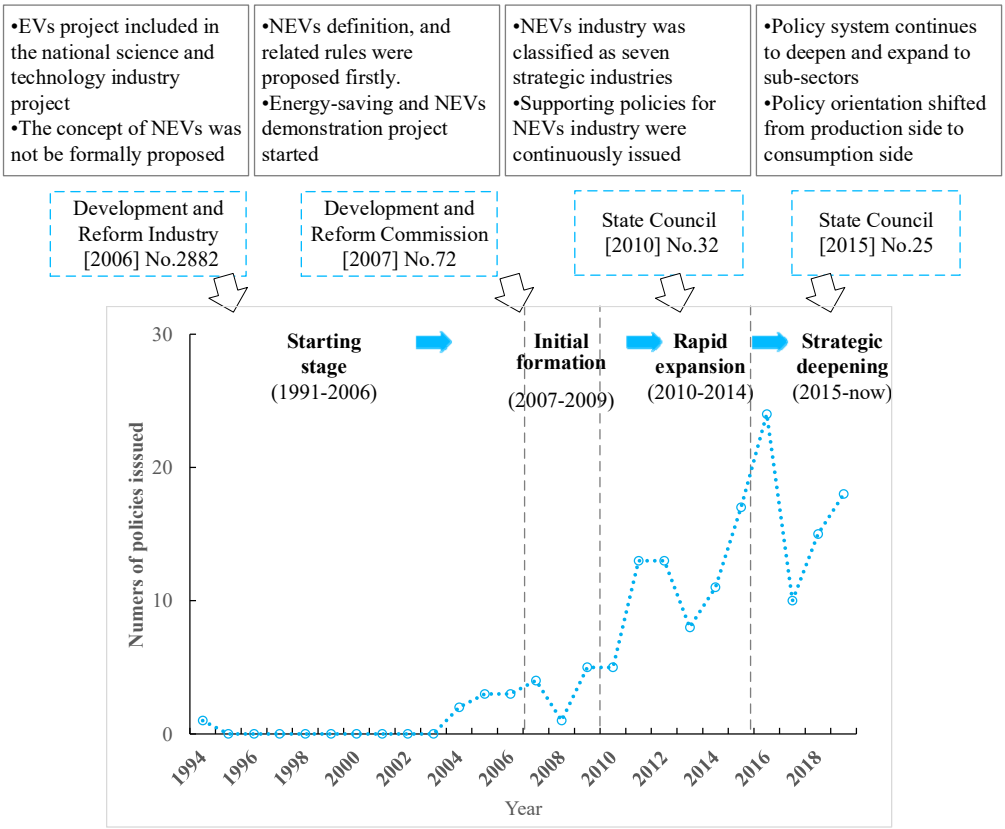

Figure 3. The evolution of NEV policies: marked policies and features issued by China's central government from 1991 to 2019. Three vertical dashed lines divide China's NEV industry policies into four stages. The rectangle with a dashed frame is the representative policy of each stage and the rectangle with solid frame is the policy characteristic of each stage.

4.2. The Starting Stage of NEV Industry Policy: From 1991 to 2006

The Measures for the Administration of the National Key Scientific and Technological Projects of the "eighth five-year plan" were promulgated in 1991. They included the research and development of electric vehicles into the national key projects of science and technology for the first time [41]. The implementation of this measure marked the beginning of China's NEV policy [65]. Since then, related policies have been announced. China's NEV industry policy system entered the starting stage. In total, 10 policy texts were collected at this stage. Clustering results according to keyword extraction is displayed in Figure 4a.

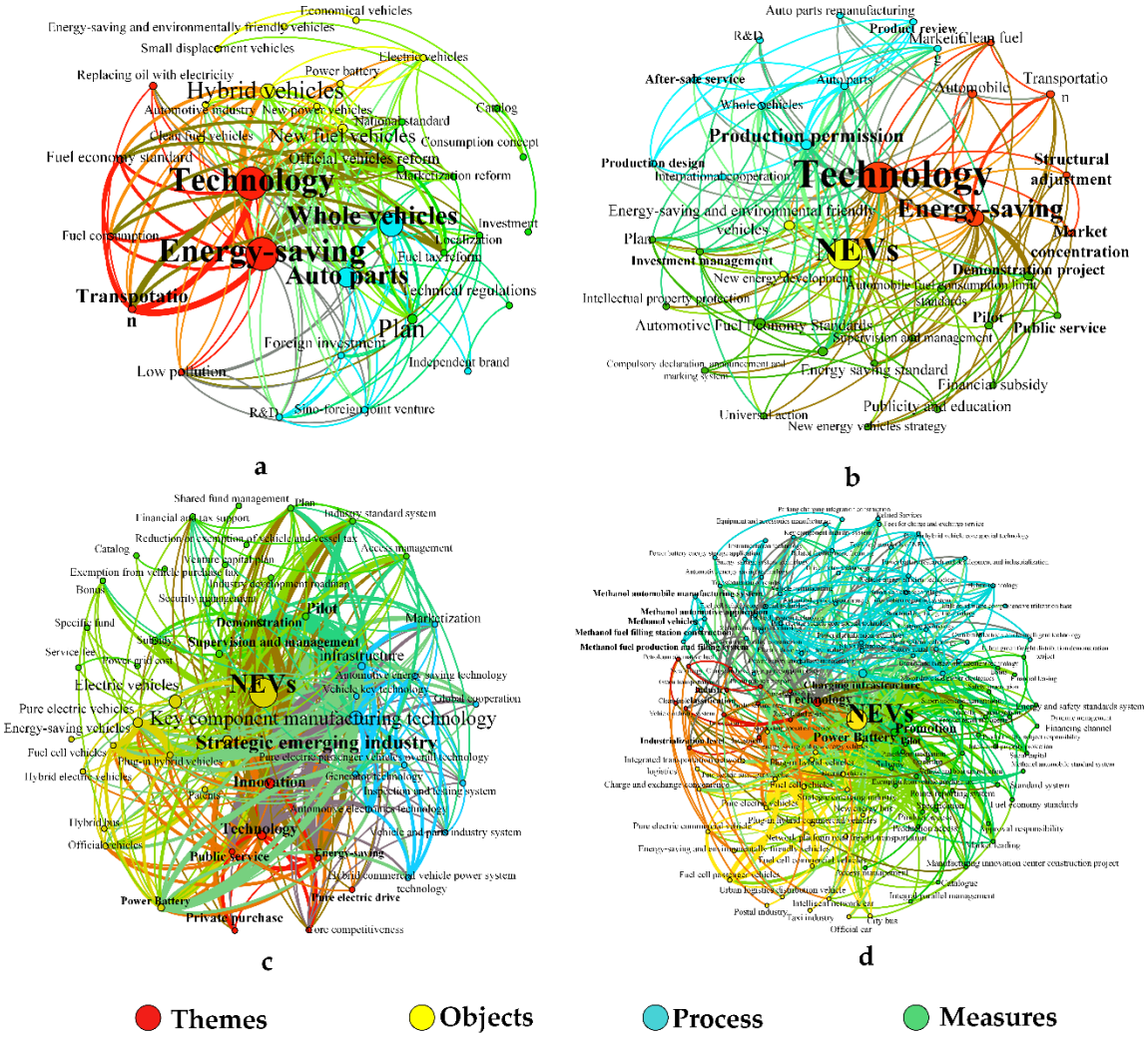

Figure 4. Keywords network of China's NEV industry policies. (**a**) In the starting stage from 1991 to 2006. (**b**) In the initial formation stage from 2007 to 2009. (**c**) In the rapid expansion stage from 2010 to 2014. (**d**) In the strategic deepening stage since 2015. Policy-related keywords are represented by dots and are divided into four categories with four colors: red, yellow, blue, and green, each of which represents a different category. Red dots represent keywords related to policy theme. Yellow dots are the category of policy objects. Industrial chains involved in specific policy is clustered by blue. Green is relevant to support measures. The larger the dot, the more frequently the keyword appears (see Supplementary Materials Table S1 for more information about typical keywords frequency). The thickness of the line between two dots indicates the number of co-occurrence, with the thicker line indicating a higher number of co-occurrence.

Policy themes, at this stage, did not clearly put forward the concept of NEVs. Industry-related topics were mainly focused on "energy saving", "technology", "transportation", and "replace oil with electricity". This is in line with the views of Howell et al. (2014) that achieving energy savings in transport through technology advancement was driven by carbon reduction and energy security goals in China, since China became the world's largest net oil importer since 1993 [12]. Other related concepts, such as "energy-saving and environmentally-friendly vehicles", "small-displacement vehicles", "new fuel vehicles", "new power vehicles", "clean fuel vehicles", and "electric vehicles" were common objects in policy texts.

Policies at this stage are mainly concentrated on the investment and RD process of vehicles and their key components. Investment was chiefly targeted during RD for key technologies. From a measures perspective, guidance catalogs, national standards, other policy tools, and the acceleration of fuel tax reforms and official car reforms, China was committed to speed up the process of localization of the automotive industry.

4.3. Initial Formation Stage of NEV Related Policies: From 2007 to 2009

The basic design of the NEV industry was constructed in October 2007 when the Guofa [2007] No.72 [55] was issued, which stipulated the classification and production access of NEVs. As discussed in Section 4.1, a demonstration project was officially launched in 2009 [2,5,10], aiming to promote the use of energy-saving and NEVs in public service areas, such as public transportation, leasing, public service, environmental sanitation, and postal services. In total, 13 cities including Beijing, Shanghai, and Chongqing were in the list of pilot cities [74] (Figure 5). With the implementation of production access management rules and the advancement of NEV demonstration projects, related industrial policies were proposed, and a NEV industry policy system was initially established. At this stage, 10 policy texts related to the development of the NEV industry were obtained (Shown in Figure 4b).

From the analysis of policy themes, keywords at this stage were still concentrated on technology and energy-saving, indicating that technology advancement and energy security remained as the drivers of policymaking of the NEV industry [12]. The frequencies of "structural adjustment" and "market concentration" increased, revealing that China emphasized the role of NEV development in the adjustment of the automotive industry structure and the improvement of industrial competitiveness.

The core concepts of NEVs at this stage were proposed as policy objects and became high-frequency words. In addition, energy-saving and environmentally-friendly vehicles and new energy development were also the main targets of the policy. The industrial chain involved in policy texts at this stage paid more attention to the production of vehicles and their key, compared with the first stage. Keywords covered the entire life production process of whole vehicles and auto parts from investment management, production access, product design, manufacturing, and after-sales service.

With regards to measures, in addition to the relevant basic standards of the industry at this stage, the keywords, such as automobile fuel consumption limit standards, automobile fuel economy standards, energy-saving standards, mandatory declaration, announcement, and labeling system performance showed the establishment track of the industry standard system. Furthermore, China carried out pilot work in key areas in key cities to ensure the effective application of NEVs, which was indicated by the high-frequency words such as "demonstration project" and "pilot".

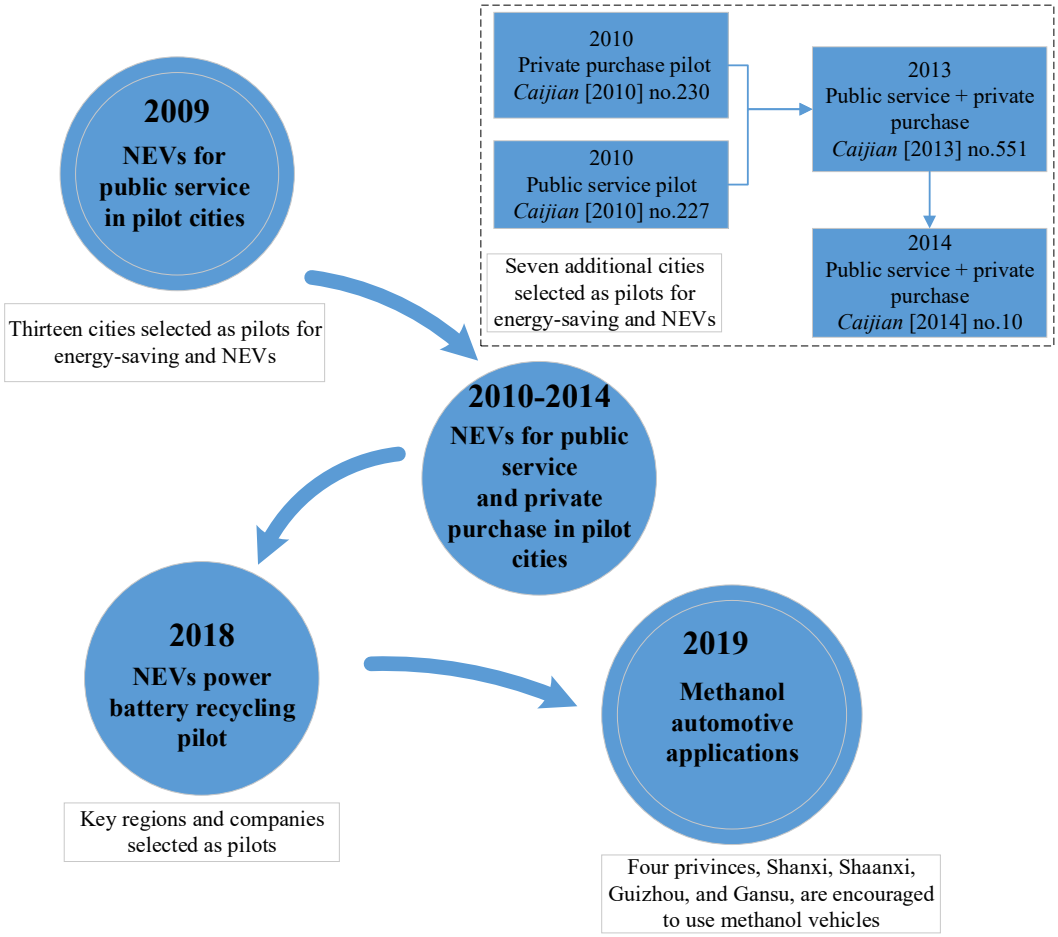

Figure 5. Evolution track of China's NEV pilot.

4.4. Rapid Expansion Stage of NEV-Related Policies: From 2010 to 2014

In 2010, the State Council issued the Guofa [2010] No.32, making the NEV industry one of seven strategic emerging industries [57]. In the same year the demonstration and promotion of energy-saving vehicles and NEVs were further expanded in public services and seven pilot cities including Tianjin, Haikou, Zhengzhou, Xiamen, Suzhou, Tangshan, and Guangzhou were added [66]. At the same time, according to MIIT [70], Shanghai, Changchun, Shenzhen, Hangzhou, and Hefei were listed as pilot cities for private subsidies for the purchase of NEVs, illustrating the start of a private consumption pilot for NEVs. Since 2013, the central government successively released relevant documents to focus on the promotion and application of NEVs, by selecting three urban agglomerations: Beijing-Tianjin-Hebei, Yangtze River Delta, and Pearl River Delta [58], and 12 cities (or regions) such as Shenyang and Changchun in 2014 [76]. However, energy-saving vehicles were no longer incorporated into the promotional scope. The above documents indicated that China's NEV industry entered a stage of rapid development after the initial RD layout and the scope of NEV promotion and application continued to deepen (to the private consumption sector) and expand (with the increase in demonstration cities and regions) [80] (Figure 5). At this stage, the number of relevant policies promulgating at the national level increased significantly (to 50) compared to the previous two stages. The co-occurrence network of policy keywords is demonstrated in Figure 4c.

From the analysis of policy themes, compared with the first two stages, "technology" was still a high-frequency word and "innovation" became a new keyword at this stage. It showed that with the continuous and effective early technology and RD, China's NEV industry has entered a new phase that emphasized innovation and core competitiveness. In addition, keywords "private purchase" and "public service" appeared with the same frequency, indicating that the coverage of NEV policy was further expanded. In addition, the keyword "pure electric drive" implied a new strategy for NEV development in China [54]. From the analysis of policy objects, "NEVs" were absolute keywords in policy texts. Under the guidance of the pure electric drive strategy, with the rapid growth of NEV production, three major categories of NEVs—namely PHEV, PEV, and FCEV—were included in the policy documents. As such, frequency of occurrence increased. In addition, "power battery" appeared as a high-frequency word, showing the role of policies in promoting the development of power batteries to the NEV industry.

Policies related to industrial process at this stage again emphasized the important role of core technologies in the NEV industry's development, with more focus on manufacturing key components, generator technology, passenger vehicle technology, and commercial vehicle power system technology. Based on the previous two stages in the industry chain, policies at this stage developed in depth toward the integrated platform construction, such as construction of standards, inspection platforms, data platforms, energy supply infrastructure platforms, application development, and integration demonstration platforms.

From a policy measure analysis, there were three main types of NEV industry development guarantees at this stage: promotion and pilot; supervision and management; and fiscal and tax subsidies. We compared the central subsidies for NEVs issued by the national government from 2009 (Table 2). Compared with the second-stage subsidy policy (the third column in Table 2 titled as 2009), subsidies for NEVs at this stage were more continuous, covering more NEV models, and could be adjusted according to NEV developments.

Table 2. National subsidy for NEVs from 2009 to 2019 [1].

Classification		2009 [71]	2013 [56]	2014 [73]	2015 [73]	2016 [57,74]	2017 [57]	2018 [15]	2019 [58]
PEV	PEPV	/	3.5 (80 ≤ R < 150) 5 (150 ≤ R < 250) 6 (R ≥ 250)	3.325 (80 ≤ R < 150) 4.75 (150 ≤ R < 250) 5.7 (R ≥ 250)	3.15 (80 ≤ R < 150) 4.5 (150 ≤ R < 250) 5.4 (R ≥ 250)	2.5 (100 ≤ R < 150) 4.5 (150 ≤R< 250) 5.5 (R ≥ 250)	2 (100 ≤ R < 150) 3.6 (150 ≤ R < 250) 4.4 (R ≥ 250)	1.5 (150 ≤ R < 200) 2.4 (200 ≤ R < 250) 3.4 (250 ≤ R < 300) 4.5 (300 ≤ R < 400) 5 (R ≥ 400)	1.8 (250 ≤ R < 400) 2.5 (R ≥ 400)
	NFCPEB **	/	30 *; 40 *; 50 *	30 *; 40 *; 50 *	30 *; 40 *; 50 *	≤25 *; ≤40 *; ≤50 *	≤20 *; ≤32 *; ≤40 *	≤5.5; ≤12; ≤18	≤2.5; ≤5.5; ≤9
	FCPEB ***	/	/	/	/	/	/	≤4; ≤8; ≤13	≤2; ≤4; ≤6.5
	PET	/	/	/	/	/	/	/	≤2 (M ≤ 3500 kg) ≤4 (3500 kg < M ≤ 12,000 kg) ≤ 6.5 (M > 12,000 kg)
PHV	PHPV (R ≥ 50)	≤5	3.5	3.5	3.15	3	2.4	2.2	1
	PHB ****	42 (L > 10 m)	25 (L > 10 m)	25 (L > 10 m)	25 (L > 10 m)	≤30 (L > 10 m)	≤24 (L > 10 m)	≤2.2; ≤4.5; ≤7.5	≤1; ≤2; ≤3.8
	PHT	/	/	/	/	/	/	/	≤3.5 (M > 12,000 kg)
New energy truck and special vehicle [#]		/	≤15	≤15	≤15	/	/	≤10	/
FCE	PV	25	20	20	18	20	/	≤20	/
	Light buses and trucks	60 (L ≥ 10)	50 ^	50 ^	45 ^	30	/	≤30	/
	Large and medium PV, trucks					50	/	≤50	/

Note: [1] Unless otherwise specified, the unit of this table is 10,000 yuan per vehicle. PEPV: pure electric passenger vehicle; NFCPEB: non-fast charge pure electric bus; FCPEB: fast-charge pure electric bus; PET: pure electric truck; PHPV: plug-in hybrid passenger vehicle; PHB: plug-in hybrid bus; PHT: plug-in hybrid truck; PV: passenger vehicle; and FCE: fuel cell vehicle. M is maximum designed mass of new energy trucks according to GB/T 15089-2001. L denotes vehicle length. R denotes pure electric mileage, both with units km. * indicates the subsidy standard for pure electric bus. From 2013 to 2018, central subsidy policies do not subdivide pure electric buses into fast-charging or non-fast charge. ** According to the vehicle length, it is divided into three categories, namely 6 < L ≤ 8 m, 8 < L ≤ 10 m, and L > 10 m. Three data represent the subsidies of the three types each year. *** Same categories as NFCPEB. **** Same categories as NFCPEB. [#] denotes public service special electric vehicles, which are mainly for postal, logistics, sanitation, etc. ^ From 2013 to 2015, central subsidy policies did not subdivide fuel cell commercial vehicles.

4.5. Strategic Deepening Stage of NEV-Related Policies Since 2015

The "Made in China 2025" issued by the State Council in 2015 proposed that China's autonomous NEV sales will reach 1 million by 2020 and 3 million by 2025 [59]. In order to achieve this projection, the central government has issued 84 policies since 2015, expanding the framework of the NEV industry policy system to the implementation subdivided industries. Furthermore, the policy system is continuously improved. The co-occurrence network of policy keywords at this stage is shown in Figure 4d.

From the analysis of policy topics, "technology" is still a high-frequency word. "Industrial classification" and "industrialization level" also appear as high-frequency words in this stage. China's NEV production in 2015 reached 379,000, an increase of 351.17% compared to 2014, marking the rapid growth of China's NEV production [81]. Therefore, classified management is required according to the development level. In addition, the emergence of the word "recycle and re-use" reveals the importance attached to the downstream development of the NEV.

In addition to NEVs and specific keywords consistent with the previous stages, "power batteries" has become the most frequently occurring keyword. This demonstrated that driven by the "pure electric drive" strategy, power batteries are a key development of NEVs. Under this strategy, China has become a global leader in the field of electric vehicles since 2017 [82]. However, due to the limited level of core technology of power batteries, China is far behind France in terms of electric vehicle technology [82]. Therefore, MIIT [17] in 2017 proposed improvement goals for China's automotive power batteries by 2020 to improve the technological level of China's NEV industry.

The number of industrial processes involved at this stage has increased. Policies included vehicle manufacturing technology, key component technology, power battery management, charging infrastructure, and related equipment manufacturing and services. In addition, the promotion and application of methanol vehicles were carried out at this stage [73]. The methanol vehicle manufacturing, production, and filling systems, as well as the construction of methanol fuel filling stations, were involved in this policy. This reveals that under the premise of adhering to the "pure electric drive" strategy, the Chinese government is trying to develop new fuel vehicles.

The analysis of policy measures exposes that this stage is similar to the third stage and involves promotion pilots, policy subsidies, and improvement of industry standards and access conditions. Since 2015, subsidies involved in the NEV industry and their corresponding subsidy standards have been continuously adjusted. Low-mileage vehicle subsidies were cancelled and standards for more categories that meet market development needs were established to encourage NEV development. Table 2 presents subsidies for NEVs, which have declined significantly over the years to further catalyze industrial competition and to help orderly and healthy development of the NEV industry.

5. Conclusions and Discussion

Based on the systematic review and periodical analysis of the development process of China's NEV industry policies, we draw the following conclusions.

Firstly, from a policy evolution analysis, China's NEV policy system has experienced four stages: the starting stage, initial formation, rapid expansion, and strategic deepening. At the starting stage, the concept of NEVs was not yet clearly put forward. Policies and measures related to the development of NEVs were focused on RD and its supporting investment. In the initial formation, issued policies clarified both the core concepts of NEVs and the specific classification involved in top-level design. They also began to pay attention to the production process of NEVs and trials in the public service area of NEVs started. In the rapid development stage, the pilot of the NEV industry was further deepened and expanded. NEV-related guarantee measures formed a system including pilots, supervision, management, and fiscal/tax subsidies. In the strategic deepening phase, the NEV industry guided by the pure electric drive strategy played a critical role for achieving the defined goals of Made in China 2025. Policy themes extended to recycling, reuse, and infrastructure construction.

Power batteries received more attention. Under this stage, special policies for the subdivided industry was continuously introduced.

Secondly, policy themes have always emphasized the core role of technology in the development of the NEV industry. At the beginning and initial formation stages, technology with energy-saving was the subject, which emphasized the development of NEV-related key technologies to energy security and environmental protection. In the rapid expansion stage, we focused on the role of innovation in technology development. During the strategic deepening phase, technological development shifted to NEV recycling and infrastructure construction. Policy objectives of NEVs at this stage include not only the development of PEVs and hybrid vehicles under the pure electric strategy, but also FCV with the experimentation of methanol vehicles. The policy gradually extended to cover the entire industrial chain. Policies and measures have gradually changed from a single pilot to pilot, to the combined development of supervision and management and the fiscal and taxation system, indicating economic incentive tools have been continuously adopted.

At last, as shown in Figure 1c, although China's NEV production is growing continuously, reaching 1.704 million in 2018, the market share of NEVs is not high. In 2018, China's NEV production only accounted for 4.57% of total automobile production and sales accounted for only 4.5% of the market [38]. The established goals are as follows: the annual production and sales of NEVs reach 2 million in 2020 and NEVs account for more than 20% of automobile production and sales in 2025 [82]. These goals are still challenging. Based on the above results on the evolution characteristics of China's NEV industry policy system, we proposed the following policy recommendations.

Firstly, the coordination of upstream and downstream policies needs to be strengthened. Entering the fourth stage, China's NEV industry policy has formed a relatively mature policy system referring to the entire industrial chain from investment, production, sales, and after-sales service. Current industrial policies, however, are skewed towards downstream whole vehicles and less attention is paid to upstream raw materials and parts. The technical mismatch between the upstream and downstream industry is likely to restrict the overall technical level of China's NEV industry. Therefore, future policy design should focus on China's NEV industry chain to ensure the coordinated development of upstream and downstream common technologies.

Secondly, full play needs to be given to economic and social incentive policies to promote the development of the NEV industry. On the one hand, economic incentives are useful to strengthen the direct relevance between NEVs and consumers by stimulating price-sensitive consumers and cost-sensitive enterprises to actively purchase and use NEVs. On the other hand, social incentives increase the use of NEVs in the field of public transport, including extensive education about resource conservation and environmental protection and a low-carbon lifestyle.

By reviewing the literature, we found potential improvements for this research in future work. As shown earlier [5,10], there is a conflict of interest between local and central governments when developing NEVs. This paper does examine the coordination and cooperation between central and local governments at the policy level to promote NEV development. Therefore, one feasible research direction is to select typical provinces and study the evolution path of its NEV-supporting policies, so as to match central policies.

Supplementary Materials: The following are available online at http://www.mdpi.com/2071-1050/12/9/3629/s1, Table S1: Frequency statistics of typical keywords of China's NEVs policy.

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