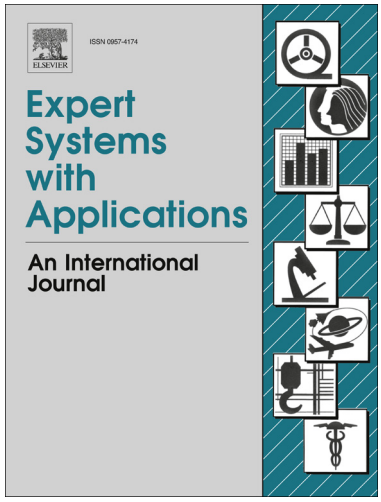

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Business Ecosystem and Stakeholders' Role Transformation: Evidence from Chinese Emerging Electric Vehicle Industry

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Abstract: Nurturing an emerging industry's business ecosystem always requires stakeholders' efforts and role transformation. By systematically reviewing and studying the evolution of the Chinese electric vehicle industry, this paper constructs a three-dimensional theoretical framework including stages of business ecosystem lifecycle, stakeholder classification and functional roles, to analyse the transformation both of different stakeholders and their functional roles. The findings show that business ecosystem stakeholders have experienced role transformation following a mechanism defined as the 'Triple Oscillation' Model during the evolution of the emerging industry. These findings also help develop a conceptual model of agent-based system for business ecosystem evolution, which could be a starting point for further emerging industry study.

Keywords: Business Ecosystem; Stakeholders' Role Transformation; Chinese Electric Vehicle

Industry; Oscillation; Agent-Based System

1 Introduction

The emerging industries often arise with the technology and market uncertainty as well as the weak industrial system (Rong et al., 2013c). Thus, in order to cope with such uncertainties of emerging industries, scholars suggested that the business ecosystem around the emerging industry must be nurtured (Moore, 1996), and a friendly and healthy stakeholders network should be set up (Iansiti and Levien, 2004; Kenney and Pon, 2011). The concept of business ecosystem would equip companies with a more comprehensive view of cross-industry collaboration, rather than directly linking partners in the supply chain, as viewed through a traditional lens (Rong et al., 2013b), which have fully addressed those emerging industries' uncertainties. Thus, the perspective of ecosystem stakeholders could supply us with a proper solution to analyse evolutions of emerging industries, which are very complicated and uncertain. Within the emerging industry's business ecosystem, the stakeholders regarded as agents conducted complex behavior by interacting with other system players (or agents) and the environment (Rammel et al., 2007). The evolution of the ecosystems was the results of those different stakeholders' (agents) self-decision and interactions (J. Moore, 1993). The agent is an entity that can be viewed as perceiving its environment through sensors and acting upon its environment (Axtell et al., 2001). Thus, the agent-based model is an ideal method to understand and govern the behavior of business ecosystems as well as their evolutions (Cao et al., 2009).

Besides the theoretical perspective, we also found similar evidence and challenges from the practical side of the industry: Chinese electric vehicle industry acting as an emerging industry is under taking the nurturing of its business ecosystem. Though with rapid development in recent years, this industry was still not well established and facing the challenges on how to encourage those stakeholders achieve collaborative innovation and secure a better business model (Kley et al., 2011; Rong et al., 2013a). For example, during the Twelfth Five-Year Plan period, the new-energy vehicle industry, such as that relating to hybrid electric vehicles (HEVs) (Ganji et al., 2014) or pure electric vehicles (PEVs) is ranked as one of the seven strategic emerging industries by the Chinese central government. The EV industry is an emerging industry with strong potential for industrialization, which requires support from all stakeholders of the business ecosystem (Rong et al., 2013). The Chinese government has initiated several research and development (R&D) projects and industrialisation explorations through a number of national key scientific research programmes (such as the major "Electric Vehicle" and "Energy-saving and New-energy Vehicles" projects established by the national "863 program") and large-scale demonstration projects (such as the Beijing Olympic Games, the "Ten cities, Ten thousand Vehicles" programme, and the Shanghai World Expo). However, certain issues, such as lack of supporting industrial policy, low R&D capability of the industrial players, not well established technical standards from industrial associations, lack of infrastructure providers, local protection and consumer subsidies, are still bottlenecks that impede the industrialisation of EV. As a result, there is demand concerning research on the electric vehicle industry evolution through the nurturing of its ecosystem. Furthermore, this Chinese electric vehicle (EV) industry is a great example, to explore the emerging industry's business ecosystem evolution and stakeholders' role transformation as well as to understand the interaction of agent roles by employing the agent-based model.

Learning from the issues from both literature and industry, there is still a lack of systematic

research on the business ecosystem of emerging industries from the perspective of the transformation of different stakeholder roles or the view of agent-based model. In regard to such research gaps, we further collected data from the Chinese electric vehicle ecosystem from different stakeholders' perspectives and explore how they interact with each other and contribute to the evolution of the emerging electric vehicle industry. The stakeholder theory can serve as an effective starting point for the analysis of Chinese EV business ecosystem. Thereafter, we would be able to grasp the emerging industry's evolutionary trajectory and the dynamic mechanism by drawing a technology roadmap and analysing the business-ecosystem-nurturing process from the stakeholders' perspective. After that, the stakeholders analysis will also provide the basic framework for the agent-based model of a business ecosystem.

This paper is structured as follows: following this introductory section, the second section will review literature on business ecosystem studies, stakeholder theories and the agent-based system; this is followed by a description of the research methodology in the third section. The fourth section will outline the nurturing process of the Chinese EV industry via the method of roadmapping, and this is followed in the fifth section by an analysis of the roles of different stakeholders, with different phases. The sixth section will then construct a conceptual model of agent-based model, and illustrate different stakeholders' (agents) initial status, trigger condition and ending status in a business ecosystem. At last, theoretical and practical contributions of the paper will be concluded, as well as future research directions will be explained.

2 Literature Review

2.1 Stakeholder theory and classification

As first proposed by Moore in 1993, the concept of business ecosystem seeks to describe a loosely connected business community composed of different levels of organisations, such as industrial players, associations, governments and other relevant stakeholders, who share a common goal and co-evolve, with the purpose of dealing with uncertain business environments (J. Moore, 1993). This concept emphasises the importance of stakeholders, which make up the principle subjects of the business ecosystem.

The theory of stakeholder was originated and developed to meet the challenge and innovation of traditional shareholder theory (a view that shareholders or stockholders are the owners of the company, and the firm has a binding fiduciary duty to put their needs first, to increase value for them.), and was mainly adopted to analyse corporate social responsibility (CSR), hostile takeovers, company governance and other issues at the corporate or organisational level. There are two most representative definitions, which focus on broad and narrow levels, respectively, and a great deal of related research has emerged since the 1960s (Clarkson, 1994; Freeman, 1984). Freeman (1984) defined a stakeholder in an organisation as any group or individual who can affect or is affected by the achievement of the organisation's objectives; this definition leaves the notion of "stake" and the field of possible "stakeholders" unambiguously open to include virtually anyone. In contrast, Clarkson (1994) offered a narrower definition of stakeholders as those who bear a level of risk as a result of having invested some form of capital, human or financial, or something of value in a firm, or those who are placed at risk as a result of the firm's activities.

With regard to stakeholder classification, Freeman (1984) suggested that enterprise stakeholders are focused on aspects of ownership, economic dependency and social interests; besides, Frederick and his colleagues divided stakeholders into direct and indirect, using criteria of

whether the stakeholders in question have any marketing relations with the enterprise (Frederick et al., 1992); Clarkson also divided stakeholders into active and passive, according to the manner in which they bear the business risk, and into primary and secondary according to the relationship strength between the stakeholder and the firm. Furthermore, based on how many (one, two or three) attributes out of power, legitimacy and urgency are present (Clarkson, 1994, 1995); Mitchell and his colleagues divided stakeholders into definitive, expectant and latent (Mitchell et al., 1997). Wheeler, meanwhile, introduced a social dimension into the definition of stakeholders, and divided them into primary social stakeholders, secondary social stakeholders, primary non-social stakeholders, and secondary non-social stakeholders (Wheeler, 1998).

However, besides the focus from corporate or organisational level, the current business model and society required more about how to make value out of the interaction with different stakeholders (Im and Cho, 2013). Stakeholders with direct and non-direct business links could contribute to benefiting the business system as a whole, especially in some emerging industries (Kenney and Pon, 2011; Rong et al., 2013c).

2.2 Structure of the business ecosystem, and role identification

As explained above, different classes of stakeholders can be identified by using different division standards. This gives rise to the following question, which is relevant to the business ecosystem structure and role identification: How do different stakeholders play their roles in the business ecosystem, and what roles do they play?

Moore (1993) proposed that the member organisations within a business ecosystem should include suppliers, lead producers, competitors and other stakeholders; he later expanded this, saying that the economic community involved core business and business environment containing other levels of organisations, such as government, quasi-government, industry associations, standards bodies, competitors, and also business opportunities (Moore, 1996). At the firm level, identified keystone players, niche players, dominators and hub landlords were identified as the four categories of players that participate within the ecosystem (Iansiti and Levien, 2004). These four roles were then further integrated into three roles, with the functions of shaper, adapter and opportunist (den Hartigh and van Asseldonk, 2004). In 2006, Iyer and his colleagues also proposed three types of roles: bridge, hub and broker (Iyer et al., 2006). In 2011, Rong defined three kinds of functional roles in the business ecosystem from a firm perspective: initiator (who is willing to build the business ecosystem with their platform and product); specialist (who will add value to central firm's platform); and adopter (who will build up final products by adopting the initiator's and specialist's co-designed platform) (Rong, 2011). Furthermore, Shang and Shi also develop that a business ecosystem should also include supply, demand, interface and support as the four essential subsystems after studying the Chinese EV ecosystem (Shang and Shi, 2013). However, this research did not consider the dynamic roles that different stakeholders play in different stages of the business ecosystem. In other words, the merging between stakeholders' roles and the business ecosystem lifecycle still requires research.

2.3 Evolution and lifecycle of the business ecosystem

Both the classes and functional roles of different stakeholders will change with the evolution of a business ecosystem. Therefore, the business ecosystem lifecycle will serve as another theoretical base within this paper, and will be improved through our research. Since an emerging industry will experience a very uncertain environment, which requires a high degree of

interoperability among the ecosystem partners (Kenney and Pon, 2011), the concept of business ecosystem has been well adopted by industrial practitioners, especially from emerging-industry perspectives (Rong et al., 2011). As referred to in relation to the evolution of a business ecosystem, we can see that the four phases of birth, expansion, leadership and self-renewal should be included in the lifecycle of a business ecosystem (J. F. Moore, 1993). Mitleton-Kelly held the view that a business ecosystem is a complex evolution system (CES) and should include ten basic features: self-organisation, emergence, connectivity, interdependence, feedback, far from equilibrium, space of possibility, co-evolution, historicity and time, and path-dependency (Mitleton-Kelly, 2003). Peltoniemi proposed self-organisation, emergence, co-evolution and adaptation as the four key features of a business ecosystem by adopting system complexity and evolutionary theory (Peltoniemi, 2006). Recently, the business ecosystem lifecycle concept has been updated by introducing the following five phases: emerging (which ranges from a new solution being proposed, to a simple supply chain being produced), diversifying (wherein solution diversity is highly encouraged and the partner network is very flexible, with high interoperability), converging (the partners' network becomes integrated and focused on certain specialised markets or solutions), consolidating (the partners' network is stable and a close alliance for mass production of a dominant design is formed), and renewing (the original market is replaced with niche emerging markets or the reorganisation of a partner's network) as the evolutionary pathway of the ecosystem using case studies from the semi-conductor industry (Rong, 2011), and we will adopt this division of business ecosystem lifecycle to test Chinese EV industry for the proper fitting to emerging industry's research.

2.4 Business ecosystem and agent-based system

By reviewing previous studies on business ecosystems, it is apparent that they only addressed parts of the ecosystem or firm strategies (Adner and Kapoor, 2010; Chen et al., 2013; Iansiti and Levien, 2004; Rong et al., 2013a, 2013b, 2013c). For example, they found the lifecycle and platform strategy linked and the platform strategy experienced changes during the lifecycle (Rong et al., 2013b); the firm could use the ecosystem strategy to enable the technology substitution (Rong et al., 2013a); firms within the ecosystem could use keystone or supplementary strategy during the industry convergence (Rong et al., 2013c). However, all of those studies only highlighted the co-evolution among those ecosystem stakeholders and implemented relevant strategies (Chen et al., 2013), but failed to cover the exact role interaction mechanisms and how those micro-role interactions impact on the macro pattern change of a business ecosystem. Thereafter, it is really necessary to present the process of ecosystem stakeholders' interaction and see how they configure a different pattern of the ecosystem. The agent based approach (Axtell et al., 2001) could exactly achieve such process so as to clearly analyze the evolution of the business ecosystem.

The agent-based approach, explicitly studies the emergent macro-level phenomena from the interactions at the micro-level between autonomous agents. Individual attributes and strategies of the agents can influence the emergent system patterns, the information derived by the agents, and the structure of the network of agents (Axtell et al., 2001; Bichraoui et al., 2013). Agent-base analysis can be performed by conceptual as well as computational approaches. The computational approach is referred to as agent-based modeling (Janssen et al., 2008), and several classical models have been proposed and applied in social science since early 1970s, such as cellular automata (von Neumann, 1966), the game of life (Gardner, 1970), segregation (Schelling, 1971),

prisoner dilemmas (PD) tournaments (Axelrod, 1984), sugarscape (Epstein and Axtell, 1996) and so on Recently, agent-based modeling has been widely applied within industrial ecology (Axtell et al., 2001; Kraines and Wallace, 2006; Schwoon, 2006) and begins to make system analysis (Cao et al., 2009; Janssen et al., 2008). The use of system analysis is very important to emerging industry's business ecosystem for its complexity and dynamics. Therefore, multi-agent system is developed to solve this kind of problems, which can be used for all types of systems composed of multiple autonomous components showing the following characteristics: (1) each agent has incomplete information or capabilities for solving problems; (2) no system global control exists; (3) data are decentralized; (4) computation is asynchronous (Cao et al., 2009). According to the above analysis concerning business ecosystem and stakeholders, we argue that business ecosystem fits for these criteria properly with its stakeholders equal as agents.

2.5 Literature review discussion: Identification of the research gap

In summary, it is clear that scholars have successfully developed stakeholder theory and endeavored to apply the theories mainly at firm level. With reference to stakeholder theory, previous studies have focused on the definition, characteristics, classification and application of stakeholders at the firm level, while a small number of scholars have begun to explore stakeholders regarding the topic supply chain or industrial chain (Lavassani and Movahedi, 2010), the relationship between stakeholders and the business ecosystem (Brody, 2003; Menzel and Teng, 2010), and stakeholders and an enterprise's lifecycle (Gu and Lago, 2007; Jawahar and McLaughlin, 2001; Roloff, 2008). In terms of the business ecosystem, the research focus has gradually transferred to *the whole ecosystem structure from the former emphasis on the ecosystem role and their strategies*. With regard to agent-based approach, literatures mainly focused on how simple rules of interaction could explain certain macro-level phenomena such as spatial patterns and levels of cooperation (Janssen et al., 2008). The application of agent-based models in sociology (Macy and Willer, 2002), political science (Kollman, 2003), economics (Tesfatsion and Judd, 2006) has been increasing for the past two decades.

However, it is apparent that the recognition of stakeholders, their different roles, their transformations, and how to model different stakeholders' (agents) interaction and cooperation have not been receiving enough research attention, especially with reference to the nurturing process of an emerging industry's business ecosystem. In fact, different stakeholders (agents) will successively play participant, dominator and opportunist roles during different stages of an emerging industry's business ecosystem, and will decide to take related actions according to their experiences and judgments. Stakeholders' functional roles and applications are mostly concentrated at the firm or organisational level, and less so at the industry or even the system level. Specifically, there is still a gap relating to the different stakeholders' transformations during various stages of the nurturing process within the business ecosystem. Furthermore, it is interesting that the EV industry is still in an early stage and confronts with many uncertainties, and perfectly matches the scope of business ecosystem study and agent-based model. By initiating several large-scale demonstration projects, the EV industry in China has made great progress while facing several challenges, so the practical value of taking this emerging industry as a case is obvious. Based on the gap, the core research question of this paper can be defined as: What are the different stakeholders' functional roles, and what transformation do they undergo during the different stages of the emerging Chinese EV industry's business ecosystem? What is the conceptual model of agent-based system, and what are different agents' initial status, trigger

condition and ending status?

Four main steps are followed to analyse the key question.

1) The different stages of the Chinese EV industry are highlighted via roadmapping;

2) The different stakeholders involved in various stages of the business ecosystem are outlined;

3) The different stakeholders' functional roles, and their transformations along the business ecosystem lifecycle, are identified;

4) The different stakeholders' interactions and triggering conditions for the roles' transformation are illustrated by agent-based approach.

2.6 Research framework

Based on the literature review, we constructed a three-dimensional framework (see Figure 1) of the business ecosystem lifecycle, dynamic functional roles, and stakeholder classes. Rong's (2011) five stages of the business ecosystem lifecycle concept will also be adopted. However, we will employ the first three phases only because the EV industry has only experienced the emerging, diversifying and converging stages. By dividing the business ecosystem's evolutionary process into several stages, a dynamic analysis can be carried out.

In relation to the functional roles, in general, the roles of different stakeholders will transform from participating to dominating, and then decline to supporting; thus, their contribution to the business ecosystem will grow and then gradually fall off along the evolutionary process of the business ecosystem. Therefore, we define the first role as "participant", which is the essential stakeholder who will play a participating role or provide some kinds of support under the guide of the business ecosystem leader; the second role is defined as "dominator", according to Iansiti and Levien's (2004) research, wherein the key stakeholder in the business ecosystem will integrate various resources into a network and lead the industry's development; finally, the stakeholder's contribution will gradually decline, but will still stay within the business ecosystem, and do all the necessary business if needed (den Hartigh and van Asseldonk, 2004), and thus we name this the "opportunist". Besides, as the behaviors of business ecosystem is decided by its stakeholders' or related agents' actions, the functional roles dimension is the key to carry out agent-based analysis.

With respect to the dimension of stakeholder classes, Mitchell et al. (1997) score-based approach is widely applied to a specific enterprise or industry. Within Mitchell et al. (1997) research, stakeholder salience is positively related to the cumulative number of stakeholder attributes – power, legitimacy and urgency. Latent stakeholders are those possessing only one of the three attributes such that expectant stakeholders possess two; and definitive stakeholders possess all three. By analysing the stakeholder classification using the standards of power, legitimacy and urgency proposed by Mitchell, *reasons can be outlined for why a specific stakeholder plays a specific role.*

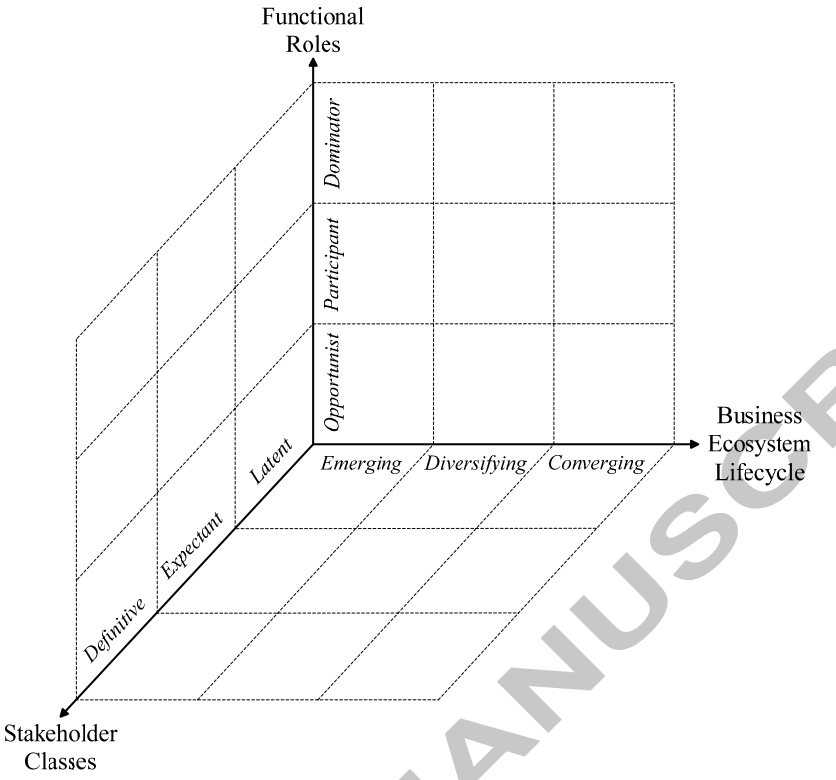

Fig. 1. Research Framework

3 Research Methodology

In this paper, the research objective is to recognise different kinds of stakeholders and the different roles they play in the various phases of the emerging industry's business ecosystem as well as propose a conceptual agent-based modeling of this ecosystem, using Chinese EV as the case industry. To answer the questions proposed in the second section, roadmapping, qualitative analysis and descriptive statistical analysis will be applied, and are considered well suited to this kind of research.

3.1 Data collection

In order to identify the EV industry's milestones and key policy initiatives, both in terms of collaborative activities with different stakeholders and key technology innovations, we collected data via conducting interviews and searching related database through official publications and websites. The interviews were conducted with companies including SAIC Motor Corporation Limited (SAIC Motor), Zhongtong Bus & Holding Co., Ltd. (Zhongtong Bus), BYD, Shandong Association of Automobile Manufacturers (SAMA), School of Automobile Studies from Tongji University (SAS, Tongji), Shanghai Electric Power Design Institute Co., Ltd (SEPD), Shanghai Zhida Science and Technology Co., Ltd (Shzhida), and China Titans Energy Technology Group Co., Ltd (TITANS). The questions focused on a brief introduction of the companies' evolutionary history, their views on the EV industry's trajectory, their major strategies and roles in different phases, and their suggestions about future EV industry development. In order to ensure the reliability and validity of the research, we compared the messages collected from literature review and the interviews. Where inconsistencies were noted, we called the interviewees to check the

detail again.

Related database searching was carried out as follows. Firstly, we comprehensively searched for policies and regulations relating to the EV industry, as issued by the State Council, the Ministry of Science and Technology (MOST), the Ministry of Industry and Information Technology (MIIT), the National Development and Reform Commission (NDRC), the Ministry of Finance (MOF). We also considered EV product bulletins (2005-2009), as well as the recommended directory for energy-saving and new-energy vehicle demonstration (batches 1–45, from 31 August 2009 to 17 May 2013) issued by MIIT. Secondly, we analysed the joint research programmes concerning EV-related research carried out by different universities and research institutions, as well as domestic companies, which had been funded by MOST (through its National Key Scientific and Technological Project, National Major Scientific and Technological Industrial Engineering, "National Clean Vehicle Action" programme, and "863program"). Thirdly, we searched for further information on R&D, manufacturing, demonstration and marketing activities from official publications, which included the *Energy-Saving and New Energy Vehicles Yearbook* (2010-2012) (which is compiled by the China Automotive Technology & Research Center), *China Automotive Industry Yearbook* (2006-2012) (compiled by the China Association of Automobile Manufacturers), *Chinese High-tech Industry Statistics Yearbook* (2004-2012) (compiled by the National Bureau of Statistics of China (NBSC)), *China Energy Statistical Yearbook* (2001-2012) (compiled by the NBSC) and other regional or industrial research reports on EV. Fourthly, we traced their activities through searches on corporate websites and related reports on TV, in newspapers and on other websites, and considered speeches presented by certain leaders and senior experts (such as Wan Gang, Miao Wei, Chen Qingquan, Guo Konghui, Yang Yusheng, Ouyang Minggao, etc.)

3.2 Data analysis

We followed four steps to analyse the data collected within this research. Firstly, we adopted the technology roadmap framework (Phaal et al., 2004; Suh and Park, 2009) to identify the four stages of Chinese EV industry development. Technology roadmapping is a method that helps organisations to plan their technologies by describing the path to be followed in order to integrate a given technology into products and services (Suh and Park, 2009). These, in turn, reach the market and meet the strategic objectives of the organisation (Phaal et al., 2011, 2007; Robert Phaal et al., 2004). Secondly, we invited five experts from related government agencies, six experts from universities/institutions, and nine experts from different EV companies to attend a workshop, and utilised an expert grading method to identify key stakeholders in the EV industry's business ecosystem. Thirdly, based on the classification of the nurturing process within Chinese EV industry, we analysed different stakeholders' variable attributes along the business ecosystem lifecycle of Chinese EV industry according to the theoretical framework proposed in the second stage. Finally, we integrated previous analyses and concluded this paper's theoretical and practical contributions.

3.3 Methods rigorous

In order to guarantee the rigor of the qualitative methodology, this paper applied four criteria to evaluate the validity and reliability of data collection and data analysis following the deployment of Campbell (1963, 1975). These four criteria include internal validity, construct validity, external validity and reliability, and have been adapted for use in case studies by

Eisenhardt (1989), Yin (1994), Gibbert et al. (2008), and others. Table 1 demonstrates that our data and analyses met these criteria to ensure the quality of this case study research.

Table 1 Methods rigorous analysis

Methods rigorous criteria	Method of addressing criteria in this study
Internal validity (Logical validity) Refers to the causal relationships between variables and results	A three-dimensional research framework explicitly derived from literature Pattern matching is demonstrated by Rong et al. (2011, 2013), Chen et al. (2013) and others Business ecosystem theory, stakeholder theory and agent-based modeling are used synthetically to guarantee the triangulation of theory
Construct validity Refers to the quality of the conceptualization or operationalization of the relevant concept	Twenty experienced experts provided sufficient suggestions and assist to establish a clear chain of evidence Documents, records, reports, policy, and summary of preliminary findings are reviewed through structured and semi-structured interviews to ensure triangulate analysis
External validity (Generalizability) Extents to which the method must be shown to account for phenomena not only in the setting in which they are studied, but also in other settings	Statistical analysis is carried out based on related industry statistics yearbook, which supply ample details on the choices of sampling The interviewees are all experienced managers and from different sectors, including government agencies, universities/institutions, different manufacturers and component companies
Reliability Refers to the absence of random error, with transparency and replication as the two key words	Case study outline is designed early and refined under related experts' advice, and can be used by all investigators in the research team Interviewers' initial interpretations are double-checked and verified with the interviewees during the interviews Data collection and analysis in this paper makes a basic preparation to construct a database, which can be referred by later investigators

4 Chinese EV Industry Journey and Roadmap

Initiated in the late 1980s, Chinese EV-related R&D and testing pace was significantly accelerated from the Tenth Five-Year Plan period, and this was followed by a convergence between the emerging transport system and the energy supply system through several large-scale demonstration projects to achieve industrialisation as soon as possible. Specifically, the EV industry's business ecosystem can be analysed according to the aspects of key components, OEMs, demonstrations, marketing, infrastructure, public platforms, and industrial alliances, by using a technology roadmap (Figure 2).

(1) For the key components, related research explored the original improvement via R&D of sodium-sulfur batteries, lead-acid batteries and nickel-cadmium batteries to lithium batteries, special driving motors and electric control systems, and further extended from the applying in large-scale demonstration projects to "Three Transverses", as muti-energy powertrain system, drive motor and power battery were emphasised on parallel lines

(2) For the OEMs, related attempts focus on using batteries to drive vehicles, modifying existing models or re-designing conceptual vehicles and manufacturing vehicles based on the new pure electric vehicle (PEV) technology platform (ROEWE E50 from SAIC). The integration of EVs has undergone a journey from developing PEV only to promoting PEVs, HEVs and fuel cell electric vehicles (FCEVs) simultaneously, and then transferring to the new "Three Longitudes", as

HEV industrialisation has been a recent goal, PEV development is a future direction, and FCEV involves the next generation of EV products.

(3) Demonstrations have been experienced by the EV industry on a small scale with the purpose of technology detection, while large-scale demonstration has mainly been used within the area of public transport. At present, it finally returns to the right track, and industrialisation is the next goal of EV industry's development.

(4) With respect to marketing, the EV industry has experienced a conversion from small-scale production and marketing, to public procurements arising from public transportation, municipal transportation and other fields. Currently, true private markets have been inspired and some private consumers begin to accept this new product.

(5) In terms of charging infrastructures, suppliers have extended their services from meeting public transportation and demonstration needs, to meeting the requirements of private consumers. At the same time, grid corporations, OEMs and municipal agencies are exploring different business models to satisfy future needs.

(6) For public platforms, in the past we only emphasised the power system, but now extend to "Three Platforms", which is made up of "The Platform for Standards, Testing and Data", "The Platform for Energy Supply Infrastructure" and "The Platform for Application Development and Integration Demonstration".

(7) In relation to industry alliances, we used the PEV, HEV and FCEV features of technology level and practical application, and upgraded the former "Electric Vehicle Industry Alliance" to the "Three Longitudes and Three Chains" technology innovation alliance, which is constituted of "HEV's Industrial Technology Innovation Alliance with Industrial Chain as the Link", "PEV's Cross Industrial Technology Innovation Alliance with Value Chain as the Link" and "FCEV's Advanced Technology Innovation Alliance with Technology Chain as the Link".

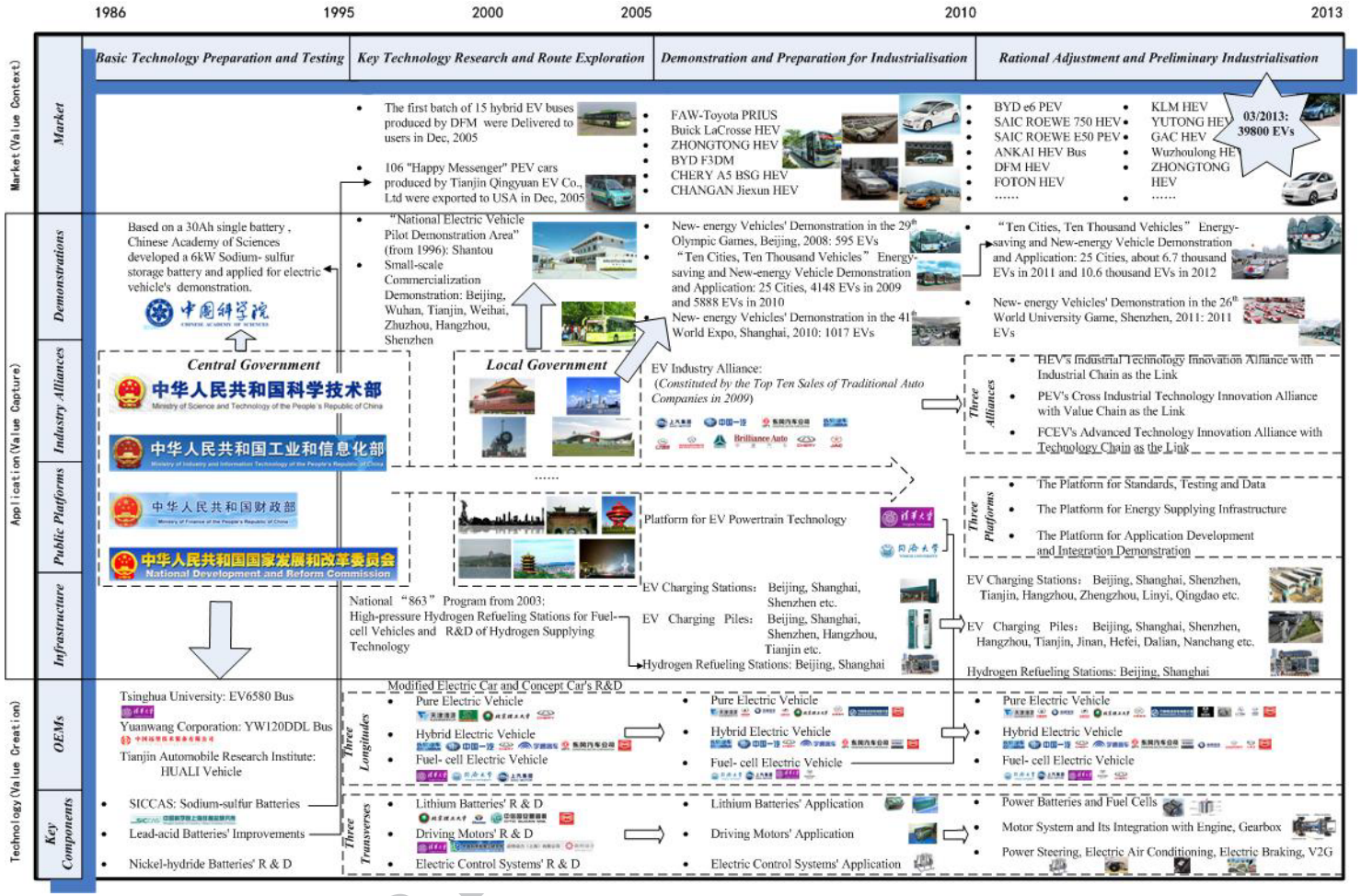

Fig. 2. Technology roadmap of Chinese EV industry

From the technology roadmap above, it can be seen that Chinese EV industry has seen great progress thanks to a strong "push" from the government; meanwhile, the evolution of Chinese EV industry also shows specific features in relation to the effects of Chinese typical "top-down" system, which can be divided into four stages as follows.

4.1 Basic technology preparation and testing

This stage lasted from the Seventh Five-Year Plan period (1986–1990), during which EV's R&D was initiated, to the Eighth Five-Year Plan period (1991–1995), during which the EV Technology Research project was established, as shown in Figure 3. Under pressure from developed countries' R&D on clean-energy vehicles, China's limited oil resources and extreme consumption of fossil fuels, a government agency (the former National Science and Technology Commission) initiated EV R&D, and several universities/institutions, such as Tsinghua University, Tianjin Automobile Research Institute, and Yuanwang Corporation, began to develop some sample vehicles. With the focus on improving the R&D on sodium-sulfur batteries, lead-acid batteries and nickel-cadmium batteries, this phase tried to apply batteries to drive small cars and to produce several prototypes. However, there were no demonstration projects, and related R&D mainly concentrated on pure electric vehicles (PEVs), so that Chinese EV business ecosystem still struggled within the stage of basic technology preparation and testing.

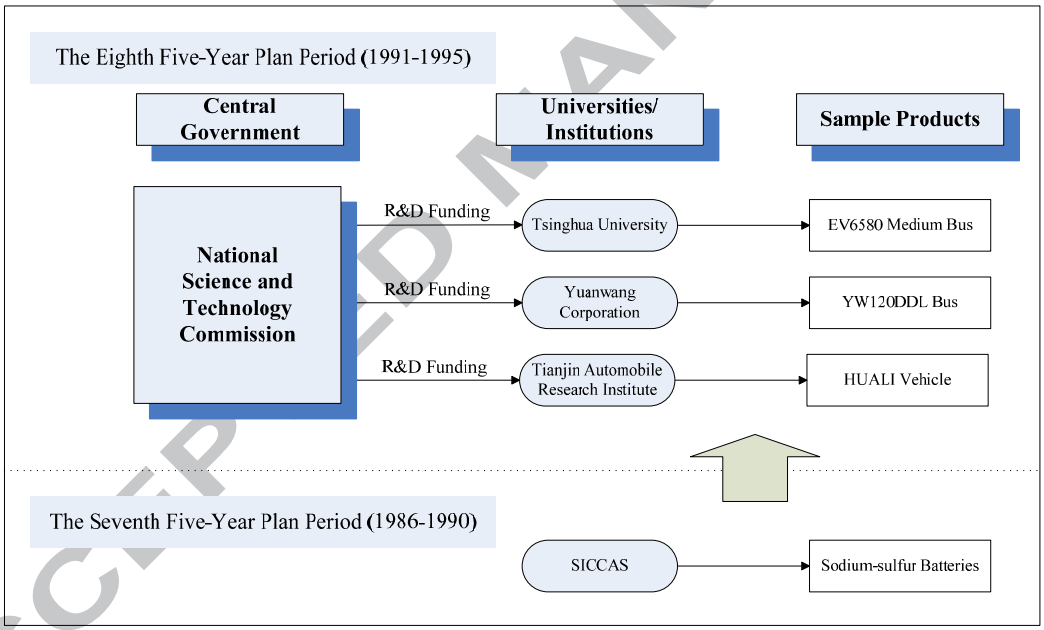

Fig. 3. Business ecosystem – basic technology preparation and testing stage

4.2 Key technology research and route exploration

This stage lasted from the Ninth Five-Year Plan period (1996–2000), during which key PEV technologies were the main R&D direction, to the Tenth Five-Year Plan (2001–2005) period, during which the layout of "Three Longitudes and Three Transverses" was properly defined, as demonstrated in Figure 4. During the Ninth Five-Year Plan period, only a small number of universities, institutions and OEMs collaborated to modify and re-design traditional vehicles, as well as to develop conceptual EVs, and the first national EV pilot demonstration area was set up in Shantou, Guangdong province. During the Tenth Five-Year Plan period, the R&D layout of "Three Longitudes and Three Transverses" was established; this refers to three types of EVs, namely

PEVs, HEVs and FCEVs as the “Three Longitudes”, and also to three auto-related technologies, namely muti-energy powertrain system, drive motor and power battery, as the “Three Transverses”. All three kinds of EVs (PEVs, HEVs and FCEVs) were initiated under the leading automobile companies, which indicates that the large scale of Chinese EV R&D was officially launched from 2001, followed by small-scale demonstration in seven cities (Beijing, Wuhan, Tianjin, Weihai, Zhuzhou, Hangzhou and Shenzhen), and emerging marketing. In general, this phase’s R&D extended from a single PEV, to HEV and FCEV, and adopted the comprehensive technological route; meanwhile, the overall design of EV, advanced battery technology (lithium battery), driving motor and electric control system, monitoring and management system, and supporting technologies were emphasised. While the government agencies invested much, and several universities and institutions undertook many R&D projects, most enterprises did not become deeply involved in this emerging industry due to the absence of a clear technology roadmap. This stage can thus be named the stage of key technology research and route exploration.

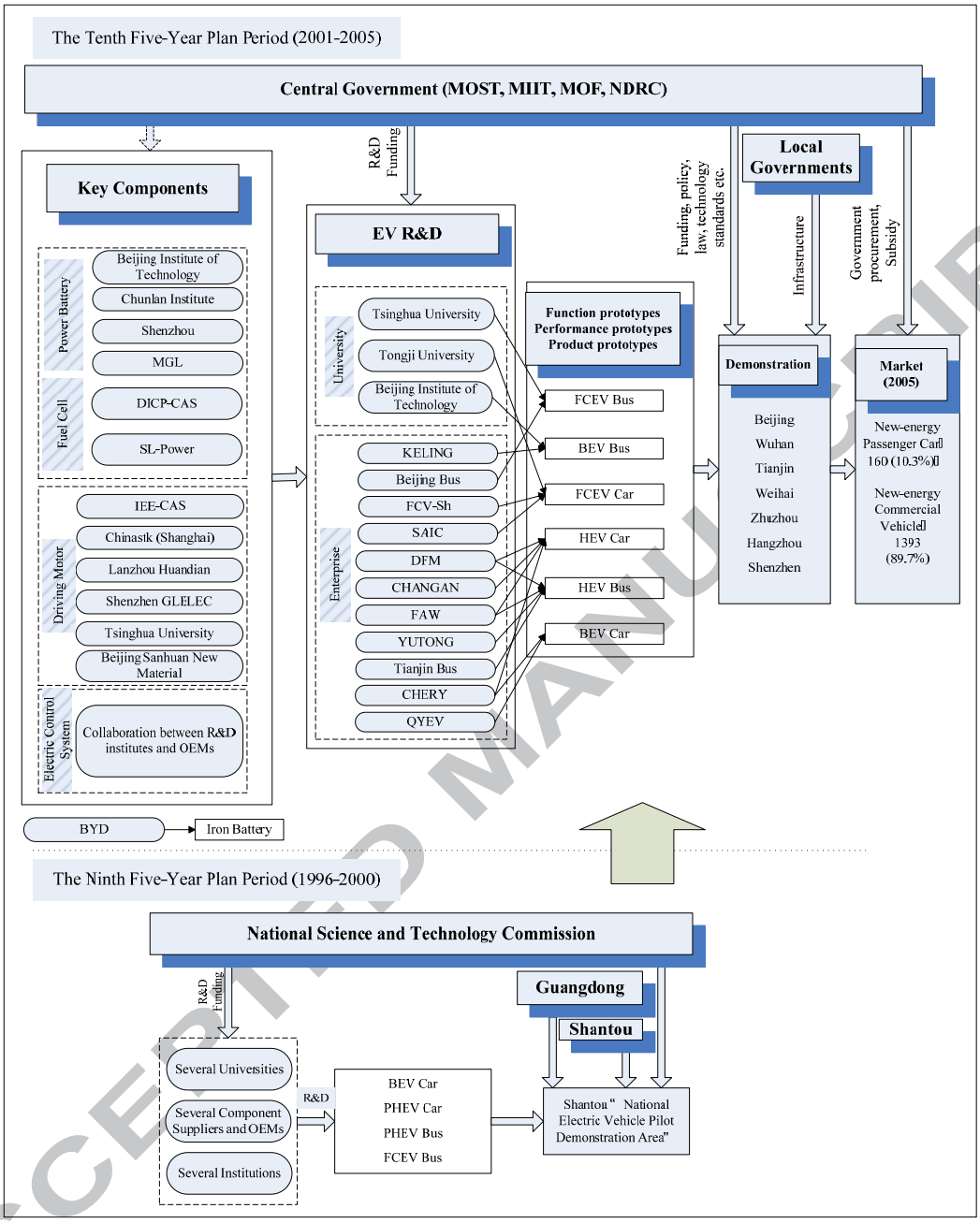

Fig. 4. Business ecosystem – key technology research and route exploration stage

4.3 Demonstration and preparation for industrialisation

As can be seen in Figure 5, this stage merged the original EV and clean-vehicle R&D projects into the new "Energy-saving and New-energy Vehicle" special project sponsored by the national "863 program", according to the strategy of transition (clean-energy vehicles) and transformation (EVs) during the period of the Eleventh Five-Year Plan (2006–2010). The layout of "Three Longitudes and Three Transverses" was still adopted to guide this stage's R&D, and a number of component suppliers and OEMs sprang up. Under the force of the "Scientific Olympics" (One of the three themes of the Beijing Olympics, which means that a lot of latest domestic and international scientific and technological achievements were applied) from the 2008

Beijing Olympics, the "Urban Low-carbon Transport Demonstration" from the 2010 Shanghai Expo, as well as the "Ten Cities, Ten Thousand Vehicles" energy-saving and new-energy vehicle demonstration, numerous projects were launched across the whole country in order to get support from policies and become listed in the national catalogue. However, this was followed by slow growth within the market. At the same time, several platforms were set up for R&D within common technology, and public services and an EV Industry Alliance were established to coordinate the industry's development, while charging stations and piles were constructed in several cities. However, many issues, such as technical routes, key core technologies, investment, policy emphasis, etc. were not identified properly, and neither were the Chinese automobile industry's basis and market characteristics defined completely. Compared with the previous stage, a large number of firms were actively involved during this period, and several large-scale demonstration projects were carried out in the area of public transportation. However, it was an early stage in terms of testing using private consumers' subsidies, and there was still a long way to go to reach EV industrialisation due to immature technologies, high prices, charging problems, etc. Chinese EV industry still lingers in the stage of demonstration and preparation for industrialization.

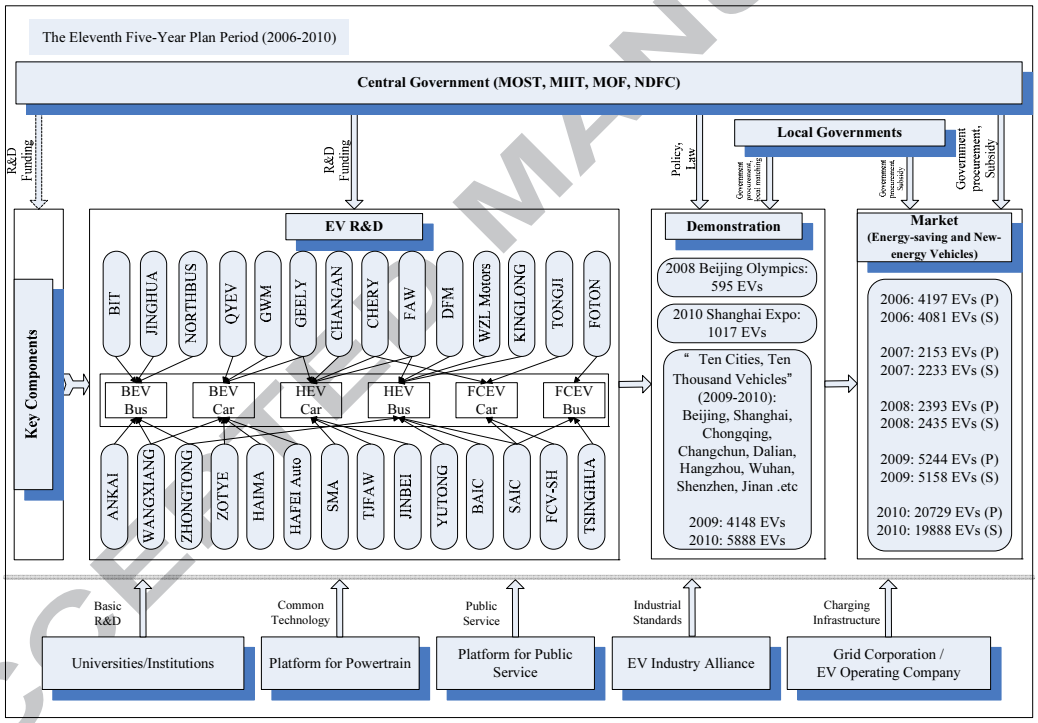

Fig. 5. Business ecosystem – demonstration and preparation for industrialisation stage

4.4 Rational adjustment and preliminary industrialisation

In response to technology bottlenecks, and the fact that the market was faced with obstacles, the government set another special project for EV R&D during the Twelfth Five-Year Plan period (2011–2015), and adjusted the EV roadmap by conducting key-technology R&D and different kinds of EV industrialisation simultaneously. As demonstrated in Figure 6, the former layout of "Three Longitudes and Three Transverses" was extended to "Three Longitudes, Three Transverses and Three Platforms" as the new guideline, while "Three Longitudes and Three Chains" industrial

technology innovation alliances were also planned in this stage. With "The Special Plan for EV's Science and Technology Development during the Twelfth Five-Year Plan Period" issued in March, 2012 and "The Development Plan for Energy-saving and New-energy Vehicle Industry (2012–2020)" issued in June, 2012 as the symbol, "driven by electricity only" was identified as the technology transformation strategy of the EV industry, while the target of the HEV industrialisation technologies during the Twelfth Five-Year Plan period was also determined. In general, this phase established "driven by electricity only" as the dominant transformation strategy from the perspective of technology, promoted HEVs as the current industrialisation strategy for the closest performance with traditional vehicles, and actively tested and stimulated the private-consumer EV market. This stage can thus be named as rational adjustment and preliminary industrialisation.

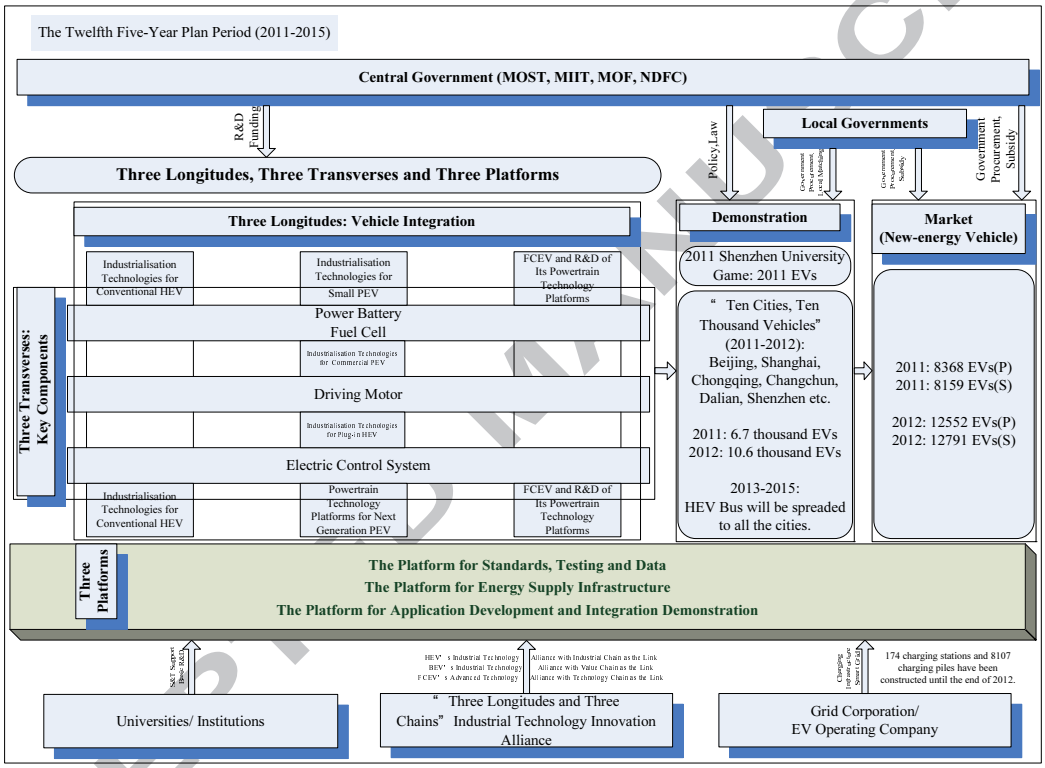

Fig.6. Business ecosystem – rational adjustment and preliminary industrialization

From the perspective of the industry's evolutionary trajectory, Chinese EV industry experienced four stages in succession: basic technology preparation and testing, key technology research and route exploration, demonstration and preparation for industrialisation, and rational adjustment and preliminary industrialisation.

5 Stakeholder Analysis during Different Stages of the Chinese EV Industry's Business Ecosystem and 'Triple Oscillation' Model

From the analysis above, and according to Rong's (2011) research on the business ecosystem lifecycle and nurturing process, we can see that Chinese EV industry has just experienced the stage of emerging and diversifying, and is now struggling with the converging stage. However, as the government will play an obvious role in strategically pushing the emerging industry's development, questions arise as to whether there are any specific characteristics within the nurturing process of this kind of industry, which kinds of stakeholders are involved in different stage of the industry's evolution, and how the different stakeholders' functional roles transform within the dynamic business ecosystem. The following analysis will answer all three of these questions.

Drawing on Freeman's (1984) definition of a stakeholder, this paper identified the stakeholders of Chinese EV industry by applying the expert grading method. We invited five experts from related government agencies, six experts from universities/institutions, and nine experts from different EV companies to attend a workshop, and gave them a list of 20 kinds of stakeholders gathered from previously conducted interviews and literature reviews. We asked the 20 experts to suggest the key stakeholders from their experience using two rounds of data collection, and the results are shown in Table 2.

Table 2 Different stakeholders identified by experts (in order of descending frequency)

EV Industry's Stakeholders	*Reference Number*	*Frequency (%)*
1. OEMs	20	100
2. Infrastructure	20	100
3. Central Government	20	100
4. Component Suppliers	20	100
5. Public Consumers	20	100
6. Private Consumers	20	100
7. Local Government	16	80
8. Universities/Institutions	15	75
9. Industry Alliances	12	60
10. Special Interest Groups	9	45
11. Industry Associations	9	45
12. Communities	8	40
13. Media	6	30
14. Investment institutions	5	25
15. Natural Environment	5	25
16. Environmental Organisations	5	25
17. Political Parties	3	15
18. Educational Institutions	2	10
19. Future Generation	2	10
20. Religious Groups	0	0

For easier comparison, we adopted '50%' frequency as the criteria to select the important stakeholders, and thus identified OEMs, Infrastructure (Infra), Central Government (C-Gov.),

Component Suppliers (CS), Public Consumers (Pub-C), Private Consumers (Pri-C), Local Government (L-Gov.), Universities/Institutions (U/I) and Industry Alliances (IA) as the nine key stakeholders of Chinese EV industry, and will analyse the different stakeholders' variable attributes during the dynamic process of Chinese EV business ecosystem in the following sections.

5.1 Stakeholder analysis – basic technology preparation and testing stage

During this period, as shown in Table 3, only C-Gov. and U/I were definitive stakeholders, according to the dimension of stakeholder classes (power, legitimacy and/or urgency (see framework proposed in part two)). While C-Gov. sponsored and invested to support certain research projects, only a handful of U/Is participated in the basic-technology R&D under the guidance of government agencies. CS, OEMs and Infra were expectant stakeholders as they were not urgent, though possessing the features of power and legitimacy. In addition, as L-Gov. and IA only had "power", Pub-C and Pri-C only fitted the feature of "legitimacy", and can thus be classified as latent stakeholders. In general, in this stage only C-Gov. initiated the layout of the EV business ecosystem, and a small number of U/Is began to undertake some preparatory work, while neither expectant nor latent stakeholders participated in the EV business ecosystem to any great extent. Thus, this was the "initiating" phase of the emerging industry's nurturing process.

Table 3 Stakeholder analysis – basic technology preparation and testing stage

Stakeholder Class / Functional Role	Definitive		Expectant			Latent			
	C-Gov.	U/I	CS	OEMs	Infra	L-Gov.	IA	Pub-C	Pri-C
Participant		√							
Dominator	√								
Opportunist									

5.2 Stakeholder analysis – key technology research and route exploration stage

During this period, as shown in Table 4, in addition to C-Gov. and a large number of U/Is, which played dominator roles in conducting research related to key EV technologies, some CSs and OEMs were also definitive stakeholders, and played the role of participants in conducting collaboration work in accordance with the "Three Longitudes and Three Transverses" layout. Meanwhile, Infra and L-Gov. began to take part in charging services and the construction of pilot areas, respectively, while several government agencies and public transport companies tried to purchase a small number of new-energy commercial vehicles. However, because of this there were not enough EVs to form a proper market; Infra, L-Gov. and Pub-C still belonged to the class of expectant stakeholders, and played a participant role due to the absence of "urgency". In addition, although IA and Pri-C had "power" to some extent, they did not actually enter the EV business ecosystem, and thus remained latent stakeholders. In other words, the business ecosystem of the EV industry exhibited several specific features, such as strong push from C-Gov., vigorous research from U/Is, participation from L-Gov., leadership from OEMs, collaboration from CSs, as well as a combination of production, study and research in this period. Following Infra's coordinated development and the appearance of marketing and a simple supply chain, the business ecosystem transferred to the "emerging" stage.

Table 4 Stakeholder analysis – key technology research and route exploration stage

Stakeholder Class / Functional Role	Definitive					Expectant			Latent
	C-Gov.	U/I	CS	OEMs	Infra	L-Gov.	Pub-C	IA	Pri-C
Participant			√	√	√	√	√		
Dominator	√	√							
Opportunist									

5.3 Stakeholder analysis – demonstration and preparation for industrialisation

During this period, as shown in Table 5, with the large-scale increase in EV demonstration, L-Gov. actively applied to become the official demonstration city, and this was approved by C-Gov. Meanwhile, OEMs enthusiastically introduced different kinds of EV models, and thus these two groups co-led the industry's development as dominators. With regard to CS and Infra, although they still supplied key components to OEMs and charging service to consumers as the participants, they took on identities as definitive stakeholders due to being fully equipped with power, legitimacy and urgency. At the same time, energy-saving- and new-energy-vehicle public platforms and related IA increased and took on the same role as Pub-C to participant in the EV industry; both of these belonged to the expectant stakeholder group. A small number of Pri-Cs tried to test or buy some EVs, but they remained latent stakeholders due to an absence of power and urgency as a result of their small market size. In addition, although C-Gov. was still the definitive stakeholder, it played an opportunist role within the new function of policy formulation and platform construction; U/Is transferred to the expectant stakeholder group, and played an opportunist role due to a loss of urgency. Overall, the business ecosystem of the EV industry exhibited several specific features, such as passionate participation from L-Gov., a marked increase in CSs and OEMs, the construction of Infra with the support of grid corporations, and an active public transportation market in this period. With the formation of complex social networks as the symbol, the business ecosystem skipped to the diversifying stage.

Table 5 Stakeholder analysis – demonstration and preparation for industrialisation

Stakeholder Class / Functional Role	Definitive				Expectant				Latent
	L-Gov.	OEMs	CS	Infra	C-Gov.	Pub-C	IA	U/I	Pri-C
Participant			√	√		√	√		√
Dominator	√	√							
Opportunist					√			√	

5.4 Stakeholder analysis – rational adjustment and preliminary industrialisation stage

During this period, as shown in Table 6, the EV business ecosystem conducted a rational adjustment according to the deficiencies exposed during the previous phase. The stage was led by C-Gov., OEMs, Infra, Pub-C, and Pri-C, which co-played a dominator role, and all served as

definitive stakeholders. CS was an essential participant in terms of supplying key parts to automobile companies, while IA played an opportunist role in formulating industry standards and regulating trade orders – both of these were expectant stakeholders. At the same time, L-Gov. switched to an expectant stakeholder role and took up an opportunist position to support the construction of public platforms, industry alliances and charging infrastructures, while the "power" of U/Is gradually faded so that they degenerated to a latent stakeholder role. In short, the EV industry's future nurturing direction was adjusted by C-Gov. In this period, more emphasis was paid on the industry's natural growth and the market's formation, while key technology breakthroughs were anticipated from the supply side and private consumption was actively guided from the demand side. In addition, Infra and IA played increasingly important roles within the evolution of the EV industry. Thanks to the improved integration and collaboration of different stakeholders, the business ecosystem moved into the "converging" stage.

Table 6 Stakeholder analysis – rational adjustment and preliminary industrialisation stage

Functional Role \ Stakeholder Class	Definitive					Expectant			Latent
	C-Gov.	OEMs	Infra	Pub-C	Pri-C	CS	IA	L-Gov.	U/I
Participant						√			
Dominator	√	√	√	√	√				
Opportunist							√	√	√

6 Triple Oscillation Model and Agent-based model

6.1 Triple Oscillation' Model

From the perspective of the emerging industry's strategic nurturing process, Chinese EV industry experienced four stages in succession: initiating, emerging, diversifying and converging. During each stage, different stakeholders entered the business ecosystem and began to play different roles. The nine stakeholders discussed above can be divided into three bundles according to the different times at which they joined the business ecosystem (as shown by the thick arrows in Fig. 7). The first bundle of stakeholders, constituted of C-Gov. and U/I, experienced a transformation from participant and dominator to opportunist, and even C-Gov. returned to the place of dominator during the fourth stage. The second bundle of stakeholders was constituted of CS, OEMs, Infra, L-Gov. and Pub-C, which joined in the business ecosystem during the second stage, and mainly upgraded to a dominator role in the fourth stage. The third bundle of stakeholders, constituted of IA and Pri-C, joined the business ecosystem during the third stage. However, IA and Pri-C did not change at the same pace, with the former turning an opportunist and the latter acting as dominator in the fourth stage. Therefore, the three bundles of stakeholders played the role of participant, dominator and opportunist sequentially in general, and some stakeholders, such as C-Gov., even exhibited a tendency to loop into the next round. This phenomenon reflects a triple-role oscillation in relation to their functional role transformation, and shows that the roles are mutually complementary. This phenomenon of the ecosystem stakeholders' evolution indicates a new evolutionary law which can be defined as the '**Triple Oscillation' Model**. This model explains the role transformation through the three bundles of

stakeholder interaction and cooperation, and presents the co-evolution of an emerging industry's business ecosystem.

(1) The role of participant, during the initiating stage, was only played by U/I from the definitive stakeholder class; during the emerging stage, CS and OEMs from the definitive stakeholder class, as well as Infra, L-Gov. and Pub-C from the expectant stakeholder class, joined in; during the diversifying stage, Infra transformed into a definitive stakeholder and took part in the business ecosystem as CS, while IA joined as an expectant stakeholder and Pri-C acted as a latent stakeholder; during the converging stage, only CS from the expectant stakeholder class remained to serve this role.

(2) The role of dominator, during the initiating stage, was played by C-Gov. alone from the definitive stakeholder class; during the emerging stage, U/I joined C-Gov. within the business ecosystem, and together they led the industry's technology research, and both belonged to the definitive stakeholder class; during the diversifying stage, L-Gov. and OEMs became the definitive stakeholders and co-led the EV industry's demonstrations and preparation for industrialisation; during the converging stage, the EV industry ran into a period of rational adjustment and early industrialisation, in addition to constructing more charging stations and piles and meeting increasing consumer demand, while C-Gov. returned to dominate adjustment of the technology roadmap's layout – therefore, C-Gov., Infra, Pub-C and Pri-C turned into definitive stakeholders, and co-led the industry's development with OEMs.

(3) The role of opportunist was always played by the dominator of former periods. During the diversifying stage, an opportunist appeared for the first time, and was constituted of C-Gov. from the definitive stakeholder class, and U/I from the expectant stakeholder class; during the converging stage, U/I turned into a latent stakeholder, while IA and L-Gov. joined as expectant stakeholders, and all of them danced in this stage.

From the dimensions of stakeholder classes and the business ecosystem lifecycle outlined above we also identify some interesting laws, which can be summarised as follows.

(1) With the evolution of the business ecosystem, the number of definitive stakeholders will increase gradually, while latent stakeholders will decrease in response to the complexity of the business ecosystem. In addition, the total number of expectant stakeholders remains in a fairly stable state within our case study of Chinese EV industry.

(2) Both of the transformation directions – from latent stakeholder to expectant to definitive, and from definitive stakeholder to expectant to latent – always transform step by step, without skipping any stages of the business ecosystem's evolution.

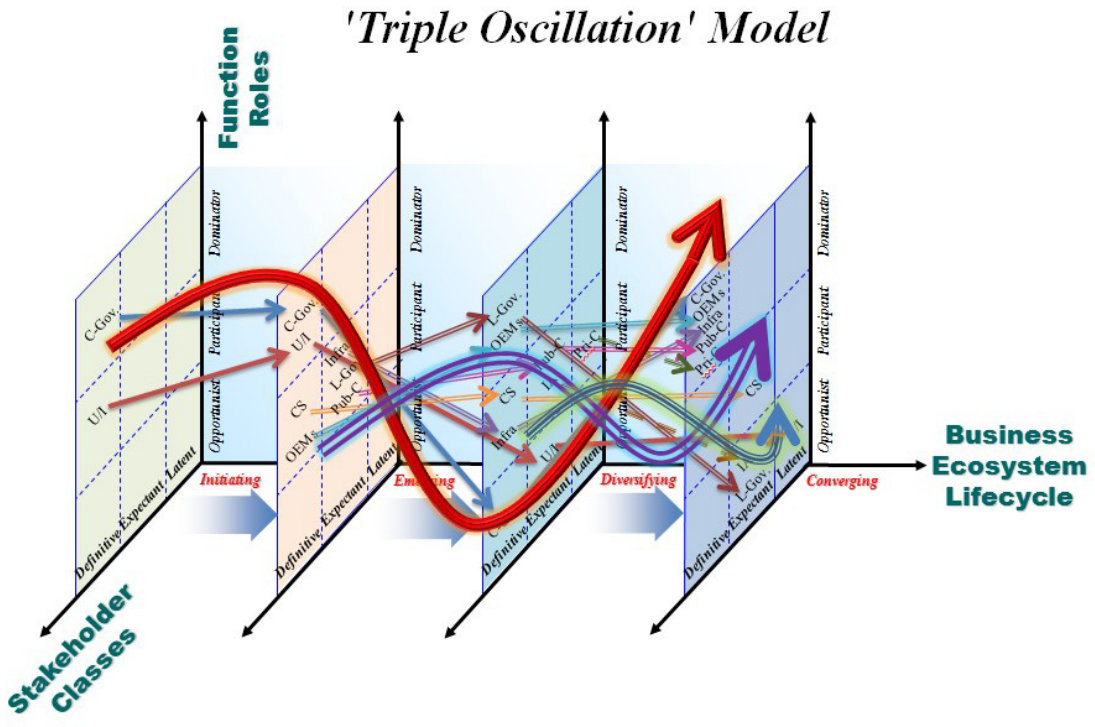

Fig. 7. Variable attributes of different stakeholders during the dynamic process of Chinese EV business ecosystem

Notes: C-Gov.: Central Government, L-Gov.: Local Government, U/I: Universities/ Institutions, CS: Component Suppliers, OEMs, Infra: Infrastructure, IA: Industrial Alliance, Pub-C: Public Consumers, Pri-C: Private Consumers
First bundle of stakeholders:
Second bundle of stakeholders:
Third bundle of stakeholders:

6.2 Developing an conceptual model of agent-based system

Learning from the above analysis of 'Tripe Oscillation' model, the agent can be equaled as stakeholder or a bundle of stakeholders in this study. Thus, the three bundles of stakeholders could be regarded as the three agents existing in the system. Therefore, the 'triple Oscillation' model could help us develop a conceptual model of agent-based system as shown in Figure 8 and try to identify the interaction rules such as the trigger conditions of different agents' dynamic transformation during the emerging industry's business ecosystem evolution.

(1) The conceptual model of agent-based system

According to the 'Triple Oscillation' model (Fig. 7), there are three bundles of agents who join the business ecosystem and play different roles sequentially, and a conceptual model of such a kind of system can be constructed (Fig.8). As C-Gov. and U/I make up the first bundle of agents, they usually stimulate the emerging industry by initiating research programs, supplying related funding, introducing industrial policies, and carrying out basic research and knowledge service, and push the second bundle of agents' actions. For the second one, it is composed by OEMs, Infra, CS, L-Gov. and Pub-C, and mainly supply components, produce EV products, construct charging infrastructures and conduct demonstration projects, and will equip the third bundle of agents with EV products and related service. In terms of the third bundle, Pri-C and IA are the main two members. They will respectively play the most important roles of consuming and using, constructing public platforms and setting industrial standards to pull and regulate the industry development in a sustainable way.

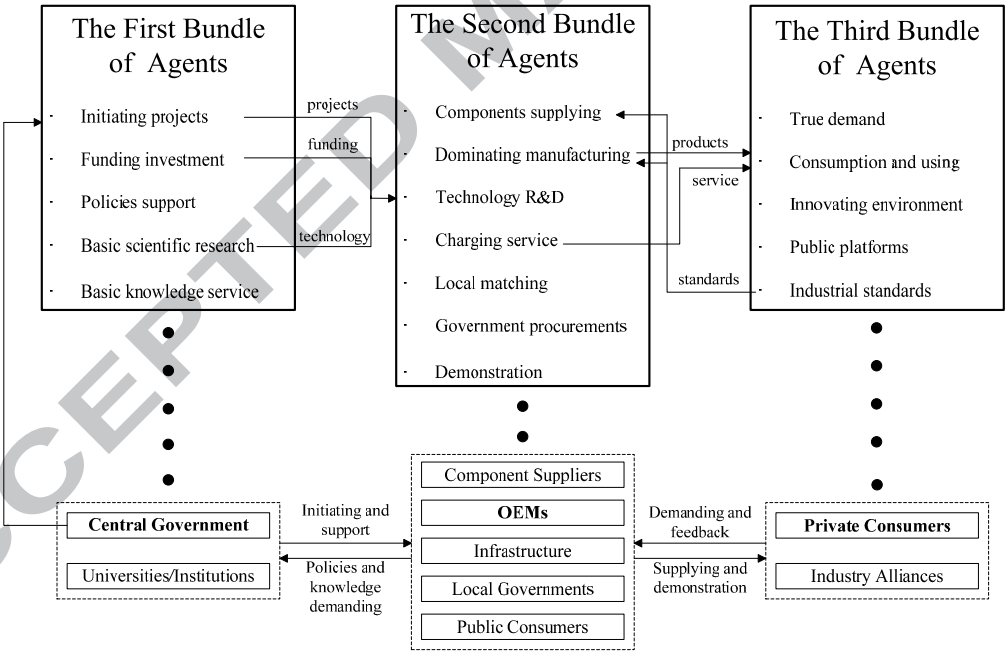

Fig. 8. A conceptual model of agent-based system

Meanwhile, the second bundle of agents will be affected by the first bundle through the supporting and initiating activities, and by the third bundle through the demanding and feedback; on the contrary, the first and the third bundle of agents will be intervened by the second one since they asked for policies and knowledge from the first bundle and supplied products, service and demonstration to the third bundle.

The ideal way of nurturing an emerging industry's business ecosystem, is structured as follows: the first bundle of agents initiates the first step and integrates resources, while the second bundle of agents actively involves to play the most important role from the side of supplying and the third one takes the role of demanding pull well, and then the system will go into a healthy cycle and followed by the rapid development of such an emerging industry. Those agents' behaviors are also identified in the above as dominator (D), participator (P) and opportunist (O).

(2) The rule of agent behavior: trigger conditions

In Table 7, the interaction rule is identified as the trigger condition of different agents' dynamic transformation by analysing the Chinese EV industry's data. Then, the interaction rule is set in the proposed agent-based model. There are the nine stakeholders (agents) experienced evolution along the business ecosystem stages and shifted different functional roles. There are different trigger conditions enabling stakeholders (agents) functional roles' shift. Actually, the agent faced various uncertainties challenges during the sequential stages of business ecosystem lifecycle; thus, the agent will take actions according to their behavior rules so as to change the role type.

Table 7 Trigger conditions- The rules of agent behavior

	Agent	Initiating	Trigger Condition	Emerging	Trigger Condition	Diversifying	Trigger Condition	Converging
1st bundle	C-Gov.	D	——	D	Marketing pull	O	Industry adjustment	D
	U/I	P	Basic research	D	Theory support	O	——	O
2nd bundle	CS			P	——	P	——	P
	OEMs			P	Technology push	D	Marketing pull	D
	L-Gov.			P	Demonstration projects	D	Local matching	O
	Infra			P	——	P	Complementary facilities	D
	Pub-C			P	——	P	Government Procurement	D
3rd bundle	Pri-C					P	Consuming demand	D
	IA					P	Related service	O

In summary, we have proposed the following agent-based system for the emerging industry' business ecosystem evolution. The agents are defined as the three bundles of stakeholders in the ecosystem. Each of them has three functional statuses (roles) such as dominator (D), participant (P) and opportunist (O). Those stakeholders will shift among those functional statuses (D, P, O) during the evolution process. There are different behavior rules (trigger conditions) enabling the stakeholder function shift (the Table 7 is just an example of trigger conditions). Learning from the data of Chinese EV industry, there are four stages of the ecosystem evolution including initiating, emerging, diversifying and converging. However, more data needs to be collected in order to generalize the interaction rules, (the triggers) and the agent role transformation process and stages. Besides the trigger conditions, there are also initial status and ending status, and the initial status relies on the country's context. For example, the Chinese EV industry is highly supported by the Chinese government, while the ending status could be identified as the maturity of an industry as shown in Figure 9. However, this is still a draft agent-based model, which can be generalized by collecting more data in other industries or the same industries in other countries.

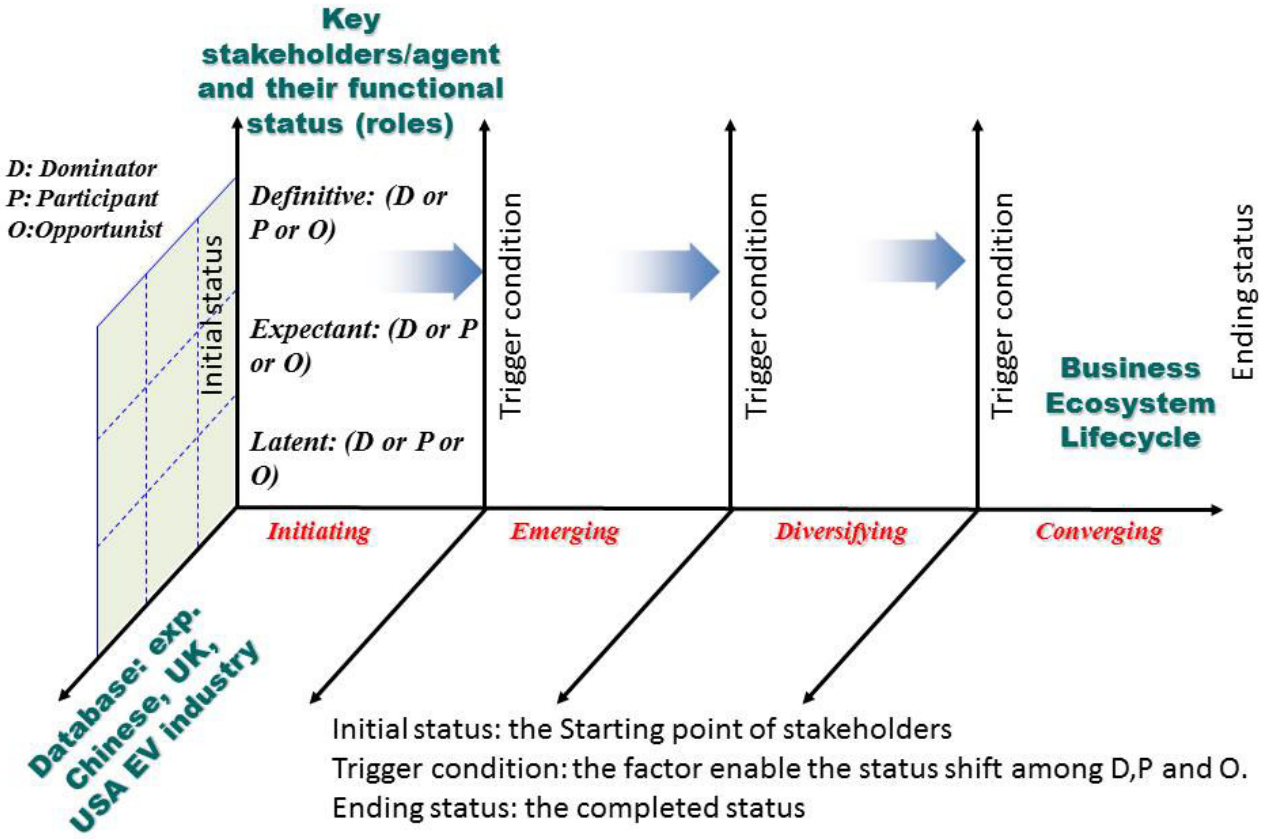

Fig.9. A agent-based model for business ecosystems evolution

7 Conclusions

This paper has identified the development trajectory of the Chinese electric vehicle industry by outlining a roadmap, explained the roles transformation that different stakeholders play in the various stages of Chinese EV business ecosystem, and proposed a conceptual model of agent-based system for ecosystem stakeholders' interaction. To elaborate, this paper has the following theoretical and practical contributions.

7.1 Theoretical contributions

The theoretical contributions of this paper:

(1) Integrating the theories of stakeholder and business ecosystem lifecycle and its role: by integrating stakeholder theory (Mitchell et al., 1997), the theory of business ecosystem lifecycle (Rong, 2011), and the theory of business ecosystem structure and role identification (Iansiti and Levien, 2004), this paper proposed a three-dimensional (business ecosystem lifecycle, stakeholder classification and their functional roles) theoretical framework which can be applied to analyse the nurturing process of emerging industries from the perspective of ecosystem stakeholders' interactions.

(2) Adding the initiating stage to the business ecosystem lifecycle: previously business ecosystem lifecycle theories suggests that it is mainly started by the industrial practitioners which were market driven (J. Moore, 1993; Rong, 2011). However in terms of this paper's finding, the EV industry in china was government driven, such that the EV industry has been identified as one of the seven strategic emerging industries by the Chinese central government. So its nurturing process has been seriously pushed by related government agencies. Compared with the nurturing process of market-driven industries, this kind of emerging industry, which has undergone deep intervention from governments, always experiences an "initiating" stage before entering the emerging, diversifying and converging track (Rong, 2011). Therefore, the lifecycle of such a nurturing process should be extended to initiating, emerging, diversifying and converging.

(3) Identifying the business ecosystem stakeholders' role transformations: By adopting the three-dimensional theoretical framework to analyse the Chinese EV industry, we found that during the different stages of the emerging industry's business ecosystem, the functional roles (den Hartigh and van Asseldonk, 2004; Iansiti and Levien, 2004) that the three bundles of stakeholders play reflect a triple role transformation, where each role is mutually complementary. Regarding this finding, we propose the '**Triple Oscillation' Model**, which presents the co-evolution of an emerging industry's business ecosystem from the perspective of transformations of different bundles of stakeholder roles through their interaction and cooperation, and makes a basic contribution to the literature which could also be used in the model-building.

(4) Introducing the agent-based model to the business ecosystem theories: the previous ecosystem literatures (Adner and Kapoor, 2010; Chen et al., 2013; Iansiti and Levien, 2004; J. Moore, 1993; Rong et al., 2013a, 2013b, 2013c) only addressed the part structure of a business ecosystem or the ecosystem strategies during the ecosystem lifecycle, but neglected the role interactions and transformations during the lifecycle and how those role interaction will impact on the different macro patterns of business ecosystems. This paper has filled such gap by proposing a conceptual framework of agent-based model for the ecosystem evolution. The conceptual model of agent-based system is to analyse the relationship and interaction between different kinds of ecosystem agents, as well as how to optimize the whole system's behavior. The database will be

expanded on top of the data of the Chinese EV industry. By comparing the database, we could generalize the ecosystem stakeholder's behavior during the emerging industry evolution and identify their trigger conditions into alternative roles.

7.2 Practical contributions

The practical contributions of this paper are shown below:

(1) To the government: by adopting the expert grading method, we identified nine key stakeholders from a list of 20 stakeholders from interviews and literature reviews. Different stakeholders will play different important roles during various stages of this industry's evolution. Thus, the government would be able to narrow down their supporting targets list and formulate relevant industrial policies and supporting measures.

(2) To the industrial practitioners: We drew a comprehensive roadmap of the Chinese EV industry at three levels: technology (value creation), application (value capture) and market (value context), which can be very useful for industrial practitioners in understanding this emerging industry. This roadmap could be a good tool for industrial practitioners to position themselves at the right places in terms of practitioners' capabilities.

(3) To the emerging industries in other countries: The 'Triple Oscillation' Model proposed in this paper can be widely applied to explain different stakeholders' co-evolutions during the nurturing process of an emerging industry's business ecosystem, as well as being referred to by other countries to capture the momentum of an emerging industry's development, and to allocate or integrate related resources effectively.

(4) To the EV industry: through the agent-based model, we explored a new framework to collect data and provided a detail explanation by taking Chinese EV industry as a case. This kind of data-analysis method can be well applied in other countries' EV industry which would definitely improve the efficiency of experts' decisions once similar problems arise.

7.3 Future directions

There are some defects in the literature, such as imperfect statistical data and inconsistent statistical standards for emerging industries, so this paper mainly adopted qualitative analysis and descriptive statistical analysis. This could be deepened to employ more quantitative analysis in the future.

Besides, since this research focused only on the Chinese EV industry, other emerging industries such as mobile computing, solar cell and wind power, should be tested in order to enrich the database to generalize the emerging industry's evolution model. Such cross-case analysis could improve the external validity of the case study.

Furthermore, this paper has proposed an agent-based model for the business ecosystem evolution. However it is still a draft one. We have to further clearly identify the agent behavior and their interaction rule. Due to the data collection only in Chinese emerging EV industry, this paper didn't perform the computational approach to make agent-based model analysis. As a result, in the future research, more data should be collected in other countries and other emerging industries to polish the agent-based model by comparing the cross-country and cross-industry data.

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Reference

Adner, R., Kapoor, R., 2010. Innovation Ecosystems and the Pace of Substitution: Re-examining Technology S-curves (working paper). Tuck School of Business, Dartmouth College.

Axelrod, R., 1984. THE EVOLUTION 0P COOPERATION.

Axtell, R.L., Andrews, C.J., Small, M.J., 2001. Agent-Based Modeling and Industrial Ecology. J. Ind. Ecol. 5, 10–13.

Bichraoui, N., Guillaume, B., Halog, A., 2013. Agent-based Modelling Simulation for the Development of an Industrial Symbiosis-Preliminary Results. Procedia Environ. Sci. 17, 195–204.

Brody, S.D., 2003. Measuring the effects of stakeholder participation on the quality of local plans based on the principles of collaborative ecosystem management. J. Plan. Educ. Res. 22, 407–419.

Cao, K., Feng, X., Wan, H., 2009. Applying agent-based modeling to the evolution of eco-industrial systems. Ecol. Econ. 68, 2868–2876.

Chen, Y., Rong, K., Xue, L., Luo, L., 2013. Evolution of collaborative innovation network in China's wind turbine manufacturing industry. Int. J. Technol. Manag. Accept.

Clarkson, M.B., 1994. A risk based model of stakeholder theory, in: Proceedings of the Second Toronto Conference on Stakeholder Theory. pp. 18–19.

Clarkson, M.E., 1995. A stakeholder framework for analyzing and evaluating corporate social performance. Acad. Manage. Rev. 20, 92–117.

Den Hartigh, E., van Asseldonk, T., 2004. Business ecosystems: A research framework for investigating the relation between network structure, firm strategy, and the pattern of innovation diffusion, in: ECCON 2004 Annual Meeting: Co-Jumping on a Trampoline, The Netherlands.

Epstein, J.M., Axtell, R.L., 1996. Growing Artificial Societies: Social Science from the Bottom Up (Complex Adaptive Systems).

Frederick, W.C., Post, J.E., Davis, K., 1992. Business and society: Corporate strategy, public policy, ethics. McGraw-Hill New York.

Freeman, R.E., 1984. Strategic Management: a stakeholder approach. Boston Pitman 46.

Ganji, B., Kouzani, A.Z., Khoo, S.Y., Shams-Zahraei, M., 2014. Adaptive cruise control of a HEV using sliding mode control. Expert Syst. Appl. 41, 607–615.

Gardner, M., 1970. Mathematical games: The fantastic combinations of John Conway's new solitaire game "life". Sci. Am. 223, 120–123.

Gu, Q., Lago, P., 2007. A stakeholder-driven service life cycle model for SOA, in: 2nd International Workshop on Service Oriented Software Engineering: In Conjunction with the 6th ESEC/FSE Joint Meeting. pp. 1–7.

Iansiti, M., Levien, R., 2004. The keystone advantage: What the new dynamics of business ecosystems mean for strategy, innovation and sustainability Harvard Business School Press. Boston MA.

Im, K., Cho, H., 2013. A systematic approach for developing a new business model using morphological analysis

and integrated fuzzy approach. Expert Syst. Appl. 40, 4463–4477.

Iyer, B., Lee, C.-H., Venkatraman, N., 2006. Managing in a small world ecosystem: Some lessons from the software sector. Calif. Manage. Rev. 48, 28–47.

Janssen, M.A., Alessa, L.N., Barton, M., Bergin, S., Lee, A., 2008. Towards a community framework for agent-based modelling. J. Artif. Soc. Soc. Simul. 11, 6.

Jawahar, I.M., McLaughlin, G.L., 2001. Toward a descriptive stakeholder theory: An organizational life cycle approach. Acad. Manage. Rev. 26, 397–414.

Kenney, M., Pon, B., 2011. Structuring the smartphone industry: is the mobile internet OS platform the key? J. Ind. Compet. Trade 11, 239–261.

Kley, F., Lerch, C., Dallinger, D., 2011. New business models for electric cars—A holistic approach. Energy Policy 39, 3392–3403.

Kollman, K., 2003. The rotating presidency of the European Council as a search for good policies. Eur. Union Polit. 4, 51–74.

Kraines, S., Wallace, D., 2006. Applying Agent-based Simulation in Industrial Ecology. J. Ind. Ecol. 10, 15–18.

Lavassani, K.M., Movahedi, B., 2010. Critical Analysis of the supply chain management theories: toward the stakeholder theory, in: POMS 21st Annual Conference, Vancouver.

Macy, M.W., Willer, R., 2002. From factors to actors: Computational sociology and agent-based modeling. Annu. Rev. Sociol. 143–166.

Menzel, S., Teng, J., 2010. Ecosystem services as a stakeholder-driven concept for conservation science. Conserv. Biol. 24, 907.

Mitchell, R.K., Agle, B.R., Wood, D.J., 1997. Toward a theory of stakeholder identification and salience: Defining the principle of who and what really counts. Acad. Manage. Rev. 22, 853–886.

Mitleton-Kelly, E., 2003. Ten principles of complexity and enabling infrastructures. Elsevier.

Moore, J., 1993. Predators and prey: a new ecology of competition. Harv. Bus. Rev. 71, 75–86.

Moore, J.F., 1993. Predators and prey: a new ecology of competition. Harv. Bus. Rev. 71, 75–86.

Moore, J.F., 1996. The death of competition: leadership and strategy in the age of business ecosystems. HarperBusiness New York.

Peltoniemi, M., 2006. Preliminary theoretical framework for the study of business ecosystems. EMERGENCE-MAHWAH-LAWRENCE ERLBAUM- 8, 10.

Phaal, Robert, Farrukh, C.J., Probert, D.R., 2004. Technology roadmapping—a planning framework for evolution and revolution. Technol. Forecast. Soc. Change 71, 5–26.

Phaal, R., Farrukh, C.J., Probert, D.R., 2007. Strategic roadmapping: a workshop-based approach for identifying and exploring innovation issues and opportunities. Eng. Manag. J. 19, 3–12.

Phaal, R., Farrukh, C.J.., Probert, D.R., 2004. Technology roadmapping–A planning framework for evolution and revolution. Technol. Forecast. Soc. Change 71, 5–26.

Phaal, R., O'Sullivan, E., Routley, M., Ford, S., Probert, D., 2011. A framework for mapping industrial emergence. Technol. Forecast. Soc. Change 78, 217–230.

Rammel, C., Stagl, S., Wilfing, H., 2007. Managing complex adaptive systems—a co-evolutionary perspective on natural resource management. Ecol. Econ. 63, 9–21.

Roloff, J., 2008. A life cycle model of multi-stakeholder networks. Bus. Ethics Eur. Rev. 17, 311–325.

Rong, K., 2011. Nurturing Business Ecosystem from Firm Perspectives: Lifecycle, Nurturing Process, Constructs, Configuration Pattern, PhD thesis, University of Cambridge.

Rong, K., Hu, G., Hou, J., Ma, R., Shi, Y., 2013a. Business Ecosystem Extension: Facilitating the Technology Substitution. Int. J. Technol. Manag. 63, 268–294.

Rong, K., Lin, Y., Shi, Y., Yu, J., 2013b. Linking Business Ecosystem Lifecycle with Platform Strategy: A Triple View of Technology, Application and Organization. Int. J. Technol. Manag. 62, 75–94.

Rong, K., Liu, Z., Shi, Y., 2011. Reshaping the business ecosystem in China: case studies and implications. J. Sci. Technol. Policy China 2, 171–192.

Rong, K., Shi, Y., Yu, J., 2013c. Nurturing Business Ecosystem to Deal with Industry Uncertainties. Ind. Manag. Data Syst. 133, 385–402.

Schelling, T.C., 1971. Dynamic models of segregation†. J. Math. Sociol. 1, 143–186.

Schwoon, M., 2006. Simulating the adoption of fuel cell vehicles. J. Evol. Econ. 16, 435–472.

Shang, T., Shi, Y., 2013. Rethinking the conceptual framework for business ecosystem: the evolutionary processes and key building blocks, 2013 European Academy of Management Conference, Istanbul, Turkey (Forth coming).

Suh, J.H., Park, S.C., 2009. Service-oriented Technology Roadmap (SoTRM) using patent map for R&D strategy of service industry. Expert Syst. Appl. 36, 6754–6772.

Tesfatsion, L., Judd, K.L., 2006. Handbook of computational economics: agent-based computational economics, vol. 2. Elsevier.

Von Neumann, J., 1966. Essays on cellular automata. University of Illinois Press, Urbana, Illinois.

Wheeler, D., 1998. Including the stakeholders: the business case. Long Range Plann. 31, 201–210.

Highlights

- The roadmapping method is applied to analyse the evolution of Chinese EV industry.
- A '**Triple Oscillation**' Model presents the emerging industry's ecosystem evolution.
- The business ecosystem lifecycle is expanded with one more initiating stage.
- A conceptual agent-based model is proposed for business ecosystem evolution.