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Adopting Strategic Niche Management to Evaluate EV Demonstration Projects in China

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Abstract: Electric Vehicles (EVs) are considered to be a potential viable technology to address the persistent unsustainable problems in transport sector. In this paper, we focus on analyzing the transition processes of EVs in China because the sustainability of developing countries is essential for the worldwide sustainability. The two-round demonstration programs of EVs in China were analyzed by adopting the strategic niche management (SNM) approach so as to find out what niche protection has been provided and which obstacles hamper the further development of EVs. The results show that the financial subsidy is the most important protective measure. However, the diffusion results of EVs in different pilot cities are greatly different. The main reason lies in the uneven geographical landscape. In addition, some obstacles were exposed during the niche internal processes including low quality of expectations and poor alignment within the network. Based on the analysis results, we develop a list of suggestions that are important to consider when developing EVs.

Keywords: electric vehicles; strategic niche management; China

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1. Introduction

The current transport sector is regarded to be unsustainable when considering its large and increasing contribution to global air pollution, greenhouse gas (GHGs) emissions and depletion of resources [1]. Much of the unsustainability comes from the widespread diffusion of internal combustion engine vehicles (ICEVs). Electric vehicles (EVs) are therefore increasingly favored by many governments [2,3].

China, one of the fastest growing developing countries, is also facing great challenges from the transport sector [4]. By 2013, private car ownership in China reached 105 million, increasing by 367 times compared to that of 1985 [5]. This soar makes the transportation become the most rapidly increasing energy consuming sector [6]. During the "Eleventh Five-Year Planning (2006–2010)" period, total new additional refining capacity was 100 million tons. This increase was almost entirely consumed by new cars. [7]. To fuel the growing vehicles, China has had to continue to increase petroleum import in recent years. The petroleum foreign degree of dependency thus increased and reached 59.5% in 2014 (Figure 1). Such a rapid increase in turn results in huge GHG emissions, which runs counter to the Chinese government's promise of reducing CO_2 emissions per unit of GDP by between 40% and 45% by 2020 on the basis of 2005 values.

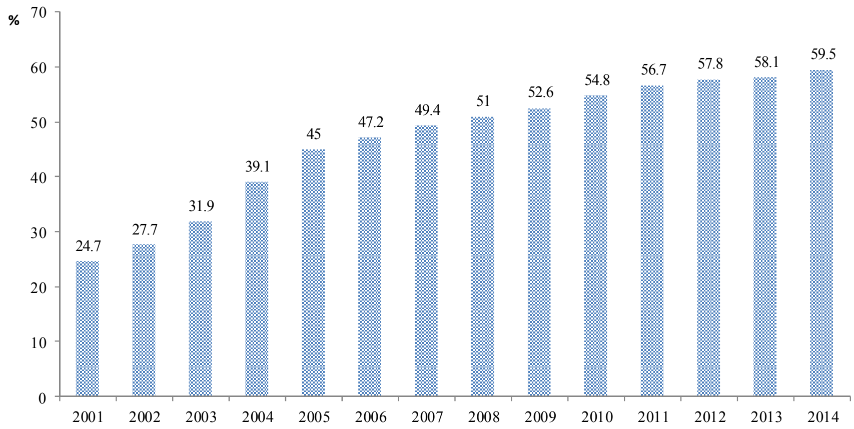

Figure 1. Petroleum foreign degree of dependency (Data source: [8–10]).

In this context, the Chinese government tries to introduce EVs to achieve a sustainable transport sector [11,12]. In 2001, the Ministry of Science and Technology (MOST), the Ministry of Industry and Information Technology (MIIT), the National Development and Reform Commission (NDRC) and the Ministry of Finance (MOF) launched two-round demonstration programs (DPs) to support the societal introduction of EVs. The first-round DP (FRDP) was from 2009 to 2012 and the second-round DP (SRDP) is from 2013 to 2015. The DP marks the beginning of official protection to support the transition of EV technology from R & D in laboratory to mass deployment [13].

Despite the great benefit for social sustainability and strong support from governments, EVs have not achieved greater market penetration. Thus, many studies tried to explore how to promote the development of EVs. Among these studies, sustainability transition has received increased attention recently [14]. These studies argue the transport sector is a socio-technical system which consists of heterogeneous elements including "*technology, policy, markets, consumer practices, infrastructure, cultural meaning and scientific knowledge*" [1] and the achievement of sustainability requires fundamental changes—a "transition"—in the current system [2,15]. However, the current transport system is characterized by lock-in and path-dependence, which poses great challenges to the transition [15]. The immaturity of EV technologies further aggravates the transition challenges. In this context, strategic niche management (SNM), one key analysis framework in the sustainability transition, advocates that real-world demonstration projects should be initiated to create niches—protective spaces—for radical innovations [16]. Indeed, the transition to a sustainable transport is a complicated process, and the policies may fail if the government does not understand the process [17]. How to manage the transition process from dominant unsustainable technologies to new technologies is just what SNM explores [18].

In China, EVs also diffuse very slowly. This paper, therefore, takes the EV DPs in China as the analysis object with the aim to explore the problems which may hinder the development of EVs and provide the Chinese government with some insights into how to cultivate the transition to sustainability. To achieve this aim, we address two research questions regarding the EV DPs: (a) What niche protection has been provided at the national and local level, respectively, and why are the diffusion results are different in the pilot cities? We also address (b) What problems are exposed during the EV DPs?

Through focusing on these questions, this paper tries to contribute the sustainability transition in two aspects. First, many of the existing sustainability transition studies focus on developed countries such as the UK [15,16], Sweden [2] and Germany [19]. Studies about developing countries are scarce by far. For example, Nykvist and Whitmarsh defined three areas of niche innovation for sustainable mobility in UK and Sweden, and the processes of co-evolution, divergence and tension within and between niches were explored [2]. Steinhilber *et al.* tried to find out the social-technical barriers to EV development in the UK and Germany [19]. Mazur combined the concept of transition with system dynamics to assess the effectiveness of EV policies with regard to transition pathways [15]. However, the suggestions proposed in these studies are based on the empirical evidence of developed studies and cannot be easily applied in developing countries. Indeed, many developing countries are increasingly suffering from unsustainability problems, and the sustainability of developing countries is essential for the worldwide sustainability [20]. This paper contributes to this by analyzing the EV DPs in China, in which EVs get strong push from the government.

The second aspect focused on is the spatial dimension, considered to be an important aspect of niche development [21]. However, its importance in forming protective spaces has been ignored by previous literature [22]. Although some attention is being paid to this dimension [23], the study about how place-specific characteristics influence the formation of niche protection and in turn influence the niche development is still being researched [22]. This paper tries to contribute to this by examining the niche protection of EVs in China from the national and local level and exploring how the specific local conditions influence the formation of local niche protection and diffusion results of EVs.

The structure of the rest of the paper is as follows. We first outline the SNM approach and review the relevant literature in Section 2. Section 3 elaborates on the research methods. Then, we adopt the SNM approach to analyze China's EV DPs from the perspective of niche protection and the niche processes in Section 4. The results are then discussed in Section 5.

2. Analytical Approach: The Strategic Niche Management

The SNM was firstly introduced by Schot *et al.* [24] and elaborated on by Kemp *et al.* [18] and Hoogma *et al.* [25]. It assumes that many sustainable innovations fail in the market competition primarily because the established technologies have always been embedded in the existing sector [18,24]. Deep-structural rules and practices often lead incumbent actors to be blind to radical new technologies [1]. Moreover, most new technology is relatively crude. In these cases, the SNM approach advocates "the creation, development and controlled break-down of test-beds (experiments, demonstration projects) for promising new technologies and concepts with the aim of learning about the desirability (for example in terms of sustainable development) and enhancing the rate of diffusion of the new technology" [26]. In other words, SNM posits that successful sustainable innovations originate from real-world experiments or demonstrations, and protected spaces, *i.e.*, niches, should be created [27]. To ensure experiments can achieve desired objects, *i.e.*, nurturing innovations, three internal processes are critical: voicing and shaping of expectations, building of social networks, and learning process [18].

Expectations are promises of new technologies [18]. They can be "problem oriented and deal with the specifications for the technology", or "function oriented and more qualitative", or "scenario oriented, general and broad" [28,29]. In terms of the uncertain outcomes of radical innovations, expectations play a vital role in attracting actors. Moreover, expectations can provide guidance and cognitive rules for actors' activities [30]. Generally, expectations are considered to be powerful when they are (a) accepted and shared by more actors (robust); (b) clear and specific; and (c) supported by experiment results (high quality) [30,31].

The development of a new technology requires supporting social networks. Different actors normally have specific perceptions, and they participate in the network for diverse reasons. Actor networks thus aim at creating co-ordination and convergence of diverging expectations [28]. Social networks are considered to be effective when more diverse actors participate and alignment between actors increases [32].

Learning aims at discovering opportunities or barriers so that innovations could develop properly [28]. Typically, a learning process is considered to be adequate when it entails both first-order and second-order learning [30]. First-order learning aims at accumulation of facts and data about different aspects such as technology, infrastructure, policy and user practice [30]. Second-order learning is a reflexive learning method which focuses on questioning the given norms and rules to reformulate expectations, redesign the technology and reconstruct the network [28].

The three internal niche processes are relevant to "understanding failure and success of sustainable technologies" [32]. Several scholars have used them to analyze the experiments of clean technology.

For example, Raven used them to compare the biomass experiments in the Netherlands and Denmark. The study pointed out that the failure of manure digestion in the Netherlands resulted from three factors: single development trajectory, discontinuity of experiments and instability. [31]. Laak *et al.* applied them to explain the success or failure of biofuel experiments in the Netherlands. Based on the analysis, they developed some policy guidelines such as building a broad network and stimulating diversity [32]. Alan combined the concepts of SNM and social marketing to analyze how the experiments can stimulate the take-up of EVs in the UK. In this paper, we will use the three processes to analyze the EV DPs in China so as to identify the problems exposed in the EV DPs.

The previous literature mainly focuses on the niche-internal dynamics and one important dimension—space—was ignored. This made sustainability transition under criticism from geographers [31]. Without considering the spatial dimension, one cannot fully explain many questions such as "Why do transitions occur in one place and not in another? How do transitions unfold across different geographical contexts?" [22]. In this context, many scholars tried to introduce spatial dimension into niche development [33]. For example, Mans compared the transition of renewable energy in Casablanca and Cape Town and illustrated how the difference between cities resulted in the different development results [34]. Fontes *et al.* drew on the socio-cognitive perspective to analyze the formation of technological niche of wave energy in Portugal and introduced the spatial dimension to extend it [23]. Sengers and Raven developed the local-global niche model by focusing on the spatiality of the production and transfer of knowledge, the geographies of the actor networks involved and the dynamics of embeddedness [21].

Within these studies, scholars use different approaches to expand the geography of sustainability transition. This can provide innovative insights but can also result in fuzzy conceptualization [35]. Therefore, it is important to conceptualize space before we proceed to analyze the niche development. Based on the empirical evidence of EV DPs in China, this paper emphasizes economic geography, which focuses on explaining the dissimilar geographical landscape of niche development. The uneven geographical landscape not only includes natural and geographical dimensions, but also "social, institutional and to some extent cultural dimensions" [22].

3. Methodology

The data collection in this paper consisted of four steps. First, we conducted a literature review on previous studies about China's EV development [4,6,11–13]. Second, we conducted field surveys in some pilot cities including Shenzhen and Shanghai, and conducted in-depth expert interviews with relevant actors. Shenzhen is one of the most influential pilot cities in the FRDP. Its electrification degree of public transport was the highest, and it was the first city to achieve commercial operation of electric taxis. Shanghai is one of the most influential pilot cities in the SRDP. It has deployed the most EVs among pilot cities, and 70% of EVs were purchased by private users [36].

Table 1 lists the main interviewees. These interviewees covered a wide range and they were all experts in the EV field, including Deputy Director and Assistant Director of Shenzhen Municipal Development and Reform Commission who are directly responsible for EV DPs in Shenzhen; Manager of Futian Charging Station, which was constructed and is operated by China Southern Power Grid Company, General Manager of Pengcheng Electric Vehicle Taxi Vehicle Company which is the only specialized and commercialized electric taxi company in Shenzhen; three professors at Automotive School of Tongji University, which is one of the most important EV research institutions in China; General Manager of Shanghai Zhida Technology Development Company, which is a new actor out of the ICEV industry and the market share of which, as a private charging service provider, is the largest in China by far; Chief Engineer of Power Systems Technology Center of Shanghai Automotive Industry Corp. (SAIC) which is the top-tier ICEV and EV manufacturer in China; Manager of the EV Test Drive Center of Shanghai International Automobile City Company Shanghai, which is the only company responsible for the daily operation of international demonstrations of Shanghai. The EV Test Drive Center provides free EV driving tests to the public to learn about the actual demands of consumers.

The interviews in Shenzhen were two-rounds. (a) We firstly organized an expert panel workshop in which all of the interviewees introduced the EV DPs in Shenzhen including their business models, policy measures and problems. The workshops lasted for about three hours and notes were taken; (b) then, we conducted semi-structured expert interviews with the actors from the taxi company and charging station. The interviews mainly dealt with the actors' activities regarding electric mobility, their motivations to do so and the problems encountered. In Shanghai, we conducted semi-structured expert interviews with the actors, respectively. Each interview lasted about thirty minutes. The interviews mainly dealt with the EV DPs in Shanghai and the obstacles that many hinder the further development of EVs in China.

Table 1. List of some interviewees.

City	Agency/Organization	Title/Division	Actor Group
Shenzhen	Municipal Development and Reform Commission New Energy Vehicles Promotion Office	Deputy Director	Government officer
		Assistant Director	Government officer
	China Southern Power Grid Company	Manager of Futian Charging Station	Energy sector representative
	Pengcheng Electric Taxi Company	General Manager	New actor representative
Shanghai	Tongji University	Professors in Automotive School	Research experts
	Shanghai Zhida Technology Development Company	General Manager	New actor representative
	SAIC	Chief Engineer of Power Systems Technology Center	Manufacturer
	Shanghai International Automobile City Company	Manager of EV Test Drive Center	New actor representative

Thirdly, the data was further supplemented through published documents by the governments and internet search. To ensure the reliability of internet data, we mainly chose data released by the authorities or public statement of representatives from government or associations.

Fourthly, the interview transcripts and documents were coded using a coding scheme that is based on the three niche internal processes introduced in Section 2. Then, we organized a remote video workshop with the native English speakers in Cambridge University and the author—Xingkun Liang—played an important role in dual communication.

4. Applying the SNM to EV Demonstrations in China

4.1. Niche Protection in EV DPs

Niche protection is essential to the SNM approach because it gives innovations a chance to be used and tested in the real world [18]. However, many studies used this approach without fully discussing the nature of niche protection [37]. Empirically, the niche protection is dependent on policy measures in China. Thus, we drew on the study of Kemp *et al.* [18], Ieromonachou *et al.* [17], and Boo and Bakker [38] to analyze the niche protection from three aspects: specific protected space, protection scope and protection measures. We will pay more attention to the influence of uneven geographical landscape.

4.1.1. Specific Protected Space

Specific protected space refers to application domains or geographical locations [12]. In China's EV DPs, public services sectors are selected as the specific application domains of EVs. The reasons for such a choice mainly include: (a) "Compared to private vehicles, public service fleets are easier to manage (interview result)"; (b) Vehicles in public service sectors are characterized by long daily mileage and high pollutant emissions. Large-scale diffusion of EVs in these sectors can effectively improve air quality and have good demonstration effects [39]; (c) Public service fleets can better adapt to the disadvantages of EVs such as limited driving range and inconvenient charging [13]. In June 2010, the central government extended the protection domain to the private market. Trying to cultivate private market and promote co-evolution between technology and consumer demand is the main reason for this inclusion.

Except for specific application domains, China also selected pilot cities as geographically protected locations to carry out the DPs (Table 2). In the FRDP, 25 pilot cities were selected. The severity degree of local air pollution, automobile industry base, city size and willingness to develop EVs are the main criteria when choosing these cities. When choosing pilot cities in SRDP, two other criteria were added. On one hand, the completion percentage of demonstration targets in the FRDP became an important selection criterion. Some cities such as Jinan and Suzhou thus were dropped because of the poor performance in the FRDP. On the other hand, the total number of pilot cities increased to 86 in the second round. Trying to expand the demonstration effect and complete the industrial development goals are the main reasons for such an increase.

Table 2. Pilot cities in the two-round electric vehicle (EV) demonstrations.

Round	Batch	Time	City/City Group
First Round	Batch 1	January 2009	Beijing, Shanghai, Chongqing, Changchun, Dalian, Hangzhou, Jinan, Wuhan, Shenzhen, Hefei, Changsha, Kunming, Nanchang
	Batch 2	May 2010	Tianjin, Haikou, Zhengzhou, Xiamen, Suzhou, Tangshan, Guangzhou
	Batch 3	August 2010	Shenyang, Chengdu, Hohhot, Nantong, Xiangyang
Second Round	Batch 1	September 2013	Beijing, Tianjin, Shanghai, Taiyuan, Jincheng, Dalian, Ninigbo, City group (Hangzhou, Jinhua, Shaoxing, Huzhou), Hefei, Wuhu, Qingdao, Zhengzhou, Xinxiang, Wuhan, Xiangyang, Chang-Zhu-Tan area, Guangzhou, Shenzhen, City group (Foshan, Dongguan, Zhongshan, Zhuhai, Huizhou, Jiangmen, Zhaoqing), Haikou, Chengdu, Chongqing, Kunming, Xian, Lanzhou, City group (Shijiazhuang, Tangshan, Handan, Baoding, Xingtai, Langfang, Hengshui ,Cangzhou, Chengde, Zhangjiakou), City group (Fuzhou, Xiamen, Zhangzhou, Quanzhou, Sanming, Putian, Nanping, Longyan, Ningde, Pingtan), City group (Nanchang, Jiujiang, Fuzhou, Yichun, Pingxiang, Shanghrao, Ganzhou)
	Batch 2	January 2014	Shenyang, Zibo, Linyi, Weifang, Liaocheng, Luzhou, City group (Kunming, Lijiaing, Yuxi, Dali), City Group (Hohhot, Baotou), Changchun, Harbin, City group (Nanjing, Changzhou, Suzhou, Nantong, Yancheng, Yangzhou), City group (Guiyang, Zunyi, Bijie, Anshun, Liupanshui, Qiandongnan)

Source: Pilot cities in Batch 1 of FRDP are presented in the "Notice on Launching Demonstration Program of Promoting Energy-saving and New Energy Vehicles (First Notice)"; Pilot cities in Batch 2 of FRDP are presented in "Notice on Expanding Demonstration Program of Energy-saving and New Energy Vehicles in Public Services" issued in May 2010; Pilot cities in Batch 3 of FRDP are presented in "Notice on Increasing Demonstration Pilot Cities of Energy-saving and New Energy Vehicles in Public Services" issued in August 2010. Pilot cities in the SRDP are complied based on the documents released by the Chinese central government.

4.1.2. Protection Scope

The categories of EVs include battery-electric vehicle (BEV), hybrid electric vehicle (HEV), plug-in hybrid electric vehicle (PHEV) and fuel cell vehicle (FCV) [40]. Selecting technologies to protect is one important dimension that protective policies should deal with. However, there is always a dilemma between "inclusiveness versus focus of a portfolio of options" [38].

On the national level, the scope of protection in the FRDP is explicitly defined at the beginning of EV DP. According to the "First Notice" issued In January 2009 by MOF and MOST, the protection scope covered all of the four EV categories because focusing too early on specific technology types may lead to suboptimal solutions. However, with the development of DPs, the Chinese government dropped HEVs out of the protection scope in the SRDP and selected "driven by electricity only" as the main development direction of EVs as indicated in "The Special Plan for EV's Science and Technology Development during the Twelfth Five-Year Plan Period (hereafter referred to as 'Special Plan')" issued in March 2012 by MOST. Making such a selection is due to many reasons: (a) Vehicle manufactures had different opinions on which EV category would eventually become dominant. From 2009 to 2012, "there was a nationwide discussion about this issue (interview result)". Due to this uncertainty, manufacturers were very cautious about investment. They wanted the government to make a clear direction. "It may not be the best solution that such a selection was made by the government, but it can enhance actors' confidence, coordinate their activities and attract more resources at that time (interview result)"; (b) "Some developed countries such as Japan have achieved first-mover advantage in HEV and the Chinese government believes that China still has a great possibility to seize a dominant position in the BEV market (interview result)"; (c) China has abundance of coal resources. Thus, "driven by electricity only" has great implication for China's energy security.

On the local level, pilot cities defined their own protection scopes within the national scope. Most of them chose the same protection scope with the central government, but some narrowed the scope. The most typical example was that PHEVs were excluded from the protection scope in Beijing. The main reason may lie in that BAIC (Beijing Automotive Industry Corp.)—the Beijing government-controlled SOE (state-owned enterprise)—does not produce plug-in hybrid electric passenger vehicles (PHEPV) models. Thus, excluding PHEVs from the protection scope can alleviate the competition pressure from other manufacturers and protect local EV manufacturers.

4.1.3. Protection Measures

SNM scholars argue that policymakers can actively use generic protection measures to shield radical innovations from selective exposure and exert pressure on existing regimes [28]. The measures typically consist for examples of financial subsidy, tax exemptions, investment grant or R&D allocations.

(1) On the National Level

In China's EV DPs, financial subsidies are the most important protection measure because "it can better tackle with the economic barrier and infrastructure barrier (interview result)." The initial price of EVs is higher than ICEVs due to technical limitations and small production scale. To make a comparable price analysis, we choose three popular EV models and similar ICEV models as counterparts, as presented in Table 3. Except for BYD E6, the two other EV models are modified based on existing ICEV models. For BYD E6, we refer to the study of Han *et al.* and choose BYD M6 as the counterpart model [41]. As shown in Table 3, the purchase prices of EVs are much higher than the counterpart ICEV model. This is one critical barrier preventing EV diffusion, because Chinese consumers are very sensitive to price [12]. Thus, the central government formulated incentive-strong purchase subsidy schemes to address the economic disadvantage of EVs.

Table 3. Price comparison between EVs and internal combustion engine vehicles (ICEVs).

EV Model	Price (Ten Thousand MB)	Counterpart ICEV Model	Price (Ten Thousand RMB)
BAIC E150 EV	22.08–23.08	BAIC E150	5.88–8.68
Roewe 550 Plug-in	24.88–25.98	Roewe 550	9.98–18.28
BYD E6	30.98–36.98	BYD M6	10.39–15.39

Source: [42].

In the FRDP, the national subsidy scheme stipulated in "First Notice" is based on two criteria: fuel saving ratio (FSR) and maximum electric power ratio (MEPR) (Table 4). Choosing FSR as one subsidy criterion could greatly stimulate manufacturers to improve fuel-saving technology of HEVs, thereby decreasing energy demand and improving air quality. MEPR is an important indicator for assessing EV technology level. Normally, the higher the MEPR, batteries and electric motors play more important roles in vehicle power systems. Therefore, choosing MEPR as one subsidy criterion could also greatly stimulate manufacturers to improve technology level and fuel saving efficiency of HEVs.

Table 4. First-round subsidy scheme (Unit: ten thousand RMB per vehicle).

Category	**FSR**	**Power System with Nickel-Metal Hydride Batteries, Lithium-Ion Battery/Super Capacitor**	
		MEPR: 20%–50%	**MEPR: above 50%**
HEB	10%–20%	20	-
	20%–30%	25	30
	30%–40%	30	36
	above 40%	35	42
BEB	100%	-	50
FCB	100%	-	60

Category	**FSR**	**MEPR**		
		10%–20%	**20%–30%**	**30%–100%**
HEPV	5%–10%	-	-	-
	10%–20%	2.8	3.2	-
	20%–30%	3.2	3.6	4.2
	30%–40%	-	4.2	4.5
	above 40%	-	-	5.0
BEPV	100%	-	-	6.0
FCPV	100%	-	-	25.0

Source: "First Notice" issued in 2009. Note: Abbreviations: HEB, hybrid electric bus; BEB, battery-electric bus; FCB, fuel cell bus; HEPV, hybrid electric passenger vehicle; BEPV, battery-electric passenger vehicle, FCPV, fuel cell passenger vehicle; BSG, belt driven starter generator. The length of HEB, BEB and FCB must be over 10 m in order to get the purchase subsidy.

In May 2010, the private purchase was incorporated in the first-round subsidy scheme as we described above. Accordingly, only PHEPVs and BEPVs purchased by private consumers in Shenzhen, Hangzhou, Shanghai, Changchun and Hefei can get subsidies. The subsidy amount is based on the power energy of battery pack, *i.e.*, 3000 RMB/kWh, with the maximum amount 50,000 RMB for a PHEPV and 60,000 RMB for a BEPV.

In September 2013, the four ministries launched the SRDP and the second-round subsidy scheme was also stipulated (Table 5). It had some differences with the first-round scheme: (a) the subsidy scope narrowed as we described above. Only BEV, PHEV and FCV can get subsidy protection, and (b) the subsidy criteria changed. Subsidies for BEPVs and PHEPVs were changed from power energy into EV's electric range. Such a change is aimed at stimulating manufacturers to focus on the improvement of driving range because it is a critical factor directly influencing the purchase intent of consumers. For BEBs and PHEBs (plug-in hybrid electric buses), the subsidy criteria were changed from "both FSR and MEPR" into the single "body length". FCVs can directly get subsidy without any limitations. (c) This new scheme clearly specified a phase-out mechanism. Subsidy amount for BEPVs, PHEPVs, and FCVs would decrease by 10% and 20% in 2014 and 2015, respectively, on the basis of 2013. The subsidy amount for BEBs and PHEBs remain the same with 2013. The purpose of this phase-out mechanism is to drive private consumers to grab the policy opportunity and purchase EVs in the short period. (Note: the phase-out rate is later changed from 10%, 20% to 5%, 10% in 2014 and 2015, respectively.)

As a product with network externalities, charging infrastructure would also greatly influence the installed base of EVs. However, charging infrastructure is capital-intensive. It is difficult for investors to earn profit, considering the limited number of EVs on the road. Therefore, financial subsidies are important to attract investors at the initial stage. In November 2014, the central government announced the granting of incentive funds to eligible pilot cities for constructing and upgrading charging infrastructure. Since the interdependence between EVs and charging infrastructure, local deployment quantity is the only indicator to evaluate whether pilot cities can get the subsidies.

Table 5. Second-round subsidy scheme (Unit: ten thousand RMB per vehicle).

EV Type	Pure Battery Driving Range (*R*) (Unit: km)			
	$80 \leqslant R < 150$	$150 \leqslant R < 250$	$R \geqslant 250$	$R \geqslant 50$
BEPV	3.5	5	6	-
PHEPV	-	-	-	3.5
FCPV	20			
SPBEV	2000 RMB per KWh with Maximum Amount 150,000 RMB per Vehicle			
EV Type	**Length (*L*) (Unit: Meter)**			
	$6 \leqslant L < 8$	$8 \leqslant L < 10$	$L \geqslant 10$	
BEB	30	40	50	-
PHEB	-	-	-	25
FCCV	50			

Source: "Notice on Continuing Demonstration Program of Promoting New Energy Vehicles" issued by the four ministries in 2013. Note: abbreviations: FCCV, fuel cell commercial vehicle.

(2) On the Local Level

The protection measures in local pilot cities not only include financial incentives but also non-subsidy measures. As to the incentives, most pilot cities introduced matching purchase subsidy with the national level in order to further decrease the purchase price and stimulate local diffusion of EVs. These local subsidy schemes are different in amount and scope with each other because of different local fiscal solvency, automobile industry foundation and openness of local governments (Table 6).

Table 6. Local subsidy schemes in 2015 (Unit: ten thousand RMB per vehicle).

City	EV Category						
	BEPV	PHEPV	BEB	PHEB	FCPV	FCCV	SPBEV
Beijing *	S	-	-	-	S	-	-
Shanghai	4	3	-	-	20	50	-
Hangzhou	3	2	S	S	S	S	S
Changsha *	S	S	S	S	S	S	S
Dalian	$0.8 \times S$	$0.8 \times S$	$0.8 \times S$	$0.8 \times S$	$0.8 \times S$	$0.8 \times S$	$0.8 \times S$
Ningbo	S	S	S	S	S	S	S
Shenzhen *	$S/0.9$	$S/0.9$	$S/0.9$	$S/0.9$	$S/0.9$	$S/0.9$	$S/0.9$

Source: complied based on the documents released by local governments. "*S*" means that the subsidy criteria and amount in pilot cities are the same as the central government in 2015; * means that total amount from central and local governments should be not more than 60% of the EV purchase price.

In addition, there are also some non-subsidy protection measures. These protection measures are mainly divided into two categories: free vehicle license plates and unlimited driving rules. Vehicle license plates for ICEVs are under strict control in some pilot cities such as Shanghai and Beijing. They are allocated through competitive bidding or license-plate lottery. In April 2015, more than 150,000 people in Shanghai bid for license plates, and the success rate was only 5.44%. The lowest bid price is as high as 80,600 RMB [43]. In Beijing, the success rate of license-plate lottery is only 0.6% in February 2015 [44]. To stimulate EV diffusion, the Shanghai government, in 2012, decided to provide BEPV, PHEPV and FCPV with free license plates and 20,000 of these have been issued to date [45]. Similarly, the Beijing government issued 20,000 dedicated license plates for BEPV in 2014, and the number is expected to reach 30,000 in 2015, 90,000 in 2016 and 120,000 in 2017. Except for the plate policy, some pilot cities such as Nanchang, Chengdu, Wuhan, Xi'an, Guangzhou, Jiangsu, Hangzhou and Beijing also announced in 2015 that BEVs are excluded from the one-day-a-week driving restriction rule and can enter the city center at any time. In Hangzhou, EVs for public car-sharing can also use the bus lanes. Since these protections are based on practical needs of local residents, sometimes they have greater effect than subsidies.

4.2. Internal Niche Processes

To further identify the factors that affect the development fate of EVs, we continue to adopt the three internal niche processes described in Section 2 to explicitly analyze the EV DPs.

4.2.1. Voicing and Shaping of Expectations

(1) Level of Robustness

Robustness means that expectations shaped in the demonstration should be shared by more actors. During the DPs, reducing emissions is one important expectation attached to EVs by the Chinese government. Urban air quality in some pilot cities such as Zhengzhou, Tianjin, Shijiazhuang, Beijing and Shanghai was very bad. Thus, this expectation was shared by most actors initially.

However, when actors knew more about EV technology, some of them including scholars and manufacturers questioned about this expectation. They argued that EV only changes the source of contamination from petroleum to coal because thermal power currently accounts for over 70% of electricity generation in China. Others insisted that, for some pilot cities such as Shanghai, thermal power plants are not in the city center. For Beijing, four thermal power plants will all withdraw from the city center by 2016. Thus, the diffusion of EVs still can address air problems in city centers. Moreover, it is easier for government to tackle the pollution from thermal power plants because "they are geographically concentrated and vehicles are scattered (interview results)".

Improving global competitiveness is another expectation that Chinese government attached to EVs, especially BEVs. For some pilot cities such as Shenzhen in which vehicle manufacturer—BYD—is located and air quality is relative good, improving competitiveness of local vehicle industry is an important expectation for them. In September 2010, the EV industry was identified as a strategic emerging industry and actors all agreed on the significance of EV for upgrading China's automotive industry.

However, with the development of DPs, there is a divergence about whether Chinese EV industry can achieve "corner overtaking". This divergence focused on whether the technology level of the ICEV industry would influence the EV industry and whether China could get a dominant position in EVs in a short period. For example, Professor of Shanghai Jiaotong University Yin Liang and Minister of MIIT Miao Yu argue that there exists a large gap between China's EV technology and developed countries. It is impossible for China to catch up in the short term. In contrast, the Chairman of BYD Wang Chuanfu and Professor of Tsinghua University Chen Quanshi believe that it is premature to judge whether China's EV industry has lagged behind, and there is great possibility for China to catch up.

(2) Level of Specificity

Expectations become more specific when they begin to "turn a promise into a requirement ... and define the design criteria" [28]. At the beginning of the DP, increasing the technology level of EVs is an expectation that actors voiced, but there is no specific requirement at that time. In 2012, the "Special Plan" was introduced and the expectation about EV technology became a little specific.

The expectations about technical specifications of battery, motor and vehicle were proposed in the form of numerical range. In 2015, the "New Energy Vehicle Special Embodiment of National Key R&D Program (draft)" was issued, and the expectations became more specific. Technical specifications about some EV parts are promised in terms of specific figures. For example, the "Special Plan" only promised that the energy density of the battery cell should be over 250 Wh/kg, and the "Special Embodiment" further promised that this indicator should reach 300 Wh/k by 2020.

(3) Level of Quality

At the beginning of the FRDP, a promise about EV diffusion scale was voiced by the central government, *i.e.*, each pilot city should deploy as many as 1000 EVs by 2012. Subsequently, local governments of pilot cities also announced their own promises and some far exceeded the national requirement. Encouraged by this, more industrial actors believed in government's determination and participated in the EV industry. However, the data from the MIIT showed that 25 pilot cities only deployed 27,400 EVs by the end of 2012, which was far below the expected level. Moreover, none of the pilot cities fulfilled its own promise. The highest completion percentage is only 47.1% (Hangzhou).

Similarly, in the SRDP, 86 pilot cities announced their ambitious deployment promises—accumulative 336,000 EVs from 2013 to 2015. However, from January 2013 to September 2015, pilot cities only deployed 147,000 vehicles, 43.75% of the target. It is clear that these promises fell through again. Except for the limitations of technology and infrastructure, the most fundamental reason for this may rely in the existing institution. Under the existing institution, these ambitious expectations are made by governments and the industrial actors and users did not participate. However, the government has no previous experience regarding EVs and does not have enough understanding about the market. This leads to the separation of expectations from the real market. Moreover, the central government did not establish monitoring or evaluation mechanisms in the FRDP. No pressure may lead to substantial inertia for pilot cities.

Although the expectations in the two round DPs were both thwarted, there are two encouraging things: (a) DPs made a great contribution to the national diffusion of EVs. According to the data from MIIT, the cumulative production of EVs had reached 240,000 by August 2015 and the SRDP witnessed a big leap [46]. EV deployment in the second-round pilot cities accounted for 66% of national deployment by July 2015. Moreover, the cumulative production and sales of EVs from January 2015 to October 2015 was 206,900 and 110,600, respectively. The critical reason for such a huge increase lied in the strong push of protection measures; (b) The overall completion percentage in the SRDP is relatively low. Some pilot cities including Shanghai, Zhejiang city group, Hefei, Guangdong city group and Hunan, however, have achieved their local deployment promises. For example, Shanghai had deployed 37,324 EVs from January 2013 to October 2015, far more than the promised target—1000 EVs [36]. The main reason for this lies in the open local policies. As described above, free vehicle plates are an important local protection measure in Shanghai. This measure greatly decreases the purchase cost of EVs and makes EV not restricted to limited driving rules. According to a survey by Shanghai Statistics Bureau, 60% of local residents regard the free-plate measure as being the most attractive instead of purchase subsidies [47]. In addition, the Shanghai government opened the local market and subsidized PHEPVs, which provided local residents with more choices. The survey by Shanghai Statistics Bureau also showed that 75.6% consumers in Shanghai are willing to purchase PHEPVs and the percentage for BEPVs is only 15% [47]. Therefore, the subsidy scheme is in accordance with user demands and greatly stimulated the diffusion of PHEPVs. Zhejiang city group also achieved good diffusion results. From 2013 to August 2015, 17,407 EVs were deployed in the Zhejiang city group, which is more than the promised target, *i.e.*, 10,100 EVs [36]. Business model (BM) innovation greatly contributes to this. In July 2013, Geely and Condit Company jointly launched a "micro-bus" model in Hangzhou, which is essentially a BEPV-sharing model. This model pays more attention to the layout of rental network and charging infrastructure. Over ninety rental stations were constructed to satisfy the rental and charging demand. Encouraged by this BM, 13,000 EVs were deployed for rental by August 2015, accounting for 74.6% of total deployment in Zhejiang.

4.2.2. Building of Social Network

(1) Level of Breadth

During the DPs, EV social networks initially were not formed spontaneously, but largely supported by governments. Based on a number of protection policies, the EV market became attractive to many actors. On the national level, the number of actors in networks continuously increased. For example, the number of EV manufacturers in the network increased from 5 to 145 from March 2011 to November 2014. (The data source here is "Recommendation List of Vehicle Types for the Demonstration Program of Promoting Energy-saving and New Energy Vehicles" issued by MIIT. Vehicles must be on this list so as to get the financial subsidy during the DPs. Therefore, the number of vehicle manufacturers in the list could represent the number of manufacturers in the EV network.) The category of actors also became diverse. Incumbent and new entrants were attracted including industrial actors, consumers, and research institutes.

Bakker pointed out that actors participating in the EV network have their own underlying rationales [48]. For SOEs, they have already occupied dominant positions in the ICEV industry, so they did not actively work toward EV innovation. However, during the DPs, the expectations about market deployment made by governments actually became a political task for them due to their state-owned nature. However, with the development of the EV market and more consumers accepting EVs, these SOEs gradually became active and enthusiastic. They began to actively deploy the EV market and make strategic planning in order to keep dominant positions. For private companies, their share in the Chinese traditional automotive industry is very small. BYD and Geely are the main private producers, but they do not occupy dominant positions in the traditional ICEV industry. Therefore, these companies are active participants, because EV presents a development opportunity for them, and they want to seize important roles in the future EV market. Except for these incumbent firms, the EV social networks also attract many new manufacturers. These new entrants participated in the network with the hope to get a position in the EV industry. Giant grid operators such as State Grid (SG) participated in the network in order to influence the configuration of EVs. They wanted to change the dominant position of manufacturers in the ICEV industry and got dominance in the EV industry by gaining their advantage in power transmission.

On the local level, some cities attracted actors through promoting BM innovation in addition to protective policies. Shenzhen (SZ), for example, initially was confronted with BM innovation difficulty due to high purchase price and inconvenient charging. This resulted in trading and profit obstacles. To solve these problems, the SZ government authorized China Potevio to build charging stations in 2010. Then, SZ government mobilized the bus companies, BEB manufacturers, China Potevio and Bank of Communications Financial Leasing Co., Ltd. (BCFL) (Shanghai, China) to sign a finance lease contract in 2011. According to the contract, BCFL would buy nude BEBs and lease them to bus companies. After paying rent for eight years, bus companies can totally own the nude BEBs. China Potevio would purchase batteries and provide them to bus companies for free. To offset the high purchase and operation cost, China Potevio can get subsidies from central and SZ governments. With this innovative BM, 3859 BEBs had been deployed by the end of May 2015, which is the most in the world.

(2) Level of Alignment

Although the EV network got broad during the DP, the alignment within the network is still low. This problem was mainly reflected in four aspects. (a) Poor alignment between property management companies (PMCs) and charging pile operators—during the DPs, how to promote the installation of charging piles in residential areas became an intractable problem. One critical reason that hinders the construction is due to PMCs. In China, private EV users must get the permission of PMCs to install charging piles. However, many PMCs are reluctant or directly refuse to give the permission because installing charging piles would increase their management costs. Many consumers in turn refused to buy EVs because of inconvenient charging; (b) Poor alignment between local governments—most local governments viewed EV as an opportunity to increase local GDP. Therefore, they only procured EVs produced by local manufactures or grant financial subsidies to local manufacturers. This resulted in market fragmentation and greatly hindered national resource optimization; (c) Poor cooperation within industry actors—during the DPs, many EV industry alliances were established such as Beijing NEV Industry Alliance and Central Enterprises EV Industry Alliance. Most of them are funded by governments and absorb vehicle manufacturers, commercial users, and component providers. Although these alliances tried to promote cooperation between industrial members, "the technological cooperation within the alliances was still limited (interview result)"; (d) The interaction between consumers and vehicle manufacturers is limited. During the DPs, most consumers were perceived with given preferences and passive information recipients. Some companies such as Shanghai International Automobile City (Group) Co., LTD (Shanghai, China) provided consumers with test drives. However, this is only for a few minutes and consumers can not experience EVs for daily use. The SNM literature argues that users, especially private users, are an important innovation source. It is important that consumers are not just outsiders of the DPs but can actively participate in the innovation. Fortunately, some research institutions and associations pay more attention to the feedback of consumers. For example, "China Automotive Consumer White Paper" issued by Nielsen and China Association of Automobile Manufacturers in 2015 showed that limited driving range, long charging time and less repair network are the three main factors influencing the purchase of consumers. Consumers expect the average maximum driving range could reach 248km, and BEPV could be fully charged within 4.7 h under regular charge model and 24 min under fast charge mode. The survey also showed that most consumers prefer PHEPVs rather than BEPVs.

4.2.3. Learning Process

During the DPs, first-order learning involved multi-dimensions including charging infrastructure, policy and technology. Moreover, the learning process was also reflexive to some degree. Some initial assumptions that affect EV innovation were discussed. Irrational behaviors were adjusted according to gained experiences. Among all the dimensions, learning around charging infrastructure was critical. This learning process involved other dimensions such as policy and market. Therefore, we take the learning process around charging infrastructure as an illustration.

(1) First-Order Learning

First-order learning in the field of charging infrastructure mainly entailed the charging price and charging technology.

In China, the electricity price is in charge of NDRC. However, there is no specific regulation about EV charging price, initially. This led to a dilemma for infrastructure operators. They did not know how to charge EV users, but they must charge in order to sustain the operation. In this context, some local governments made temporary policies. However, these policies cannot provide social capital with enough confidence to invest. With the development of DPs, the central government learned that it is necessary to regulate charging price for the sustainable development of charging infrastructure. In August 2014, NDRC officially issued a "Notice about the Electricity Price Policy of EVs". According to this notice, charging service providers can price EV users with both electric fees and service fees. The electric fee varies from industrial rate to residential rate, according to the nature of charging facilities.

In addition, there was no EV charging facility in a real sense at the beginning of DPs. EVs were charged through wiring board just like electric bikes. With the development of DPs, more consumers purchased EVs, which stimulated the technology development of charging facility. The real charging piles appeared on the market and accounting functions and multiplayer components were integrated into charging piles. The degree of charging safety, speed and intellectualization all increased during the DPs.

(2) Second-Order Learning

During the DPs, second-order learning in the field of charging infrastructure mainly entailed its importance, charging mode and construction qualification.

At the early stage, price is regarded as the most critical barrier. Governments, at that time, only granted purchase subsidies. However, during the usage, customers learned that availability of charging facilities is another significant factor. This factor sometimes was even more important than price. Correspondingly, the government gradually learned that, without enough charging facilities, customers would hardly buy EVs, despite the low price. Considering that charging facilities are capital-intensive, the central government decided to subsidize it, as we discussed earlier.

At the initial stage of DPs, charging infrastructure operators were guided by deep-structural rules and routines of the ICEV regime. They considered that public charging stations should be the main charging mode not only for public transportation but also for private EV users. They built charging stations in a way similar to gas stations and did not perceive the importance of charging piles. However, some problems were exposed. Due to long charging time and limited public charging stations, private users prefer charging piles installed at home rather than public charging stations. Moreover, limited land supply in the inner city and large investment increased the construction difficulty of charging stations. In this context, charging infrastructure operators and governments gradually learned that the importance of private charging piles and public charging facilities only took a complementary role in private charging.

Charging infrastructure operator is an indispensable participant in social networks. In the early stage of DPs, only giants in the grid and fossil fuel industry can enter this market. Other social capitals were not permitted to enter. However, with the development of DPs, the power grid oligopolies learned that it was very difficult for them to undertake the role alone due to the huge investment and profit barrier. They realized that opening this market with other social capital was necessary. In May and July 2014, the SG and State Council successively announced to encourage other social capitals to build charging facilities [49,50]. SG promised to provide power transmission service for other companies. In this context, many private companies began to enter this market and gradually played important roles in the charging market. For example, Shanghai ZhiDa Company, which "focuses on producing charging piles and providing installation service, has cooperated with many EV manufacturers such as Tesla, BMW and SAIC to install private charging piles for over 5000 EV users (interview result)".

5. Discussion

The analysis of Chinese EV DPs offers some insights into the geographical differences that influence the process of niche development in different cities, as well as into the problems that may hinder the development of EVs in developing countries.

5.1. Spatial Difference

The EV DPs in China is a typical example of a government-inspired transition. The central government, as expected in the literature, plays a leading role in the transition process. By providing incentive-strong policies, it built a protective space for EV innovation so that it can be tested and developed. However, under the same national condition, different pilot cities demonstrated different diffusion results. The main reason lies in the uneven place specificity.

5.1.1. Industry Base

Local industrial foundation is often the outset for local protection policies, which in turn influence the transition process. EV is considered to be an opportunity for local cities to improve their economies, and it requires the support from the automotive industry. Therefore, the pilot cities such as Beijing, Shanghai, Shenzhen and Hangzhou, which have strong automotive industry bases, especially powerful manufacturers (BAIC, SAIC, BYD and Geely), are inclined to actively stimulate EVs. The interaction between automotive industry, policies and EVs forms a loop. The deployment of EVs in these cities all ranked in the top five [47]. In contrast, the pilot cities such as Xinxiang and Tangshan, of which the automotive industry is weak, presented poor diffusion results. This shows that policies in Chinese cities normally try to combine ecological goals with economic competitiveness.

5.1.2. Natural Resource Endowments

The importance of natural resource endowments for transition is often ignored by previous studies [22]. The battery and electric motor are the key parts of EVs and their development requires the support of mineral resources. On the national level, China has abundant mineral resources such as lithium, iron, alkenes, graphite and graphene, which is a necessary natural condition for the large-scale diffusion of EVs. "That's one important reason that the Chinese government has confidence in the further development of EVs (interview results)". However, on the local level, the influence of natural resource endowments is complex. For example, Chengdu and Jiangxi have a rich supply of mineral resources such as lithium, graphite and rare earth. That may be one important reason for including them as pilot cities in the SRDP. Based on the resource endowments, the EV parts industry has developed well in these cities and industrial clustering is taking place. The diffusion of EVs in these cities, however, is very limited. Jiangxi only deployed 800 EVs by March 2015, and Chengdu deployed 4000 EVs by November 2015 [51,52]. This demonstrates that the transition process is complicated and involves many dimensions. Sometimes, the influence of natural features on sustainability transition may be hampered by some other factors such as existing social attachments and infrastructure [53].

5.1.3. Consumers and Local Market Formation

The role of regulations and policies for market development has been emphasized by the previous studies [38]. Shanghai and Beijing have strict license plate rules. On one hand, drivers with non-local license plates in Beijing must apply for temporary certificates every twelve days so as to enter the inner city. Similarly, cars with non-local license plates in Shanghai are not allowed to use the viaducts during the rush hours on weekdays. On the other hand, it is difficult for ICEV drivers to apply for the local license plates as we described above. Therefore, free license plates for EVs greatly stimulate the purchase intention of consumers. The deployment number of EVs in Beijing and Shanghai ranked in the top two among second-round pilot cities, and this policy contributed a lot [36]. In contrast, this policy of free license plates has a very limited role in the pilot cities, in which ICEV drivers can get local license plates much easier, such as Tianjin and Xinxiang. Therefore, finding and introducing appropriate policies can effectively stimulate the formation of local market.

5.2. Internal Niche Processes

5.2.1. Expectations

The expectations shaped in the DPs are formulated by central and local governments. The expectations about technical dimension gradually become specific and clear. However, the robustness and quality of expectations is relatively low.

The expectations about EV sustainability and the possibility of "corner overtaking" do not get broad support. It is not surprising that different actors have different ideas and expectations when considering the EV market is still in a highly immature phase. However, it is important to formulate shared expectations and promote the convergence into robust expectations when the EV market gradually becomes mature.

The expectation about market deployment was not fully realized. It indicates that this expectation is not supported by facts and is not credible. However, our analysis also reveals that there is a big difference among different pilot cities. In the SRDP, the completion percentage in five pilot cities was over 100% and below 40% in 23 pilot cities such as Chongqing, Taiyuan and Lanzhou. This further demonstrates the spatial dimension plays an important role in the EV DPs.

5.2.2. Social Network

The analysis shows that the size of the EV social network initially was small, but it continues to expand as DPs go on. Many industrial actors such as EV manufacturers and charging infrastructure operators were attracted in the network. The structure of the network and alignment within the network, however, are still unsatisfactory. Most manufacturers in the current EV network are dominant producers in the ICEV industry, and the industry alliances are dominated by state-owned companies. The number of new entrants is limited overall.

5.2.3. Learning Process

During the DPs, the learning process around EVs entails both first-order and second-order learning. Many innovative outcomes have appeared. However, there are still some limitations in the learning process.

Our analysis revealed that there was very little communication between consumers and manufacturers. Consumer demands about EVs were presumed the same as ICEVs in advance. Few measures were made to promote the co-evolution of technology and demand. The level of consumers' knowledge about EVs is generally low. "China Automotive Consumer White Paper" showed that only 53.9% of consumers know the EV subsidy policies and the percentage is even as low as between 16% and 28% in some pilot cities such as Hangzhou, Guiyang and Chengdu.

The scope of second-order learning is somewhat narrow. Most of this type of learning is around the policies, and industry companies seldom conduct such learning about their own production, technology and organization structure. Making use of past lessons and conducting more broad and in-depth reflexive learning is needed.

6. Conclusions

In this paper, we have tried to explore how the transition process of EVs develops in one developing country—China. To explain this, we studied China's EV DPs and introduced the niche development in the DPs. Spatial dimension was introduced in order to better understand how the different diffusion results of EVs appear in pilot cities, and the dynamics of three internal niche processes were adopted to find out the obstacles hampering the niche development.

The analysis shows that financial subsidies are the most important protective measures on the national level. It aims to reduce the purchase costs of EVs and construction costs of charging infrastructure so as to stimulate the niche development. However, on the local level, the protective measure differs due to the uneven geographical landscape, which in turn influences the niche development. The industry base, consumer demands and the openness degree of local governments play great roles in the uneven geographical landscape. The natural resource endowment, however, has little impact on the niche development.

For the obstacles exposed in the EV DPs, the following issues need to be addressed. (a) Actors still have inconsistent expectations. Governments, therefore, should give sufficient attention to the different and possibly conflicting expectations. It does not mean depressing different voicing, but trying to find out the reasons for conflict, learning about the feasibility of different expectations and translating it into a shared expectation; (b) The failure of expectation about EV deployment may discourage the confidence of actors. The central government therefore should strengthen the evaluation component of the DPs. Our study shows that pilot cities will not be punished if they did not fulfill their promises, and there is also lack of exit mechanism. This may lead to inertia. The data from MIIT shows that 33 pilot cities in the SRDP have not introduced any local protection measures by the end of May 2015. Thus, a well-designed monitoring mechanism is necessary for DPs. For local governments, there are two important things that should be paid more attention in order to fulfill the deployment promises. On one hand, local governments should formulate attainable expectations based on their own industry conditions and economic development level. Communicating and meeting with other actors would be necessary for governments before they shape expectations. On the other hand, breaking local protectionism and keeping an open mind is necessary to attract resources and meet the real needs of consumers; (c) New actors in the EV networks are still relatively few. The SNM approach argues that dominant incumbent actors have much competence and resources, but are lack of radical innovation force. Therefore, involving more new industrial actors is important because they have the potential to bring in new ideas and business models [54]. Governments should further lower the market access threshold to give new actors more opportunities to participate; (d) Local governments should specify the responsibilities of PMCs in old residential districts and strengthen the monitoring mechanism. Our analysis revealed that charging infrastructure is a critical component during BM innovation. However, the alignment between PMCs and charging pile operators is poor. Although some pilot cities such as Shanghai and Beijing have explicitly specified the installation percentage of charging piles in new residential districts, responsibilities of PMCs in old residential districts still need to be emphasized and supervised; (e) The poor alignment within the network actors requires that governments should pay more attention and make dedicated efforts to coordinate different interests and maintain the emerging networks. Industry alliances should hold regular meetings to promote the technological cooperation within the network. Regular discussions should be organized between pilot cities and industrial actors to share the successful experiences so that good experiences can be applied in many pilot cities and the DPs could scale up.

We would like to argue that this paper adds to the literature on the development of EVs in China from the perspective of SNM. We introduce the spatial dimension into niche protection and contribute to the on-going debate on the role of space in niche development. Further, we discuss the dynamics of internal niche processes. By doing so, one can learn more about the sustainability transition in developing countries and see the differences of obstacles that may hinder the development of niche innovation in developed and developing countries.

The geography of sustainability transition involves different concepts and approaches [22]. Our study only focuses on the concept of economic geography, and it needs to be further explored on the basis of "overall niche space", which spatializes the role of abstract socio-cognitive processes at both local and global levels [23]. This would provide more multiple insights into EV development in China.

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