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Innovation ecosystems: What makes them responsive during emergencies?

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INNOVATION ECOSYSTEMS: WHAT MAKES THEM RESPONSIVE DURING EMERGENCIES?

Abstract

In this paper, we examine what makes an innovation ecosystem responsive during emergencies. We studied the innovation ecosystem within Kerala (India) during emergencies that led to two emergency-oriented innovations, namely KeralaRescue (developed for Kerala Floods 2018) and CoronaSafe (developed for COVID-19), drawing on insights from strategic agility and institutional theory literature. We identified the enactment of three meta-capabilities of agility by the innovation ecosystem, which made it responsive during the emergencies, namely, eco-centric strategic sensitivity, eco-centric resource fluidity and eco-centric collective commitment. Further, we found that cognitive, structural and symbolic institutional arrangements facilitated the enactment of these eco-centric strategic agility meta-capabilities within the innovation ecosystem during the emergency. Our paper advances theory on innovation ecosystems and strategic agility, and generates implications for innovators and policymakers, developing solutions for COVID-19 and other emergencies.

Keywords – COVID-19, Innovation ecosystem, Strategic agility, Institutions, India, Emergency.

Introduction

The scale, scope and complexity of emergencies are clearly rising; within the Asia-Pacific region alone, in 2019, natural disasters affected nearly 55 million people (UNOCHA, 2019) and this situation has been exacerbated by the COVID-19 pandemic (Ramalingam et al., 2020; Rush et al., 2021). As timely, novel and impactful innovations are needed to handle such emergencies, it is important that innovation ecosystems are responsive and adaptive to the turbulent environment to aid the development of such innovations (Dedehayir et al., 2018; Linde et al., 2021). Emergencies, like COVID-19, pose unique challenges to ecosystem responsiveness by introducing a high degree of uncertainty, information asymmetry, and very low response time available for individuals to come together, brainstorm and develop solutions (Budhwar and Cumming, 2020; Majchrzak et al., 2007; Verbeke, 2020). Thus, during emergencies, innovation ecosystems lack "both a formal process and within that underdeveloped or missing behavioural 'routines' to enable innovation activity to take place" (Rush et al., 2021: 12). Therefore, we explore the questions: What capabilities make an innovation ecosystem responsive during emergencies? Under what conditions can an innovation ecosystem enact these capabilities?

The majority of the research on innovation ecosystems has focussed on technological aspects or has taken a firm-centric view (Adner, 2017; Klimas and Czakon, 2021). However, innovation ecosystems, especially during emergencies, develop and operate without a focal actor orchestrating the process (Oskam et al., 2021). Further, firm-centric innovation ecosystems tend to discount the role of key stakeholders such as communities affected by the emergency, and relevant non-technological and social innovation aspects (Aryan et al., 2021). Despite the acknowledgement of limitations of firm-centric view, we have a limited understanding of the capabilities and support structures that facilitate innovation ecosystems to be responsive to the uncertain and dynamic contexts of emergencies (Dedehayir et al., 2018;

Linde et al., 2021; Sklyar et al., 2019). This has led to calls for future research that adopts an eco-centric innovation ecosystem view moving away from a firm-centric focus (Adner, 2017; Gomes et al., 2018; Holgersson et al., 2018; Klimas and Czakon, 2021). An eco-centric view of innovation ecosystems considers the perspective of different actors and their coordination in a decentralized approach (Klimas and Czakon, 2021). This helps in understanding the development of bottom-up practices and capabilities in responding to emergencies (Farny et al., 2019; Williams and Shepherd, 2016).

To answer the above-mentioned research questions, we studied the innovation ecosystem in Kerala, India, during emergencies, particularly two impactful cases of emergency-oriented innovation, namely KeralaRescue (developed for Kerala Floods 2018) and CoronaSafe (developed for COVID-19). Both these innovations emerged within a short period of understanding the nature and needs of the emergency, and were successful in offering solutions. This was subsequently acknowledged by the Government and related stakeholders (IEEE Kerala Section, 2018; Saikiran, 2020). Comparing these two cases from the same innovation ecosystem enabled us to develop robust theoretical insights. We integrate strategic agility, which highlights the ability to flexibly adapt resources to meet dynamic conditions, with institutional theory lens, which discusses the rules and norms that support coordination, to study eco-centric innovation ecosystem during emergencies (Ahammad et al., 2021; Koskela-Huotari et al., 2016; Thomas and Autio, 2014). Inspired by the strategic agility literature (Doz and Kosonen, 2010; Junni et al., 2015; Weber and Tarba, 2014), at first, we illustrate the enactment of meta-capabilities of strategic agility at an ecosystem-level (which we refer to as eco-centric strategic agility) during an emergency, namely eco-centric strategic sensitivity, eco-centric resource fluidity and eco-centric collective commitment. We argue that the eco-centric strategic agility makes an innovation ecosystem responsive to the uncertain and dynamic context of emergencies, thereby supporting the development of innovations in a

limited time. Then, we build on the literature on institutional arrangements and place-based work (Farny et al., 2019; Lawrence and Dover, 2015) to unravel the nature of institutional arrangements that facilitated the enactment of agile meta-capabilities within the innovation ecosystem during the emergencies. Our findings demonstrate the importance of different cognitive, structural and symbolic institutional arrangements in making the innovation ecosystems enact agile meta-capabilities during an emergency. These arrangements offer place-based templates for individual or collective behaviour and cognition (Lawrence et al., 2011), thereby guiding the development of bottom-up practices within innovation ecosystems during emergencies.

Our study makes three key contributions. First, we extend the literature on innovation ecosystems (Dedehayir et al., 2018; Linde et al., 2021; Ritala and Almpanopoulou, 2017) to underexplored dynamic and uncertain context of emergencies where innovation ecosystems may function without a focal actor orchestrating it. In this regard, we make the case to move beyond the dominant firm-centric view and respond to calls for more research on the eco-centric innovation ecosystem (Adner, 2017; Gomes et al., 2018; Klimas and Czakon, 2021), and unravel the system-level capabilities and institutional arrangements that make them responsive to emergencies. Second, in order to understand how ecosystems can be responsive within the emergency contexts, we introduce the concept of eco-centric strategic agility, an ecosystem-level capability, developed between networks of actors, that allows to renew itself and flexibly adapt its resources to respond to dynamic and uncertain environmental conditions. Through this, we elaborate literature on strategic agility, which predominantly has a firm-centric or inter-firm focus (Doz, 2020; Junni et al., 2015; Pereira et al., 2021), to the ecosystem-level. Finally, our insights at an ecosystem-level, drawn from the integration of strategic agility and institutional theory literature, hold the potential to provide a fresh systemic view towards tackling grand challenges which are inherently complex, uncertain and evaluative (Eisenhardt

et al., 2016; Ferraro et al., 2015). We demonstrate the critical role played by the innovation ecosystem and its institutional arrangements in solving grand challenges emanating from emergencies.

The rest of the paper is structured as follows. In the literature review section, we provide an overview of innovation ecosystems literature and highlight the importance of agility during emergencies. We also make the case for integrating strategic agility and institutional theory in the study of innovation ecosystems during emergencies. In the subsequent section, we discuss our research context, and outline our data collection and analysis approach. In the next section, we highlight the two key sets of findings from our research. Finally, we outline the contributions, limitations and future research opportunities.

LITERATURE REVIEW

Innovation ecosystems and agility during emergencies

An innovation ecosystem is "the evolving set of actors, activities, and artifacts, and the institutions and relations, including complementary and substitute relations, that are important for the innovative performance of an actor or a population of actors" (Granstrand and Holgersson, 2020: 3). It is argued that collective value creation, including for actors such as communities of interest and communities of users is the distinguishing characteristic of the innovation ecosystem compared to other types of ecosystem, such as business ecosystems (Gomes et al., 2018; Thomas and Autio, 2014). The four basic elements of an ecosystem structure are: (a) activities, which are the actions taken for the value proposition to materialize; (b) actors, who undertake the activities; (c) positions, which highlight the flow of activities between actors; and, (d) links, which are about the transfers between actors (Adner, 2017).

The majority of extant innovation ecosystem literature is based on a firm-centric view, wherein a focal firm is responsible for the innovation and its direct relationships (Klimas and Czakon, 2021). In this approach, focal firm orchestrates and centralizes the activities of the

ecosystem. The focal firm defines the overall blueprint and value proposition for the ecosystem, and identifies and engages with other relevant stakeholders to build the ecosystem (Iansiti and Levien, 2004), for example, Apple's smartphone innovation ecosystem (Hannah and Eisenhardt, 2018). The focus being on trying to increase the ecosystem value through direct and indirect network externalities, thereby increasing the centrality and power of the focal firm (Adner, 2017).

The context of emergencies poses unique challenges to coordination within innovation ecosystems, which constrains the effectiveness of firm-centric innovation ecosystems. During large-scale emergencies like floods, pandemics and earthquakes, prior preparations and response plans often have limited use (Williams et al., 2017). The context of emergencies are characterised by lack of established authority structures, breakdown in communication channels, unstable task definition, and low availability and credibility of information (Majchrzak et al., 2007). Formal roles and processes are often incompatible, bringing informal roles and new institution creation activities to the fore (Zietsma and McKnight, 2009). The expectation to work with a high degree of urgency and flexibility adds to the complexity (Williams and Shepherd, 2018). Under such conditions of rapid response aimed at tackling complex problems, innovation ecosystem may evolve without a focal firm-actor orchestrating the process (Oskam et al., 2021; Rush et al., 2021). Furthermore, firm-centric top-down approaches to innovation ecosystems would be inadequate or even exacerbate the crisis as they tend to undermine the role of important stakeholders such as communities affected by the emergency, and the role of non-technological and social innovations relevant to the context (Aryan et al., 2021).

This calls for a need to focus on an eco-centric innovation ecosystem view, rather than a firm-centric view during emergencies, which enables exploitation of diverse perspectives, their direct or indirect relationships, resources and capabilities, to develop innovative and

urgent solutions (Klimas and Czakon, 2021; Oskam et al., 2021). Eco-centric ecosystem approach starts with a value proposition and then identifies the actors and activities needed in order to achieve the proposition (Adner, 2017), which is appropriate for the context of emergencies where the core value proposition of humanitarian relief takes prominence with actors and activities contributing to it. However, our knowledge on eco-centric innovation ecosystems, particularly what makes them responsive during emergencies is very limited.

To respond to emergencies, innovation ecosystems will have to work with limited information, resources, organizing structure, and in a dynamic manner, by redeploying and reorganizing their resources, as internal and external circumstances warrant. In other words, they need to enact capabilities of agility at an ecosystem-level, as informed by our data (we offer a brief introduction to the concept here).

The concept of strategic agility has been used predominantly at a firm-level where it is defined as "the capacity of an organization to efficiently and effectively redeploy/redirect its resources to value-creating and value protecting (and capturing) higher-yield activities as internal and external circumstances warrant" (Teece et al., 2016: 17). Agility represents nimbleness, speed and ability to change course in a short period of time (Doz, 2020). There are three meta-capabilities for firm-level strategic agility, namely, strategic sensitivity, resource fluidity and collective commitment[1] (Doz and Kosonen, 2010). Scholars have observed strategic agility to be a source of competitive advantage for firms in different contexts such as human resource management, supply chain management, governance of international joint ventures and acquisitions (Junni et al., 2015; Pereira et al., 2021; Soundararajan et al., 2021).

[1] Strategic sensitivity is about the sharpness of perception and awareness to environment changes. It has a future-oriented focus with a high level of shared strategic alertness and quality interactions among senior team members. It needs to be contextually grounded in order to capture the subtle nuances of the particular context within which the organization operates. Resource fluidity is the ability to restructure knowledge and resources, and redeploy them quickly to new opportunities. In an organizational setting, it can be enabled through flexible structures, temporary teams, knowledge mobility, decentralized initiatives and transparency. Collective commitment is the ability of the leadership team to quickly make and execute bold joint strategic decisions. Collective commitment to decisions is achieved through mutual dependency and collaboration between team members on a shared strategic agenda (Doz, 2020; Doz and Kosonen, 2008, 2010).

Drawing inspiration from these works (Doz, 2020; Doz and Kosonen, 2010), we attempt to understand how strategic agility functions at an ecosystem-level. We define eco-centric strategic agility as ecosystems' ability to renew itself and flexibly adapt its resources, to respond to dynamic and uncertain environmental conditions. Agility does not occur by itself, rather it is dependent on actors making and acting on decisions (Franken and Thomsett, 2013). In a firm-centric approach, within hierarchically structured organizations, having clear division of roles and responsibilities, the top management team takes such decisions. However, in an eco-centric approach, this is typically not the case, as it involves actors with varying degrees of information and power asymmetry (Franken and Thomsett, 2013). Thus, at a network-level, a different approach that draws on aspects such as shared purpose, identity, vision, norms, and beliefs is needed (Benkler, 2017). Prior research highlights the importance of shared understanding and representations for coordination within temporary group networks in emergency settings (Bigley and Roberts, 2001; Valentine, 2018). Therefore, while agility has been predominantly studied as a firm-centric concept, research is beginning to emerge suggesting its usefulness beyond firms.

In summary, turbulent and dynamic environment around emergencies pose high uncertainty, in turn producing insufficiencies of information and resources. A pivotal challenge of innovation ecosystem is lack of ability to manage such uncertain environments without established routines and capabilities for it (Dedehayir et al., 2018; Sklyar et al., 2019). However, while emerging research has highlighted the importance of firm-level strategic agility during crises, such as the global financial crisis (Pereira et al., 2021) and COVID-19 (Verbeke, 2020), less is known about agile capabilities at the ecosystem level for tackling turbulent and uncertain environments (Linde et al., 2021; Rush et al., 2021). To understand the enactment of agility at an ecosystem-level during emergencies, consistent with the eco-centric view, we build on institutional theory. Institutional theory is a useful theoretical lens to study

agility in innovation ecosystems as it helps in understanding the rules and norms that support informal coordination and organizing in uncertain and dynamic contexts (Ahammad et al., 2021; Koskela-Huotari et al., 2016; Thomas and Autio, 2014).

Institutional arrangements and innovation ecosystems during emergencies

Scholars have adopted an institutional approach to understanding evolution and coordination in innovation ecosystems (Almpanopoulou et al., 2019; Sahasranamam et al., 2019; Thomas and Autio, 2014). Thomas and Autio (2014) argue that the innovation ecosystem is an organizational field, in that, it includes institutional actors, logics and governance structures. Koskela-Huotari et al. (2016: 2964) outlines institutional perspective on ecosystems as "… a complex, self-adjusting system of resource integrating actors connected by shared institutional arrangements and mutual value creation".

Emergencies such as floods and earthquakes affect the place where people live (Perry, 2009). According to Lawrence and Dover (2015: 382), place is the "intersection of location, material form, and a set of meanings and values". They argue that places are socially constructed by people, and undergo continuous revision and reconstruction. Institutional arrangements are social or community arrangements that act as a guide for everyday social life and offer place-based templates, for individual or collective behaviour, cognition and emotions (Lawrence et al., 2011; Zietsma and Toubiana, 2018). Institutional arrangements create a commonly shared understanding of routine and legitimate behaviour (Schatzki, 2005).

During emergencies, formal institutional arrangements and institutionalized templates based on prior plans are substantially disrupted, failing to respond to specific needs (Marquis et al., 2007; Zietsma and McKnight, 2009). Majchrzak et al. (2007) argue that in the aftermath of Hurricane Katrina, despite the existence of formal arrangements, a structural breakdown happened due to the large scale of the crisis. This meant that volunteers with little knowledge

of the city and with limited training to handle emergencies had to step in to fill the vacuum, further exacerbating the crisis.

Recent research highlights the importance of community-level institutional arrangements in responding to emergencies (van der Vegt et al., 2015; Williams and Shepherd, 2016). Specifically, they highlight the emergence of bottom-up social practices creating new local templates for post-disaster organizing (Farny et al., 2019; Majchrzak et al., 2007). For instance, using the context of the Haiti earthquake, Farny et al. (2019) argue that recovery post-disaster requires the creation of new institutional arrangements based on shared emotional responses. We build on these insights to identify the institutional arrangements that make innovation ecosystems enact agility to meet the dynamic and uncertain conditions posed by emergencies like COVID-19.

Methods

Research context

The objective of the study is to understand the capabilities and institutional arrangements enabling innovation ecosystems to be responsive to emergencies. As there are two aspects of innovation ecosystems that we focus on (i.e. capabilities and institutional arrangements), consistent with the literature (Yin, 1981), we adopted an embedded case study design and studied the innovation ecosystem in Kerala, India, particularly, the successful emergence and execution of two emergency-oriented innovations – KeralaRescue, developed during Kerala Floods in 2018; and CoronaSafe, developed during COVID-19. The two innovations were chosen purposively as they were both innovations developed within the same innovation ecosystem (i.e., Kerala) and focused on solving the challenges posed by the emergencies in that ecosystem. Both the innovations were developed within a short period of understanding the needs of the emergency and were closely linked to the contextual deficiencies related to the emergency. The significant value of both the innovations were acknowledged by multiple

stakeholders soon after their development, including an explicit endorsement from the Kerala government (IEEE Kerala Section, 2018; Saikiran, 2020). We adopted a "contextualized explanation" approach to theorizing from case studies which is in between the "inductive or deductive process of theory development" (Welch et al., 2011: 748).

The successful development and execution of these two innovations (KeralaRescue and CoronaSafe) for emergencies encouraged us to select the innovation ecosystem in Kerala for this study. Focussing on these two innovations within the same innovation ecosystem enabled us to develop comparative and generalized theoretical insights. In August 2018, Kerala faced unprecedented levels of rainfall, 96% above the long-term average for the state, leading to massive floods (Krishnakumar, 2019), which required over 1.5 million people to move to relief camps and claimed over 450 lives (The Indian Express, 2018). KeralaRescue was an innovation started by student volunteers of the Institute of Electrical and Electronics Engineers (IEEE) Kerala Section during this emergency, which later became the official initiative of the Kerala Government for effective collaboration and communication. During COVID-19, Kerala reported the first positive case of COVID-19 within India on 30th January 2020 and declaring the pandemic as a state disaster by February 4th, 2020 (The Times of India, 2020). Soon after this, a multi-disciplinary team of innovators and volunteers developed CoronaSafe, an innovation that supports the efforts of the state government. CoronaSafe developed a live data system on patient inflow (Coronasafe Network, 2020), which none of the Indian states had at that time (ACT grants, 2020). They also supported in setting up care centres, in-patient care management, and logistics for ambulances and relief[2]. Table 1 provides a summary of the two innovations.

---------- Insert Table 1 about here ----------

[2] Author's interview

Data collection

The data were collected between March 15 and November 15, 2020. We collected retrospective data to understand the development of KeralaRescue as well as live data to capture the real-time development of CoronaSafe. We relied on multiple data sources and informants to develop an in-depth understanding of enactment of agile capabilities and institutional arrangements in the innovation ecosystem in Kerala that led to the successful development and execution of KeralaRescue and CoronaSafe. This also helped in data and informant triangulation (Flick, 2018). We collected data from two sources: interviews, and documents. We avoided direct observations due to COVID concerns. Although we could not directly engage in observation due to COVID, we gathered some observational data with the help of a lead volunteer from the KeralaRescue project who was also working as a research assistant on this project, providing us with deep insights into the context and the innovation. The data collection process ended on reaching theoretical saturation (Glaser and Strauss, 1967). Overall, the data collection process followed all the necessary criteria recommended in the literature to ensure rigorousness and truthfulness of findings (Gibbert and Ruigrok, 2010; Guba and Lincoln, 1994; Yin, 2003).

Interviews: We conducted in-depth semi-structured interviews with a wide range of actors related to both KeralaRescue and CoronaSafe. We used the purposive sampling method and chose interviewees based on their role and involvement in the development of both innovations and their knowledge of the innovation ecosystem in Kerala. We initially accessed interviewees with the help of some core members and volunteers of the innovation. We then gained access through the snowballing method. Due to COVID, the first author, along with the research assistant, conducted all the interviews via phone and video conferencing. They consulted the rest of the team before and after each interview. This ensured that the whole team was aware of the data gathered. In addition, it enabled the team to constantly plan and reflect. In total, we conduced 20 interviews with volunteers, industry professionals, start-up founders,

health staff and government authorities closely related to each of the two innovations (see Tables 2 & 3). We used an interview guide, which had a wide range of topics such as roles, activities, resources and support with numerous probing questions; and it evolved over time. In some instances, we followed up on the interviews with WhatsApp messages to clarify details. We stopped interviewing upon receiving repetitive answers and reaching theoretical saturation (Glaser and Strauss, 1967). The purposive sampling aided in collecting rich information regarding both the innovations and the ecosystem. We recorded the interviews upon receiving consent. When no consent was given for recording, detailed notes were taken. The interviews were carried out either in English or Malayalam, the local language. Both the first author and research assistant are well versed in both languages. All the interviews were transcribed. The interviews conducted in Malayalam were translated into English, and a selection of transcripts was back translated into Malayalam by the research assistant, to ensure accuracy (Brislin, 1970). Each interview ranged from 15 minutes to 70 minutes and, in total, this produced over 500 minutes of interviews.

Documents: The interviews were supplemented by secondary data in the form of documents. The documents include government reports and advisories, alongside project reports on the innovation (see Table 2 for samples). In total, over 34 reports were collected totalling over 400 pages. Further, we undertook a systematic search for newspaper and other press articles on the topic through the Gale OneFile database using keywords such as 'Kerala', 'COVID', 'corona', and 'floods' to collect details about the challenges of the emergency, the two innovations and the innovation ecosystem within Kerala (see Table 2 for samples). This resulted in approximately 150 pages of press articles. We carefully selected the documents based on relevance, accuracy, legitimacy and clarity (Bell et al., 2018).

---------- Insert Table 2 and 3 about here ----------

Analysis

Consistent with the "contextualized explanation" (Welch et al., 2011) approach to theory development, we analysed the data to unravel causal explanations for the successful development and execution of innovations - KeralaRescue and CoronaSafe - during emergencies. Especially, we sought to understand the capabilities and institutional arrangements that made the innovation ecosystem within Kerala responsive to emergencies. We systematically coded the data using an established analysis approach (Lawrence, 2017; Strauss and Corbin, 1990; Zietsma and Lawrence, 2010) as outlined in Figure 1. See Tables 4a and 4b for a demonstration of our coding process.

---------- Insert Figure 1 about here ----------

Although the constructs of agile capabilities and institutional arrangements are consistent with the broader literature on strategic agility and institutional theory, our study expands them by showing how eco-centric agile capabilities are enacted and how different institutional arrangements facilitate its enactment. Such a theory elaboration process is consistent with the contextualized explanation approach (Ketokivi and Choi, 2014; Welch et al., 2011). We ensured the 'trustworthiness' (Guba and Lincoln, 1994) of the theoretical constructs by examining for internal homogeneity and external heterogeneity (Patton, 2002), rereading the narratives and raw data, consulting several stakeholders, and iterative discussion between ourselves. We ensured inter-coder consistency (Hemmler et al., 2020), by consensually developing a coding scheme and iteratively developing the codes and constructs based on constant discussions between authors.

Findings

There are two key sets of findings from our study. First, we demonstrate the presence of eco-centric strategic agility in the innovation ecosystem within Kerala during emergencies. Second, we highlight the institutional arrangements that enabled the ecosystem to enact agility during

the emergency. We present the conceptual model in Figure 2, and the coding process in Tables 4a and 4b respectively.

---------- Insert Figure 2, Table 4a and 4b about here ----------

Agile meta-capabilities in the innovation ecosystem during emergencies

Within the innovation ecosystem in Kerala, during both the emergencies (floods and COVID-19), we observed the enactment of three meta-capabilities of strategic agility at an ecosystem-level, namely *eco-centric strategic sensitivity*, *eco-centric resource fluidity* and *eco-centric collective commitment*.

Eco-centric strategic sensitivity

Eco-centric strategic sensitivity is manifested in the form of a) understanding of future needs and b) contextual awareness, facilitating alertness to the emergency and quality dialogue within the innovation ecosystem. With respect to understanding future needs, for instance, during COVID-19, a key volunteer started CoronaSafe as an information repository for authentic medical information and related coordination based on news emerging from other countries such as China and Western Europe. Subsequently, upon realising the impact that the pandemic would have on hospitals, critical care and ambulances in the near future, the Coronasafe team moved their attention to building an end-to-end logistics and database management system, as discussed by CoronaSafe volunteer 3:

> *"We had a dashboard… We worked closely with health mission… First tool was for patient management ... later, it became a hospital management system … We had also set up a tele consulting unit … We also had an ambulance management system.*"

Further, our data suggests that the ecosystem actors within Kerala and their activities were grounded within a strong contextual understanding. This emanated through their networks with relevant stakeholders and through their prior experience of working on projects developed for use during emergencies. This helped them with an understanding of the strength and

weakness within the ecosystem, and mapping the nature of support needed for the emergency. For example, during COVID-19, the contextual understanding on lack of integrated data management systems, encouraged the ecosystem actors to explore the scope for a software-based solution, as revealed by CoronaSafe volunteer 2:

> "*They always want software that can do everything in an integrated way. We know it from KeralaRescue. We know the need and usefulness for the community.*"

Eco-centric resource fluidity

Eco-centric resource fluidity is manifested in the form of a) redeployment of existing resources and b) tolerance with uncertainty and adaptation to needs. Ecosystem actors exhibited a strong degree of mutual sharing and redeployment of existing resources, as they were feeding off each other's expertise and resources, while responding to the emergency. During KeralaRescue, the initial pool of volunteers came from within the IEEE student network. These students started the flood-relief collection points using the existing facilities of their respective engineering colleges, as this volunteer suggests:

> "*We created collection points out of the IEEE student branch colleges and students there helped us as volunteers*" - KeralaRescue volunteer 4

In the case of Coronasafe, the physical space of the Indian Medical Association and government offices were opened up to other ecosystem actors to work together. Some of the volunteers were working from home as well, supporting the activities of the ecosystem. For instance, CoronaSafe volunteer 4 explained:

> *"We also have a call centre here (at district administration office), manned by us (volunteers), and some volunteers are also working from home.*"

Further, our data suggested that the established plans or blueprint were not adequate amidst the sudden and unprecedented nature of each emergency. This meant that the ecosystem had to develop new solutions in a dynamic and flexible manner depending on new information

coming up. During COVID-19, the nature of requirements was varying dynamically with changing directives from the World Health Organization (WHO) and national government. Therefore, the ecosystem actors had to acknowledge this inherent uncertainty and adapt their resources and responses accordingly, as the following quote illustrates:

> "*There was no blue print… See the administration was also unprepared right, they did not know what was happening, there were so many directions coming from both the centre and the state. So they had to be ready for whatever was coming in*" – CoronaSafe volunteer 3.

Eco-centric collective commitment

Eco-centric collective commitment is manifested in the form of a) integrated decision-making and b) authentic leadership. This helped to agree on decisions and execute the work amongst all actors. We observed evidence of integrated decision making which involved listening to diverse inputs through joint brainstorming sessions and experts within each of the areas of emergency leading the decision-making. In the case of CoronaSafe, key ecosystem actors such as medical doctors, volunteers and government staff were part of joint brainstorming sessions to identify the needs of the ecosystem and develop corresponding solutions. After incorporating the diverse inputs, when it came to decision-making, ecosystem actors relied on niche expertise, with medical doctors taking the final decisions on medical related matters and technical volunteers deciding on technology implementation needs. This quote from CoronaSafe volunteer 3 reveals this:

> "*Each have niche areas of expertise and everyone's opinion is heard. Overall, everyone is connected to everyone…. We don't have expertise in administration or health. We met officials of the health department, Dr. M (anonymized) particularly; we rely on him for medical aspects… We focus on tech design and architecture. Actual implementation is led by senior government officials*" – CoronaSafe volunteer 3

Further, in both innovations, we observed evidence of authentic leadership[3] displayed by the leadership team of the ecosystem. In both cases, the authentic leadership emerged from their past reputation and experience of leading on humanitarian projects. For instance, some core volunteer leaders from KeralaRescue were involved in CoronaSafe too, so they had developed confidence with government and medical officers through their past successes in emergency-specific projects. The authenticity of the leadership team was also crucial in identifying and attracting other relevant ecosystem actors to join. For instance, CoronaSafe volunteer 3 commented:

> "*I knew Y (anonymized) personally that is how I started volunteering… Whole thing was kick-started by CoronaSafe volunteer 1 and Y… We had a huge pool of volunteer applicants. The CM had made the call for volunteers, Sannadha sena, so the administration had access to that pool. We pulled volunteers form there.*"

Institutional arrangements supporting the innovation ecosystem's enactment of agility

The data demonstrated the presence of various cognitive, structural and symbolic institutional arrangements supporting the enactment of eco-centric strategic agility within the innovation ecosystem in Kerala.

Cognitive institutional arrangements

Cognitive institutional arrangements are about the expected standard of behaviour in a specific local cultural setting (Scott, 2014). In the innovation ecosystem in Kerala, we found the presence of a) collective shared memory and b) collective learning, helping to structure perception and understanding of an emergency environment.

In both our innovations, we found evidence of collective shared memory within the innovation ecosystem. In the case of KeralaRescue, the team developed shared memory

[3] Research on authentic leadership highlights that for a team to work together well, its members have to earn each other's respect and confidence (Avolio et al., 2004). Being authentic helps the team in making decisions quickly and in a united manner, cutting down the time lost in sorting out internal differences and counter-planning, helping the firm to be strategically agile (Avolio and Gardner, 2005; Doz, 2020).

through the pre-existing network of IEEE Kerala Section, which constitutes engineering students, young industry professionals, academics from universities, and senior practitioners from industry. As a network, they had prior experience in working on social projects such as rural electrification and assistive technology in non-emergency settings (IEEE India, 2019; Sankar et al., 2012). The presence of social media tools such as WhatsApp further facilitated coordination within the pre-existing network, aiding the collective shared memory exchange. For instance, a volunteer explained:

> *"…we were due to have an IEEE event in Kochi when the news of dams opening came. We had a WhatsApp group with active IEEE volunteers from across the state, and in that, there was a suggestion about starting a website to help flood victims"* - KeralaRescue volunteer 2

In terms of collective learning, we observed that regular meetings and knowledge exchange with experts in technical and emergency aspects was a common feature in both projects. For instance, in KeralaRescue, ecosystem actors learned about humanitarian mapping through the expertise shared by a leading proponent of Open Street Map. Similarly, in CoronaSafe, technology professionals from leading MNCs were mentoring the core ecosystem actors. The use of open source software like Django and GitHub further facilitated both the projects. This supported collective learning between the ecosystem actors based on community-developed narratives and protocols of the open-source community, and through the observations and actions of the ecosystem actors to different scenarios. The open-source community, with limited barriers to entry, also helped in attracting more volunteers to contribute to the ecosystem. For instance, CoronaSafe volunteer 1 mentioned:

> "*We have a public Slack account; communication was open in public. Everything works on GitHub… So when a message comes up, everyone subscribed to that channel is*

alerted... Everyone wants to be part of the open-source developer community because that is the geeky developer trend right now."

The presence of cognitive institution arrangements such as collective shared memory helped ecosystem actors to have strategic sensitivity to its unique characteristics and needs. In addition, their experience of working together on social projects helped in developing collective commitment between the actors. The access to volunteer and technical expertise through the IEEE network, and networks with open source communities offered scope for resource fluidity.

Structural institutional arrangements

Structural institutional arrangements are about the socially constructed capacity to undertake certain types of work (Scott, 1992). Meyer and Rowan (1977) highlight that organizing efforts conform to expectation by adopting appropriate structural arrangements and rules. Our data suggested the presence of a) a legitimating actor, b) voluntary participation and c) purpose-specific intermediaries helping to bring together the diverse actors who are motivated and are willing to put together the resources needed to meet the expectations of emergency.

In terms of the legitimating actor, in both projects, we observed the importance of an actor from the ecosystem who lends legitimacy to the ecosystem and its activities for its acceptance by diverse stakeholders, which involve resource providers and beneficiaries. In both our case studies, the legitimating actor was the government. The predominant inputs to other ecosystem actors came from the government and they had to coordinate with the government in shaping the ecosystem responses. For instance, CoronaSafe volunteer 1 said:

"Without government support, we could not have done anything. ... a government bureaucrat (anonymized) was involved with the project from the initial phase."

Similarly, in the case of KeralaRescue, in the initial few days, beneficiaries were hesitant to share the help requests on the portal as they were unsure whether it was a legitimate effort.

During the first three days, around 4,000 help requests were made on the portal (IEEE Kerala Section, 2018). However, after the state government, through its Facebook page, officially recognized KeralaRescue, there was a rapid increase of help requests to 57,000 in five days (IEEE Kerala Section, 2018). In this regard, KeralaRescue volunteer 4 explained:

> *"Initially people thought it might be spam, so they were not willing to share it. After the government recognized it, there was more sharing."*

In terms of voluntary participation, in both case studies, the volunteers were important ecosystem actors. Both projects saw volunteer participation from diverse fields such as health, engineering, third sector and logistics. Even experts from academia and industry volunteered their time in offering mentoring support to the projects. We observed, in our case studies, that some volunteers who came together for developing KeralaRescue were also active in the development of CoronaSafe. The coordination practices of the ecosystem were also planned to facilitate inputs from volunteers, supporting the resource fluidity of the ecosystem. For instance, KeralaRescue volunteer 2 said:

> *"Since it is a volunteering effort, there is no single ownership. The best platform for that is GitHub, to ensure openness."*

Intermediaries could be individuals or organizations that act as agents linking between multiple parties. Given the social complexity and diversity of ecosystem actors involved in emergencies such as government, health staff, disaster management staff, and volunteers, purpose-specific intermediaries within the ecosystem are crucial in fostering connections and ensuring coordination between them. In CoronaSafe, this role was played by the former head of a government-run start-up incubator (Nidheesh, 2020). In KeralaRescue, volunteer 1 said:

> *"In the IEEE committee, we already had X (name anonymized) as the co-chair for government relations. X was also the Head of the e-Governance Mission of the state*

government. So one of my initial calls went out to X to discuss what we can do. X then coordinated with relevant government authorities."

The active intermediary role of start-up incubators, think tanks and policy advocacy organizations was also a key enabler. During KeralaRescue, Kerala State IT Mission, a government organization under the Department of Information Technology acted as an intermediary in coordinating with the legitimating actor (government) in ensuring rapid action (IEEE Kerala Section, 2018). For CoronaSafe, Kerala Start-up Mission (KSUM), a government-supported entrepreneurship development agency, and Kerala State Disaster Management Authority (KSDMA), were important intermediaries playing similar coordination and resource supporting roles (Coronasafe Network, 2020).

The presence of the legitimating actors aided in developing collective commitment with the ecosystem as it rendered authenticity and confidence to relevant stakeholders. Similarly, purpose-specific intermediaries, through their bridging role, provided authentic leadership for the volunteer-led efforts with the legitimating actor. The presence of intermediaries situated at the intersection of industry-academia-government positioned them ideally to mobilize network resources from multiple areas within the ecosystem, supporting resource fluidity of the ecosystem. Similarly, government (legitimating actor) and volunteers, through their close contact with affected communities and prior experience of dealing with emergencies within the context, offered strategic sensitivity to the ecosystem.

Symbolic institutional arrangements

Symbolic institutional arrangements are shaped by local norms that, when managed, offer symbolic power for substantive action (Emirbayer and Goldberg, 2005; Hallett, 2010). Our data suggested the presence of a) trust in other actors and b) a sense of community development offering symbolic power to the ecosystem actors in responding to the emergencies.

We observed trust amongst the ecosystem actors, as they exhibited confidence in each other's abilities and reputation. In the case of KeralaRescue, this trust emanated from their experience of working together on other projects as part of IEEE. For instance, a volunteer commented:

> *"It was personal connection-based trust. KeralaRescue volunteer 3 (anonymised) I brought in; I had never seen him before. I was familiar with him through an IEEE project, knew he was doing Django. So I called him and added. In IEEE, we have a sort of implicit trust."* – KeralaRescue volunteer 2

During CoronaSafe, the mutual confidence and faith built up between the ecosystem actors during past emergencies like Nipah and Kerala Floods helped in developing a mutual trust and understanding in each other's eyes, as illustrated in this quote:

> *"After Nipah and Kerala floods, government has high faith in techies"* – Startup founder 1.

We also observed a sense of community development within the ecosystem actors. This was evident from their involvement in different community development projects over the years. Within IEEE globally, Kerala Section and its leadership team were pioneers in setting up humanitarian technology-focussed projects (IEEE SIGHT, 2017). They have implemented a number of technology-based community development projects focussed on rural contexts and in healthcare (IEEE Kerala Section, 2014). In the case of CoronaSafe, lead volunteers were earlier involved in supporting entrepreneurship and an open source community in the state, through a government supported start-up incubator. For instance, CoronaSafe volunteer 1 said:

> *"I am working in Y's (anonymized) start-up and he is leading on the communications with the government on this… I was part of Startup Village as a student (government-run incubator), a lot of us knew each other through that… we had a bond with other open source developers…"*

The presence of collective trust helped in developing collective commitment within the ecosystem, as it created mutual trust among the ecosystem participants with regard to decision-making. The collective sense of community development enhanced strategic sensitivity to the contextual aspects, and offered access to relevant stakeholders and resources within the ecosystem, supporting resource fluidity.

Discussion and Conclusion

Emergencies like COVID-19 and floods pose distinctive challenges, and our research highlights the capabilities and institutional arrangements that make innovation ecosystems responsive to emergencies. Drawing on strategic agility (Doz, 2020) and institutional theory literature (Lawrence and Dover, 2015), we studied the innovation ecosystem in Kerala. Particularly, we focused on two impactful emergency-oriented innovations KeralaRescue and CoronaSafe, to illustrate (a) the enactment of eco-centric strategic agility, that make the ecosystem responsive, namely eco-centric strategic sensitivity, eco-centric resource fluidity and eco-centric collective commitment; and (b) a combination of cognitive, structural and symbolic institutional arrangements facilitating the enactment of agile capabilities by the innovation ecosystem.

We develop the concept of eco-centric strategic agility. Eco-centric strategic agility differs from a firm-centred agility on multiple aspects. First, eco-centric strategic agility is a network-level concept. So, enacting eco-centric strategic agility involves coordinating an aggregation of actors with diverse interests, power and information asymmetry (Franken and Thomsett, 2013). The enactment of agility happens through people who make and act on decisions. Therefore, to enact agility at a network-level, a shared purpose, identity, vision, norms, and beliefs is needed (Benkler, 2017). In firm-centric strategic agility, however, this happens through clear division of rules and responsibilities under top management leadership. Second, unlike firm-centric agility, the actors enacting eco-centric agility do not necessarily

know in advance, how to agree and achieve shared goals. Therefore, to develop agility at a network-level, there is a need to "open spaces" for robust dialogue and experimentation, so that bottom-up initiatives can occur through collaboration and interaction of resources at hand (Bollier and Helfrich, 2012). Through this provisioning of space, bottom-up social practices allow network actors to discover and implement new ways of doing things in a decentralized manner. Finally, actors engaging in eco-centric strategic agility often have intrinsic and pro-social motivations that are in the interests of common good, unlike the centrality attached to extrinsic motivations, particularly material incentives in firm-centric agility. For example, in Free or Open Source Software (FOSS) ecosystem, contributors to the network are motivated by non-monetary incentives such as status and sense of shared community identity (Benkler, 2017).

Large-scale emergencies require quick, innovative and, most importantly, careful responses, as inappropriate responses can lead to fatalities. Our research shows that multiple actors, including civil society, government, scientists and the public within an innovation ecosystem need to come together with their resources and knowledge to conjointly develop and implement solutions. Nevertheless, such 'functional diversity' (Page, 2007) can lead to coordination problems. Our findings suggest the important role played by different institutional arrangements in addressing coordination problems in innovation ecosystems. Cognitive institutional arrangements increase familiarity and learning; structural institutional arrangements improve legitimacy and commitment; and symbolic institutional arrangements increase accountability and self-regulation. Further, our findings show that open dialogue played an important role in connecting different actors and levels of the ecosystem, thus facilitating coordination. The findings further show that for such dialogue to occur, the ecosystem should have supporting leaders to legitimize decisions, accountability mechanisms

to correct behaviour and decisions, a sense of community development, and trust in other actors.

Our findings links to the seminal research on interactions between resources and institution (Oliver, 1991), wherein we find that the institutional arrangements enabled the creation and maintenance of agile capabilities to facilitate innovation development. Further, we build on the works of Lawrence and Dover (2015) on place-based templates and institutional arrangements, to find the profound influence they have on innovation ecosystem creation, in terms of how ecosystem actors understand problems specific to the context, identify and adapt the resources, and develop routines and decision-making approaches, during uncertain and dynamic contexts such as emergencies.

Contributions

This study makes three critical theoretical contributions. First, we contribute to the literature on innovation ecosystems by exploring its role in the context of emergencies. Emergencies pose distinctive challenges for innovation ecosystems by substantially disrupting established formal arrangements (Marquis et al., 2007; Zietsma and McKnight, 2009). Our study shows the appropriateness of an eco-centric innovation ecosystem approach (Klimas and Czakon, 2021), which considers the views of diverse actors and their coordination relationships. With the help of insights from strategic agility and institutional theory, particularly the literature on place-based work and institutional arrangements (Farny et al., 2019; Lawrence and Dover, 2015), we expand the understanding of the eco-centric innovation ecosystem by identifying capabilities and institutional arrangements that facilitate ecosystem responsiveness to emergencies. Through this, we respond to calls for future research focused on the eco-centric innovation ecosystem rather than firm-centric aspects (Adner, 2017; Holgersson et al., 2018; Klimas and Czakon, 2021). We also highlight the importance of bottom-up practices and informal coordination through community-level institutional arrangements, rather than formal

institutional arrangements, in supporting innovation ecosystems to be responsive during emergencies.

Second, to illustrate how ecosystems can be responsive in contexts of high uncertainty and dynamism, such as emergencies, we introduce the concept of eco-centric strategic agility. We argue that eco-centric strategic agility is different from firm-centric strategic agility, as it involves developing agility between a network of actors with diverse interests, motivations, and varying levels of information and power asymmetry. Specifically, we identify that enactment of eco-centric strategic agility through eco-centric strategic sensitivity, eco-centric resource fluidity and eco-centric collective commitment support the responsiveness of innovation ecosystem amidst the constraints imposed by an emergency. Past research on strategic agility has predominantly had a firm-centric or inter-firm level focus (Doz, 2020; Weber and Tarba, 2014), including recent research highlighting it to be an essential capability for the uncertain and dynamic situations of crisis (Pereira et al., 2021). We extend this literature to the ecosystem-level by introducing the concept of eco-centric strategic agility, highlighting its difference from firm-centric strategic agility and displaying its importance in the context of emergencies.

Third, by integrating strategic agility and institutional theory literature, our ecosystem-level insights offer a fresh systemic lens for tackling grand challenges which are inherently complex, uncertain and evaluative (Eisenhardt et al., 2016; Ferraro et al., 2015). We highlight the importance of ecosystem-level capabilities and institutional arrangements facilitating it, in solving grand challenges emanating from emergencies. Prior research has highlighted the role of community-based responses to disasters. For instance, Majchrzak et al. (2007) discusses the role of knowledge coordination and transactive memory systems in emergent response groups during emergencies, which are cognitive institutional arrangements. Past research has also identified the importance of collective emotions and trust in supporting post-disaster institution

creation (Farny et al., 2019). We observe evidence integrating these research insights, and additionally bring close attention to the structural institutional arrangements within innovation ecosystems such as the presence of legitimating actors and purpose-specific intermediaries who foster legitimate connections between ecosystem actors. This also adds to the research on innovation management in emerging market contexts (Chatterjee and Sahasranamam, 2018).

Our study also has practical implications that are of relevance for emergencies such as COVID-19 and a post-COVID world. First, we demonstrate the importance of innovation ecosystem to be agile to respond to emergencies, which are dynamic and fast evolving. The institutional arrangements for making an innovation ecosystem agile, that we outline in the study, can offer guidance to policymakers and innovators for supporting innovation development during other emergencies. This ecosystem view will help them to understand the complexities and inter-relationships operating within the system, and guide innovation work in practice. Second, an understanding of institutional arrangements for ecosystem agility will aid ecosystem leaders to make adaptations within existing innovation ecosystems to make them more dynamic. The presence of such institutional arrangements is likely to lower the barriers between innovation ecosystem actors such as universities, industry, and government, presenting an opportunity for greater cross-disciplinary innovation development. Third, emergencies pose similar nature of challenges around data infrastructure and healthcare in other developing country contexts. Therefore, the innovations and innovation ecosystem configurations we highlight can act as a source of idea that encourage the replication of similar efforts in other parts of the world.

Limitations and Future research

Despite its important contributions, the scope of the study is limited by its focus on a single innovation ecosystem and two of its innovations. While we engaged in efforts to increase transferability of findings by offering thick descriptions (Guba and Lincoln, 1994), we cannot

reach empirical generalizations, even for India, as India is a federal system and governance of innovation ecosystems differs. Our research also has limitations around the duration for which we explored the innovation ecosystem development. Given the context of emergencies, our focus was specific to the initial period, which is most crucial for emergencies. There is a need for future research on eco-centric innovation ecosystem development beyond the initial stages, and focus on other innovation ecosystems across India, and the world, to derive more generalized insights and theoretical propositions. We offer a detailed future research agenda with regard to Theory, Methodology, and Context in Table 5.

In conclusion, emergencies can create a high degree of uncertainty and destabilize routines, requiring innovative context-specific responses. Well-designed innovation ecosystems can facilitate development of impactful innovations capable of addressing emergencies. Our study offers some guidelines on how such innovation ecosystems can be developed. Specifically, our study demonstrates the importance of enactment of eco-centric strategic agility, and cognitive, structural and symbolic institutional arrangements that can facilitate its enactment.

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Figure 1. Analysis approach for coding the data

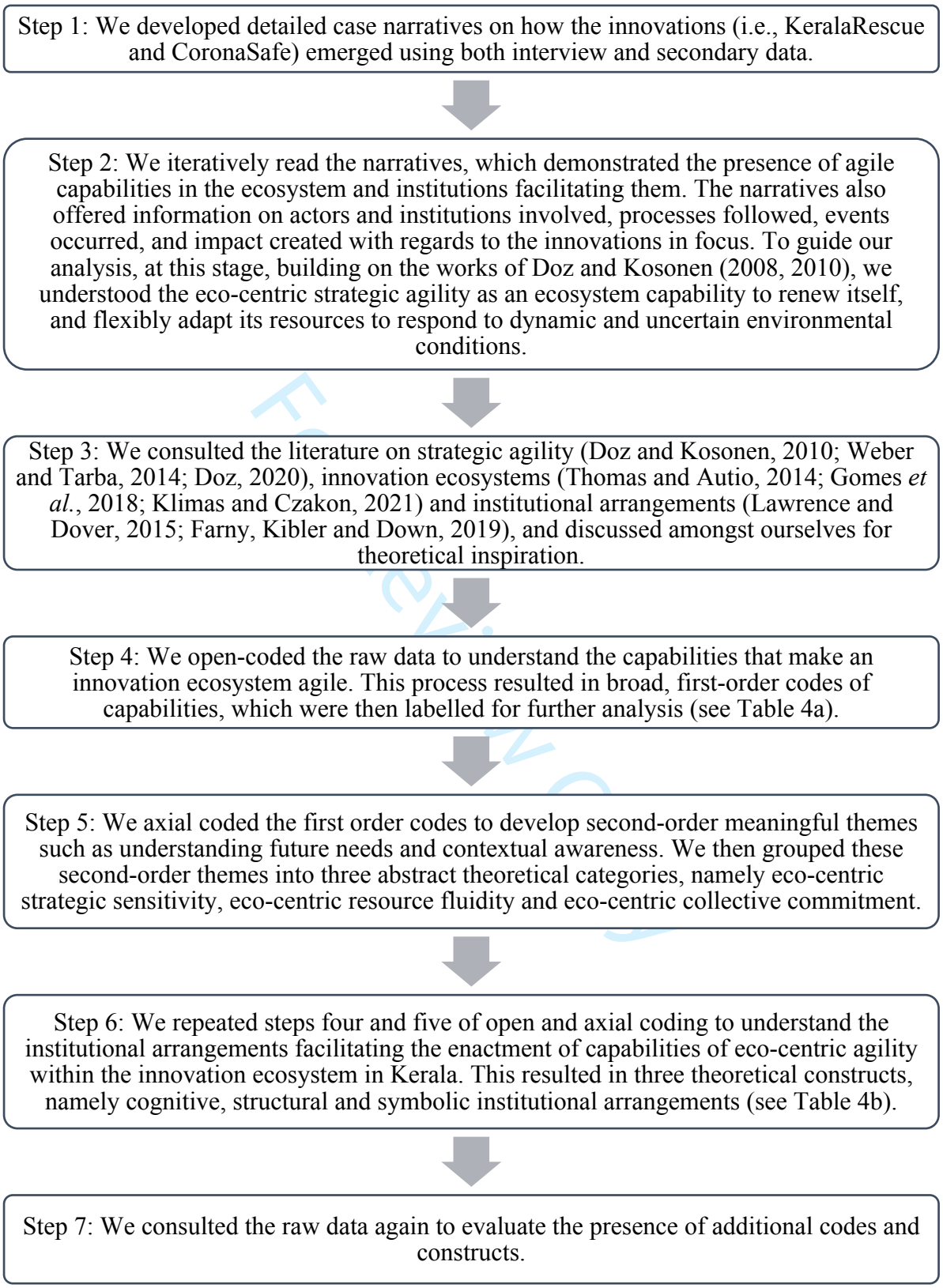

Figure 2. Conceptual model

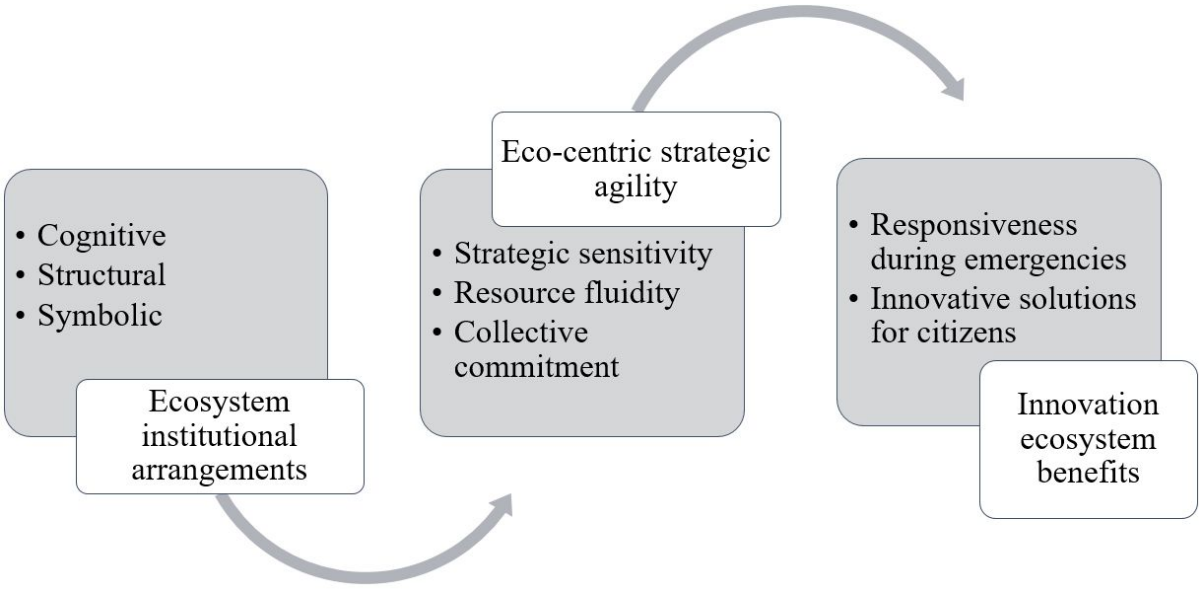

Table 1. Overview of the two case studies

	KeralaRescue	**CoronaSafe**
Region	Kerala	Kerala
Year of development	2018	2020
Aim(s)	Effective collaboration and communication for flood rescue, relief and rehabilitation, between government authorities, non-profits, volunteers and the public	1. Active collaboration with government, public, volunteers, university, and industry on COVID-19 response 2. Developing a live data system that would give information on healthcare system load, and manage technology and logistics for ambulance and relief efforts

Table 2. Data sources

Interview sources	**Total**
Volunteers part of KeralaRescue	5
Volunteers part of CoronaSafe	4
Medical experts part of the government COVID-19 team	2
Start-up founders part of the ecosystem supporting the innovations from outside	3
IEEE Kerala section committee members	2
Innovation ecosystem participants	4
Documents and other material	
Sample news reports Krishnakumar, R. (2019). Kerala flood of 2018 in list of world's worst extreme weather events in five years. Retrieved May 2, 2020, from https://frontline.thehindu.com/dispatches/article29530296.ece Nidheesh, M.K. (2020) Covid-19: How Kerala is using tech to prepare for worst-case scenario**,** Livemint**,** Retrieved May 2, 2020, from https://www.livemint.com/news/india/covid-19-how-kerala-is-using-tech-to-prepare-for-worst-case-scenario-11585572325985.html The Times of India. (2020). How Kerala managed to flatten the COVID graph. Retrieved May 2, 2020, from https://timesofindia.indiatimes.com/india/how-kerala-managed-to-flatten-the-covid-graph/articleshow/75131011.cms	
Documents developed by the project team IEEE Kerala Section. (2018). The Story Behind Keralarescue.in. Retrieved April 5, 2020, from https://ieeekerala.org/reports-2/reports/the-story-behind-keralarescue-in/ Coronasafe Network. (2020). Coronasafe Network. Retrieved May 2, 2020, from https://coronasafe.network/	
Sample government documents PIB (2020). NRLM Self Help Group network rises to the challenge of COVID-19 situation in the country, April 12, 2020, *Ministry of Rural Development*. Available at: https://pib.gov.in/PressReleasePage.aspx?PRID=1613605 Kerala Government (2020). Advisory on home quarantine for COVID-19 Available at: https://go.lsgkerala.gov.in/files/cr20200327_25941.pdf	
Sample research publications Wani, S., Yadav, D., & Verma, O. P. (2020). Development of Disaster Management and Awareness System Using Twitter Analysis: A Case Study of 2018 Kerala Floods. In *Soft Computing: Theories and Applications* (pp. 1165-1174). Springer, Singapore. Joseph, J. K., Anand, D., Prajeesh, P., Zacharias, A., Varghese, A. G., Pradeepkumar, A. P., & Baiju, K. R. (2020). Community resilience mechanism in an unexpected extreme weather event: An analysis of the Kerala floods of 2018, India. *International Journal of Disaster Risk Reduction*, 101741.	

Table 3. Interview respondents

Code name	Respondent position
KeralaRescue volunteer 1	Founding team volunteer who was managing the overall project
KeralaRescue volunteer 2	Founding team technical volunteer 1
KeralaRescue volunteer 3	Founding team technical volunteer 2
KeralaRescue volunteer 4	Founding team operations volunteer 1
KeralaRescue volunteer 5	Founding team operations volunteer 2
CoronaSafe volunteer 1	Founding team technical volunteer 1
CoronaSafe volunteer 2	Founding team technical volunteer 2
CoronaSafe volunteer 3	Founding team operations volunteer
CoronaSafe volunteer 4	Volunteer part of contact tracing support team
Medical expert 1	Heads a department at Medical College Hospital
Medical expert 2	Nodal health officer for Public Health Emergency of International Concern
Startup founder 1	Developed a contact tracing app for the government
Startup founder 2	Developing technology solutions for COVID
Startup founder 3	Leads a volunteer effort of technology experts developing solutions for COVID
IEEE committee member 1	Lead for multiple humanitarian technology projects
IEEE committee member 2	Was part of IEEE Kerala Section committee during KeralaRescue
Innovation ecosystem participant 1	Part of Kerala Startup Mission
Innovation ecosystem participant 2	Headed an association of industry professionals and startup founders
Innovation ecosystem participant 3	Part of research team that developed COVID testing related innovations
Innovation ecosystem participant 4	Part of Kudumbashree, a women empowerment initiative of the government, that supported multiple innovations during COVID

Table 4a. Coding process on eco-centric strategic agility meta-capabilities

1st order quotes	2nd order themes	Aggregate theoretical constructs
• Started as an information repository to provide authentic information • Realized that hospital and ambulances in the future were bound to be stretched, so focussed on developing a database management system for end-to-end monitoring of patient management	• Understanding future needs	Eco-centric strategic sensitivity
• Part of similar prior projects during emergencies like floods and Nipah epidemic in this region • Aware of the situation and connected with other stakeholders and projects (e.g., experts who have created solutions for emergencies like OpenStreetMap)	• Contextual awareness	
• Some of the volunteers work (operational and technical) in government facilities to directly feed in data • Volunteers use the physical facility of Indian Medical Association (IMA) • IEEE student branch colleges as collection points	• Redeploying existing resources	Eco-centric resource fluidity
• Technical team had no blueprint to start with so they had to develop solutions through discussion, feedback and iterations. • At the start, district administration had varied information sources and limited authentic inputs. Situation was changing fast and adapted based on inputs from the administration and from the ground.	• Tolerance with uncertainty and adaptation to needs	
• Everyone is connected to everyone • All inputs are heard • Joint brainstorming sessions wherein medical decisions are taken by senior doctors, administration inputs and implementation from the government side, technical team leads on platform and technical assistance.	• Integrated decision making	Eco-centric collective commitment

• Leadership team of the volunteers had past experience and reputation in humanitarian projects • Leadership team had legitimacy with other volunteers, government and related stakeholders	• Authentic leadership

Table 4b. Coding process on institutional arrangements

1st order quotes	**2nd order themes**	**Aggregate theoretical constructs**
• Prior shared experience in KeralaRescue team • Similar structure between projects • Part of pre-existing networks - Part of IEEE Kerala section student network, part of the Start-up village team • Use WhatsApp groups they already had	• Collective shared memory	Cognitive institutional arrangements
• Regular meetings, almost daily during the initial relief or urgent need period • Use Slack channels for communication, there is opportunity for technical volunteers from outside to evaluate the code and provide feedback • Developer community network is well connected, with senior developers, some who are CTOs, even, offered support that helped to quickly learn	• Collective learning	
• Chief minister endorsed the project in five days, and they then had a sudden increase in relief requests • District administration of the government provided them with inputs to be incorporated in CoronaSafe	• Legitimating actor	Structural institutional arrangements
• Participation of open source community volunteers and IEEE volunteers • Some of the volunteers work in government facilities • They came together for a social cause and not for financial reasons	• Voluntary participation	

• In the IEEE committee, they already had a co-chair for government relations who connected them with the government • CoronaSafe had links with the government through the prior chairman of a government-supported start-up incubator • They got support from Kerala IT Mission/KSUM resources and networks	• Purpose-specific intermediaries	
• As part of IEEE, worked on joined projects, thus had trust in each other • Government had confidence in the open source community and volunteers in the region, given their involvement in prior similar projects with the government	• Trust in other actors	Symbolic institutional arrangements
• Key actors had reputation of working on technology projects for community development (e.g., rural electrification, assistive healthcare) • They are driven by the need to help community	• Sense of community development	

Table 5. Future research agenda with regard to Theory, Methodology, and Context

THEORY	
Future research question	Theory/literature streams to consider
Q1: How ecosystem actors identify, accumulate and use resources and capabilities in uncertain environments? Q2: How can agile capabilities be incorporated within mature innovation ecosystems to renew themselves in dynamically changing contexts?	Strategic management theories such as dynamic capability and resource dependency (Pfeffer and Salancik, 2003; Teece et al., 1997) Adds to literature that uses dynamic capabilities lens for understanding innovation ecosystems, in contexts such as service innovation (Lütjen et al., 2019) and smart cities (Linde et al., 2021)
Q3: What is the role of eco-centric agility and other eco-centric capabilities in commons-based organizing for innovations?	Collective action theory (Ostrom, 2000) Adds to literature on peer production for innovations (Aryan et al., 2021; Benkler, 2017)
Q4: What are the innovation governance mechanisms needed during emergencies?	Experimentalist governance theory (Overdevest and Zeitlin, 2014) Adds to literature on governance during emergencies (Majchrzak et al., 2007) and agile governance (Soundararajan et al., 2021)
Q5: What are the institutional arrangements and institutional work practices needed for developing different types of innovation ecosystems such as product-, service-, or social-innovation?	Institutional theory (Lawrence and Dover, 2015; Zietsma and Lawrence, 2010) Adds to literature on institutional arrangements and work practices for ecosystem development (Dattee et al., 2018; Farny et al., 2019)
METHODOLOGY	
Future research question	Methodology to consider
Q6: How responsiveness of innovation ecosystems is maintained over different development phases? Q7: How agile capabilities evolve over time within the innovation ecosystem?	Longitudinal case studies or panel data approaches
CONTEXT	
Future research question	Contexts to consider
Q8: What is the value of agile innovation ecosystems for start-ups and innovators in non-emergency contexts?	Non-emergency contexts
Q9: Will the absence of specific institutional arrangements hinder ecosystem agility development during emergencies?	Compare case studies of successful and unsuccessful innovation ecosystem in the context of emergencies
Q10: How are developed country innovation ecosystems coping with contextual challenges of emergencies?	Developed country context

Innovation ecosystems: what makes them responsive during emergencies?

Responses to Editor and Reviewer Comments

Response to the Editor

E.1. I am pleased to say that your paper will be accepted subject to the final modifications indicated below. Therefore, I invite you to respond to the comments and revise your manuscript. In doing so please refer to our guidelines for optimizing your article for search engines - http://authorservices.wiley.com/bauthor/seo.asp.

Authors' response: We are glad to note that reviewers and you liked the revised version of the manuscript. We would like to thank all of you for detailed feedback you had provided in prior versions of the paper. We have referred to guidelines on SEO and slightly revised the abstract to optimize it for easier search identification. Thanks for this suggestion that will help to improve the visibility of the article.

E.2. The third reviewer has recommended some additional changes that I hope you will find to be helpful. I think the suggestions look very appropriate. I look forward to reading your revised paper.

Authors' response: We are glad to see that reviewers 1 and 3 are satisfied with our revisions. Reviewer 2's additional minor suggestions were quite valuable. We have revised the manuscript and responded to the comments below.

Response to the Reviewers

Reviewer: 1 Comments

R1: The authors have successfully addressed my comments and incorporated my suggestions in the revised version of the paper. I have nothing else to add.

Authors' response: Thanks a lot for your valued efforts and time towards strengthening our manuscript.

Reviewer: 3 Comments

R3: Thank you for addressing my comments and revising the manuscript. I have no more comments to add.

Authors' response: Thanks a lot for your valued efforts and time towards strengthening our manuscript.

Reviewer: 2 Comments

R2.1. Thanks for the opportunity to review this manuscript again. I am glad that the authors found my comments helpful in improving the paper. Also, I thank the authors for revising the manuscript and providing an in-depth answer to the reviewers' comments. From my own reading of the revised version of the paper I note that the manuscript has significantly improved, in terms of focus and readability. By updating the theoretical underpinning, the argumentation of the paper has been significantly strengthened. Therefore, the literature review now looks much more solid, and the discussion of the results shows a greater alignment to the theoretical frame. I also noted that the authors have re-written most of the introduction, discussion and conclusions section, an effort that I positively value. Now, the paper's contribution has gained on clarity and the research gap makes a

case for the paper. Authors have clarified the unit of analysis and better positioned the paper in the extant literature. As a result of the modifications introduced in the revised version, I believe that the manuscript is a solid analysis of the innovation ecosystem topic.

Authors' response: Thank you for your efforts and time towards closely reading our manuscript and providing feedback. Your feedback strengthened the manuscript. We are glad to note that we are now positioning the paper better.

R2.2. But, I still consider that some minor aspects should be addressed before publication acceptance. As before, I will list my minor suggestions:

The introduction has been improved. Nevertheless, at the start of the introduction, it paints a landscape so vast that the reader is unable to linked to the title. With regards the scope, readers need to know the scope of this work and evaluate how well this solution might work on innovation ecosystem topics. I suggest to use the answer to "why this way" to make the scope more precise while improving attractiveness and highlighting novelty.

Authors' response: Thanks for highlight a potentially vast landscape being painted at the start of the introduction. We have revised the introduction to highlight the research questions in the first paragraph itself, to clearly scope the objective of the paper. However, we maintain wider relevance of our topic.

R2.3. Finally, while most arguments in the discussion/conclusions section are well supported by prior work, some lines need extra fine-tuning and/or further elaboration. Conclusions bring closure, not on what the abstract announced, but on what the introduction and discussion opened.

Authors' response: Thanks for the feedback. We have fine-tuned discussion and conclusion sections.

R2.4. I hope that my comments are useful to the authors in revising and improving the manuscript.

Authors' response: Thanks a lot for your valued efforts and time towards strengthening our manuscript.