Orchestrating an innovation ecosystem: the role of hub firms and ecosystem based on dynamic capabilities

Jian Chen[1,a], Yimei Hu[2,b], Yuchen Gao[3,c,*], Qian Wang[4,d] and Zhuoran Liu [5,e]

[1] Institute of Science and Technology for Industrial Development, Chinese Academy of Science and Technology for Development, Beijing, China

[2] Department of Business and Management, Aalborg University, Aalborg, Denmark

[3] School of Economics and Management, Tsinghua University, Beijing, China

[4] School of Economics and Management, University of Chinese Academy of Sciences. Beijing, China

[5] ABB China Corporate Research, Beijing, China

[a] chenj@casted.org.cn, [b] yimei@business.aau.dk, [c] gaoych@sem.tsinghua.edu.cn,

[d] junewangqian@163.com, [e] zhuoran.liu@cn.abb.com

*corresponding author

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Abstract. This study attempts to answer the research question about how does a hub firm orchestrate innovation ecosystem of complex product development through dynamic capabilities, and how to make sense of such ecosystem-based dynamic capabilities. Using an exploratory single case study, this research analyzes the electricity power industry in China, which is rising with the ambitious expansion and emergence of several magnates. The study finds that three ecosystem-based dynamic capabilities, namely environment scanning, collaborative arrangement and value integration, are important for a hub firm to orchestrate the innovation ecosystem. Furthermore, at the different stages, i.e. co-vision, co-design and co-create, of complex product development, the focus of a hub firm's dynamic capabilities differs. Based on the case findings, this study is expected to contribute to extant innovation ecosystem literature by extending the understanding of the role of ecosystem hub firms as orchestrators and related dynamic capabilities for the orchestration. In addition, this study could provide a new perspective of considering how Chinese SOEs leading the indigenous innovation strategy by orchestrating an innovation ecosystem.

1. Introduction

The current S&T policy framework of China focuses on stimulating indigenous innovation in order to reduce dependence on foreign technology and enhance the innovative capabilities of Chinese firms [1,2]. SOEs are the main players of innovation, particularly in typical industries with complex product systems (CoPs) [3]. SOEs have been increasingly given autonomy to make strategic decisions their innovation investment domains and directions [4,5,6]. However, some pessimistic views criticize a significant proportion of SOEs are being inefficient and reluctant to market signals due to their bureaucratic organizations' rigidity and long dependence on government planning [5,7,8,9]. Especially in a world of rising complexity and uncertainty, where innovation is not a result of single endeavor but rather an ecosystem based on interactions of diverse stakeholders with different interests [5].

An innovation ecosystem integrates the specialized complementary technologies, knowledge, and other resources across organizational boundaries in unique ways [10,11,12], while presents a broader and more fluid structure and boundary relative to bilateral partnerships [13,14]. Under the ecosystem concept, an interesting issue is the role that the hub firm plays in ecosystem governance, i.e. how a firm can shape the structure and orchestrate tasks of the innovation ecosystem around it

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[15,16,17]. Literature shows that a hub firm works as an orchestrator that shapes the ecosystem indirectly rather than through direct command and control [14,15,16]. Dynamic capabilities are regarded as key for hub firms orchestrating innovation ecosystems [18,19]. However, most of the existing researches have been focusing on how the hub firm gains its own competitive advantage through leveraging ecosystem resources. Few studies explore how the hub firm promotes the competitive advantages of the overall innovation ecosystem by its orchestrating initiatives. Furthermore, discussions about firm-level dynamic capabilities are mainly focus on how firms deploy their resources according to the change of external environment for obtaining firms' own competitive advantages [20,21,22]. Few studies concern about how firms can orchestrate the ecosystems with dynamic capabilities.

Thus, this study attempts to answer the main research question: how does a hub firm orchestrate CoPs based innovation ecosystem through dynamic capabilities, and how to make sense of such ecosystem-based dynamic capabilities. Using an exploratory single case study, this research analyzes the electricity power industry in China, which is rising with ambitious expansion and emergence of several magnates. The theoretical framework of this study is developed by integrating the stage model of complex product development created by Liu and Rong [23], as well as innovation network orchestration developed by Dhanaraj and Parkhe [24]. We find that three ecosystem-based dynamic capabilities, namely environment scanning, collaborative arrangement and value integration, are important for a hub firm to orchestrate the innovation ecosystem. Furthermore, at the different stages, i.e. co-vision, co-design and co-create, of complex product development, the focus of a hub firm's dynamic capabilities differs. Based on the case findings, this study is expected to contribute to extant innovation ecosystem literature by understanding the role of ecosystem hub firms as orchestrators and make sense of related dynamic capabilities for ecosystem orchestration. In addition, this study could provide insights on how Chinese SOEs pioneer the indigenous innovation strategy by orchestrating an innovation ecosystem.

The remainder of this paper is organized as follows: Section 2 reviews the literature on CoPs based innovation ecosystem, the role of hub firm and ecosystem orchestration. Section 3 depicts the methodology used in this study, of which a single case inquiry is central. In the Section 4, we analyze the case of SGCC and the UHV AC projects in China and present the key findings of our case study. Discussion is depicted at Section 5 based on case findings. Finally, we draw some generic conclusions, discuss the managerial implications, and posit several limitations and further research directions.

2. Literature Review

2.1 CoPs Based Innovation Ecosystem

CoPs can be regarded as 'an applied system whose components have multiple interactions and constitute a non-decomposable whole' [25]. CoPs are high-technology and high-value capital goods, supplied as one-off items or in low volumes tailored to unique requirements of users [23,26]. At the same time, the complex product development has different stages. Liu and Rong [23] divided the process into three stages, namely co-vision, co-design and co-create. The activities and focus differ at various development stages [14,26]. Thus, dynamic capabilities are required to carry out solutions for complex product development at higher effective level.

Due to blurred boundaries between organizations and knowledge ownership, ecosystem has become more important to help firms to overcome blocked embeddedness by providing flexibility for partner selection and system design, improving the necessary symbiosis [27]. Thus, the complex

product development relies on innovation ecosystems [28]. Ecosystem constructs illuminates collaborative arrangements through which firms draw in all sorts of resources and combine their individual offerings into a coherent, customer-facing solution by simultaneous cooperation and competition [13]. At the same time, the innovation ecosystem perspective also emphasizes the dynamic and evolutionary views of related activities [29,30].

2.2 Hub firm and Ecosystem Orchestration

In many contexts, a hub firm exists that coordinates services to the ecosystem [13,31]. The hub firms are required to coordinate t influence and manage he various actors in the ecosystem to ensure the value creation and establishment of the competitive advantages [10]. In many industries, conventional studies argued that powerful companies have been able to bestow authority, strength, and even invulnerability to get what they want [32]. Today, however, positions of leadership are in a challenge different in significant ways from those faced by dominant companies in the past [31,33]. Hub firms have to balance of several tensions, such as tensions between efficiency and inclusiveness, self-interested motivations and collective benefits, as well as complexity and high-cost [34,35], and make decisions while taking into account what every other company active in the network of interlocking parts is doing. They may control the technological architecture or the brand that drives value in the ecosystem, or regulate access to a given shared platform [10]. In this way, hub firms are known as ecosystem orchestrators [16,17,36] who purposefully build and manage inter-firm innovation ecosystem by using its prominence and power to perform a leadership role in pulling together the dispersed resources and capabilities of ecosystem players [15,36].

Value creation (expand the pie) and capture (gain a larger slice of the pie) from the network are the main goals of orchestration [24,37], which hinge on two orchestration processes that a hub firm must perform-namely, managing knowledge mobility and innovation appropriability. Knowledge mobility is defined as the ease with which knowledge is shared, acquired, and deployed within the network, and the hub firm shoulders the responsibility for enhancing knowledge mobility and leveraging competencies in the ecosystem [12]. At the same time, a hub firm must also concern another central issue, i.e. appropriability, to ensure equiTable distribution of value among ecosystem players and prevent potential free riding and opportunism [13,38].

2.3 Dynamic capability of hub firms and ecosystem

The general framework proposed by Teece [21] sees dynamic capabilities as the foundation of enterprise-level competitive advantage in regimes of rapid technological change to achieve evolutionary fitness. It indicates that the extent to which an enterprise develops and employs superior dynamic capabilities will determine the nature and amount of intangible assets it will create or assemble and the level of economic profits it can earn [21]. However, under the background where the competition between individual firms are now becoming the race between innovation ecosystems [13], the concept of dynamic capability should be reconsidered at the ecosystem level [18].

Under the ecosystem context, the activities of adaptation and renewal were dispersed across the entire ecosystem, and no single firm can make this move alone. Hub-firms of ecosystem should contribute more on the arrangement and coordination of ecosystem partners for not only value creation but also value capture [13,18]. Ecosystem-based dynamic capabilities of hub-firms are regarded as the key to underpin such adaptation and renewal of the interaction between partners across the entire ecosystem [18,23].

3 Research Design

3.1 A case study approach

In this study, we adopt a single case study to investigate the orchestration activities of the hub firm in ecosystem governance and the role of ecosystem-based dynamic capabilities in forming competitive advantages. Case study methodology is preferred when the units of study are not fully understood, complex and hard to isolate from real-life context [39]. It enables detailed tracking of processes which cannot be controlled in the lab and are difficult to find in archival data [39]. Especially when we are willing to examine the complex interactions among multiple actors and build exploratory theories based on "how" or "why" questions, case study method is appropriate.

3.2 Case selection: SGCC and UHV electricity transmission in China

3.2.1 Introduction of SGCC and UHV AC Demonstration Project

SGCC was established as a state-owned enterprise (SOE) in 2002. As the largest utility in the world, SGCC constructs and operates power grids as its core business, serving 88% of the national territory. Before 2002, the State Power Corporation's (SPC) of China had been monopolizing the power industry. To encourage competition and revamp pricing mechanisms, China's State Council conducted reforms, separating power generating plants from power-supply networks. Thus, SPC was dismantled into 11 smaller companies and SGCC was one of the two electric power grid operators.

China is the world's largest electricity consumer, characterized by fast growth and enormous installed bases. At the end of 2004, based on the fact of serious supply shortage and unbalance between energy resources and load centers in China, SGCC planned to construct the first 1000 kV Ultra-high-voltage (UHV) AC power transmission project1, the Jindongnan-Nanyang-Jingmen (JNJ) demonstration project, which was officially put into operation in January, 2009. After that, China was ready for the follow-up mass application of UHV AC power transmission, with 6 more projects currently operating or under construction and additional projects being planned, based on experience of the UHV AC demonstration project, and 600 billion RMB would be invested into UHV development until 2020.

In fact, UHV transmission is not a new idea, as UHV AC circuits have already been planned in different parts of the world in the 1960's and 1970's [40]. However, only few of them got success and most of these lines are currently operating at lower voltage due to insufficient power demand or other reasons. Thus, the JNJ project which is currently the highest voltage in operation with the most advanced technological level and over 90% localized equipment, marks China's major breakthrough in independent innovation in the energy sector, and SGCC and other related players have seized this opportunity in the new revolution to win competence in the global market of electricity. In 2015, SGCC's sales revenue increased dramatically to 2,075 billion, with that annual profit reaching 86.5 billion, which allowed it to rank the 7th on Fortune Global 500.

3.2.2 Case selection rationale

We chose SGCC as the focal case in our study for two reasons. Firstly, the UHV AC project has

[1] Except for the long-distance ultra-high-voltage AC (UHV AC, referring to 1000 kV), SGCC was also deploying ultra-high-voltage DC (UHV DC, referring to ±800 kV) transmission at the same time. As these projects adopted similar organizational and technological models, we focus on UHV AC as the case in this paper.

reached a high degree of sophistication. Through collaborating with equipment manufacturers, research institutions, universities and other players within the ecosystem, SGCC has become an expert in effectively managing parallel projects and complex stakeholders with diverse interests in CoPs. Therefore, the case of SGCC offers a particularly worthwhile and typical context to explore the governance of an innovation ecosystem. Secondly, as a SOE with natural monopolistic quality, in along with satisfying social responsibility and nation mission, SGCC has been trying to practice open market-driven mechanism, organizational reconstruction and technological innovation. As a successful exploration of SOE in the market economy, SGCC's experience will definitely represent insightful implications applicable under a broader context, which enhances the external validity of the study.

3.2.3 Case description

The operation of the UHV AC project includes six phases: scientific evaluation, fundamental research, engineering design, equipment development, field construction and commercial promotion (See figure 1). UHV transmission technology is not a simple technology upgrade of the extra-high voltage (EHV) power transmission technology. It requires a reconstruction of the innovation ecosystem based on the experience in constructing and operating the 500kv and 750kv power grid. Therefore, SGCC broke up the traditional model that each institute worked independently and adopted an open innovation mode based on industry-university-research collaboration, with joint efforts and integrated R&D resources. It set up a UHV leading group and experts committee as the overall coordinator (see Figure 2). At different stages of the project, it established specific working groups, combined with CPECC and ACECC, which are two of the most excellent power engineering and construction integrative service providers in China, and other institutes and technical expertise of research, design, and manufacturing in power and machinery industry, acting on major principles and programs and as an intermedium between SGCC and other institutions. As the hub firm in the ecosystem, SGCC has played an important role in orchestrating ecosystem players to seek to create value and extract value from the ecosystem.

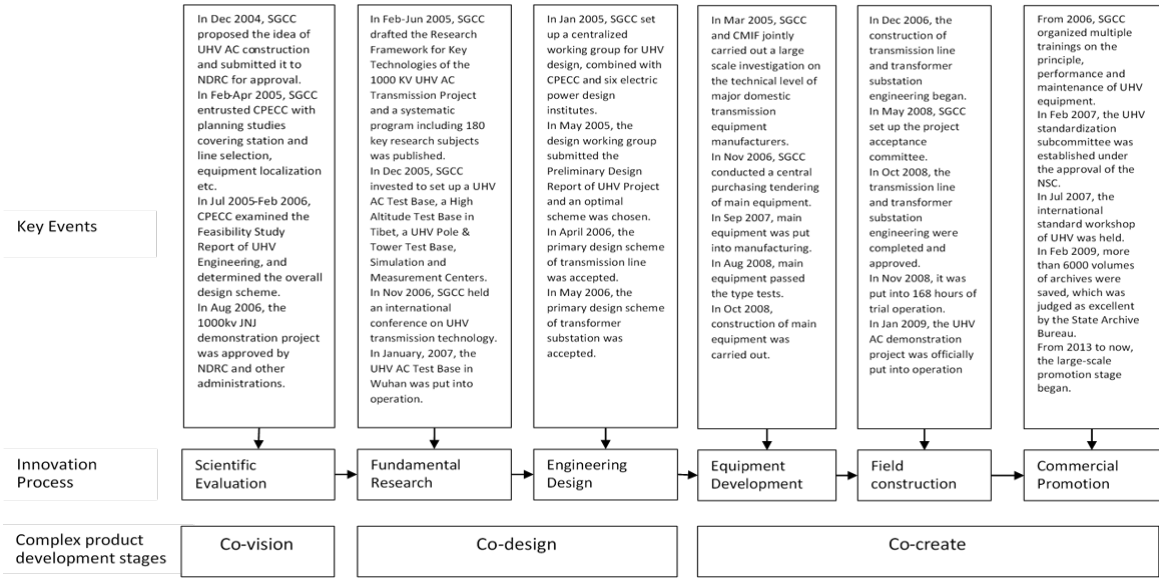

Figure 1 the key activities and Complex product development stages

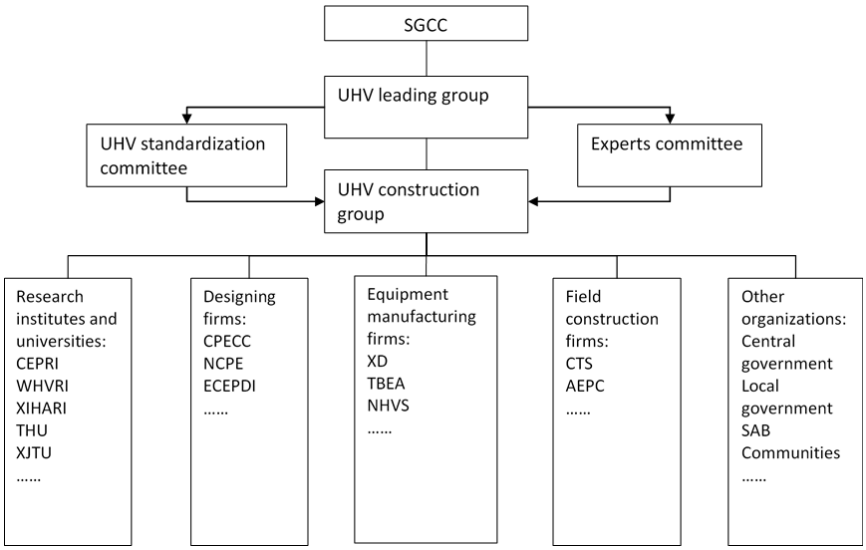

Figure 2 the ecosystem structure of SGC

3.3 Data collection and analysis

3.3.1 Data collection

Both secondary and primary data are used in this case study. In terms of secondary data sources, we examined various open access publications about SGCC and electricity industry from multiple channels, including the webpages of government agencies and industry associations relating to electricity transmission, major policies and regulations, SGCC's annual reports and internal documents, in comparison with introductions of its partners such as China Power Engineering Consulting Corporation (CPECC) and China XD Corporation (XD). What's more, we explored academic papers and research programs concerning electricity industry, as well as traced activities through newspaper articles and consulting reports in hopes of learning the public voice and towards UHV AC projects. Our secondary research took about ten months, from May 2014 to February 2015, and we performed subsequent updates with information from the latest news reports at the end of March 2016. With regards to primary data, from June 16, 2015 to Jun 18, 2015, we stayed in SGCC for three days with intensive interaction. Under the support of China Enterprise Confederation, we conducted multiple interviews with 9 industry experts, from a variety of positions within the ecosystem, covering head of the project, R&D staff, equipment manufacturers, constructors, project managers and consultants, most of whom had been involved in the UHV AC project from beginning to end. The interviews were semi-structured combined with observations.

3.3.2 Data analysis

Due to the exploratory nature of the study, technique of categorical analysis is adopted inductively in the data analysis stage [41]. Interviewing and analyzing initially proceeded concurrently during the data collection. This led to an initial list of first-order concepts, related to firms' actions, emerging from the data. With iteration between coding and data collection, we started to focus on the research idea about the dynamic capabilities related to orchestration of innovation ecosystems

We coded and sorted the primary and secondary data as well as new questions and ideas, by documenting a database, generating around 200 pages of notes with more than 100,000 words. These data were then mapped in sequence in terms of critical events. Each author of this study

independently cross-checked information from diverse sources to keep them in line with each other, and then followed up via emails and phone calls to interviewees for verification where inconsistencies and confusions were noted. Furthermore, the five authors exchanged reflections and thoughts constantly, and as one of the authors was a PhD candidate in electricity engineering, he worked as a bridge in transforming terminologies in engineering into research questions in managerial areas. Overall, we followed the triangulation principles and ensured precise documentation of the database [39] as much as possible in order to mitigate the bias and ensure the validity and reliability of the evidence.

Then we compared data across informants to identify key concepts and the relationships among them, and classify them under refining categories for identifying second-order dimensions, linking with “orchestration behaviors”. These second-order themes enable us to capture higher level Abstraction. After the creation of second-order dimensions, we returned to extant related literature to check the discovery of new concepts after cycling data, findings and theories. At last, we aggregated second-order dimensions into several key factors, namely ecosystem-based dynamic capabilities, and integrate them together into a novel framework. The data structure came from iterative analysis is presented in Figure 3.

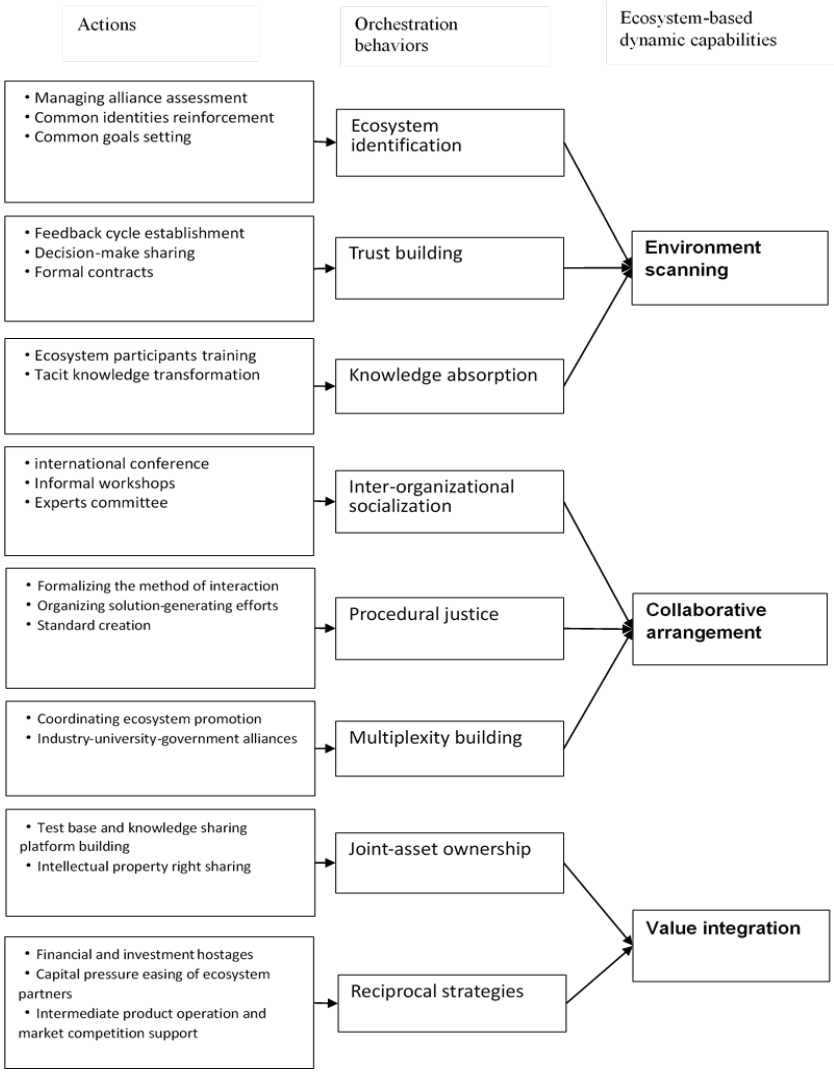

Figure 3 Data Structure

4 Case Findings

4.1 Environment scanning

According to the study of Helfat and Raubitschek [18], environment scanning capability of hub firms is key for them to combine knowledge from their own and related complementary asset providers to capture the opportunities and response to external environment for the enhancement of the ecosystem advantages. Meanwhile, environment scanning capability also implies that hub firms should have capabilities to assess and select appropriate partners for the ecosystem formation [23,42]. More specifically, we find that the environment scanning capability of hub firms is comprised of network identification, trust building and knowledge absorption.

4.1.1 Ecosystem identification

SGCC, as the operator, brought forward its demands and made great efforts to stimulate all participants' initiatives and responsibilities of meeting its requirements to realize a win-win situation. At the initial stages, SGCC drafted the Research Framework for Key Technologies of the 1000 KV UHV AC Transmission Project and the Preliminary Design Report of UHV Project, which constructed a systematic program including 180 key research subjects and more than 20 design topics. It provided a common set of goals covering the overall process of UHV development and also reinforce a common identity among ecosystem players.

Due to the high uncertainty of new complex product development, SGCC set up pilot mechanism to deliver the common goals and identities to the ecosystem partners specifically. The pilot mechanism helped the ecosystem participants to understand the common goals better and reinforce the common identities as well. Usually, the first pilot was led by the construction department, and then other construction institutes came to inspect and summarize the experience, and then established following pilots. These pilots were supervised by ACECC, and once they got approval, further special training would be carried out until the constructors met the qualifications. By instilling co-visions and cultivating a favorable learning atmosphere in various forms, ecosystem identity was finally set up, and even the first-line constructors began to exert great initiative in knowledge sharing and process innovations considering each detail. At the same time, by using the pilot mechanism, SGCC can also assess, identify and select ecosystem partners.

4.1.2 Trust building

For innovation ecosystem, trust is crucial for the strengthening of ecosystem identities among related partners, underpinning them to cope with the uncertainty of external environment [10]. In our case, the three main paths for trust building of the hub firm are feedback cycle establishment, decision-make sharing and formal contracts.

SGCC drives the dynamic circle of "design-feedback-redesign-re-feedback" based on the interaction of ecosystem participants as the basic principle. With the dynamic feedback circle, various partners can communicate well with each other, especially when problems or design faults take place or problems which could not be solved by the design institutes. The feedback circle help ecosystem participants avoid misunderstanding by create a clear communication channel. Based on feedback circle, the specific working groups enabled ecosystem members to share decision making, conduct internal audit and divide governance responsibilities among various subsets. Formal contracts play an important and complementary role in promoting trust levels. For example, before the construction of the UHV project, SGCC combined with researchers and constructors composed

systematic specifications and regulations for field construction management; likewise, traditional mode of one-time assessment was replaced by step by step assessments on intermediate and final achievements, as well as classified assessments according to the difficulty and importance of the technical projects, and an open working system was also set up for equipment development. These formal contractual provisions function as a controlling device by effectively specifying the responsibilities and actions of partners, and ensure them to have similar value proposition and behavior pattern against self-interested behavior by the other party [43].

4.1.3 Knowledge absorption

Knowledge absorption is another key factors for hub firms to sense the opportunities from external environment and improve the ability of its partners to identify, assimilate, and exploit knowledge from the environment [24]. More specifically, SGCC provide ecosystem participants training and tacit knowledge transformation for knowledge absorption.

SGCC adopted the method of “inviting in and going out” by conducting simulated rehearsal and holding experts lectures, and paid high attention to carrying out frequent technical training towards front-line operators and maintenance personnel. For example, from 2006, SGCC had organized technical staff from 9 UHV equipment manufacturers and 14 secondary manufacturers to learn the principle, performance and maintenance of UHV equipment. They also dispatched 15 employees of different majors to take part in equipment manufacturing and learn more about production processes.

SGCC also adopted tactics to transform tacit knowledge into explicit knowledge, so that it can be transferred much more smoothly. For example, Furthermore, document filing was also undoubtedly a very important issue. During the construction process, the archival department had to keep in touch with the design and construction institutes all the time, and made continual adjustment in order to ensure the quality of the construction drawings. Finally, 6394 volumes of archives were saved, including 4227 paper archives, 1629 drawing, 65 picture archives and 383 pieces of CD, which were in accordance with the actual operation data and was judged as excellent by the State Archive Bureau.

4.2 Collaborative arrangement

The collaborative arrangement capability support hub firms to connect and organize ecosystem partners in appropriate ways to leverage and gain the essential resources for the innovation development [12,13]. According to the case analysis, we find that the collaborative arrangement capability contains inter-organizational socialization, procedural justice and multiplexity building.

4.2.1 Inter-organizational socialization

Broader inter-organizational socialization based on formal and informal linkages and communication channels is an important way to promote knowledge mobility among ecosystem members. SGCC mainly sets up experts committee and provides international conference as well as informal workshops and to improve inter-organizational socialization. For instance, in March 2005, SGCC and China Machinery Industry Federation (CMIF) jointly organized 30 academicians and domestic senior experts to carry out large scale investigation on the technical level of 12 major domestic transmission equipment manufacturers. In order to strengthen international communication and cooperation, SGCC held an international conference on UHV transmission technology in November 2006, which attracted more than 350 senior managers and experts from 19

countries and regions. Informal workshops were also held irregularly for open discussion. Meanwhile, inter-organizational communications were also involved with partners who would be potential competitors.

4.2.2 Procedural justice

To fully leverage ecosystem members and strengthen the innovation appropriability, the hub firm should also employ several designing principles of procedural justice [24]. The procedural justice, including bilateral communications, ability to refute decisions, full account of the final decisions, and consistency in the decision-making process, can have a strong, positive impact on voluntary cooperation, and discourages hoarding of ideas [24]. SGCC adopts hybrid decision mechanisms according to various situations and significance of tasks. By setting up a UHV leading group and experts committee, SGCC takes on some significant tasks critical for overall network maintenance and survival. The regular meetings and open discussions of designated organizational representatives result in a dense and highly decentralized and inclusive form. Furthermore, numerous simulation tests, strict demonstration procedures, adoption of information system, as well as supervision and evaluation of third party organizations also play an important role in assuring procedure justice. For example, in December 2004, SGCC proposed the idea of UHV AC construction at the internal meeting. However, this was only the first step. As a major project, it needed to be submitted to the National Development and Reform Commission (NDRC) and got approved, before which open panel discussions and feasibility meetings to gather opinions and fully prepare for the program was an essential.

SGCC also entrusted CPECC to examine the Feasibility Study Report of UHV Engineering, and determine the overall design scheme of the UHV project. By setting up an engineering management information system, it commanded the overall situation by milestone plans like weekly common meetings, monthly common meetings, special sessions and deadline warnings. In August 2006, after numerous simulation tests and more than 200 seminars with 7000 participants, the 1000kv JNJ demonstration project was finally approved and strongly supported by the NDRC and other administrations on environmental protection and land utilization etc. This ended the debates and a widespread common ground was reached among social sectors.

Meanwhile, SGCC had paid great attention to the construction of UHV standard system from the very beginning. In February 2007, the UHV standardization subcommittee was established under the approval of the National Standardization Committee, which was formed by SGCC, China Electricity Council (CEC), CMIF and other domestic experts. It formulated the UHV AC technology standard system including 77 standards, which were then fully applied in subsequent projects and promoted to achieve internationalization.

4.2.3 Multiplexity building

It is argued that more robust relationships can be built by a hub firms via promoting multiplexity. The multiplexity is defined that more than one relationships occur at the same time within an ecosystem [24]. Increasing multiplexity can help to expand the scope of relationships so that firms interact more broadly and deeply with each other. In our case, SGCC establishes industry-university-government alliances and generates coopetition between partners by coordinating ecosystem promotion.

At first, an in-depth and comprehensive research on the feasibility of UHV AC project was carried out with allying with institutions of research, design, and manufacturing in power and

machinery industry, universities and associations, as well as relevant government departments. For the coordinating ecosystem promotion on coopetition, SGCC divide tasks into multi-units and allot one unit to two different experts. They do not communicate with each other, which can be called back to back calculation. After both experts finished calculation, their processes and results will be mutually compared and confirmed. Although this back-to-back strategy can enhance the competition, but it is negative for several complex product development which require strong collaborations between ecosystem participants at horizontal boundaries. Thus, hub firms need to improve the cooperation by ecosystem coordination.

For example, transformers are one of the most important UHV equipment, whose function is to transform between 500kv and 1000kv. As UHV equipment could only be developed and manufactured jointly, sharing intellectual property right became a very essential term in the bidding contracts. Baoding Tianwei Electric Corporation (BTEC) and TBEA Shenyang Transformer Corporation (STC), as the only two bid winners in UHV transformer manufacturing, initially adopted back-to-back strategy. However, problems existed when the two sample transformers were delivered. Owing to back-to-back design, these two manufactures did not communicate technology and experience with each other, which would surely influence the efficiency and overall progress of modifying the design.

Therefore, SGCC made a strong intervention to persuade the two manufacturers to look at the big picture and complement each other's advantages by breaking up the technical barriers and sharing know-how and resources. SGCC established two expert panels to check out problems together with manufactures. To prevent mutual effect of each other's opinions, separated reports were conducted to analyze the possible faults. Finally, insulation fault was made sure and further improvements were conducted.

4.3 Value integration

The ultimate task of hub firms is to capture the value created via innovation ecosystem [13,44]. Thus, hub firms should have capabilities to integrate the value created by arranging and leveraging the ecosystem partners. This value integrative capabilities are fundamental to hub firms to orchestrate their partners, and align with them in regarded to the activities and products [18]. According to our case study, joint asset ownership and reciprocal strategies are two main paths for SGCC to integrate the value from arranged ecosystem partners.

4.3.1 Joint asset ownership

In various studies scholars have found that joint asset ownership between a hub firm and other actors is particularly effective at joint problem-solving arrangements and innovation appropriability enhancement [23,24,45]. Joint asset ownership in SGCC is mainly the intellectual property right sharing with the ecosystem partners so that self-interested motives could be aligned with common interest. SGCC also makes efforts to persuade and coordinate the ecosystem partners to break up the technological barriers and share know-how and resources. Moreover, SGCC invests to set up a UHV AC Test Base, a High Altitude Test Base in Tibet, a UHV Pole & Tower Test Base, Simulation and Measurement Centers, with overall experimental functions and superior standards, which provide a platform of knowledge sharing. One of the typical example is the UHV transformer manufacturing which is mentioned before.

4.3.2 Reciprocal strategies

With the evolvement of the ecosystem, especially under multi-parallel projects, new connections are created all the time and old ones are dissolved. In this process, informal social interactions with partners based on goodwill trust will be altered by reciprocal behaviors to improve the prospects of ecosystem [24]. In our case, SGCC has become the role of formal financial and investment hostages of partners with the development of the ecosystem. SGCC also substantially increased the proportion of advance payments to ease the capital pressure of manufacturers. In addition, SGCC underpins its partners to apply for the government's policy supports in R&D projects and tax relief by joint applications. Meanwhile, it also provides supports for intermediate product operation and market competition.

As a result, the ecosystem partners also acted together by investing a large sum of funds, purchasing advanced processing equipment, absorbing excellent talents, and building world-class test bases. For example, XD specially established a UHV equipment test hall; TBEA built up modern workshops introducing the world's most advanced producing and testing equipment; New Northeast Electric Group High Voltage Switchgear Co., Ltd. (NHVS) regarded UHV as the NO.1 project, and founded a special working group. In the context of China, SGCC also adopts reciprocal strategies with broader stakeholders, such as local government and society. For example, it had to be responsible for coordinating the relationships with local governments in land acquisition and compensation.

5 Discussion

The monopolistic nature of SGCC and the increasingly open and complex context around it put it into a dilemma in which governance based on a complete hierarchical or market mechanism is inappropriate any more. Therefore, the most important contracts governing network relationships are community governance systems and quasi-democratic mechanisms. SGCC conducts the intermediate ecosystem governance internalizing the hierarchical system of firms and the markets, and influences evolution of the network operations through a series of orchestration processes. It establishes a common structure on the basis of which joint actions of interaction and collaboration among ecosystem partners are conducted, which ultimately improves the competitive advantages of the overall ecosystem.

Prior studies show that there exist several tensions in the ecosystem governance, including the efficiency-inclusiveness tension, i.e. the need for efficient operation and member involvement [46], the individual-collective tension, i.e. the conflicts between individual and the whole interest [34]; the complexity-cost tension, i.e., equilibrium between complexity and high coordinating cost [34,35]. In line with the above views, the case findings reveal that these tensions take place at almost every stage of the ecosystem governance. More specifically for complex product development, the stages can be divided into co-vision, co-design and co-create [23].

According to our case findings, we argue that the ecosystem-based dynamic capabilities of hub firms are required in each development stages for the ecosystem orchestration. However, the focus and the use of ecosystem-based dynamic capabilities in different stages may differ due to the development characteristics of each stages. At co-vision stage, the core task of hub-firms is to identify the external environment of ecosystems and provide common visions to partners with high uncertainty [42]. Thus, environment scanning capability is the most important for hub firms for constantly scanning, searching, and exploring across technologies and markets to cognitively sense and shape opportunities and threats, at the same time, strengthening the common goals and visions for partners. At this stage, hub-firms also need to formalize the method of interaction to create

mutual-trust mechanism, which can be regarded as initial attempts by using collaborative arrangement capability.

At co-design stage, the focus of the hub-firms of ecosystems has shifted to making adaptive and unbiased solutions with the ecosystem partners. This help hub-firms to response to sensed opportunities or threats by valid processes, procedures, products, and incentives with ecosystem partners [23]. It involves having a deep understanding of the changes and analyzing multiple alternatives, and making problem–solving heuristics associated with how to adapt to the changes in a cost-effective and timely fashion. The orchestration behaviors of the hub firm is different from managing a typical internal process; it requires a more fluid approach that empowers partners and employees and give them the needed dexterity and flexibility to operate in a dynamic and uncertain world, while maintaining control at the same time [47,48]. Thus, an appropriate collaborative arrangement of ecosystem partners is the most important at this stage. Hub firms need to keep a balance between authority and openness [49] and create an ecosystem-wide common communication structure or a context for interaction and joint problem-solving arrangements typically consisting of routines of negotiation and mutual adjustment [24]. At the same time, the common identities should also be strengthened to provide the “big picture” to strive for a common goal and prevent ecosystem drift of ecosystem partners.

At the co-create stage, the focus of hub firms have shifted to integration of values created based on smooth resource flow and alignment of initiatives within the ecosystem. The value integration capability has become the core for hub-firms. Hub-firms adopt patent sharing and reciprocal strategies to leverage such values. At the same time, hub-firms also need to extend and coordinate the relationships between ecosystem firms, set up standard with collaborative arrangement capability. Common identities should also be strengthened at this stage to help hub firms prevent opportunism of partners and align their self-interested motives with common interest. This can underpin the success of value integration of the whole ecosystem. The relationship between ecosystem-based dynamic capabilities and complex product development stages are shown in Table 1.

Table 1 ecosystem-based dynamic capabilities and complex product development stages

	Co-vision	Co-design	Co-create
Environment scanning	**Network identification:** Managing alliance assessment Common identities reinforcement Common goals setting **Trust building:** Feedback cycle establishment Formal contracts	**Network identification:** Common identities reinforcement **Trust building:** Decision-make sharing Feedback cycle establishment **Knowledge absorption:** Ecosystem participants training Tacit knowledge transformation	**Network identification:** Common identities reinforcement
Collaborative arrangement	**Procedural justice:** Formalizing the method of	**Inter-organizational socialization:** international conference Informal workshops	**Procedural justice:** Standard creation **Multiplexity building** Coordinating

	interaction	Experts committee **Procedural justice:** Formalizing the method of interaction Organizing solution-generating efforts **Multiplexity building :** Industry-university-government alliances	ecosystem promotion
Value integration		**Joint-asset ownership:** Test base and knowledge sharing platform building	**Reciprocal strategies:** Financial and investment hostages Capital pressure easing of ecosystem partners intermediate product operation and market competition support **Joint-asset ownership:** Intellectual property right sharing

6 Conclusions

This research carries out an in-depth case study on SGCC, which has gained a firm foothold in the global electricity industry as a latecomer by building a CoPs based innovation ecosystem. By combining the stage model of complex product development created by Liu and Rong (2015) with the theoretical framework of orchestration developed by Dhanaraj and Parkhe (2006), we illuminate the dynamic capabilities of the hub firm and discuss the role of these capabilities in each development stages of the ecosystem around complex products. We answer the question about how does a hub firm orchestrate CoPs based innovation ecosystem through dynamic capabilities. We find that SGCC acts as an orchestrator in shaping and managing the ecosystem. The process of value creation and appropriation is also a process of enhancing the whole ecosystem's dynamic capability. The hub firms perform their orchestrator functions in ecosystem operations by offering fertile ground for illuminating an open-but-owned structure of collective action. Although the specific activities of orchastrating an ecosystem are idiosyncratic depending on various CoPs projects and contexts, there exhibits a common ground. Therefore, we believe the case study of SGCC provides further research directions in innovation ecosystem and useful implications for practitioners.

6.1 Theoretical contributions and implications

This research contributes to existing literature in three aspects. First, we verify the framework on network orchestration under the context of developing countries. Secondly, it enriches prior literature on innovation ecosystem, particularly in terms of the role of the hub firm in an ecosystem

and how we can measure the health and competitive advantages of an ecosystem. We broaden the studies on dynamic capabilities from the perspective of an individual firm's behavior of self-renewal to group-level joint action and provide a more comprehensive and integrative construct. Lastly, we put forward a new angle of considering how Chinese SOEs leading the indigenous innovation strategy by orchestrating an innovation ecosystem.

The findings also offer valuable managerial implications for similar cases in China and other developing countries. SOEs continue to play a significant role in Chinese economy and have been characterized as the hub firm in China's indigenous innovation strategy of many CoPS industries with their transforming from planned producers to market-oriented organizations and the government's more delegation of power to them (Cheung Liu, 1995; Li, et al., 2007). However, these attempts failed or had limited impacts. It shows that China fails owing to incomplete ecosystem. Thus, it is vital for companies to have strategic vision which takes ecosystem as a new source of competence. However, to orchestrate an innovation ecosystem is therefore critical, but not easy. It takes considerable management skill because it is not the same as managing internal collaboration. Instead, it requires us to re-think how the SOEs as the hub firm might change its role to be effective as an orchestrator that shapes the ecosystem indirectly rather than through direct negotiation, command, and control. A successful ecosystem cannot emerge and evolve naturally, as it relies on effective management and interactions among players. Accordingly, one of the SOE's roles is to construct an open-but-owned structure or platform whereby which ecosystem players can together develop the ecosystem-based capabilities of self-renewal and become a symbiotic value community by co-learning and co-evolving based on the specific requirements of different projects. Last but not least, it is a fact that China used to focus on a single critical technology or the innovation capability of an individual firm (Li et al., 2007). In fact, evolution of technology should be judged in a systematic manner; short-term indicator of firms' performance should be replaced by long-term dynamic perceptions on capabilities to both react to the ever-changing environment and lead the future direction of the ecosystem. Just as Thomas& Wind (2012) refer, it is akin to assembling the musical composition, the orchestra of musicians, the conductor, the concert hall, and the communication and practice required to deliver an experience to the audience.

6.2 Limitations and future research directions

We recognize that our study suffers from several major limitations. These limitations also yield future research opportunities. Firstly, our case is based on a SOE and focuses on the high-centrality subset that is often associated with power and influence stemming from control over critical resources. Further research will extend to broader context, e.g. situations where hub firms lack the authority to issue commands and autonomous network members are not obliged to obey. Secondly, we put forward a framework to analyze the governance structure of an ecosystem and ecosystem based dynamic capability. More specifically, our findings indicate that there are two sets of activities under the orchestration process, but our data cannot provide a clear picture of how these sets of activities connect with one another due to our research design. Future researchers can use our findings as a basis for conducting further study to explore the detailed connections among these sets of activities to provide an overarching picture of ecosystem orchestration. Lastly, to overcome the limitations of the single case study, we will further extend our research to other industries, such as the automotive industry in China, which is also typical CoPs but has different product features, industrial structure, and institutional and social contexts in which ecosystem players compete and evolve. It would also be well worth comparing the case of SGCC with that of other emerging countries, which share similar characteristics with China.

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