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Circular economy startups and digital entrepreneurial ecosystems

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Abstract

Circular economy (CE) is the way forward to protect an endangered environment, promote social justice, and advance sustainable and balanced regional economic development. The proliferation of the CE concept and the circular startup (CSU) boom coincides with digital transformation, a socioeconomic change propelled by the widespread adoption of digital technologies. This paper uses a systems theory perspective to study the digital entrepreneurial ecosystem's (DEE) role in CSU formation. Fuzzy-set qualitative comparative analysis (fsQCA) is used to empirically explore the configurational recipes for the presence and absence of a high CSU formation rate. The results reveal that for a high CSU formation, DEE elements, such as digital protection and access, act as critical drivers, while other DEE elements take on a supportive role. The findings also show the complementarity effects, substitution effects, and neutral permutations of DEE elements among the configurations.

KEYWORDS

circular economy, circular startup, configurational analysis, digital entrepreneurial ecosystem, fsQCA, systems theory

1 | INTRODUCTION

United Nations Environment Programme (UNEP) considers the “circular economy” (CE) as a model for a sustainable future. The concept of the CE shows great potential in addressing various sustainable development goals (SDGs) such as SDG 6, which focuses on energy; SDG 8, concerning economic growth; SDG 11, centered on sustainable cities; SDG 12, emphasizing sustainable consumption and production; SDG 13, addressing climate change; SDG 14, related to oceans; and SDG 15, which focuses on life on land (UNGA, 2019). CE startups or circular startups (CSUs) are novel ventures that follow the CE principles of reuse, renovation, refurbishment, repair, recycling, and remanufacturing (Linder & Williander, 2017). Analyzing the role of technologies in driving a CE, Gartner Inc. acknowledges that no single technology can enable organizations toward the CE; rather, multiple combinations of digital technologies, including artificial intelligence, blockchain, Internet of Things, and machine learning, can advance the CE activities (Gartner, 2020; Neri et al., 2023a, 2023b).

Widespread availability, increased affordability, and integration of digital technologies underlying the industry 4.0 revolution (Nascimento et al., 2019), coupled with legacy socio-technical systems, allow CSUs to retain, restore, and increase the value of materials in the production-consumption processes (Rusch et al., 2023). Digital technologies also help reduce maintenance and shutdown time,

Abbreviations: CE, circular economy; CSU, circular startup; DEE, digital entrepreneurial ecosystem; DIG, digital infrastructure governance; DPB, digital platform business; DTE, digital technology entrepreneurship; DUC, digital user citizenship; fsQCA, fuzzy set qualitative comparative analysis; GEDI, Global Entrepreneurship Development Institute; ICT, information and communication technology; QCA, qualitative comparative analysis; SDGs, sustainable development goals; UNEP, United Nations Environment Programme.

optimize material flows, reduce pilferage, improve traceability and transparency throughout operations (Neligan et al., 2023), facilitate urban mining (Ottoni et al., 2020), and explore new markets (Nambisan et al., 2019). According to Sussan and Acs (2017) and Song (2019), the rise of digital technologies has been facilitated by digital infrastructure, digital users, agents, and institutions collectively constituting a 'digital entrepreneurial ecosystem' (DEE).

Extant literature has investigated the DEE's components, for example, digital infrastructure (Langley et al., 2023), use of digital technology by local communities or digital user citizenship (Kurniawan et al., 2022), digital sharing platforms (Schwanholz & Leipold, 2020), adaptation, and absorption of emerging digital technologies (Kristoffersen et al., 2020) as individual drivers of circular entrepreneurship and startups. Scholars have also explored barriers that prevent the realization of the full potential of digital technologies in driving a CE, such as policy and regulatory barriers (Andersson et al., 2019; Trevisan et al., 2023), cultural and customer-related barriers (Kirchherr et al., 2018), market-related barriers (Tura et al., 2019), financial barriers (Geissdoerfer et al., 2023), technological barriers (Tura et al., 2019), and skill barriers (Sharma et al., 2023). However, the DEE elements that eliminate the above-mentioned barriers in CSUs are interlinked and often interdependent. The interdependency of DEE elements renders the investigation of individual causal drivers of CSUs insufficient and calls for the adoption of an ecosystem approach grounded in systems thinking (Bhardwaj et al., 2023; Cabrera et al., 2008), wherein the interdependent DEE components (e.g., users, agents, institutions, and infrastructure) interact and collectively drive the formation of CSUs. Literature has not investigated the impact of DEE on CSU from a systems theory perspective. Hence, the research objective of this study is to examine the role of DEE in the formation of CSUs using a systems theory perspective.

Adopting an ecosystem lens allows for considering complex configurations of ecosystem elements, including multiple actors, institutions, and often interdependent technologies (Phillips & Ritala, 2019). The interdependency among causal DEE elements suggests the possibility of multiple conjunctural causations and equifinality of outcomes (Muñoz et al., 2022). The set-theoretic qualitative comparative analysis (QCA) (Ragin, 2000, 2008) is an established methodological approach to studying multiple conjuctural causations and equifinality. Hence, we investigate the research question: *what configurations of the digital entrepreneurial ecosystem (DEE) elements affect the formation rate of circular startups (CSUs)?*

The study makes several research contributions and policy implications. First, we advance a system theory perspective to link the role of DEE by identifying configurational typologies for a high CSU formation rate. In doing so, we also establish the "circular startup formation rate" as a "sustainable entrepreneurship-oriented outcome measure" of a DEE. Second, our configurational analysis establishes that some DEE elements are critical, some are relatively more important, and a few are relatively less important. This complements the extant view that all ecosystem elements are either necessary or equally important for startup formation. Third, we identify the digital protection and digital access elements as "critical drivers" to high CSU formation. In all the configurations for the presence of high CSU formation, we found these two elements to be present either alone or in combination, while both were jointly found to be absent in all configurations for the absence of high CSU formation. Fourth, our study has practical implications for policymakers and entrepreneurs as both can leverage the knowledge of high CSU formation configurations. Policymakers can prioritize the DEE elements to transition toward a recipe that matters the most for high CSU formation and focus on dealing with the elements that constrain the emergence of CSUs in their region. Entrepreneurs looking to establish digitally enabled CSUs can assess a DEE's conduciveness for their future startup.

This paper begins with the theoretical background of systems theory, CSUs, DEE, and the role of DEE in driving CSU formation. A discussion of the data, variables, and analysis methods follows in the methodology section, concluding with an in-depth discussion of the results. Finally, the conclusion section, including research contributions, policy implications, research limitations, and the future scope of the study, has been presented at the end.

2 | THEORETICAL BACKGROUND

2.1 | Systems theory

A system is "an organized or complex whole; an assemblage or combination of things or parts forming a complex or unitary whole" (Johnson et al., 1964, p. 367). It offers a structure for perceiving the integration of internal and external environmental factors as a unified entity. Systems theory has emerged as an approach to understanding the complexity of intricate systems to offer holistic solutions (Bhardwaj et al., 2023). The fundamental system thinking principle, known as the "principle of wholeness," entails directing attention toward the entire system as a cohesive entity rather than individual components (Midgley & Lindhult, 2021). More precisely, the interaction of several components is as important as the individual elements. Thus, systems theory provides a framework for understanding the structure and behavior of a complex system (Bhardwaj et al., 2023).

2.1.1 | Systems theory and DEE

In its broadest sense, an ecosystem, also referred to as an "ecological system," encompasses a biotic community, its surroundings, and the intricate exchanges among its living and non-living elements (Tansley, 1935). System theory has been widely adopted and used in the management discipline (Johnson et al., 1964; Von Bertalanffy, 1972; Schleicher et al., 2018), entrepreneurship (e.g., Belousova et al., 2020), and entrepreneurial ecosystem (e.g., Cao & Shi, 2021). The DEE approach has its foundational basis in ecological systems theory. DEE consists of a community of institutions and actors such as regulatory institutions, policymakers, digital technology creators, digital solution providers, and digital users (individual customers and organizations), and there is a continuous exchange of digital products and services among these community members. One of the pillars of DEE, digital infrastructure governance (DIG) has been termed a "socially embedded mechanical system" consisting of human and technological elements, networks, and processes that generate self-reinforcing feedback loops (Henfridsson & Bygstad, 2013; Hussain et al., 2010; Tilson et al., 2010). Similarly, another pillar of DEE, 'digital platform businesses' (DPB), is a system consisting of platform owners, demand-side users, supply-side providers, and complementors coming together to co-create value (Hein et al., 2020). Extant literature such as Romanelli (2018) has also used a systems perspective to analyze small-medium enterprises' digital and sustainable ecosystems.

2.2 | DEE

'Digital Entrepreneurial Ecosystem' (DEE) is a comprehensive conceptual framework advanced for explicating entrepreneurship in this digital age (Song, 2019; Sussan & Acs, 2017). Sussan and Acs (2017) define DEEs as "the matching of digital customers (users and agents) on platforms in digital space through the creative use of digital ecosystem governance and business ecosystem management to create matchmaker value and social utility by reducing transaction costs." The DEE framework emerged by integrating literature on the entrepreneurial ecosystem and digital ecosystems. DEE's four pillars, as presented in Figure 1, are digital infrastructure governance (DIG), digital user-citizenship (DUC), digital platform business (DPB), and digital technology entrepreneurship (DTE) (Bejjani et al., 2023; Song, 2019).

2.2.1 | DIG

In the DEE framework, infrastructure governance concerns all contextual imperatives—policies and regulations—that govern the socioeconomic activities among entities (Sussan & Acs, 2017; Tilson et al., 2010). The three elements comprising DIG are openness, freedom, and protection. Digital openness refers to the degree of institutional support, while digital freedom reflects the degree of freedom institutions provide toward developing and advancing digital technologies. Digital protection captures protection from piracy and cybercrime provided by law and regulation.

2.2.2 | DUC

For this paper, digital users are the entities—consumers and producers—served by digital businesses. DUC concerns the proficiency and legitimacy of digital businesses among its users. A mature DUC will reflect high participation, increased acceptance, self-monitoring, and self-governance among digital users (Eisenmann et al., 2009; Sussan & Acs, 2017). Digital literacy, access, and rights are three elements of DUC. Digital literacy is the ability of citizens to use digital devices, technologies, and platforms. Digital access captures the degree of digital technology access to the citizens, while digital rights refer to the human and legal rights of using digital technology and privacy rights.

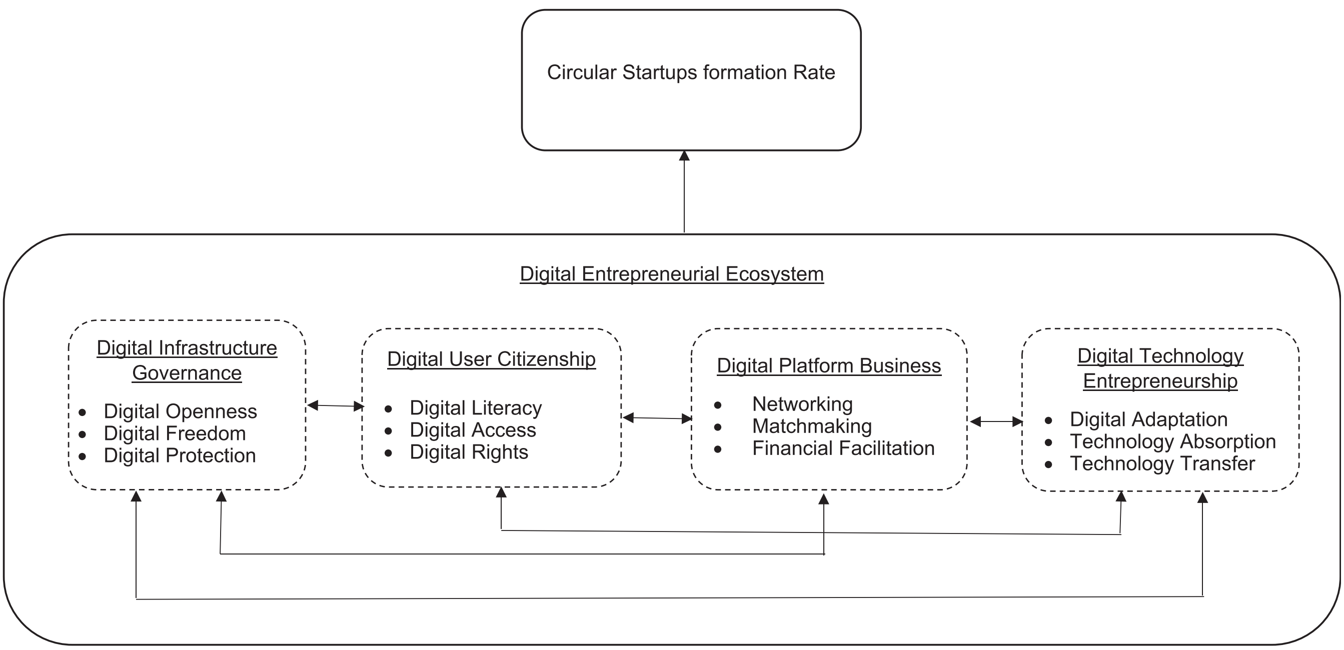


FIGURE 1 Conceptual model.

2.2.3 | DPB

DPB are technology-enabled solutions facilitating value creation and delivery among their affiliates. The central value proposition of DPBs is reducing search, transaction, and product-development costs among their affiliates (Evans & Schmalensee, 2016; Song, 2019). The three elements of DPBs are networking, matchmaking, and financial facilitation. While networking captures the strength and size of the DPB network effect, matchmaking captures the platform model effect. Digital financial facilitation reflects the "financial aspects that aid matchmaking, facilitate online financial transactions, and funding platforms for fund providers and users" (Song, 2019).

2.2.4 | DTE

DTE concerns aspects of initiatives and entities engaged in creating and delivering value-added novelty. Such value is created through technology-enabled experimentation and commercialization but not limited to new hardware, software, products, and platforms (Giones & Brem, 2017; Song, 2019). The three elements of DTE are digital adaptation, absorption, and technology transfer. Digital adaptation is the agents' essential ability to use digital technologies, while absorption refers to advanced capabilities to build products and business models using digital technologies. Digital technology transfer captures the knowledge spillover effect generated by agents while pursuing digital technological opportunities.

2.3 | CE and CSUs

A CE is based on the "closing loops" concept in which goods that have completed their useful life are converted into resources to produce new ones (Stahel, 2016). In this sense, CE is the antithesis of the "linear economy model" that dominates the traditional production and consumption model and has caused large-scale exploitation of natural resources and unprecedented environmental degradation (Lieder & Rashid, 2016). Geissdoerfer et al. (2017) have defined the CE as a regenerative system that minimizes input resources, energy leakage, and emission output and waste achieved through "slowing, closing, and narrowing material and energy loops." Thus, CE is envisaged as a substitute for the linear economy model, a solution to the increasing global climate change problem, and a tool to transition toward a sustainable future (Geissdoerfer et al., 2017). The term "circular startups" (CSUs) refers to ventures pursuing CE principles or a circular business model involving the concept of "closing loops" through reuse, renovation, refurbishment, repair, recycling, and remanufacturing (Linder & Williander, 2017).

CSUs differ from traditional startups in several ways. Traditional startups may not prioritize sustainability or CE principles as their core mission, while CSUs follow CE principles and circular business models. Traditional startups are primarily profit-oriented, focusing on growth, market share, and revenue generation (Steffens et al., 2009), while CSUs' focus remains on environmental sustainability and profit (Zucchella & Urban, 2019). The business model logic of traditional startups is commercial, while for CSUs, it combines commercial, welfare, sustainability, and institutional change (Laasch, 2018). Traditional startups' consumer orientation is generally hedonistic consumers (Migone, 2007). CSUs' consumer orientation is mostly conscious consumers (Borrello et al., 2020). Traditional startups and CSUs share similarities in some parameters, such as high innovation potential, high market uncertainty, and high difficulty in gaining legitimacy (Awana et al., 2023).

2.4 | DEE elements as a facilitator of CSU

Literature has explored multiple barriers to the advancement of CE and CSUs, for example, policy and regulatory barriers (Awana et al., 2023; Kazancoglu et al., 2021; Van Opstal & Borms, 2023), customer-related barriers (Awana et al., 2023; Berchicci & Bodewes, 2005; Singh & Ordoñez, 2016), supply chain and market-related barriers (Geissdoerfer et al., 2023; Guldmann & Huulgaard, 2020; Prendeville & Bocken, 2017), financial barriers (Kirchherr et al., 2018; Van Opstal & Borms, 2023), technological barriers (Tura et al., 2019; Van Opstal & Borms, 2023), and skill barriers (García-Quevedo et al., 2020; Mishra et al., 2022). In the following paragraphs, we describe how the elements of DEE help overcome these barriers and aid in CSU formation.

Recent studies on CE and CSUs show that the government may inadvertently hinder CE implementation through inadequate legislation and regulations for promoting and protecting circular practices (Awana et al., 2023; Van Opstal & Borms, 2023). Most countries historically lacked concrete, coherent, and strict legislation and supportive public procurement policies concerning CEs (Rizos et al., 2016). There is a lack of comprehensive, effective governmental recycling policies (Andersson et al., 2019), made worse by low awareness and doubtful attitude about the CE in government institutions (Kazancoglu et al., 2021). Certification procedures are lengthy, and there is no dedicated avenue for clarification and redressal (Rizos et al., 2016). Such regulatory stringency acts as a barrier to the establishment of CSUs. DIG refers to overcoming the inadequate and piecemeal regulatory approach to using and regulating digital technologies through comprehensive policies promoting digital openness and freedom and offering protection from piracy and cybercrime (Song, 2019). Policy and legislation that provide active support across the firm lifecycle can be crucial in developing CSUs and circular business models (Centobelli et al., 2020; Pollard et al., 2021). As highlighted by Pollard et al. (2021), some notable past instances of effective regulatory measures include the implementation of Extended Producer Responsibility rules (Ghisellini et al., 2016) and the adoption of Circular Economy Action Plans by the European Union (European Commission, 2020). Thus, high DIG helps overcome policy and regulatory barriers in CSU development.

One of the barriers to CE is the ignorance or apathy of most customers toward the environment (Awana et al., 2023; Nuβholz, 2017).

Customer insensitivity or irrationality can limit the acceptance of circular goods and services as they may focus more on owning goods than sharing. In general, most customers also prefer cheap goods irrespective of the high environmental costs associated with such goods. The CE emphasizes durable goods while evolving fashion trends for goods among consumers might also be a concern (Mont et al., 2006). Longer product life necessitates high-quality parts and product development processes, which raises costs and makes consumers less likely to buy resultant expensive products.

Additionally, some believe that recyclable materials are unsafe or unhygienic, which also lowers the social status of products made from recycled materials and those mended, reused, upgraded, or remanufactured (Berchicci & Bodewes, 2005; Singh & Ordoñez, 2016). Higher digital user citizenship removes these barriers by promoting digital literacy and digital access to consumers and citizens. A digitally literate citizenry with easier access to mobile and internet facilities can search for the pros and cons of products available in the market, including recycled products, thus alleviating undue concerns about such products' safety, quality, and aspirational value. A digitally empowered consumer can know about circular products' long-term societal and environmental benefits, thus facilitating the broader acceptance of circular products.

Supply chain and market-related barriers exist in CSU development (Geissdoerfer et al., 2023; Guldmann & Huulgaard, 2020). Circular supply chains face difficulties with logistics. A few of these are long distances to clients, disjointed supply chains that inhibit circularity, and a shortage of suitable vendors (Prendeville & Bocken, 2017). While original replacement parts may be hard to find or expensive to ship, supply chain stakeholders may lack resources and awareness, which prevents them from collaborating effectively (Sabbaghi et al., 2017). Digital multisided platforms, through their networking and matchmaking elements, may facilitate the discovery and subsequent transactions with vendors, supply chain partners, and other collaborators. Because circular firms must leverage new technology and expertise, they must incur substantial upfront investment expenses (Cantú et al., 2021). Recycling and making the material amenable to further production requires expensive quality control. This makes it challenging for businesses to identify and fine-tune the economic model for circular products (Kirchherr et al., 2018). Hence, CSUs become expensive to launch and struggle to get funding for operations (Rizos et al., 2016). Digital financial facilitation through various crowdfunding platforms helps CSUs secure capital through credit and equity crowdfunding. The digital financial facilitation element also ensures timely and seamless financial transactions at a reduced cost, thus saving significant resources for CSUs.

The advancement of the CE also faces technological and informational barriers (Tura et al., 2019). Rapid technology advancements might need frequent design modifications, preventing product recycling and reusing (King et al., 2006). According to Bechtel and Scheve (2013), the technical expertise needed to support the CE is scant. Production of high-quality remanufactured goods is still a concern in many businesses due to a lack of data, inefficient data management systems, and improper impact assessment (Jabbour et al., 2019). The efficient utilization of resources by the CSUs can be facilitated by generating, processing, and disseminating data using digital technologies (Kristoffersen et al., 2020). DTE addresses CSUs' technological and informational issues through digital adaptation, technology transfer, and digital absorption. A higher digital adaptation ensures CSUs' basic digital technologies utilization capabilities. Digital absorption takes care of the development of advanced digital capabilities of CSUs to build innovative products and business models harnessing the opportunities bestowed by modern digital technologies. After reviewing 174 studies, Liu et al. (2022) identified 13 critical digital functions of digital technologies and associated seven mechanisms that facilitate CE strategies.

The availability of skills (both organizational competencies and individual workforce skills) as a barrier to CSU has been noted by several scholars (e.g., Awana et al., 2023; García-Quevedo et al., 2020; Guldmann & Huulgaard, 2020; Mishra et al., 2022). Describing the "lack of in-house competencies" as one of the major barriers, Guldmann and Huulgaard (2020) state that the product redesign process for circular products necessitates a distinct skill set. Multiple digital skills, such as software development for servitization-based models, conducting remote diagnosis and repair on products, information technology support to consumers, and other information and communication technology (ICT) skills, are required to run a CSU (Borms et al., 2023). At the same time, the absence of a skilled and experienced workforce capable of implementing digital technologies in circular supply chains has been described as a barrier by Sharma et al. (2023). DEE element "digital adaptation" focuses on developing the basic skill set of the workforce to use digital technologies, while "digital technology absorption" is about developing the advanced skill set of entrepreneurs and managers to build new business models, digital products, and services. Thus, a higher level of digital adaptation and technology absorption helps overcome the digital skill barrier encountered in CSU development. Figure 1 represents the conceptual model depicting the interconnection between DEE elements and CSU formation rate.

3 | METHODOLOGY

To investigate our research question, "What configurations of the digital entrepreneurial ecosystem (DEE) elements affect the formation rate of circular startups (CSUs)," we adopt the QCA methodology (Ragin, 2000, 2008). QCA is a well-suited method to investigate causal complexity characterized by three features—multiple conjunctural causations, equifinality, and causal asymmetry (Fiss, 2011; Misangyi et al., 2017). Multiple conjunctural causation refers to the phenomenon where several factors can combine to contribute to a specific outcome (Schrijvers et al., 2023). It considers the potential interactions between different elements in a system that might lead to a particular outcome, also referred to as "interdependencies of causal elements." Equifinality denotes the possibility that different entities starting with different states and employing diverse recipes may achieve the same outcome (Misangyi et al., 2017). Causal asymmetry occurs when the same outcome may result from the presence or absence of a particular attribute, contingent upon its combination with other attributes

(Misangyi et al., 2017). The authors consider QCA an appropriate methodology to investigate the collective influence of multiple DEE elements on the outcome "high CSU formation rate" for the following reasons.

1. The DEE consists of 12 elements, and the different combination of these elements presents a case of "multiple conjuctural causation." Conventional linear regression analysis examines the net effect of variables on the outcome, while QCA allows researchers to examine the combined effect of multiple conditions on the outcome. Conjunctural causation can be somewhat captured through interaction effects in the linear regression models. However, interpreting an interaction involving more than two variables is very difficult (Braumoeller, 2004; Vis, 2012). In the present case, examining the interaction effect of 12 DEE elements is not feasible through conventional linear regression analysis. On the contrary, QCA allows for the straightforward investigation of multiple conjunctural causation by utilizing the combinatorial logic of Boolean algebra.
2. Further, the development level of digital technologies and the associated DEE are expected to differ in different countries depending on local idiosyncrasies. Therefore, more than one combination of DEE conditions is expected to generate the equifinal outcome, that is, high CSU formation rate. Hence, QCA is an appropriate method to investigate equifinality in the case of DEE and high CSU formation rate.
3. Linear regression analysis checks for symmetric relations between independent and dependent variables. In symmetric relations, high (low) independent variable values always correspond to high (low) dependent variable values. In asymmetric relations, both the high and low values of an independent variable, depending upon its combination with other variables, may produce the same outcome in different contexts. Woodside (2013) found that most relationships are asymmetric, reducing the explanatory ability of regression analysis. In the case of DEE, there is a low possibility that any particular DEE element will always be high in every country, but a high CSU formation rate can still occur across countries due to the presence of a high level of other DEE elements; hence, the asymmetric association is expected. Asymmetric relationships can be identified and explained using fuzzy-set qualitative comparative analysis (fsQCA).
4. QCA bridges the world of qualitative analysis (small N) and quantitative analysis (large N). QCA is a valuable method for analyzing study designs that involve small to medium-sized sample sizes, often ranging from 10 to 50 (Ragin, 2008). Researchers have too many cases within this range to retain all the case knowledge mentally. At the same time, these cases are insufficient for most standard statistical procedures (Ragin, 2008). Our medium sample size of 29 countries falls within this range and makes a perfect fit for applying QCA.

The above-noted issues of multiple conjunctural causations, equifinality, causal asymmetry, and the medium sample size of the study make the set-theory-based QCA method appropriate for this study. Accordingly, we adopt a fuzzy set variation of QCA (Ragin, 2000, 2008), that is, fsQCA, to identify configurations of DEE elements leading to a high formation rate of CSUs. fsQCA uses Boolean algebra and set methods to assess each case as a combination of causal elements and subsequently produces the configurations of causal elements (Fiss, 2007; Ragin, 2000, 2008). The flowchart of the fsQCA method is presented in Figure 2.

3.1 | Sample and data

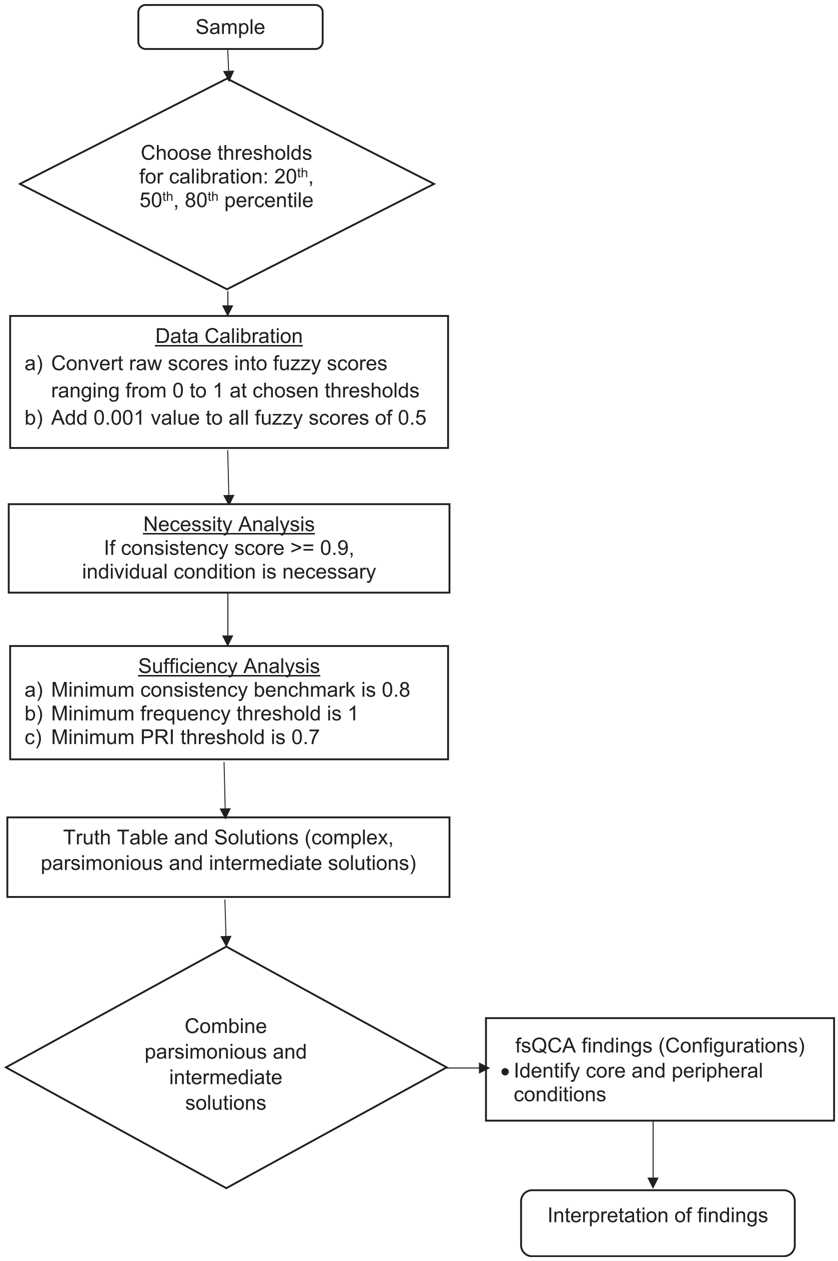
We used secondary data from 29 countries. The CSUs' formation rate has been measured as the total number of CSUs birth to the total number of startups born (in thousands) in 2021 for a given country. We obtained data on CSUs at the country level from the Tracxn database (retrieved on February 1, 2023). Tracxn is a private database that provides information on more than 10 million companies around the globe and has been widely used in research (e.g., Nigam et al., 2021; Sabarinathan, 2019). The Tracxn database allows to filter companies based on different sectors, business models, year of foundation, and country of origin. The categorization "circular economy" is available among the multiple filters, and we used this categorization to select CSUs that follow the CE. We further used country and year of foundation filters to extract the relevant CSU formation rate data.

The causal conditions are the 12 elements of the DEE: digital openness, freedom, protection, literacy, access, rights, financial facilitation, matchmaking, networking, adaptation, absorption, and technology transfer. We obtained data on DEE elements from "The Digital Platform Economy Index 2020" developed by Acs and Song, available in the Global Entrepreneurship Development Institute (GEDI) database. We lagged all causal conditions to the outcome variable by 1 year to attenuate reverse causality concerns. Finally, we used fsQCA software (version 3.1b) for our analysis. A detailed description of the outcome and causal conditions is provided in Table 1. Table 2 lists the top 29 countries in the sample with the highest number of CSUs born in the year 2021. Table 3 contains the descriptive statistics and values of calibration thresholds for all the variables. Table 4 presents the variables' pairwise Pearson correlation coefficients at the significance level of $p < .05$.

3.2 | Set calibration

In QCA methodology, calibration is an important step that converts variable raw scores into fuzzy scores ranging from 0 to 1.0 (Ragin, 2008). First, we define sets that represent outcomes (e.g., the set of countries with high CSU formation rates) and causal conditions (e.g., the set of countries with high levels of DEE elements). Through the calibration process (Ragin, 2008), we assigned each case a degree of membership in each set. We applied the direct method of calibration (Ragin, 2008) for obtaining fuzzy sets. We added a 0.001 value to all the scores of 0.5 to avoid the theoretical and methodological difficulties of analyzing sets having 0.5 scores (Fiss, 2011; Ragin, 2008). In line with the current practice (Gupta et al., 2020; Pappas & Woodside, 2021), we calibrated all variables using the 80th percentile

FIGURE 2 Flowchart of fsQCA method.



for full membership, the median for crossover, and the 20th percentile for null membership. Hence, a case (country) will fall into the set of "high CSU formation rate" when the value of the CSU formation rate for that specific case (country) is greater than or equal to the 80th percentile value of the sample. The values of thresholds are presented in Table 3.

4 | RESULTS AND DISCUSSION

4.1 | Necessity analysis

First, we conducted a necessity analysis of individual causal conditions for the outcome (Ragin, 2008). The necessity analysis determines whether any individual condition is necessary for the outcome (Ragin, 2008). If the consistency score exceeds the value of 0.90, only then is a condition considered necessary (Schneider & Wagemann, 2010). Necessity analysis in our study revealed that no individual condition (presence or absence) is necessary for either the presence or absence of a high CSU formation rate.

4.2 | Sufficiency analysis

Sufficiency analysis was conducted using Ragin's (2008) fsQCA truth table approach. We used three criteria: (a) a consistency benchmark of 0.80, (b) a frequency threshold of 1, and (c) a proportional reduction in inconsistency (PRI) threshold of 0.7 following the recommended level and standard practices (Fiss, 2011). The results of the sufficiency analysis are presented in the form of configuration charts in Tables 5

TABLE 1 List of outcome, causal conditions, and context (description and source).

Outcome/Conditions		Abbreviation	Description	Data source
Outcome	Circular startup formation rate	PERCESU	"Number of circular startups birth to total number of startups (in thousands) birth in a year"	Tracxn
Causal conditions	Digital openness	OPENNESS	"Country's institutional support to the reach and use of digital technology"	Global Entrepreneurship Development Institute
	Digital freedom	FREEDOM	"Freedom given by government and institutions to digital technology development"	
	Digital protection	PROTECTION	"Degree to which law and regulation protect from piracy and cybercrime"	
	Digital literacy	LITERACY	"Abilities of citizens to use computers, digital technology and platforms"	
	Digital access	ACCESS	"Access level of digital technology including computers and internet"	
	Digital rights	RIGHTS	"Human and legal rights that make possible citizens to use digital technology and protect their privacy"	
	Networking	NETWORK	"Network and other externality effect of multisided platform"	
	Matchmaking	MATCHMAK	"Multisided platform model effect"	
	Financial facilitation	FINFACIL	"Finance that fuels matchmaking startups, facilitate financial transactions via internet"	
	Digital adaptation	ADAPT	"Basic capabilities of entrepreneurial agents to use digital technologies"	
	Technology absorption	ABSORP	"Advanced capabilities of the agents to build new business models and/or digital products/ services"	
	Technology transfer	TRANSF	Knowledge spillover effect by agents working on discovery, evaluation, and exploitation of new opportunities brought about by evolving technologies	

TABLE 2 List of countries included in the sample.

Sl. No.	Countries	Sl. No.	Countries	Sl. No.	Countries
1	United States	11	Sweden	21	Russia
2	Canada	12	Switzerland	22	South Africa
3	Mexico	13	Denmark	23	Nigeria
4	Brazil	14	Ireland	24	Korea
5	Netherlands	15	Belgium	25	China
6	Germany	16	Estonia	26	India
7	France	17	Austria	27	Indonesia
8	Spain	18	Italy	28	Singapore
9	United Kingdom	19	Türkiye	29	United Arab Emirates
10	Norway	20	Australia		

and 6 for the two outcomes, respectively.[1] Our solution's overall consistency is 0.91, and solution coverage is 0.37 for the presence of high CSU formation configurations. For the absence of high CSU formation rate configurations, the overall consistency is 0.92, and solution coverage is 0.19.

[1]Truth tables for the solutions are available upon request.

Following Fiss (2011), we identified core conditions as those that appeared in both the parsimonious and the intermediate solutions and peripheral conditions as those that appeared in only the intermediate solution. Large black circles represent the presence of a core condition; small black circles represent the presence of a peripheral condition; large crossed circles indicate the absence of a core condition; small crossed circles indicate the absence of a peripheral

TABLE 3 Descriptive statistics and crossover points.

Variables	Mean	SD	Min	Max	20th percentile	50th percentile	80th percentile
PERCESU	2.60	2.62	0.48	13.82	0.94	1.90	3.05
OPENNESS	57.90	26.86	1.04	91.13	27.08	69.79	80.48
FREEDOM	51.34	24.87	11.91	100.00	26.66	50.82	75.05
PROTECTION	61.94	25.81	17.20	100.00	33.00	67.62	86.71
LITERACY	55.14	22.11	16.42	100.00	40.32	52.92	78.08
ACCESS	60.62	28.56	5.33	96.72	35.17	65.50	84.94
RIGHTS	51.22	26.22	6.85	81.00	18.51	59.47	78.20
NETWORK	55.15	25.68	9.32	95.35	28.35	50.47	82.30
MATCHMAK	57.17	21.55	9.42	100.00	34.55	60.96	73.98
FINFACIL	58.76	23.59	9.35	90.07	31.98	62.87	82.54
ADAPT	56.16	23.09	10.09	100.00	30.58	59.36	75.07
ABSORP	55.86	20.58	30.52	100.00	33.85	54.24	73.92
TRANSF	59.50	20.96	21.27	100.00	34.53	60.96	77.73

condition; and blank spaces indicate irrelevance of the causal condition (Ragin, 2008). Fiss (2011) states that core conditions are strongly related to outcome and hence are essential for the outcome, while peripheral conditions are weakly related to outcome and hence less critical. Building on this argument, we consider core conditions as primary drivers and peripheral conditions as supportive drivers of the DEE, leading to the high CSU formation rate.

4.3 | Typologies of DEE leading to high CSUs formation

4.3.1 | Digital infrastructure governance and platform business ecosystem

In configurations A1 and A6 (Table 5), the presence of four elements, digital openness, protection, networking, and financial facilitation, are core elements. The first two (digital openness and protection) are part of digital infrastructure governance, while the other two (digital networking and financial facilitation) are part of digital platform business. Hence, we label configurations A1 and A6 as "Digital infrastructure governance and platform business ecosystem." The United States, Canada, and Germany in configuration A1 and Australia in configuration A6 are exemplary cases of this typology.

4.3.2 | Digital infrastructure governance and digital access ecosystem

In configurations A2 and A4 (Table 5), the presence of digital protection and digital access are common core elements. The digital openness element is also present in these configurations, although as core in A2 and peripheral in A4. Since digital protection and openness are part of digital infrastructure governance, we label configurations A2 and A4 as a "Digital infrastructure governance and digital access ecosystem." Austria in configuration A2 and Estonia in configuration A4 are exemplary cases of this typology.

4.3.3 | Digital openness, access, and platform business ecosystem

Configuration A3 has the presence of digital openness, access, networking, and financial facilitation as core elements. Since digital networking and financial facilitation are part of DPB, we label configuration A3 as "Digital openness, access, and platform business ecosystem." South Korea is an exemplary case of this typology.

4.3.4 | Digital protection and platform business ecosystem

Configuration A5 has the presence of digital protection, networking, and financial facilitation as core elements. Since digital networking and financial facilitation are part of digital platform business, we label configuration A5 as "Digital protection and platform business ecosystem." Belgium is an exemplary case of this typology. Table 7 summarizes the four typologies with respective configurations and exemplar cases.

4.4 | Complementarity, substitution, and neutral permutations of DEE elements

The set-theoretic methods can explain relationships within configurations, particularly complementarity and substitution effects typically left unexplained by more conventional statistical methods (Fiss, 2011). Following Fiss (2011), Misangyi and Acharya (2014), and Furnari et al.

TABLE 4 Pairwise Pearson correlations.

Variables	PERCESU	OPENNESS	FREEDOM	PROTECTION	LITERACY	ACCESS	RIGHTS	NETWORK	MATCHMAK	FINFACIL	ADOPT	ABSORP
PERCESU	1											
OPENNESS	.4263*	1										
FREEDOM	.1834	.7383*	1									
PROTECTION	.3187	.8925*	.8753*	1								
LITERACY	.0605	.6889*	.7231*	.7539*	1							
ACCESS	.3300	.9030*	.7936*	.8670*	.8092*	1						
RIGHTS	.2728	.6904*	.8648*	.8055*	.4837*	.6700*	1					
NETWORK	.2329	.8371*	.6929*	.7896*	.6841*	.7699*	.4999*	1				
MATCHMAK	.1269	.7560*	.9150*	.8425*	.7851*	.8659*	.7819*	.6915*	1			
FINFACIL	.2065	.9042*	.7911*	.9128*	.8455*	.9087*	.6642*	.8228*	.8351*	1		
ADAPT	.1406	.8050*	.8192*	.8366*	.7659*	.8256*	.7338*	.7023*	.8766*	.8801*	1	
ABSORP	.0567	.7229*	.7671*	.8349*	.8148*	.7828*	.5324*	.7618*	.7951*	.8686*	.8052*	1
TRANSF	.1107	.7518*	.7785*	.8184*	.8876*	.8512*	.5873*	.7089*	.8787*	.8648*	.8210*	.8809*

$^{*}p < .05$.

(2021), we identify complementarity, substitution, and neutral permutations of DEE elements. For complementarity, both elements need to be present in all configurations; that is, their presence co-occurs always; for substitution, either one or the other element only needs to be present in all the configurations (Misangyi & Acharya, 2014). "Neutral permutation" occurs when configurations share the same core conditions while differing in only peripheral conditions (Fiss, 2011).

4.4.1 | Complementarity between digital protection and digital rights

Digital protection and rights generally complement each other as their presence co-occurs in all six configurations except configuration A3. Complementarity indicates that these two attributes enhance each other's contribution to the outcome and are synergistic (Furnari et al., 2021). Higher digital protection from piracy and cybercrime by law and regulation enhances citizens' human and legal rights to use digital technology and privacy rights. Modern society's judiciary and other institutions cannot enforce citizens' digital rights without appropriate digital protection laws. Higher awareness and exercise of digital rights further force policymakers to refine existing digital protection laws and regulations. Thus, digital protection and rights reinforce each other and go hand in hand. For reliable routines, circular data tracking, end customer protection, and deterring intrusions into supply chains or final products, the privacy and protection of circular chain stakeholders must be ensured (Berg & Wilts, 2018; Voulgaridis et al., 2022). Well-defined norms and standards reduce the fears over data protection and encourage data sharing between stakeholders across circular value chains (Hedberg & Šipka, 2021).

4.4.2 | Complementarity between digital networking and financial facilitation

Digital networking and financial facilitation mostly complement each other as they co-occur in four out of six configurations, producing a high CSU formation rate. Digital networking augments financial facilitation through digital platforms. A strong digital network reflects the presence of a higher number of users and agents on digital platforms, including entrepreneurs, potential business partners, investors, and consumers. There is evidence of entrepreneurs' increasing use of digital network sites such as LinkedIn, Facebook, Twitter, Instagram, and other social networking platforms to build their social capital for business purposes (Smith et al., 2017). The more the users and agents of the CE are present on digital platforms, the more digital financial transactions may materialize among them. A higher presence of well-connected users and agents on digital platforms makes it easy to transact and increases trust in digital financial transactions. CSU entrepreneurs have also started using online digital crowdfunding platforms as an alternative to bridge their venture financing gap (Guan et al., 2020; Leone et al., 2023). On the other hand, an increasing degree of digital

TABLE 5 Configurations leading to the presence of a high CSU formation rate.

	Configurations					
	A1	**A6**	**A2**	**A4**	**A3**	**A5**
Digital openness	⬤	⬤	⬤	●	⬤	⊗
Digital freedom	●	●	●	⊗	⊗	●
Digital protection	⬤	⬤	⬤	⬤	⊗	⬤
Digital literacy	●	●	⊗	⊗	●	⊗
Digital access	⨂	⨂	⬤	⬤	⬤	⊗
Digital rights	●	●	●	●	⊗	●
Digital networking	⬤	⬤	⊗	⊗	⬤	⬤
Digital matchmaking		●	⊗	●	⊗	●
Financial facilitation	⬤	⬤	⊗	⊗	⬤	⬤
Digital adaptation	●	●	●	⊗	●	●
Digital absorption	●	⨂	⨂	⨂	⨂	⨂
Technology transfer	●	⨂	⨂	●	⨂	●
Raw coverage	0.247	0.102	0.073	0.065	0.067	0.084
Unique coverage	0.146	0.007	0.027	0.027	0.026	0.019
Consistency	0.91	0.89	1.00	1.00	1.00	0.98
Cases	United States, Canada, Germany	Australia	Austria	Estonia	South Korea	Belgium
Overall solution consistency 0.91			Overall solution coverage 0.37			
Presence of core condition ⬤			Absence of core condition ⨂			
Presence of peripheral condition ●			Absence of peripheral condition ⊗			

transactions attracts more financial source providers, investors, and CSU entrepreneurs seeking funds for their startups to the platforms, thus further strengthening digital networks.

4.4.3 | Substitution between digital access and digital networking, digital access, and financial facilitation

Digital access and digital networking substitute each other as the presence of one is generally accompanied by the absence of the other in all six configurations except configuration A3. Since digital networking and financial facilitation exhibit complementarity, digital access and financial facilitation also substitute each other in all configurations except configuration A3. Substitution indicates the functional equivalence of these elements and is closely related to the concept of "equifinality" (Misangyi & Acharya, 2014). Digital networking and financial facilitation act as substitutes for digital access in configurations A5, A1, and A6, while digital access acts as a substitute for networking and financial facilitation in configurations A2 and A4. This substitution can be observed clearly in Figure 3.

4.4.4 | Substitution effect between digital matchmaking and digital absorption-technology transfer pair

Configurations A1 and A6 are similar, except for digital matchmaking and digital absorption-technology transfer pair. In configuration A6, digital matchmaking is present as a peripheral element, while the digital absorption-technology transfer pair is absent. The converse is true for configuration A1, where the digital absorption-technology transfer

TABLE 6 Configurations leading to an absence of high CSU formation rate.

	Configurations		
	B1	B2	B3
Digital openness	⊗	●	⊗
Digital freedom	⊗	●	●
Digital protection	⨂	⨂	⨂
Digital literacy	⬤	⬤	⬤
Digital access	⨂	⨂	⨂
Digital rights	⬤	⬤	⬤
Digital networking	⊗	⊗	●
Digital matchmaking	●	●	⊗
Financial facilitation	⊗	⊗	●
Digital adaptation	⬤	⬤	⬤
Digital absorption	⊗	⊗	●
Technology transfer	⊗	●	●
Raw coverage	0.082	0.111	0.096
Unique coverage	0.028	0.048	0.050
Consistency	0.90	0.87	0.91
Cases	United Arab Emirates	Singapore	France
Overall solution consistency 0.92		Overall solution coverage 0.19	
Presence of core condition ⬤		Absence of core condition ⨂	
Presence of peripheral condition ●		Absence of peripheral condition ⊗	

TABLE 7 Typologies of high circular startups (CSUs) formation ecosystems.

Typology	Primary drivers	Supportive drivers	Configuration	Cases
Digital infrastructure governance and platform business ecosystem	"Digital Openness, Digital Protection, Networking, & Financial Facilitation"	"Digital Freedom, Digital Literacy, Digital Rights, Digital Adaptation, Digital Absorption, & Technology Transfer"	A1	United States, Canada, Germany
		"Digital Freedom, Digital Literacy, Digital Rights, Matchmaking, & Digital Adaptation"	A6	Australia
Digital infrastructure governance and digital access ecosystem	"Digital Openness, Digital Protection, & Digital Access"	"Digital Freedom, Digital Rights, & Digital Adaptation"	A2	Austria
	"Digital Protection & Digital Access"	"Digital Openness, Digital Rights, Matchmaking, & Technology Transfer"	A4	Estonia
Digital openness, access, and platform business ecosystem	"Digital Openness, Digital Access, Digital Networking, & Financial Facilitation"	"Digital Literacy & Digital Adaptation"	A3	South Korea
Digital protection and platform business ecosystem	"Digital Protection, Networking, & Financial Facilitation"	"Digital Freedom, Digital Rights, Matchmaking, Digital Adaptation, & Technology Transfer"	A5	Belgium

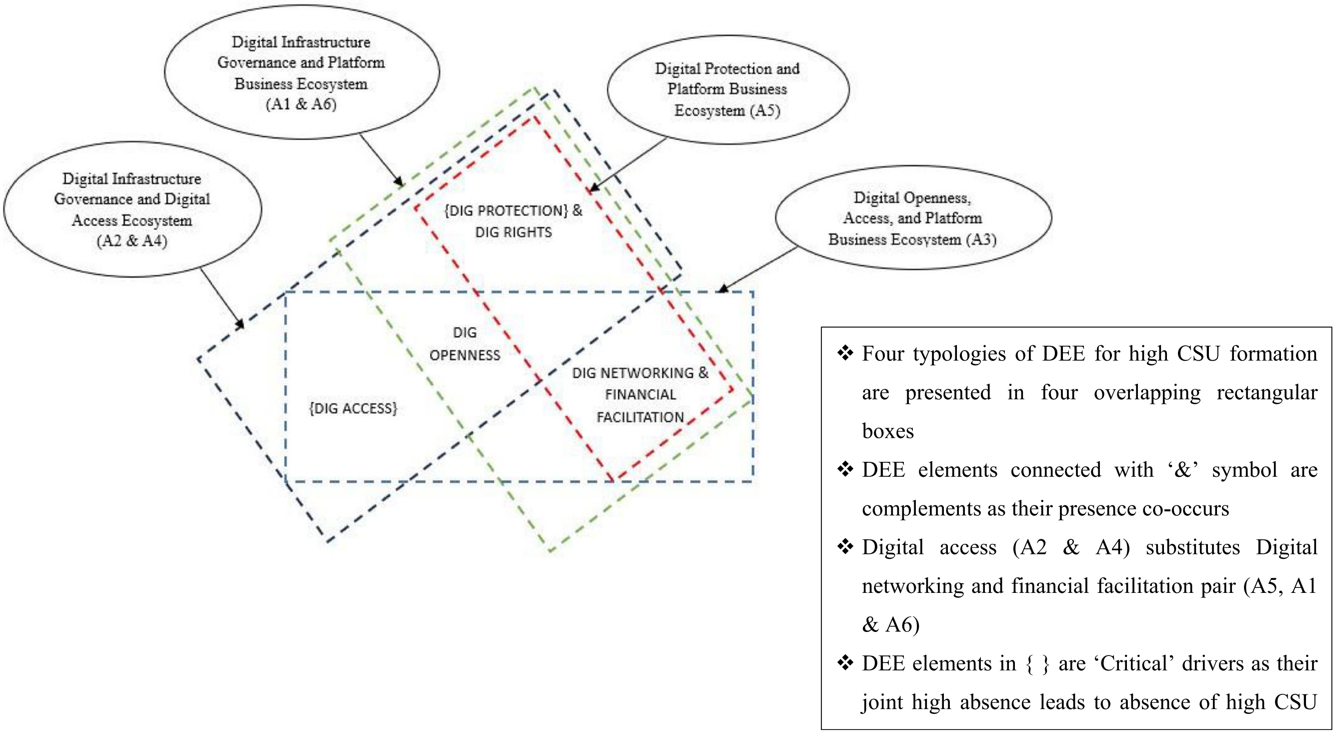


FIGURE 3 Summary of four typologies and key findings.

pair is present as peripheral elements while digital matchmaking does not matter. It indicates the "substitution effect" of digital matchmaking with digital absorption-technology transfer pair in configurations A1 and A6, ceteris paribus.

4.4.5 | Substitution effect between digital freedom-adaptation and digital matchmaking-technology transfer pair

Configurations A2 and A4 are similar, except for the digital freedom-digital adaptation and digital matchmaking-technology transfer pairs. In configuration A2, digital freedom and adaptation are both present as peripheral elements, while digital matchmaking and technology transfer are absent. The converse is true for configuration A4, where digital freedom and digital adaptation are absent, while digital matchmaking and technology transfer are jointly present as peripheral elements. It indicates the "substitution effect" of these two pairs of DEE elements between configurations A2 and A4, ceteris paribus.

4.4.6 | Neutral permutations in configurations for the absence of high CSU formation rate

All three configurations for the absence of high CSU formation rate share the same core or central conditions combinations, while they differ in peripheral conditions and hence show the "neutral permutation" (Fiss, 2011). The common core conditions among all three configurations are the presence of digital literacy, rights, and adaptation and the absence of digital protection and access.

4.4.7 | Criticality of digital protection and digital access

All three configurations leading to the absence of a high CSU formation rate in Table 4 reveal that the combined absence of a high degree of digital protection and digital access leads to the absence of a high CSU formation rate. These two elements are the primary drivers (alone or in combination) for the high formation of CSUs. Out of six configurations leading to a high CSU formation rate, digital protection is one of the primary drivers in three configurations (A1, A6, and A5). In one configuration (A3), digital access is one of the primary drivers, and in two configurations (A2 and A4), both digital protection and access are primary drivers. This finding aligns with the literature's emphasis on digital protection for a well-functioning CE (e.g., Liu et al., 2022; Voulgaridis et al., 2022). Ensuring the privacy and protection of circular chain stakeholders is essential for establishing reliable procedures, monitoring circular data, safeguarding end users, and preventing unauthorized access to manufacturing, supply chains, and final products or services (Voulgaridis et al., 2022). Digital access to citizens has been described as a critical driver of CSUs by Tunn et al. (2020, 2021). Increased digital access through smartphones has promoted circular business models through access-based product-service systems such as mobility sharing (Tunn et al., 2020, 2021).

4.5 | Robustness checks

We conducted three robustness checks for the outcome "presence of high CSU formation rate" per recommended best practices (Greckhamer et al., 2018). First, we changed the consistency to a higher threshold of 0.85 and ran the analysis. We obtained the same configurations with the same overall solution consistency of 0.91 and overall solution coverage of 0.37. Second, we increased the PRI threshold by 5% and observed no change in the original configurations, consistency, and coverage scores. Third, we changed the calibration threshold for the outcome variable to the 85th percentile, median, and 15th percentile for full membership, crossover, and null membership. We obtained five configurations A1–A5 instead of the original six configurations, with an overall solution consistency of 0.89 and a solution coverage of 0.435. When we changed the calibration threshold for the outcome variable to the 75th percentile, median, and 25th percentile, we again obtained five configurations A1–A5 with an overall solution consistency of 0.89 and a solution coverage of 0.38. Thus, we find minor changes in the results on both occasions of calibration threshold change; however, the interpretation of the findings remains fundamentally unchanged.

5 | CONCLUSION

Employing the lenses of "systems theory," the current study examines the combined impact of different DEE components on CSU formation. To answer the research question, what configurations of the DEE elements affect the formation rate of CSUs, we provide multiple configurational paths based on fsQCA. Using an fsQCA (Ragin, 2008) on cross-sectional data from 29 countries, our analysis reveals various ecosystem types emerging from diverse combinations of DEE elements that lead to the high formation of CSUs. We found six configurations for the presence of a high CSU formation rate and three for the absence of a high CSU formation rate. We show that even though all the DEE elements contribute to the formation of CSU, some DEE elements take a primary role, while others act as supportive drivers for a high CSU formation rate. This finding is consistent with recent research on DEE by Torres and Godinho (2022) and Venâncio et al. (2023). Torres and Godinho (2022) concluded that some DEE elements should be at a high level while it is enough for other elements to reach a minimum threshold to generate a higher number of digitally enabled unicorns. Venâncio et al. (2023) investigated the role of DEE in startups' time to unicorn and concluded that although all factors of DEE contribute to the outcome, some are more relevant than others.

We find complementarity effects between digital protection and digital rights and between digital networking and financial facilitation. Among most configurations, digital access substitutes digital networking and financial facilitation. We also observe "neutral permutations" among configurations that lead to the absence of high CSU formation. We find two DEE elements, that is, digital protection and access, as critical drivers whose joint absence may lead to the absence of high CSU formation. This finding validates the argued role of "digital protection" in a CE by Liu et al. (2022) and Voulgaridis et al. (2022) and the role of "digital access" in driving circular business models by Tunn et al. (2020, 2021). We summarize our results in Figure 3.

5.1 | Research implications

Our study contributes to the literature on the CE, CSUs, and DEE by examining the DEE conditions that drive CSU formation. Our study empirically discovers the presence of multiple configurational paths leading to a high CSU formation rate, providing evidence of multiple conjunctural causation and equifinality. To the best of our knowledge, our study is one of the first to analyze the impact of DEE elements on CSU formation using QCA methodology. Thus, our study extends the application of "systems theory" to explore the phenomenon of CSU and the role of DEE in CSU formation from an integrative perspective. Traditional literature has argued that all ecosystem elements are necessary (Isenberg, 2010; Stam & Van de Ven, 2021) and consequently ignored exploring ecosystem elements' relative importance for the output. Complementing the traditional literature, our results reveal that not all DEE elements are equally important. The results show that some elements are critical, some are relatively important, and a few are relatively less important. Our empirical analysis reveals digital protection and digital access as the two critical elements of DEE and identifies their joint absence as a "bottleneck" to high CSU formation.

We also expand the current stream of research that treats unicorns as performance measures of the DEE (e.g., Bruns et al., 2017; Torres & Godinho, 2022) by proposing CSUs as a "sustainable entrepreneurship-oriented outcome measure" of a DEE. In doing so, we respond to the call for research that asks for going beyond the economic manifestations and valuation of startups to include the societal and ecological performance of ventures, including CSUs.

5.2 | Implications for policymakers and entrepreneurs

A DEE can foster the emergence of CSUs through multiple configurational paths. This study shows what combinations of DEE elements influence the formation rate of CSUs at the country level. Although all the elements of DEE facilitate CSU formation, policymakers should prioritize the elements that matter the most for high CSU formation and focus on the elements that constrain the emergence of CSUs. We have shown that digital protection and access are the two critical elements of the DEE whose combined absence can lead to a relatively lower formation rate of CSUs; hence, these two DEE elements are too critical for policymakers to ignore. In attaining a high formation rate of CSUs, we have also shown possible substitution effects of DEE elements, which provide options for policymakers to choose among the substitutes depending upon the country's strengths and weaknesses. The critical thing to remember is that while focusing on one substitute over another, the less prioritized elements must not be ignored entirely. A minimum threshold of all the elements having their presence in the configurational recipe must be maintained.

Policymakers can start by assessing the present state of their region's DEE and then find the configuration closest to their existing level of DEE. This comparison would help identify the DEE elements that need improvement to achieve the desired configuration, leading to high CSU formation. Young entrepreneurs looking to establish digitally enabled CSUs can take advantage of the knowledge of multiple configurational pathways to assess a digital ecosystem's attractiveness and suitability to set up and operate their enterprise. Transnational entrepreneurs (Portes et al., 2002) looking to internationalize their future operations and searching for suitable foreign locations conducive to the digitally enabled CSU can also benefit from our study.

The top five industrial sectors with CSUs are waste management, food and agriculture, energy, chemicals and materials, and consumer goods, according to the Tracxn database. These sectors have a lot of new value-creation and appropriation opportunities by adopting circular practices, as evidenced by the increasing number of CSUs in these sectors. First, these sectors' leading players and industrial associations should proactively focus on strengthening the DEE elements, especially digital access and protection. Second, rather than being competitive, the firms in these sectors can explore collaborative opportunities for the application of digital technologies and digital ecosystem development. For example, a large incumbent firm in the food and agriculture sector can collaborate with a CSU to explore solutions to product/raw material wastage in its supply chain. An incumbent in the chemicals and materials sector can include CSU extracting metals and chemicals through recycling as its supplier. In summary, in the industrial sectors where ample value creation and capture opportunities exist through circular strategies, the incumbents and startups should be more collaborative in fostering a digital entrepreneurial ecosystem. Further, the multiple players in these sectors should come together to shape common norms and standards on "digital technology use" in their sector and work with regulators to remove the regulatory barriers and facilitate new regulations promoting circularity and digital governance.

5.3 | Limitations and future research

Our study has a few limitations. Our study includes 29 countries due to limited data availability for the DEE in the GEDI database. Our dataset could not include a higher number of countries from South America and African continents. Given differing levels of DEE development in these continents, different configurations of DEE elements leading to high CSU formation can be expected. Due to the cross-sectional nature of our data, the present analysis shows a snapshot of DEE configuration. Future research using longitudinal data can explore how these DEE configurations evolve over time for a broader geographical context. Further, to develop a comprehensive understanding of the differential impact of DEE on circular and non-CSUs, future research may include data on both types of startups. Our study has analyzed the DEE and CSU relationship at the country level; future studies may benefit from looking at more granular geographical units such as states and cities. We have used the QCA method, and one acknowledged limitation of QCA is its sensitivity to the number of conditions. As QCA produces several configurations of causal conditions, its solution is sensitive to the range of causal conditions included. Inclusion or elimination of any condition may produce significantly different solutions (Ordanini et al., 2014). Finally, we have limited our causal conditions to DEE elements only. Future studies may combine DEE elements with startup-level factors to see their holistic impact on the CSU formation rate.

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CONFLICT OF INTEREST STATEMENT

There is no conflict of interest among the authors.

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