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The Nature of the Co-Evolutionary Process: Complex Product Development in the Mobile Computing Industry's Business Ecosystem

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Abstract

A business ecosystem is a community that consists of various levels of interdependent firms which co-evolve in an ongoing cycle and constantly renew themselves. By undertaking an in-depth, qualitative study of multinational companies in the mobile computing industry based in the Great China region, the United Kingdom, and the United States, we explore the nature of the co-evolutionary process and its influence on complex product development. We find that this process consists of three domains of activity: co-vision, co-design, and co-create. We also find that each domain of activity plays a different but important role in stimulating collaborative innovation for complex product development in the mobile computing industry's business ecosystem. We also discuss the implications for theory and future research directions.

Keywords

business ecosystem, co-evolutionary process, business community, collaborative innovation, mobile computing industry, new product development

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Introduction

Complex products, which are "the high technology capital goods which underpin the provision of services and manufacturing," play a critical role in the modern economy (Hobday, Rush, & Tidd, 2000, p. 794). The mobile computing industry has emerged from the convergence of the mobile phone and personal computer (PC) industries, which has improved the performance of portable devices (Schindler, 2007). To meet people's growing expectations, firms have tended to focus on "Smartphones" or "Mobile Internet Devices" rather than 2G phones to add more computing functions that enable customers to carry out simple computing tasks (Kaul, Ali, Janakiram, & Wattenstrom, 2008). Thus, firms are producing products in the mobile computing industry that are complex in nature, as they comprise many parts, such as the baseband processor, application processor, operating system, application software, and content. Pursuing innovation in complex product development presents a challenge for firms because the development of this type of product usually faces high uncertainty in the marketplace, and requires longer new product development time and investment (Charbonnier-Voirin, El Akremi, & Vandenberghe, 2010; Dougherty & Dunne, 2011; Hobday et al., 2000). To capture the benefits and mitigate the risks related to the development of highly complex products, Iansiti and Levien (2004a) suggested that firms have begun to create a business ecosystem to orchestrate their knowledge resources and capabilities related to supporting such projects.

A business ecosystem is a community that is supported by interdependent firms, which interact with each other and evolve in an ongoing cycle to renew themselves and stimulate collaborative innovation (Iansiti & Levien, 2002; Moore, 1993; Peltoniemi & Vuori, 2004; Rong, Hu, Lin, Shi, & Guo, 2015). Scholars refer to such co-evolving movement that is driven by mutually influencing interactions, as a "co-evolutionary process" (CEP, hereafter; Koza & Lewin, 1998; Van den Bosch, Volberda, & De Boer, 1999; Volberda & Lewin, 2003). Even through CEP is at the heart of the business ecosystem strategy and has been discussed in almost every business ecosystem study (e.g., Kapoor & Lee, 2013; Nambisan & Baron, 2013; Pierce, 2009; Ramachandran, Pant, & Pani, 2011), a close examination of the literature reveals a lack of understanding about the nature of CEP and its influence on product innovation. In this research, we attempt to address this deficiency in the literature.

To explore CEP, scholars have implied that we should pay attention to the range of activities that the firms within the business ecosystem (ecosystem firms, hereafter) jointly carry out with regard to innovation and technology development because this process is triggered by mutually influencing interactions for the purpose of co-evolution (Kapoor & Lee, 2013; Koza & Lewin, 1998; Murmann, 2013; Volberda & Lewin, 2003; Wareham, Fox, & Cano Giner, 2014). Therefore, in this research, we focus on investigating the domains of activity (jointly carried out by the ecosystem firms) that support innovation practices for complex product development. Specifically, our study is motivated by two research questions:

Research Question 1: Which domains of activity constitute CEP?
Research Question 2: How does CEP support innovation for complex product development?

We answer these research questions by taking a disciplined qualitative approach to study the process of complex product development in three mobile computing industry business ecosystems based in the Great China region, the United Kingdom, and the United States: Advanced RISC Machines (ARM), Intel, and MediaTek (MTK), respectively.

Based on an analysis of 211 hr of interviews with 70 informants who represent 35 ecosystem firms at the executive level, we find that CEP consists of three domains of activity: co-vision, co-design, and co-create. More specifically, the "co-vision" process enables ecosystem firms to select and establish a communication structure with appropriate business ecosystem partners to develop a common set of goals and objectives related to innovation and new product development. Next, we find that ecosystem firms engage in a co-design process to roll out a new product development plan, develop a platform-based innovation strategy, and work collaboratively to develop solutions that address their customers' needs. Finally, we find that ecosystem firms participate in the process of the co-create value by promoting ecosystem-based products to external firms that can help develop additional applications for these products, and work together to optimize the manufacturing process to speed up the production and delivery of ecosystem-based products.

In developing our arguments, this research study makes three important contributions to knowledge. First, we draw attention to the widely acknowledged yet underexplored mechanism within the business ecosystem—CEP—and explore the domains of activities that, together, form the very nature of such a mechanism. Second, by focusing on the influence of CEP on product innovation, we further our current understanding of how ecosystem firms can coordinate their efforts with regard to innovation activities that aim to develop complex products. Finally, we shed light on the impact of ecosystem firms' interactions and collaboration, whereby they can together develop the ecosystem-based capabilities of self-renewal and adapt to the ever-changing business environment.

Theoretical Context

Organizational ecology was introduced by Hannan and Freeman (1977, 1989) to address the organization–environment relationship. Organizational ecology aims to understand the dynamic changes that take place within organizational populations, as well as understand how organizational characteristics, ecological determinants, and macro-environmental conditions affect the rates of organizational founding, change, and mortality (Amburgey & Rao, 1996; Hannan & Carroll, 1995). Some researchers have begun to use this organizational ecological metaphor to describe a range of business transactions and interactions among ecosystem firms (Iansiti & Levien, 2002, 2004b; Moore, 2006). For example, Frosch and Gallopoulos (1989) presented an environmentally friendly manufacturing concept as the industrial ecosystem, in which materials were well used to reduce harm to the future environment. Rothschild (1992) applied the ecosystem concept to describe the importance of the interactive relationship among ecosystem firms in sharing information, and developing new and better products to fuel economic development. Moore, Iansiti, and Levien developed business ecosystem theory from the perspectives of business activities, life cycle, role types, key strategies, and evolution (Iansiti & Levien, 2002, 2004b; Moore, 1996, 2006). Ecosystem firms can expand their views beyond the supply chain partners of their core business to include other non-direct business partners, such as government agencies, industry associations, stakeholders, and competitors, who share their ideas and vision for future development (Anggraeni, Hartigh, & Zegveld, 2007; Chang & Uden, 2008). Through interaction and knowledge sharing, these interdependent organizations will "co-evolve" with one another and develop new sets of competences in response to changes in the business environment to enhance their commercial performance (Moore, 1996; Tan & Tan, 2005).

To date, there exist four primary streams of literature related to business ecosystem research. The first stream emphasizes the definition of the concept and domain of the business ecosystem, and discusses its life cycle together with related activities (e.g., Gawer & Cusumano, 2014; Moore, 1993, 1996, 2006; Nambisan & Baron, 2013). The second stream focuses on investigating the role played by the various ecosystem firms and their strategies for surviving and thriving within a business ecosystem (e.g., Iansiti & Levien, 2002, 2004a, 2004b; Pierce, 2009). The third stream studies knowledge transfer within the business ecosystem and the ways in which the various ecosystem firms are interconnected (i.e., through competition and cooperation) with each other in relation to innovation (e.g., Adner & Kapoor, 2010; Anggraeni et al., 2007; Dougherty & Dunne, 2011; Kapoor & Lee, 2013; Ramachandran et al., 2011). The final stream studies the governance framework and sustainability of the business ecosystem (e.g., Chang & Uden, 2008; Child, Rodrigues, & Tse, 2012; den Hartigh & van Asseldonk, 2004; Rong et al., 2015; Wareham et al., 2014). Scholars generally treat CEP as an inherently volitional phenomenon and draw heavily on this concept, either explicitly or implicitly, to explain the impact of firms' interdependent and mutually influencing relationships within the business ecosystem on their competitive strategy development.

More recently, researchers have begun to focus more narrowly on understanding how CEP can be initiated and managed to serve specific purposes. One important group of scholarship investigates ecosystem firms' capacity and strategic intentions to engage in CEP to stimulate organizational transformation (e.g., Child et al., 2012; Dijksterhuis, Van den Bosch, & Volberda, 1999; Kapoor & Lee, 2013; Volberda & Lewin, 2003). For example, Tan and Tan (2005) found that certain managerial practices can enhance the interactions within the business ecosystem to enable ecosystem firms to transform themselves and improve their competitiveness. Another strand focuses on understanding how environmental forces fuel the development of CEP among ecosystem firms to increase innovation activities (e.g., Gawer & Cusumano, 2014; Murmann, 2013; Nambisan & Baron, 2013; Ramachandran et al., 2011; Van den Bosch et al., 1999). For example, in a study of the Taiwanese business incubation experience, Tsai, Hsieh, Fang, and Lin (2009) made certain recommendations for promoting business incubation in the future, such as industrialization, virtualization, and globalization, that can greatly improve the intensity of the co-evolvement among ecosystem firms. Despite its many important contributions, a closer examination of this literature reveals that we know very little about the nature of CEP and its role in facilitating activities within the business ecosystem. To gain a deeper understanding of how ecosystem firms can better cope with CEP and direct its influences to achieve specific organizational objectives, we need to explore these critical gaps in our understanding. In this research, we use qualitative study to investigate how domains of activities that constitute CEP support innovation practices for complex product development in the mobile computing industry ecosystem to address these gaps.

Research Method

This research adopts a theory building approach using qualitative methods (Goulding, 2002; Locke, 2001; Maxwell, 2005). We studied three business ecosystems in the mobile computing industry based in the Great China region, the United Kingdom, and the United States. Table 1 presents the

Table 1. Characteristics of Participants.

	Business ecosystem		
Leading firm	ARM	Intel	MTK
Interview participants	ARM (9[a])—Intellectual property provider[b] Synopsys (1)—Electronic design assistant ST(STMicroelectronics) (3)—Integrated circuit design Hisilicon (1)—Integrated circuit design Spreadtrum (1)—Integrated circuit design Datang (1)—Integrated circuit design Symbian (2)—Operating system vendor Montavista (1)—Operating system vendor Google (2)—Operating system vendor Microsoft (1)—Operating system vendor Tecent (2)—Independent software vendor eBay (1)—Service provider TSMC (3)—Foundry provider Huahong-NEC (2)—Original design manufacturer Wistron (3)—Original design manufacturer Samsung (2)—Original equipment manufacturer ZTE (2)—Original equipment manufacturer Aigo (1)—Original equipment manufacturer Aiside (1 —Agency	Intel (6)—Semiconductor provider Marvell (1)—Integrated circuit design Montavista (1)—Operating system vendor Tecent (2)—Independent software vendor TSMC (3)—Foundry provider Wistron (3)—Original design manufacturer Compal (3)—Original design manufacturer Asus (1)—Original equipment manufacturer Lenovo (2)—Original equipment manufacturer	MTK (3)—Integrated circuit design ARM (1)—Intellectual property provider VIA (1)—Central processing unit provider Sanmu (1) —Independent design house Tecent (2)—Independent software vendor Tanqi (1) —Original equipment manufacturer Coolpad (1)—Original equipment manufacturer Zhang's (1)—Original equipment manufacturer NEO (1)—Integrated device manufacturer Caixin Plastic (1)—Casing provider Global & Source (1)—Media Triones (1)—Media Shenzhen government (1)—Regulatory Authority

Note. ARM = Advanced RISC Machines; MTK = MediaTek.
[a]Number of interview participants.
[b]Business functions in business ecosystems.

descriptive characteristics of the ecosystems and the interview participants from their representative ecosystem firms.

Business Ecosystem Selection

To enhance the external validity, we selected business ecosystems in different countries and main product categories within the mobile computing industry. We then developed the selection criteria for the business ecosystems: (a) the business ecosystem and its leading firm, which is central to its participants' network, are clearly identified; (b) the leading firms in the business ecosystem have engaged in sequential projects to demonstrate collaboration among the participants and the process of nurturing their own business ecosystems; and (c) the business ecosystems continuously innovate to introduce future products to the mobile computing industry. These selection criteria enabled us to identify the business ecosystems that are very active in terms of collaboration. Such a context suits our research objective and allows us to explore CEP.

Following these criteria, we selected ARM, Intel, and MTK (leading firms), together with their associated business ecosystems. According to Moore (1993), the participants in a business ecosystem consist of an ecosystem leader and an extended web of suppliers (participants) who play supporting roles. The leading firm in an ecosystem is valued by the participants within the ecosystem community because it enables the participants to move toward creating a shared vision of aligning their investments and playing a mutually supportive role. ARM is the intellectual property provider (the fundamental basis of chips). It started to build its ecosystem in the early 1990s and set up a designated functional department within the organization (a connected community) in 2003 to enhance ecosystem development. ARM's ecosystem proved very successful, as 98% of mobile phones were based on ARM's platform, with more than 500 partners in its ecosystem, and this number gradually rising (ARM, 2012). Intel also started to build an ecosystem at a very early stage, when it focused on the PC industry. It first developed a public interface with an open code to connect the chip set of each of its partners in the business ecosystem. Having dominated the PC industry, Intel aimed to transfer its PC model to the mobile computing industry but without success. Then, Intel entered a transformation phase, in which it re-considered its ecosystem strategy (Intel, 2010; Shaughnessy, 2012). The leading firm of the third ecosystem is MTK, which is a unique company with well-accepted product solutions. It provides a turnkey (one-chip solution) model chip, which integrates all of the chips and software with essential functions for mobile phones. As a result, it tremendously reduced the entry barriers to the industry and enabled down-stream supply chain innovation due to the emerging ideas (MTK, 2012). In 2008, almost 200 million shipments of mobile phones were based on MTK's single-chip solution, which accounts for 20% of the world market.

Data Collection

The field research consisted of in-depth "elite" interviews, which focus on gathering information from the key decision makers in the field, thus enabling the researcher to understand how decisions are made within the organization (Blumberg, Cooper, & Schindler, 2005). Using the interview method for the data gathering enables the informants elaborate on their beliefs, priorities, activities, and life circumstances in their own words. The primary data were collected through email exchanges, visits, conversations, and in-depth interviews held between 2008 and 2010. We visited ARM and its ecosystem to conduct 39 interviews within 19 companies, gathering 87 hr of in-depth, semi-structured interview data. At Intel, we visited 22 interviewees from nine companies, producing 60 hr of in-depth, semi-structured interview data. At MTK, we interviewed 16 people from 13 companies, providing a total of 62 hr of in-depth, semi-structured interview data. The job titles of the interviewees include CEO, vice president, deputy director, head of division, and unit manager. Furthermore, we also used email to contact interviewees, if we had any queries about their answers or wanted to request additional information to support their answers. In general, we sent one to three email(s) to each informant for this purpose, and our informants appeared happy to assist with this during non-office hours. This kind of email exchange did not count toward the total interview hours.

In this research study, 13 interviewees across five companies were involved in projects related to other ecosystems that we selected as our research focus (see Table 1). For example, 1 interviewee from Montavista had participated in two of the ecosystems (ARM-led and Intel-led) that we selected. When faced with this situation, we asked the interviewees to respond to our questions separately for each of the ecosystems in which they have participated. This meant that the interviewee from Montavista (a company) first answered our questions regarding the situation in the ARM-led ecosystem, then answered the same questions based on his or her experience with the Intel-led ecosystem. To promote the clarity of the answers further, we also asked our interviewees to compare their experiences with the two different ecosystems and point out any similarities and differences between them. As a result, the time frame for these particular interviews was usually longer. Moreover, not all of the interviewees from firms involved in multiple ecosystem relationships had experience of every one of these relationships. For example, we interviewed 9 informants from ARM. Only 1 informant had experience of participating in both an ARM-led and a MTK-led ecosystem. In total, we interviewed 70 informants, who represented 35 firms at the executive level.

We first introduced the idea of the business ecosystem, explained the concept of CEP, and drew the necessary links between them and the interviewees' personal experience. Following this introduction, we started to engage in detailed discussions with the interviewees regarding their experience of collaborating with others within the business ecosystem. Each interview started with a question about the interviewee's organizational role and the details of the projects in which he or she had been involved recently. We followed the suggestion of Lee (1999) to focus on basic issues, such as how a business ecosystem helps ecosystem firms to co-evolve in the self-renewal and development process, and probed more deeply into their interpretation of the collaborative projects related to the CEP that had taken place within the business ecosystem. For each of the projects, we asked three sets of questions as shown in Appendix table to guide the informants to explain their underlying motives and strategic concerns when making decisions, and it was frequently necessary to explain and clarify certain questions. For example, the interviewees did not tend to recognize the *ecosystem* terminology and often used the terms *alliance, community, collaboration* and *partner* to explain what happens within a business ecosystem. The first set of questions helped us understand the driving force behind the formation and nurturing of the business ecosystems by seeking information about each ecosystem participant's motive in engaging in collaborative activities. The second set of questions explored how the business ecosystem influences the development and improvement of individual ecosystem firms by focusing on the effects of CEP on individual ecosystem firms' development paths. Finally, the third set of questions focused on exploring how the business ecosystem influences specific business functions, such as marketing, product design, and manufacturing, in relation to new product development. We conducted pilot studies by interviewing two informants each from ARM, Intel, and MTK (leading firms) using the set of questions that we had developed. Our pilot studies showed that no obvious problems existed with regard to our interview questions (i.e., lack of clarity, double meanings, etc.). Overall, we collected 211 hr of interview data, and the majority of the interviews lasted from 120 to 180 min. The researcher recorded all of the interviews on a MP3 recorder. To ensure the confidentiality of the interviewees, we followed the Economic and Social Research Council (ESRC) Framework for Research Ethics (2015) guidelines, which many U.K. universities use as a base for their social science research ethical guidelines.

Data Analysis

The data analysis proceeded in three stages: data reduction, data display, and conclusion drawing (Strauss & Corbin, 2008). Data reduction is the process of simplifying, abstracting, and transforming data from notes. Data display involves the assembly of the reduced data into a specific style from which conclusions may be drawn. Conclusion drawing aims to present the research conclusion as well as verify the result. We began the process by transcribing all of the audio files into written form and then checking the transcripts against notes taken during the interviews. There were no major discrepancies between the content, apart from the editing and correction of the interview quotes. We transcribed all of the interviews, then adopted grounded theory principles that involved coding and categorizing the content themes and the respective interpretation of the transcribed interviews (Goulding, 2002; Strauss & Corbin, 2008) to perform our coding process.

We began coding the interview transcripts and notes to identity the range of activities jointly carried out by firms within a business ecosystem to support innovation practices for complex product development. This allowed us to identify a set of first-order categories such as "categorize business partners according to their business type and capability" and "initiate ideas for new applications." We then looked for the connections that would allow us to collapse these first-order categories into a smaller number of second-order themes. This is a recursive process that involves moving between the first-order categories until an adequate number of conceptual second-order themes have emerged (Eisenhardt, 1989; Strauss & Corbin, 2008). For example, we collapsed categories containing instances in which the interviewees talked about designing solutions using either the connect community or leader-partner strategies into a second-order theme that we labeled "organizing solution generating efforts." Toward the end, it became clear that each of the second-order themes related to different aspects of actions that were driven by mutually influencing interactions among ecosystem firms to renew themselves and stimulate innovation for new complex product development. Some were concerned with selecting and establishing a communication structure to develop a common set of goals and objectives related to innovation and new product development (co-vision). Others were concerned with working collaboratively to design new products and services (co-design), or working together to enhance the value of the ecosystem-based platform and products (co-create). Co-vision, co-design, and co-create therefore became our aggregated theoretical dimensions.

In addition to the above procedures, we relied on one technique to help ensure the trustworthiness of our conclusion. That is, we each coded the data independently, then compared our answers. We then discussed the codes,

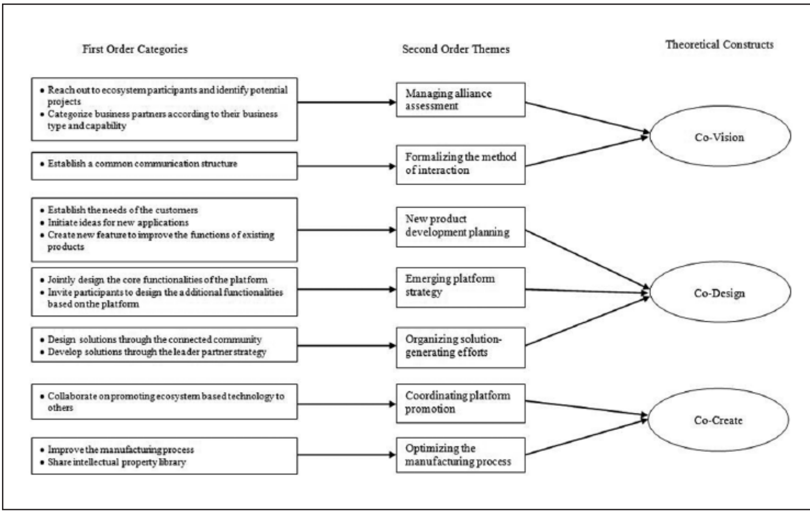

Figure 1. Data structure.

categorization, and connections until we reached strong agreement. Where there was disagreement, we revisited our interview data together and modified our positions until we reached agreement. Once we had agreed on the findings, we developed a more formal interpretation of the relationship between the interview answers and the parallel literature. We moved back and forth between the theory and data, analyzing and comparing the data with the existing theory, developing insights to support new theory, verifying that the new theory matched the data, and finally returning to the theory for further revision.

Findings

Figure 1 illustrates our final data structure that underpins the theory development from the qualitative analysis. It shows the categories and themes which we developed based on our findings and the relationship between them. Our data suggest that CEP consists of three domains of activity: co-vision, co-design, and co-create. We will elaborate on each of these in the following sections but, due to limitations of space, we will only provide samples of the interview data collected under each of these themes.

Co-Vision

Our analysis suggests that the domain of activities under the co-vision process consists of “managing alliance assessment” and “formalizing the method of interaction." Collectively, these encourage ecosystem firms to align their innovation objectives with one another. This vision alignment allows ecosystem firms to combine their research and development efforts, and work together in an innovation project to develop new complex products.

Managing alliance assessment. Managing alliance assessment refers to the process whereby the top management purposely accesses potential project opportunities and identifies appropriate business partners to join the team to exploit these opportunities. Our evidence suggested that ecosystem firms that are interested in developing complex products are actively seeking collaboration on innovation opportunities and evaluating each other for possible alliances regarding the project. One design engineer suggested,

> In the future, there will be mainly two hardware platforms (and their ecosystem partners) competing with each other. As a result, we have to develop a specific version to be compatible with these platforms. We thought they both have a future market. . . . In return, they also provided the relevant support as well.

One project manager added,

> To handpick partners [from our ecosystem], we assess their capabilities in manufacturing and their previous collaboration activities with us and select the two top companies to work with us on product design and manufacture. . . . They also evaluate us in the same way.

As these quotes illustrate, ecosystem firms identify business partners based on a careful assessment of their capabilities and track records. This process does not happen unilaterally. It is a bilateral selection, as both sides are seeking to work with the best in the industry.

Ecosystem firms also keep detailed, categorized records of each other according to individual firms' business types and capabilities. This process gives ecosystem firms a greater awareness of who is available and what types of expertise they possess in the business ecosystem. Such records can be used to determine whom an individual firm wishes to invite to join forces on different product development projects. One sales director discussed the individual firm's networking strategy in this regard as follows:

> We categorize our potential partners into different groups, like OEM [original design manufacturer], design house, operating system vendor, ISV [Independent Software Vendor], OSV [Operating system Vendor], and so on. We will share our development information with them and sometimes offer financial support [to build a relationship with them].

One sales manager also remarked,

> We encourage the different players with different complementary positions along the supply chain to participate in our ecosystem. As a result, we can provide a total solution for mobile computing products.

One product manager further described how the individual firm keeps detailed records about their potential partners:

> For example, there were thousands of IDHs [independent design houses] based in the Shenzhen area. In order to select partners more effectively, our company categorized potential partners based on their design capability and the amount of shipment they can produce.

These responses reflect the rationale behind categorizing business partners from the viewpoint of the individual firm: not to keep contact information under different categories but to conduct a detailed assessment of each potential partner and selectively build different levels of relationships with them through information sharing and financial support. In other words, differentiating its business partners allows an individual firm to use its resources wisely to develop a relationship with them and produces a better understanding of the types of projects over which the two parties might collaborate (Iansiti & Levien, 2004b; Koza & Lewin, 1998).

In practice, this categorization also allows ecosystem firms (leading firms, in particular) to facilitate collaboration in the innovation process. One sales director from a leading firm within the ecosystem explained,

> We divide our business partners into three broad groups—hardware partners, tool development partners and other functional partners. We work with our hardware partners to design hardware based on our intellectual property with the intention of seeking returns on the loyalty fee once the product is shipped. We work with our tool development partners to design tools to support our hardware partners. We aim to work with our other partners, like manufacturing services, universities, industry associations, and so on, to develop manufacturing solutions and technology to support both our hardware partners and tool development partners.

As this response suggests, this categorization allows the individual firm to manage innovation more effectively and to transform its innovation alliance from a very complicated, disordered structure into a specialized, optimized one. This categorization matches the three different streams of specialized subindustries, which also helps the partners in the network to concentrate their innovation projects around these specific sub-industries. This process finally helps divide a huge complicated business network into many smaller, product-driven business ecosystems with more specialized capabilities and products.

Moreover, managing alliance assessment activity is not only about finding the right player with the right ability but also about convincing the right players to work together on a new product development project. According to the interviewees, collaboration on innovation and the development of potential business projects start with regular communication among the ecosystem participants to identify potential projects and partners. This is followed by persuading them to join forces to exploit such opportunities. One marketing manager shared his perspective on this issue:

> When deciding to enter a new business, we will assess the players' potential and convince them to work with us on developing new applications for products [mobile devices].

This statement was echoed by a marketing director:

> We plan to further enter the third generation mobile telecommunications (3G) market . . . In 3G products, there are three main industry standards: WCDMA, CDMA2000 and TDSCDMA. Therefore, we need to search for a potential partner that has a manufacturing license that conforms to these standards. At the same time, qualified manufacturers who possess these capabilities also reach for us [to persuade us to work together on a project].

Scholars have long suggested that the competition in a highly innovative, fast-changing business environment (i.e., the mobile computing industry), where fresh streams of complex products are constantly emerging, usually takes place among ecosystems rather than between individual firms (Cooper, 2000; Dougherty & Dunne, 2011; Volberda & Lewin, 2003). Thus, to ensure the competitiveness of the ecosystem and maintain ongoing innovation in complex product development, it is critical for ecosystem firms to constantly reach out to one another to build connections. This helps build the foundation of future business collaboration.

Overall, jointly participating in managing alliance assessment allows each individual firm to build a relationship with its ecosystem participants and establish collaboration in innovation. The result is that each individual firm has a better understanding of its business partners' expertise and capability. This also allows the ecosystem firms to align their business vision more easily, because a clearer understanding of what each can do may lead to interactions involving the sharing of business ideas and objectives for future business development.

Formalizing the method of interaction. To move toward a shared vision and the identification of mutually supportive roles in product development, ecosystem firms usually wish to formalize their method of interaction to orchestrate knowledge and ideas exchange that will support their design and production activities. This allows ecosystem firms to generate clear and transparent ways to connect and interact with one another in sharing knowledge regarding product development. One CEO from a leading business system firm provided his insights into this issue:

> We proposed our own interface to connect our component providers and encouraged them to contribute their ideas [through this communication structure]. It is free for our suppliers and allows us to communicate across the same platform. The brand owner could also use the networked partners to propose their products.

Similarly, one sales manager from a software vendor described his experience of using the common communication structure to share information about design and production within the ecosystem:

> We share information on the connection interface and facilitate our partners along the supply chain. We invite everyone to contribute their ideas to our design. We also [use this communication structure] to integrate whole supply chain partners to identify the potential difficulties related to product engineering and the best method for mass production.

To formalize the method of interaction, ecosystem firms set up a common communication structure to stimulate their partners' involvement and encourage them to contribute to the design and development of complex products. This common communication structure enables ecosystem firms to share their ideas and knowledge within a formalized system (Corallo, Passiante, & Prencipe, 2007; Hirsch, Opresnik, & Matheis, 2015; Willianson & De Meyer, 2012). The strategic actions undertaken here were intended to maximize the support that the ecosystem firms receive from each other through sharing ideas within the ecosystem. In sum, our first finding is that CEP in a business ecosystem involves the practice of co-vision, in which ecosystem firms align their respective business and innovation objectives to engage in concentrated research and development activities.

Co-Design

The practice of co-vision, outlined in the previous section, enables the ecosystem firms both to align their business and innovative objectives and to consolidate their research and development efforts. Our analysis suggests that it allows ecosystem firms to work together to support multiple innovation projects. Once ecosystem firms create a joint vision, they proceed to plan and design ecosystem-based products and platforms. We label this process "co-design." According to our findings, we define the co-design process as ecosystem-wide engagement in new product development planning, emerging platform strategy and organizing solution-generating efforts. We will elaborate on this in our discussion below.

New product development planning. New product development planning involves carefully organizing knowledge resources to develop new products in response to customers' demands (Mäkinen, Kanniainen, & Peltola, 2014; Salomo, Weise, & Gemünden, 2007). Our analysis suggests that ecosystem firms that collaborate in innovation to develop complex products begin by learning about their customers' needs. One sales director from a leading ecosystem firm suggested,

> [To learn more about our customers], we hired a consultancy company to investigate the customer demand trends in the mobile computing industry. For example, more and more people like to use [mobile devices] when they travel. Thus, they want to have one with a long battery life.

One Chinese CEO from another company made a similar suggestion:

> [During our market research], we learnt that more and more customers require many computing functions, which the previous product version lacks, on a mobile phone.

Learning about the customers' needs, as reflected in the above comments, is important in enabling ecosystem firms to identify the needs of their customers and the future directions of their product development (Krishnan & Ulrich, 2001). During the process, ecosystem firms learn about the challenges that customers face when using the current version of the products available in the marketplace. As a result, ecosystem firms can work together to design a new version of the product that addresses these challenges.

Once ecosystem firms have generated a sufficient understanding of their customers' needs, they will start to approach other ecosystem participants and work with them to create ideas about new product features that address these needs. One project manager from one of the original equipment manufacturers admitted,

> A firm [ecosystem participant] approached us and shared their vision about the future of the mobile computing industry. They wanted us to join their network to deliver the proposed products. Because we are the top consumer electronics OEM [original equipment manufacturer] in China, they trusted that we were capable of delivering that kind of product. We conducted a brainstorming session to come up with ideas for new product features, such as "all day on," "always connected," and "always available," to enhance the user experience of future mobile computing devices in daily life.

Creating new products together means that both parties can access each other's technology, then recombine it to create new product ideas (Dougherty, 2001). This practice is not only useful for initiating new product ideas but also generates ideas for improving existing products. One manager from an independent software vendor described his experience:

> XXX [an ecosystem participant] wanted to integrate our online instant messenger into their existing products since the use of instant messaging on mobile phones has increased dramatically. We worked together to discover how we could facilitate this integration.

Moreover, this practice also sometimes triggers the initiative to improve the original products by incorporating the new features. One sales director from an independent design house commented:

> We worked with our business partner to further integrate an online-camera into its main product. Later, this firm realized that new functions like this can dramatically improve the value of its product. Therefore, it further improved its product to make it easier to add new functions and so adapt to changes in the marketplace.

Dougherty and Dunne (2011) suggested that innovation in complex products requires the active participation of multiple organizations, because one of them may provide an essential clue about how to develop a specific new product. Our findings endorse this idea and provide empirical evidence to support the view that, through combining their technology, different ecosystem firms can produce new product ideas or add new features to their existing products to meet their customers' needs.

Emerging platform strategy. A platform, in the mobile computing context, refers to the set of hardware architecture and software frameworks shared across a product family (Ceccagnoli, Forman, Huang, & Wu, 2012). For example, Intel won the dominant design role as they introduced the peripheral component interconnect interface as the standard industry platform interface. In the early 1990s, Intel began to establish a free industrial standard interface system (peripheral component interconnect), which was an interface that enabled its processors to connect to peripheral components from this supplier and so allow them to work more flexibly and efficiently (Gawer & Cusumano, 2002). By using Intel's platform, its ecosystem members became free of IBM's restrictions and controls, and able to assemble computers in their own way. Our data suggest that the ultimate objective in organizing a business ecosystem in the mobile computing industry is to join forces to establish an ecosystem-wide platform strategy and encourage others to develop new products based on this platform, which enhances the value of the platform.

Our results suggest that platform-based product development begins with the lead firm inviting key players within the business ecosystem jointly to design and determine the core functionalities of the platform. This lays the foundation for the other ecosystem firms to work together, combining and recombining different ideas related to new product development. One marketing manager from a semiconductor company explained,

> The platform owner encouraged us to adopt their platform by providing the necessary support [financial, technical, and so on]. They sent their marketing team and design team to work with us. They embedded our requirements into their key platform. We then license its platform. Thus, we can work closely with them to design our applications based on their platform. This is the combination of our specific capabilities.

Our data also suggest that not all of the ecosystem firms have a chance to design the platform core together with the specific platform owner. Most of the time, ecosystem firms simply develop additional functionalities (applications) based on the platform. In other words, once the basic functionalities of the platform have been developed, the platform owners usually invite their ecosystem partners to develop additional functionalities, over and above the core functions. As one sales manager commented,

> By learning from the turnkey model for mobile phone products, we also proposed a turnkey model for netbook products. We shared the design information on the connection interface and facilitated our partners along the supply chain. We also integrated all of our supply chain partners to offer a total solution platform and shared that total solution with many white brand companies regarding the netbook product. We hope to remove the industry entry barrier, encourage many OEMs and win the competitive advantage.

Ecosystem firms from different streams can now work together through the ecosystem platform to solve innovation challenges and introduce complementary innovations (Ceccagnoli et al., 2012; Mäkinen et al., 2014). These synergies stem from the notion of complementary expertise and collaborative innovation, whereby every party benefits from the technological advancement. One manager from a leading ecosystem firm, who is in charge of this kind of cooperation, commented,

> We have already developed different streams of intellectual property. . . . We share them on our common interface to facilitate the partners' design. We call this interface XXXX, which allows the easy re-use of intellectual property and makes the design easier and more standardized.

This ultimately leads to improved competitiveness across the entire ecosystem, as the ecosystem platform becomes more valuable. The key in this approach is to persuade the ecosystem firms to adopt the platform as a base for their new application development, as participants who do so will concentrate their R&D efforts on further developing marketable applications for this platform to secure their position in the marketplace (Eisenmann, Parker, & Van Alstyne, 2010).

Organizing solution-generating efforts. A solution, in the context of business and operation research, is a combination of a product and service which addresses customers' specific problems (Shi & Gregory, 2003). When applying this concept to the scope of the business ecosystem, the notion of providing solutions to customers can be referred to as the ecosystem participants working collaboratively to design a product that fulfills a specific function and solves multiple problems in a single step. Our data analysis suggests that there are two types of strategies for completing this task: the connected community and the leader-partner strategy. For the first strategy, we found that ecosystem firms will establish a connected community in which the initiating firm offers relevant design tools to each partner in this community and pools their knowledge and expertise together to contribute to designing solutions for the mobile device. More importantly, such movements enable ongoing product development by maintaining engagement and expanding it when new opportunities appear. One product manager from an Original Design Manufacturer (ODM) described how the firm engaged in persuading the other participants to join in the ongoing development of the operating system:

> The smartphone industry required an operating system with more functions. . . . We designed the software for the smartphone and turned it into a connected community. We encouraged all of the OSVs [operating system vendors] and ISVs [independent software vendors] to contribute ideas about improving the software and developing their products based on our platform [ecosystem platform].

A sales manager of another firm made a similar remark:

> We coordinate different levels of partners to work together [in a connected community], and persuade and support them, using tools to develop appropriate versions for this device.

Creating and maintaining the robustness of the community by attracting wider participation in the business ecosystem appears to be an effective method for ensuring the ongoing development of the product. In this community, ecosystem firms open up their knowledge base to some degree or offer relevant design tools to the members of the connected community. Everyone is encouraged to contribute ideas regarding solutions and to work together to develop the end user products.

Besides setting up a connected community, we found that some ecosystem firms also adopt a leader-partner strategy. When new product opportunities appear, the focal firm that possesses important technology (related to such opportunities) will select the top players in the ecosystem who also hold important solutions as its leader-partners. Together, the focal firm and its leader-partners form the core product design team. The focal firm integrates its technology with its leader-partners' solutions to develop new products and exploit opportunities. At the same time, the other ecosystem firms will help design complementary applications to improve the products and make them more competitive in the marketplace. One marketing manager from another firm provided an example of the leader-partner strategy:

> By learning from our previous experience of working with top IC [integrated circuit] design companies . . ., we firstly identified the top players in the existing industry, then approached them, sharing our initial version of the chips. We then selected XXX as the leading firm [the leader-partner] for this project. Then, we integrated their technology [with our chips] and promoted this combination to our network partners [for further innovation and development of the associated hardware and software add-ons].

The leader-partner strategy allows individual firms continuously to develop new technology and maintain their presence in the business ecosystem as it expands. They can not only attract and join forces with the top players in the ecosystem but also access the knowledge capabilities of the other ecosystem firms. As a result, the markets become more specialized and ecosystem firms form strong alliances to strengthen the solutions. In sum, our interviews with the ecosystem participants broadened our understanding of the co-design process, which consists of three clusters of activity: new product development planning, devising platform strategy, and organizing solution-generating efforts.

Co-Create

So far, we have argued that CEP is formed by two domains of activity that are carried out jointly by the ecosystem firms: co-vision and co-design. In this section, we will present the third domain of activity that appears to have a profound impact on the innovation of complex products in the mobile computing industry, because it allows further integration of the network of innovation to make the product more valuable, as well as increasing the ecosystem-wide capability to appropriate returns on these innovations. We refer to this domain of activity as co-create, which combines two major distinct collaborative undertakings: coordinating platform promotion and optimizing the manufacturing process.

Coordinating platform promotion. Coordinating platform promotion in the context of this research refers to the activities that ecosystem firms undertake jointly to promote the ecosystem platform to external parties for the purpose of developing complementary applications based on such a platform. A senior manager, responsible for managing collaboration among ecosystem participants, described the situation in his firm:

> We wished to build up an ecosystem that all of our partners could use and to promote our platform. We organized many industrial conferences and invited everyone in the industry, and we [my firm and its partners] will present many products that were designed based on our platform. We want to convince as many firms as possible to develop solutions and applications based on our platform.

One product manager from another firm made similar remarks:

> After producing the new interface, we will work with our partners [ecosystem participants] to promote our work at exhibitions to attract more potential partners to develop applications based on our work.

To promote their ecosystem platform, ecosystem firms join forces to attempt to attract as many other external firms to develop complements based on the ecosystem platform. Gawer and Cusumano (2002) suggested that a firm often encourages third-party innovation to produce a variety of complements that can be used with its own technology and so make its technology more valuable. We found that this is not only based on the efforts of the leading firms in the business ecosystem but also the joint efforts of all of the ecosystem participants, given that everyone has a stake in succeeding. These movements increase the ecosystem firms' ability to generate appropriate returns from their innovation efforts. Such returns will fuel the further development and improvement of ecosystem firms, as they enable them to reinvest in new innovation projects (Adomavicius, Bockstedt, Gupta, & Kauffman, 2007; Amburgey & Rao, 1996; Ceccagnoli et al., 2012). As a result, ecosystem firms will coordinate their efforts to promote the platform to other external firms, which have the capability to develop complementary applications based on the platform.

Manufacturing process optimization. Collaboration on manufacturing process optimization allows ecosystem firms to scale up their shipment and dominate the marketplace, as well as to respond quickly to the market demands to create value (Li, 2007). There are two activities that we identified contribute to this process. The first activity emphasizes the pooling of the ecosystem-wide knowledge capabilities to enhance the effectiveness and efficiency of the manufacturing process in producing the end product. This activity helps enhance the manufacturability of the products that the ecosystem firms co-design. One sales manager from one of the leading firms explained,

> We [the ecosystem firms] not only collaborate on designing the products, but also have to help to improve the manufacturing process of our product. We work together to improve the design of the product to speed up the manufacturing process.

The above comment suggests that ecosystem firms actively engage in improving the manufacturing process to reduce the lead time and enhance manufacturing feasibility. To accomplish this, the informant suggested that ecosystem firms work together to improve the product design. Studies have suggested that the design of a product has a strong effect on the manufacturing process (Jacobs, Droge, Vickery, & Calantone, 2011; Liker, Collins, & Hull, 1999). In other words, changing the product design can subsequently improve or decrease the efficiency of the manufacturing process. We found that the ecosystem firms work together to improve the design of the product, so that they can integrate their manufacturing process to speed up production.

The second activity is to share the ecosystem firms' intellectual property library. This activity helps improve the connections among different product components and complementary product applications that the participants create for the platform. A director of an industrial engineering manufacturer explained,

> We found that many manufacturing cases are replicating certain processes, so we set up a common intellectual property library to share with many IC [Integrated circuit] design companies in order to speed up the process.

A product manager from the same company added,

> We not only set up an intellectual property library and shared it with our partners, but we also continued to design a manufacturing ecosystem with our partners. We encouraged them to contribute manufacturing related intellectual property to our library to enrich our knowledge of manufacturing. We were thus able to speed up the manufacturing process and improve the quality.

The above statement indicates that ecosystem firms can work together by sharing what they have learned about the manufacturing process to improve the ecosystem-wide capabilities related to manufacturing. The manufacturing process for mobile devices often faces many challenges, such as uncertain orders, high overhead costs, and intellectual property incompatibility (Couillard, 2006). To deal with these challenges, the informants suggested that sharing an intellectual property library can enhance the manufacturability across the ecosystem. This is because an intellectual property library consists of a set of intellectual property records and instructions regarding the design and manufacturing process of product components. This type of information sharing helps ecosystem firms design product components with greater compatibility. It also enables design-focused ecosystem firms to test the manufacturing feasibility of product components before introducing them to manufacturing-focused ecosystem firms. As a result, the manufacturing process can become more straightforward, with a short lead time and low cost. In sum, we found that collaborative efforts regarding operations are critical in activating co-evolution within a business ecosystem and creating value.

Discussion and Conclusion

Our research objective in this study was to understand the nature of CEP and its influence on product innovation. We studied three business ecosystems in the mobile computing industry based in the Great China region, the United Kingdom, and the United States. We identified three domains of activities (co-vision, co-design, and co-create) that support innovation practices for complex product development. Our findings also signal a sequential linkage among them. When encountering an opportunity to develop a new complex product, leading firms in the business ecosystem will initiate CEP by encouraging other ecosystem firms to align their business and innovation objectives with them (co-vision). The co-vision process involves ecosystem firms communicating with one another to obtain more information about each party's expertise and capability, and build an alliance relationship. The co-vision process also encourages a formalized method of interaction. This allows ecosystem firms to share knowledge and support new complex product development. Once the vision is aligned among ecosystem firms, they proceed to work together to plan and design a new complex product (co-design). Our findings suggest that, when collaborating on designing a new complex product, ecosystem firms first seek to collaborate on product decisions, whereby they share their knowledge about the customers and propose ideas about a product that will address the customers' needs. Then, the ecosystem firms will work together to develop platform and solutions to translate the concept of the product into reality. Finally, ecosystem firms will join forces to make the ecosystem-based platform and new product more valuable (co-create). More specifically, collaborative efforts over coordinating platform promotion enable ecosystem firms to work together to promote an ecosystem-based platform for external firms, which can help develop additional applications for these products and so increase the commercial value of innovation. However, collaborative efforts to optimize the manufacturing process enable ecosystem firms to join forces to improve the manufacturing process and speed up the production of ecosystem-based products through modifying the design of the products and sharing knowledge. This confirms the conclusion of Brettel, Heinemann, Engelen, and Neubauer (2011) that the integration of the R&D, marketing, and manufacturing functions can enhance the effectiveness of innovation commercialization.

In general, our findings allow us to achieve our research objective and develop theoretical and managerial implications. First, this article extends our understanding of the nature of CEP. The concept of CEP is mentioned and discussed in almost every relevant study about business ecosystems (e.g., Iansiti & Levien, 2004b; Koza & Lewin, 1998; Moore, 1993, 1996; Tan & Tan, 2005; Tsai et al., 2009; Volberda & Lewin, 2003). Despite its frequent appearance in the ecosystem literature, however, we have little understanding of the essential nature of CEP, apart from the fact that ecosystem firms will co-evolve in an ongoing cycle and constantly renew themselves. In this research, we identify that CEP consists of three domains of activity: co-vision, co-design, and co-create. More specifically, CEP involves the business ecosystem-wide alignment of organizational goals and business objectives (co-vision), the orchestration of knowledge capabilities to design ecosystem-based products, platforms, and solutions (co-design), and the integration of resources to increase the value of the ecosystem-based platform and related products through platform promotion and manufacturing process optimization (co-create). These findings are important because they extend our understanding of the nature of CEP in the current literature (e.g., Koza & Lewin, 1998; Murmann, 2013; Tan & Tan, 2005; Van den Bosch et al., 1999; Volberda & Lewin, 2003). Our research provides a more comprehensive picture of the specific activities that ecosystem firms are undertaking to engage in CEP. These findings also have important implications for ecosystem management. Managers of ecosystem firms can enhance these activities using incentives (i.e., monetary awards) to stimulate co-evolution within the business ecosystem.

Second, this article aims to highlight the influence of CEP on product innovation derived from collaborative efforts. Collaborative innovation focuses on the joint development of innovation projects, which allows the partners to benefit from joint research efforts and resources (Ahuja, 2000; Powell, Koput, & Smith-Doerr, 1996). Past research on the mechanisms for collaborative innovation has focused on the establishment of strategic alliances (Davis & Eisenhardt, 2011; Koza & Lewin, 1998), a R&D consortium (Mathews, 2002; Sakakibara, 2002), and open source (Chesbrough & Appleyard, 2007; West & Gallagher, 2006). In this research, we study collaborative innovation from the perspective of the business ecosystem. We find that each domain of activity that forms CEP plays a different but important role in stimulating collaborative innovation to develop complex products in the business ecosystem. In particular, our results suggest that the co-vision process enables ecosystem firms to become more closely connected and develop a better understanding of each other's expertise and capabilities to develop ecosystem-based product innovation projects. The co-design process, however, allows ecosystem firms to orchestrate their knowledge capabilities to support innovation projects related to designing ecosystem-based products, platforms, and solutions. Finally, the co-create process integrates the innovation, marketing, and manufacturing functions to increase the value captured by the ecosystem firms' efforts to engage in collaborative innovation projects and deliver comprehensive end products to customers.

Finally, the results of this article have implications for the development of group-based (i.e., ecosystem) dynamic capability. In the fast-paced competitive business environment, firms are required to constantly adapt to changes and renew themselves to meet the new challenges and so maintain their competitiveness (Helfat, 1997; Winter, 2003). Teece, Pisano, and Shuen (1997) introduced the concept of dynamic capability as "the ability to integrate, build, and reconfigure internal and external competences" in a way that matches the changes in the business environment, and this general usage has continued to this day (p. 516). Most of the research studies on dynamic capabilities pay more attention to an individual firm's behavior of self-renewal, which enables it to build a competitive advantage in the ever-changing business environment (e.g., Rindova & Kotha, 2001; Teece, 2007). However, from the perspective of business ecosystems, we found that the activities' adaptation and renewal were dispersed across the entire ecosystem, and that no single firm or small group of firms can make this move alone. Prior studies on dynamic capability and strategic alliance emphasize the role of alliance capacity in managing the process of dynamic capability building among collaborating firms (Draulans, DeMan, & Volberda, 2003; Schilke & Goerzen, 2010). In contrast to previous studies, the results of our study indicate that an ecosystem-based dynamic capability building process is facilitated by a business ecosystem-wide adoption of a common communication structure and platform. In other words, the level of formalization regarding how to interact with one another in the process of dynamic capability building is high in the business ecosystem setting compared with the alliance situation. This also leads us to consider business ecosystem-related issues, such as adaptive solutions, functional roles, solution platforms, extended resources, new vision development, partner governance, the core business process, and enabling mechanism development. We found that the close integration of innovation, marketing, and manufacturing on a common communication structure or platform enables ecosystem firms to interact with each other more easily, and so improves the ecosystem-based capabilities to respond to environmental demand. In other words, ecosystem firms co-evolve their competences collectively in light of changes in the business environment.

Limitations and Future Research Opportunities

We recognize that our study suffers from several major limitations. These limitations also yield future research opportunities. First, the findings of our research suggest that CEP consists of three domains of activities—co-vision, co-design, and co-create—which support innovation practices for complex product development. This also raises the question of whether these three domains of activities are connected. Looking at the big picture, our findings generally suggest that firms within the business ecosystem need to create a joint vision (co-vision) before collaborating on product and platform design (co-design). This phase is followed by coordinating platform promotion and manufacturing process optimization (co-create). However, our data sets provide little evidence regarding the connections among each individual set of activities within each process. More specifically, our findings indicate that there are two sets of activities under the co-vision process (i.e., managing alliance assessment), three sets of activities under the co-design process (i.e., new product developing planning), and two sets of activities under the co-create process (i.e., coordinating the platform promotion). Our data cannot provide a clear picture of how these sets of activities connect with one another due to our research design. For example, we were unable to ask questions regarding (a) the connections or feedback loops among specific activities and (b) the length of time frame from one activity to the next, if these activities are not clearly identified in the first place. Nevertheless, we clearly identified the sets of activities that support innovation practices for complex product development in this research. 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 CEP.

Second, a business ecosystem consists of various levels of organizations and their relevant activities (Moore, 1996). However, many studies of business ecosystems focus on the firms' perspective rather than business environment issues, such as the policymakers and societal system. This research studies industrial phenomena at the system level together with their impact on an ecosystem organization's strategies. However, it also lacks an understanding of the full meaning of the contexts, such as the market, policy, and societal influence. Furthermore, we focus solely on CEP in the mobile computing industry in this research, which industry is known for its fast-moving, highly innovative, highly dynamic, and very uncertain nature. Other industry sectors may not share these characteristics. In addition, these three selected business ecosystems (ARM, Intel, and MTK) in our study already have well-established shared architectures and collaborative mode that Gawer and Cusumano (2014), Ceccagnoli et al. (2012), Kapoor and Lee (2013), Ramachandran et al. (2011), and others have discussed. This context setting may limit the generalizability of our findings and raise additional questions regarding CEP within the business ecosystem that has less well-established shared architectures and collaborative modes. To address these concerns, future researchers might explore CEP in other sectors or other context settings with less organized collaborative activities, and compare their results with this study to produce a more generalized view of this concept.

Third, our research does not produce any quantitative measurements regarding CEP. For example, we recognize that it is important for ecosystem firms to align themselves with the business objective, but our data sets cannot provide a precise quantitative scale to reflect its degree of importance. As a result, it is difficult to determine how far ecosystem firms should proceed in this activity. Future research might explore the weight of the different dimensions of CEP. Furthermore, the development of a metric scale for the domains of activities constituting CEP has also opened up new avenues for quantitative research opportunities to access the antecedence conditions, consequences, and contextual factors that make CEP either more or less influential in achieving particular business objectives. For example, future research can use the survey method to access the impact of CEP on innovation performance (i.e., the number of patents registered by ecosystem firms).

Fourth, 13 interviewees across five companies were involved in projects related to other ecosystems that we selected. This raises a potential concern regarding allowing interviewees to discuss multiple sets of relationships in a single interview. To address this concern, in our study, we used two methods to disentangle this limitation: (a) asking them to discuss their respective ecosystem experiences in sequence and (b) asking them to compare their experience of two different ecosystems and point out any similarities and differences. Even though the interviewees' responses enrich the findings of our study, however, this limitation still exists. Future qualitative research on business ecosystems should avoid this potential limitation.

Fifth, we explore the nature of the evolutionary process and its influence on product innovation in this research. An important related area for further research is to understand the antecedent conditions and other consequences of CEP. For example, further study might investigate the antecedent conditions of CEP regarding the methods for mitigating the risk of sharing knowledge and intellectual property libraries. It is possible that firms will decide not to participate in the business ecosystem due to concern about losing their intellectual advantage as a result of sharing their knowledge with others. Further study might also investigate the other consequences of CEP regarding the types of competences that can be developed by participating in a business ecosystem. In this research, we only focus on understanding the influence of CEP on product innovation competence.

Finally, while our findings highlight that ecosystem firms work together to optimize the manufacturing process, our study does not directly explore in detail how this mechanism operates. This raises some questions of interest: How do ecosystem firms address cost issues (i.e., payment or transfer costs), given that they are tightly linked with one another in the manufacturing process? What role does ownership structure play in either fostering or discouraging cooperation within the manufacturing process? Future research could explore these questions. In addition, our results indicate that ecosystem firms are sharing their intellectual property libraries. However, our data do not provide any further explanation regarding how ecosystem members deal with the intellectual property issue. Nevertheless, some interviewees did address this concern partially and indirectly. For example, the interviewees suggested ARM, using the intellectual property license model, which contains a license fee and loyalty. The license fee is a one-off payment, whereas the loyalty fee is collected based on the amount of customers' shipments. Intel and MTK change a one-off payment. Most of the other (non-lead) ecosystem members tend to charge a small license fee. These findings only reveal a partial picture regarding the issue of intellectual property access. Future work should design interview questions in a qualitative study to address these intellectual property issues directly.

Appendix

Sample Questions.

Question set	Sample questions[a]
1 Motivation	What are the motivation and strategies for developing and nurturing your ecosystem? What is the difference between a business ecosystem and a typical supply network? What is the essential role of a business ecosystem from your company's perspective?
2 Co-evolutionary path	How do your business ecosystem partners help improve or renew your business (i.e., technology transfer; IP; customer requirement; market dynamic; R&D support; etc.)? How are innovative ideas generated among the members of your ecosystem? How do you organize your networked partners?
3 Business function	How do your ecosystem partners influence new product (or service) development (i.e., R&D; design; product development; manufacturing; market; service)? How do your ecosystem partners help your product (or service) sales (i.e., idea; value chain; capability; relationship; etc.)?

[a]The exact wording of the interview questions may have varied from time to time.

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