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From effectuation to circular value creation: The knowledge pathways of open innovation and sustainability-oriented learning

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ABSTRACT

Firms looking to transition toward the circular economy often confront persistent uncertainty while striving to balance innovation, sustainability, and profitability. This study explores how effectuation – conceptualised as higher-order entrepreneurial logic – is linked to circular value creation (CVC) through knowledge-based mechanisms and how a paradox mindset influences these relationships. Anchored in Effectuation Theory, the Knowledge-Based View (KBV), and Paradox Theory, the research advances an integrated model that connects entrepreneurial cognition, organisational learning, and circular innovation. Drawing on data from 294 professionals across manufacturing and technology sectors, the study applies Partial Least Squares Structural Equation Modelling (PLS-SEM) to examine the proposed relationships. The study further integrates Tensor Product (TP) modelling to generate Takagi-Sugeno (TS) fuzzy rules based on the resulting PLS-SEM model, providing a complementary rule-based characterisation of the key SEM-identified associations that converge on CVC. The findings show that Effectuation is significantly associated with both Open Innovation Capability (OIC) and Sustainability-Oriented Learning Capability (SOLC), which operate as parallel and sequential pathways linking Effectuation with Circular Value Creation. These findings suggest that the relationship between effectual reasoning and circular outcomes is partly associated with capability-based mechanisms rather than deliberate strategic design. Moreover, the Paradox Mindset strengthens the Effectuation–SOLC–CVC pathway, indicating that paradoxical cognition is associated with a stronger sustainability-oriented learning pathway under conditions of uncertainty. Using the TP modelling approach, the study derives a compact set of seven fuzzy rules that reconstruct the PLS-SEM results to a meaningful degree. These rules also reveal the key value ranges within the OIC and SOLC latent dimensions that are most strongly associated with different levels of CVC. The study enriches theoretical understanding by linking entrepreneurial cognition, knowledge-based capability development, and paradoxical thinking within the domain of the circular economy. From a practical standpoint, it underscores the value of nurturing effectual reasoning, fostering open collaboration, and embedding sustainability-oriented learning systems that help firms transform uncertainty into regenerative value.

Introduction

Organisations are increasingly moving toward more sustainable operations and away from the linear model of 'take-make-dispose' (Awan & Sroufe, 2022; Jesus & Jugend, 2023). The concept of circularity refers to reducing, retaining, and restoring resources and requires these principles to be integrated into the design of organisations and innovation processes (Nikolaou et al., 2021; Showkat & Nagina, 2025; Tambovceva et al., 2021). However, changing from a linear to a circular model requires more than just implementing new technologies,

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as organisations must adapt their way of thinking and their ability to acquire, retain, assimilate, and apply information management in a manner that fosters sustainable practices (Audretsch & Fiedler, 2024; Ul-Durar et al., 2023). As a result, major questions remain concerning what organisational capabilities and decision-making approaches enable businesses to implement circularity.

Open Innovation (OI) has become an important facilitator of circular economy (CE) developments because it allows companies to gather, combine, and develop knowledge from sources outside their own organisations (Chesbrough, 2024; Chesbrough et al., 2024). OI is also increasingly understood as a dynamic capacity that combines circular transformation through collaboration and knowledge exchange with suppliers, start-ups, universities, and other ecosystem participants (Abbate et al., 2022; Ferreira & Teixeira, 2019; Kreiling & Paunov, 2021). In this respect, Open Innovation Capability – the capacity of an organisation to manage its inward and outward flows of knowledge – can become a very important supporting element in circularity implementation through cooperation in creating new solutions and closing resource loops (Sahabuddin et al., 2023; Ullah et al., 2025). However, prior research has largely examined OI and CE from structural or ecosystem perspectives, offering comparatively limited insight into how organisational-level entrepreneurial reasoning relates to the development of OIC under uncertainty surrounding sustainability transitions (Nikolaou et al., 2021; Rosa et al., 2023).

Sustainability-Oriented Learning Capability represents an important pathway through which firms can embed circularity within organisational thinking and routines by internalising sustainability-related knowledge (Showkat & Nagina, 2025; Zgrzywa-Ziemak & Walecka-Jankowska, 2021). However, the antecedents of learning behaviours that support sustainability-oriented innovation remain underexplored. In particular, limited attention has been devoted to understanding how entrepreneurial reasoning logics, such as effectuation, are associated with firms' willingness to learn, adapt, and co-create sustainability solutions through open knowledge exchange. Effectuation Theory explains how decision-makers act under uncertainty by leveraging available means, forming stakeholder relationships, and responding to contingencies rather than attempting to predict future outcomes (Sarasvathy, 2001). These characteristics make effectuation a particularly relevant theoretical lens for examining organisational responses to uncertainty in sustainability transitions.

Circular economy transformation extends beyond process redesign and intentions to pursue circular innovation; it also concerns the value generated through circular practices. Circular Value Creation captures the extent to which firms generate economic, environmental, and social value through closed resource loops, stakeholder co-benefits, and long-term engagement (Sahabuddin et al., 2023). Although prior research has linked CE adoption with sustainable performance, comparatively less attention has been devoted to the knowledge-based mechanisms through which firms translate open knowledge exchange and organisational learning into circular value outcomes (Sahabuddin et al., 2023; Ullah et al., 2025). This capability-based gap warrants closer examination of the knowledge pathways associated with firms' efforts to navigate uncertainty while pursuing circular value creation.

CE transitions often require organisations to deal with contradictory pressures between financial efficiency and ecological duty, short-term results and long-term viability, and practice and risk management (Dagilienė & Varaniūtė, 2023; Rosa et al., 2023; Tosi et al., 2024). In such tension-filled environments, the Paradox Mindset – the cognitive capacity to embrace and engage constructively with contradictions rather than seeking to eliminate them – may represent an important boundary condition that shapes how decision-makers employ effectual reasoning in relation to innovation and circular outcomes (Griffin et al., 2022; Khan et al., 2025; Yang et al., 2024). Because circular transitions require organisations to accommodate competing demands simultaneously, the paradox mindset may strengthen particular effectuation-related pathways by enabling decision-makers to accept uncertainty, manage dualities, and engage in open-ended solution exploration (Agwu & Oftedal, 2025).

The literature increasingly recognises the role of OI and learning in enabling the circular transition, yet three critical gaps remain. First, there is a limited understanding of how entrepreneurial decision-making logic shapes the development of circular enablers such as OIC and SOLC. Second, the role of effectuation as a knowledge-based logic that mobilises open collaboration and sustainability learning remains underexplored in the CE context. Third, the influence of cognitive conditions, such as a paradox mindset, on how firms leverage effectuation for circular outcomes is not well understood.

Accordingly, this study addresses the following research questions:

RQ1: How does effectuation influence circular value creation in firms pursuing sustainability-oriented innovation?
RQ2: Do open innovation capability and sustainability-oriented learning capability mediate this relationship, both individually and sequentially?
RQ3: Do paradox mindsets moderate the direct and indirect relationships between effectuation and circular value creation?

To address these questions, we developed and empirically tested a hierarchical model in which Effectuation is conceptualised as a second-order reflective–reflective construct comprising five foundational dimensions: Means Orientation, Affordable Loss, Partnership Orientation, Leveraging Contingencies, and Control Orientation (Chandler et al., 2011; Sarasvathy, 2001, 2008). Drawing on the Knowledge-Based View, we propose that Effectuation is associated with OIC through collaborative resource recombination and with SOLC through experiential learning and adaptation (Braun & Mauer, 2022; Chesbrough, 2024). We further examine the Paradox Mindset as a boundary condition shaping selected direct and indirect pathways, thereby accounting for decision-makers' capacity to engage with competing innovation and sustainability demands during CE transitions.

This study makes four principal contributions. First, it extends Effectuation Theory to the circular economy context by examining how entrepreneurial reasoning under uncertainty is associated with circular value creation. Second, by integrating Effectuation Theory with the Knowledge-Based View, the study identifies OIC and SOLC as complementary capability-based pathways linking entrepreneurial cognition with circular value outcomes. Third, it introduces the Paradox Mindset as a boundary condition and demonstrates that its role is selective rather than uniformly beneficial across effectuation-related pathways. Fourth, by complementing PLS-SEM with TP-based fuzzy rule extraction, the study provides an additional interpretability layer that identifies value ranges within key latent capabilities associated with different levels of CVC. Collectively, these contributions offer a more integrated understanding of how entrepreneurial cognition, organisational knowledge capabilities, and paradoxical thinking are associated with circular transformation under conditions of uncertainty.

Literature review

Theoretical background

The study makes use of Effectuation Theory as the basis for the research. According to Effectuation Theory, entrepreneurs and members of organisations respond to uncertainty not by trying to predict the future, but by using the capabilities and resources available at the time. According to Chandler et al. (2011) and Sarasvathy (2001), Effectuation Theory is based on five principles that work together to provide an adaptive and creative approach to decision-making in an environment of ambiguity. The ‘Bird-in-Hand’ principle suggests that people should work with their available resources, skills, and networks as a starting point for their entrepreneurial ventures. ‘Affordable loss’ suggests that entrepreneurs should invest only what they can afford to lose in any

particular venture. 'Crazy quilt' stresses the importance of establishing partnerships and collaborations in the early stages of the entrepreneurial process through the co-creation of value. 'Lemonade' recognises that unexpected events can be viewed as opportunities for new beginnings. The 'Pilot-in-the-Plane' principle highlights how individuals and organisations shape the future through decisions and actions, rather than through prediction alone. Together, the five principles of Effectuation Theory represent a flexible, experimental, and collaborative approach to the development of innovative products and services in uncertain and highly dynamic business environments.

The Knowledge-Based View posits that knowledge is a strategic resource that enables firms to achieve competitive advantage (Grant, 1996; Spender, 1996). Thus, effectuation is an important engine of knowledge transfer, collaboration, and experiential learning in organisations (Showkat & Nagina, 2025; Zgrzywa-Ziemak & Walecka-Jankowska, 2021). By helping organisations recombine and use resources and engage diverse stakeholders through partnerships, effectuation creates opportunities to develop new capabilities and respond dynamically to changing conditions. As a result, effectuation and related models of cognitive logic are becoming even more important for the transition to a circular economy (Huang & Zhou, 2025; Jesus & Jugend, 2023). Organisations employ Open Innovation Capability to harness and utilise sustainability-focused knowledge that is available within their external ecosystems, and Sustainability-Oriented Learning Capability to embed this knowledge into organisational processes as a regenerative practice (Ul-Durar et al., 2023). Together, these capabilities facilitate the application of entrepreneurial thinking to generate innovative and regenerative value within the circular economy. Although sustainability-oriented learning capability and absorptive capacity share certain conceptual similarities, they are distinct constructs. Absorptive capacity is concerned with an organisation's ability to obtain, incorporate, and utilise outside knowledge. In contrast, sustainability-oriented learning capability centres on developing routines for learning through environmental and social knowledge to develop organisational processes and innovative methods.

Paradox theory emphasises the inherent complexities of how companies pursue circularity in their strategies, including both cognitive and behavioural aspects (Smith & Lewis, 2011). Companies that wish to strike a balance between profit and sustainability, efficiency and experimentation, and control and flexibility must have what is referred to as a 'paradox mindset' – the capacity to view, accept, and engage with conflicting demands in a productive way, according to Smith and Lewis (2011). Individuals with a paradox mindset use the tensions arising from competing demands as a source of creativity, innovation and learning (Smith et al., 2017).

By synthesising these theoretical perspectives, this research proposes Effectuation as a cognitive orientation associated with OIC and SOLC and, through these capabilities, with circular value creation. The Paradox Mindset is further proposed to condition the relationships through which effectual reasoning is associated with knowledge-based capabilities and circular value creation. Together, these theoretical perspectives provide a multi-theory framework linking entrepreneurial cognition, organisational learning, open innovation, and paradoxical thinking in the context of circular transformation.

Conceptual justification of the mediating and moderating mechanisms

Effectuation Theory explains how firms make decisions under conditions of uncertainty, but it provides limited insight into the organisational mechanisms that may link effectual reasoning with circular value creation. To address this, the present study draws on the Knowledge-Based View, which suggests that strategic outcomes emerge through the development and deployment of organisational knowledge capabilities. Within this perspective, Open Innovation Capability and Sustainability-Oriented Learning Capability are conceptualised as complementary mediating mechanisms linking entrepreneurial cognition with circular value creation.

OIC refers to a firm's capability of obtaining, connecting, and combining knowledge acquired from outside stakeholders in discovering circular opportunities and developing innovations collaboratively. However, external knowledge cannot generate stable circular value on its own unless organisations learn from it and make it a part of their processes. SOLC serves this purpose as it makes companies adopt, redefine, and utilise knowledge about sustainability in the redesign of their products, processes, and business models. Overall, this capability can explain the connection between effectuation and circular value creation.

Including Paradox Mindset as a moderating variable is grounded in the understanding that circular economy transitions demand that organisations navigate conflicting requirements at the same time, such as commercial performance versus sustainability, or stability versus innovativeness. Although effectuation provides a rationale for acting in uncertain situations, the Paradox Mindset refers to the mental capability to understand and manage conflicting requirements. Therefore, it is expected to affect the degree to which effectual reasoning translates into capability building and circular value creation.

Open innovation capability and effectuation

Effectuation is an entrepreneurial way of thinking that allows businesses to operate under conditions of uncertainty by utilising what is already available, committing only to risks that are deemed acceptable, collaborating with stakeholders early in the process, and treating unexpected events as opportunities rather than limitations (Chandler et al., 2011; Sarasvathy, 2001). Organisations that use effectuation place the greatest value on learning through experimentation, iterative processes, and flexible goal setting, rather than predicting what may happen through advanced planning. Effectual organisations focus on working with their stakeholders and learning from one another as they develop ideas into products and services, rather than relying on a single path or linear framework for decision-making (Braun & Mauer, 2022; Roach et al., 2016).

The principles of effectuation closely align with those of open innovation (OI), which is based on the notion of creating value collaboratively with other organisations through the exchange of ideas and resources (Chesbrough, 2024; Chesbrough et al., 2024). OI is based on the belief that for organisations to innovate successfully, they need to develop collaborative relationships with other organisations and actively share knowledge, both internally and externally. Those capabilities related to collaborative innovation constitute the foundation of an organisation's ability to innovate (Dabrowska, 2018; Yazdanparast et al., 2010).

The term Open Innovation Capability describes a company's ability to collect and utilise external resources through a systematic approach of acquiring, sharing and combining knowledge with external partners to develop innovative products and services, which in turn is linked to mutual benefits between both parties involved in the collaboration (Hosseini et al., 2017; Lichtenthaler & Lichtenthaler, 2009).

Effectual reasoning and Open Innovation Capability conceptually converge in the Crazy Quilt principle, which focuses on establishing partnerships and co-creating with stakeholders, while the Bird-in-Hand principle emphasises resource reuse and recombination based on the means available to a company. Furthermore, the Lemonade principle reflects the role of contingencies and the ability of open innovation systems to leverage flexibility through collaboration among different parties across markets (Hensel et al., 2021).

In addition to their ability to adapt quickly when faced with uncertainty, companies that operate according to effectual reasoning also tend to be more likely than their traditional business counterparts to engage in collaborative innovation ecosystems. As a result, these companies are more likely than others to leverage a wide variety of external sources and experts to create new solutions that go beyond their own

organisational boundaries. Thus, we propose:

H1: A positive association exists between effectuation and open innovation capability.

Sustainability-Oriented learning capability and effectuation

Firms that effectuate are characterised by their ability to use uncertainty as a source of experimentation and iterative learning rather than as a restriction or constraint, typically learning through direct experience (Chandler et al., 2011; Sarasvathy, 2008). The adaptive and experiential characteristics of the effectuation process closely resemble those of sustainability-oriented learning capability within an organisational context, which involves the acquisition, assimilation, and transformation of sustainability-related knowledge. (Claro & Esteves, 2021; Ortiz-Avram et al., 2024). Because effectuation is inherently iterative, it is conducive to experiential learning cycles through which firms can adapt their strategies based on real-time stakeholder input and emerging contingencies (Dawa & Marks, 2024; Haneberg, 2019).

The principle of Affordable Loss is a key part of effectual reasoning, as it emphasises the trial-and-error learning organisations may undertake when applying it. Therefore, organisations can experiment on a small scale without taking too much risk financially or damaging their reputation. Such calculated experimentation may facilitate the development of sustainability-related insights and learning routines relevant to sustainability-oriented innovation (Dagilienė & Varaniūtė, 2023; Tosi et al., 2024). Thus, we propose,

H2: A positive association exists between Effectuation and Sustainability-Oriented Learning Capability.

Circular value creation and effectuation

CVC reflects an organisation's ability to generate interconnected economic, environmental, and social value through resource circulation, product-life extension, and stakeholder-enabled regeneration (Sahabuddin et al., 2023; Tapaninaho & Heikkinen, 2022). Effectuation is an approach to circular transformation that provides a cognitive and strategic framework through which organisations view transformation not as a linear, pre-planned event but as a continuous opportunity for development and adaptation to changing conditions. By focusing on the reconfiguration of existing resources to create new value, leveraging partnerships to share knowledge and resources, and accepting that uncertainty is inherent to business, organisations can explore innovative pathways for the realisation of sustainable value (Schuld, 2022).

The Bird-in-Hand principle emphasises the creative application of an organisation's existing resources (e.g., materials, skills, and networks) to identify their untapped regenerative potential. Similarly, the Lemonade principle emphasises that organisations can use past sustainability failures to drive new circular innovations (Chandler et al., 2011; Dawa & Marks, 2024). The effectuation model, which encourages organisations to pursue an ecologically and economically sustainable agenda through collaboration with multiple stakeholders to co-create sustainable circular ecosystems across the full life cycles of products and materials (Chandler et al., 2011; Woldesenbet Beta, 2025), illustrates the outcome of this partnership-oriented philosophy.

Based on these mechanisms, it appears that companies that use effectuation as a reasoning approach have a greater capacity to deal with uncertainty and explore new ways of working with partners to generate regenerative value. Thus, we propose that effectuation provides opportunities to advance circularity in the pursuit of sustainability. Accordingly,

H3: A positive association exists between Effectuation and Circular Value Creation.

The mediating role of open innovation capability

Open Innovation Capability is closely aligned conceptually with effectuation, since both emphasise co-creation, collaboration, and knowledge combination as approaches to innovation under conditions of uncertainty. Firms that use effectual reasoning rely on their current means to develop opportunities through partnerships, highlighting the importance of collaboration and resource integration (Braun et al., 2017; Chandler et al., 2011). This outward orientation facilitates boundary-spanning behaviours that are central to OIC, as firms interact with external actors to access complementary knowledge, ideas, and resources (Jesus & Jugend, 2023).

At the same time, circular value creation depends on firms' ability to leverage knowledge from a variety of ecosystem partners, including third-party logistics providers, reverse logistics providers, resource recovery providers, and extended product life-cycle partners (Sahabuddin et al., 2023). These collaborative orchestration mechanisms connect cognitive logics such as effectuation with organisational outcomes (Showkat & Nagina, 2025) within the Knowledge-Based View. Hence, OIC acts as a knowledge-bridging capability relating effectual reasoning with CVC through the sharing, recombination, and deployment of sustainability-related knowledge.

Connecting with external stakeholders and fostering relationships based on contingency can help businesses create networks for open innovation that aid in the validation of circular technologies, closed-loop systems, and regenerative business models (Abbate et al., 2022; Kreiling & Paunov, 2021). In this context, effective communication with external stakeholders can help identify and create circular value opportunities through knowledge-exchange cooperation. Therefore, we propose the following hypothesis:

H4a: Open Innovation Capability mediates the relationship between Effectuation and Circular Value Creation.

The mediating role of sustainability-oriented learning capability

The iterative nature of sustainability-oriented learning – cyclical experimentation and the incorporation of feedback leading to adaptive reflection – is consistent with the core principles of effectuation (Smith et al., 2017; Sarasvathy, 2001). Sustainability-Oriented Learning Capability refers to an organisation's ability to build on internalised environmental and social knowledge, redesign processes around circular innovation, and develop competencies related to regenerative practices (Ul-Durar et al., 2023).

Sustainability-oriented learning works iteratively and aligns with core principles of effectuation, meaning feedback is incorporated into the learning process, making it cyclical (Smith et al., 2017; Sarasvathy, 2001). Sustainability-Oriented Learning Capability refers to an organisation's ability to build an environment to internalise knowledge obtained internally, rethink processes based on circular principles, and develop sustainable competencies (Ul-Durar et al., 2023).

Using the Knowledge-Based View, the role of learning capabilities is to help transform entrepreneurial thought processes into strategic action and performance (Del Gesso & Parravicini, 2025; Keya & Kinyua, 2025). By engaging in effectual decision-making, the firm utilises lessons learned through small-scale, iterative experimentation and learning through doing (Breit & Volkmann, 2025). Through these iterations, the firm can build institutionalised sustainability knowledge and develop circular innovations oriented toward regenerative value creation.

Sustainability-Oriented Learning Capability may link entrepreneurial knowledge and sustainable development approaches with circular economy outcomes by enabling businesses to use resources and technology effectively and create value from materials otherwise perceived as waste. Therefore, we propose:

H4b: Sustainability-Oriented Learning Capability mediates the relationship between Effectuation and Circular Value Creation.

The serial mediation of open innovation capability and sustainability-oriented learning capability

Through Open Innovation Capability, firms can leverage the sustainability-related knowledge of different actors in the ecosystem, such as suppliers, customers, and technology partners, through collaborative partnerships (Breit & Volkmann, 2025; Chesbrough, 2024; Chiu & Lin, 2022). While acquiring knowledge from external sources represents an initial step in the circular economy transition, firms also need to develop Sustainability-Oriented Learning Capability by internalising, assimilating, and applying knowledge gained through collaborative partnerships before implementing strategies and practices based on it (Claro & Esteves, 2021).

Previous studies have indicated that acquiring and applying knowledge are not independent activities but instead represent stages in a sequence of interrelated processes. For example, the externalised or 'opened' flow of information obtained through 'open innovation' can stimulate a company's internal learning routines, which facilitate experimentation, the reinterpretation of the implicit meanings of knowledge, and the progressive modification of organisations' circular practices (Dagilienė & Varaniūtė, 2023; Vanhamäki et al., 2021). This interrelationship is especially important in dynamic circular ecosystems. Organisations need to be able to interpret stakeholder feedback over time and adapt to emerging sustainability challenges through the effective utilisation of external knowledge.

OIC and SOLC work in collaboration to provide a continuous knowledge pathway associated with CVC. OIC assists organisations in identifying and investigating potential circular business opportunities, while SOLC enables absorption, contextualisation, and institutionalisation of the associated knowledge within their operations in a sustainable manner. Thus, OIC and SOLC represent a sequential pathway through which effectual thinking may be associated with circular value creation through the research, design, and development of new circular business opportunities.

H4c: Open Innovation Capability and Sustainability-Oriented Learning Capability serially mediate the relationship between Effectuation and Circular Value Creation.

The moderating role of paradox mindset

The path towards circularity involves inherent tensions between growth and resource preservation, efficiency and experimentation, and short-term costs and long-term sustainability benefits (Chirumalla et al., 2024; Dagilienė & Varaniūtė, 2023). To manage these tensions, organisations need more than technical or structural capabilities; they also require the cognitive capacity to hold conflicting beliefs without immediately resolving them into a single outcome, thereby allowing tensions to inform innovative responses rather than become limiting constraints (Alzamil, 2025; Khan et al., 2025; Smith & Lewis, 2011).

Effectuation supports action under uncertainty through openness to flexibility, changes in goals, and responses to contingencies (Sarasvathy, 2001). However, the relationships between effectuation, organisational capabilities, and circular outcomes may depend on the cognitive frame of reference adopted by actors within an organisation. An actor with a strong paradox mindset is more likely to view the perceived contradictions associated with experimentation versus control, exploration versus exploitation, and sustainability versus profitability as complementary and thus compatible components of productive tension rather than trade-offs that must be resolved (Wang et al., 2024; Yin, 2022).

When decision-makers adopt a paradox mindset in these situations, effectuation may be more strongly associated with Sustainability-Oriented Learning Capability and Circular Value Creation, as decision-makers may be better able to embrace competing stakeholder expectations and integrate sustainability knowledge through reflective practice. Additionally, firms characterised by a paradox mindset may view external partnerships as a means of balancing independent and collaborative approaches rather than as a trade-off between these two alternatives.

Moreover, the relationship between paradoxical mindset and collaborative activity is likely to be reciprocal. Although a paradoxical mindset may introduce some hesitation in decision-making by encouraging the careful evaluation of competing demands, such reflective evaluation may help decision-makers consider additional information when developing partnerships and engaging in knowledge sharing. Therefore, paradoxical cognition may play a differentiated role across learning and collaborative processes by encouraging reflective engagement with competing demands while potentially constraining some immediate outcomes.

Thus, Paradox Mindset is anticipated to moderate the direct and indirect relationships between Effectuation and Circular Value Creation, particularly under conditions of persistent tension and uncertainty. Hence, we propose the following hypotheses:

H5a (mod-med): Paradox Mindset moderates the indirect effect of Effectuation on Circular Value Creation through Open Innovation Capability and Sustainability-Oriented Learning Capability (serial mediation).
H5b (mod-med): Paradox Mindset moderates the indirect effect of Effectuation on Circular Value Creation through Sustainability-Oriented Learning Capability.
H5c (mod): Paradox Mindset moderates the relationship between Effectuation and Circular Value Creation.

Fig. 1 presents the conceptual framework.

Research design and approach

Choice of analytical approach

Given the explanatory and predictive objectives of this study, Partial Least Squares Structural Equation Modelling was employed using SmartPLS 4.1. PLS-SEM is widely recognised as a causal-predictive modelling approach that evaluates theoretically specified relationships while maximising the predictive performance of endogenous constructs (Hair et al., 2024). Consistent with this perspective, the objective of the present study was not only to explain theoretically derived relationships but also to evaluate the model's ability to predict endogenous constructs associated with circular value creation. The present study develops directional hypotheses grounded in Effectuation Theory and the Knowledge-Based View while also assessing the predictive capability of the proposed model. Accordingly, PLS-SEM provides an appropriate analytical framework for simultaneously examining direct, mediating, moderating, and higher-order relationships together with out-of-sample predictive performance.

In addition, PLS-SEM is particularly suitable for estimating hierarchical component models, including reflective–reflective higher-order constructs, and accommodates complex structural relationships without imposing restrictive distributional assumptions (Hair et al., 2024). These characteristics make it well suited for estimating the proposed conceptual model.

To complement the PLS-SEM analysis and enhance interpretability, the recently proposed Tensor Product-based fuzzy rule extraction method is applied (Sudár et al., 2025). This approach aggregates the latent variable scores of the PLS-SEM model into an N-dimensional data tensor (where N is the number of latent variables), which is subsequently decomposed using Higher-Order Singular Value Decomposition (HOSVD) into a core tensor and a set of weighting matrices (De Lathauwer et al., 2000; Baranyi, 2013). The weighting matrices are

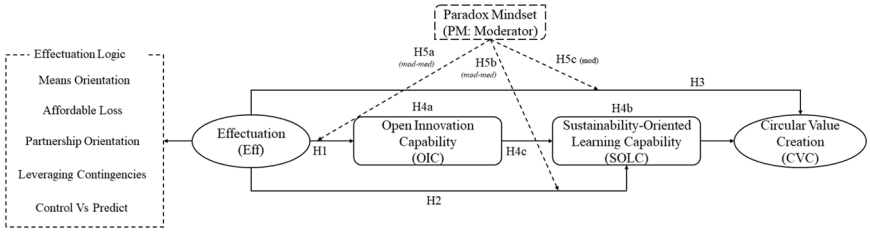


Fig. 1. Conceptual framework.

transformed into the Close-to-Normal canonical form, yielding weighting functions that exhibit dominant peaks within each latent dimension and can therefore be interpreted as normalised fuzzy membership functions (Baranyi, 2013; Sudár et al., 2025). This transformation facilitates the systematic sampling of a compact set of Takagi–Sugeno fuzzy rules that describe the associations between the PLS-SEM latent variables and CVC in a piecewise manner. Both the tensor aggregation and fuzzy rule extraction stages are optimised using a genetic algorithm. It should be emphasised that this supplementary analysis is not intended as an independent validation of the PLS-SEM results. Rather, since the fuzzy rules are derived from the same latent variable scores generated by the PLS-SEM model, the analysis is best understood as an exploratory, complementary exercise aimed at supporting interpretability. Its added value lies in the fact that – as opposed to PLS-SEM, which estimates global relationships among the latent constructs – the TP-based rule extraction pipeline yields a piecewise, granular description of these associations, highlighting the specific value ranges within the latent dimensions that co-occur with lower or higher levels of CVC, and allowing the latent-level patterns to be mapped back onto observable questionnaire responses.

Target population and sampling

The final sample consisted of 294 respondents recruited from Prolific (Mehrotra et al., 2025; Tandon et al., 2023), representing a variety of industries, primarily the manufacturing and technology sectors, which are key contributors to the transition to a circular economy. All survey participants occupied managerial or technical roles related to innovation, operations, or strategic decision-making and were therefore positioned to provide relevant information on organisational learning, collaboration, and sustainability practices (Köhler et al., 2022; Sahabuddin et al., 2023).

Non-response bias was evaluated using the early-late comparison method proposed by Armstrong and Overton (1977). Independent-samples *t*-tests (Table 1) show no significant differences in responses between early and late participants for any of the constructs tested (all p-values greater than .05), thus suggesting that non-response bias is unlikely to impact the findings of this research.

Sample characteristics and adequacy

The final sample comprised 294 professionals employed across diverse industries, including manufacturing, information technology, consumer services, consumer goods, and other sectors. Although respondents represented multiple industries, the largest proportion originated from the manufacturing and technology sectors. These sectors provide an appropriate empirical context for the present study because they have been at the forefront of adopting open innovation practices, digital transformation initiatives, and circular economy strategies. Consequently, organisations operating within these industries routinely engage in inter-organisational collaboration, sustainability-oriented innovation, and knowledge-intensive decision-making, making them especially suitable for an examination of the proposed relationships among effectuation, organisational capabilities, and circular value creation.

The respondents also occupied a broad range of managerial and professional roles associated with innovation and sustainability decision-making, ensuring that they possessed the organisational knowledge necessary to evaluate the study constructs. Accordingly, the sample should be viewed as theoretically relevant and empirically appropriate for examining the proposed relationships rather than as statistically representative of the broader population of firms undergoing circular economy transitions. This distinction is consistent with the explanatory and theory-testing objectives of the present study.

To assess whether the sample size was sufficient for the proposed research model, an a priori statistical power analysis was conducted using G*Power 3.1. Assuming a medium effect size ($f^2 = 0.15$), a significance level of 0.05, statistical power of 0.95, and the maximum number of predictors associated with any endogenous construct, the minimum required sample size was substantially lower than the final sample of 294 respondents. The final sample therefore exceeds the minimum statistical requirement for estimating the proposed structural model, providing sufficient statistical power to detect meaningful relationships among the constructs.

As a supplementary benchmark, the sample also exceeds the minimum threshold suggested by the traditional 10-times rule commonly reported in the PLS-SEM literature. Nevertheless, consistent with recent methodological recommendations, the present study relies primarily on the G*Power analysis as the principal justification for sample adequacy (Hair et al., 2024).

Respondent demographics

The research targeted professionals from many industries, organisational structures, and levels of experience, with 294 acceptable responses from professionals across these categories. The total sample was approximately 60.5% male and 38.8% female, showing a fairly balanced mix relative to the industry and management orientation of this study. The majority (55.1%) of respondents were between 35 and 54 years old, indicating a mature sample group that is likely to have a high level of experience in both the areas of management and innovative development. As a result, this demographic maturity is highly relevant to research on decision-making logics (i.e., effectuation) and cognitive orientations (i.e., the paradox mindset).

In terms of educational qualification, the majority of respondents held at least a bachelor's degree (44.9%), while a large proportion also reported having completed some form of postgraduate qualification.

Table 1
Assessment of non-response bias (Early vs Late Respondents).

Construct	Early Mean	Late Mean	Mean Difference	t-value	p-value
Eff	3.97	3.86	0.11	1.25	0.21
OIC	3.82	3.89	−0.07	−0.48	0.63
SOLC	3.75	3.61	0.14	0.87	0.39
CVC	4.08	3.84	0.24	1.70	0.09
PM	3.73	3.64	0.09	0.67	0.51

CVC: Circular Value Creation, Eff: Effectuation, OIC: Open Innovation Capability, PM: Paradox Mindset, SOLC: Sustainability-Oriented Learning Capability.

The educational profile suggests that respondents were well positioned to engage with organisational issues related to sustainability, innovation management, and circular business models. The professional experience of respondents increases the credibility of the sample, with approximately 71% reporting over 11 years of professional experience. Furthermore, more than half of the sample had been with their respective companies for six years or more. Together, these factors indicate that the sample is both organisationally embedded and well-positioned to provide an informed opinion on internal learning and open innovation capabilities.

The largest number of survey respondents were employed in managerial and mid-level management positions (55%), while professional employees working in the areas of innovation and R&D comprised the second-largest share (19%). This workforce composition is particularly relevant because these roles are closely associated with strategic and operational decision-making, innovation, sustainability learning, and the development of circular business practices. Within these industries, manufacturing (38.8%) and information technology (37.8%) represented the largest segments in terms of employee count, supplemented by consumer services (7.8%). As they tend to exhibit high levels of innovation and transformation due to sustainability issues, these sectors play an important role in providing context for circular transition research. Most organisations that participated in this study were well established (69% >20 years old), and two-thirds (69%) were privately held, creating stable but adaptable socio-institutional environments for the study of the evolution of circular and knowledge-based capabilities. Participant organisations were evenly distributed across company size, with 35.4% employing >1000 workers, ensuring representation from large organisations with substantial resources and established infrastructures for innovation.

The demographic characteristics provide additional context for assessing the relevance of the study sample. The sample consists primarily of seasoned professionals from well-established, innovation-generating industries, adding depth and reliability to the research findings regarding effective reasoning, developing knowledge-enabled capabilities, and circular value creation. In addition, the diversity of firm sizes, positions, and industries broadens the empirical context within which the proposed relationships are examined.

Measurement scale

The constructs in this study were assessed using the multi-item rating scales developed from established research that has been validated through previous work. The items in the constructs were rated from '1' (Strongly Disagree) through '5' (Strongly Agree), using a five-point Likert-type scale. The primary measure of effectuation was a second-order reflective-reflective (shared) construct that contained five first-order components: means-realisation (bird-in-hand), affordable-loss, partnership-orientation (crazy quilt), leveraging-contingencies (lemonade), and control-orientation (pilot-in-the-plane). The five first-order component measures illustrate non-predictive, means-driven entrepreneurial action and were derived from prior work by Chandler et al. (2011) and Sarasvathy (2008). Each first-order component was assessed with five reflective items emphasising creating opportunity by realising and/or using current resources; minimising risk; working collaboratively with others; testing and adapting; and maintaining agency and control over outcomes.

The study measured a company's Open Innovation Capability using five questions from Cheng and Chen (2013) to assess the degree to which companies (1) incorporate external sources of information, (2) build strategic alliances, and (3) utilise distributed networks for innovation to produce new value. OIC refers to companies' outward-looking capacity to access, develop, and use knowledge not found within their own organisation.

We further assessed company Sustainability-Oriented Learning Capability based on five questions proposed by Mushtaq and Akhtar (2025). This construct describes how well companies can obtain, absorb, and use sustainability-related knowledge. SOLC focuses on the ways in which companies learn to convert insights regarding environmental and social issues into adaptive and innovative practices that facilitate a shift towards a circular transition.

Circular Value Creation was measured by adapting five items from Kuzma and Sehnem (2023). The purpose of these questions is to determine the company's ability to create economic, environmental, and social value through (1) regenerative production systems; (2) efficient resource use; and (3) co-creation with stakeholders. As such, the CVC scale captures how well companies implement circular principles into actual value-generating results.

Miron-Spektor et al.'s (2018) five-item scale was adapted to create a Paradox Mindset (PM) measure of an individual's cognitive flexibility to see, accept, and combine conflicting requirements into one coherent approach. PM reflects how much tension (e.g., efficiency vs experimentation, control vs adaptability) a decision maker perceives not as contradictory but rather as beneficially influencing innovation.

Understanding effectuation as a higher-order construct

Chandler et al. (2011) proposed that effectuation be viewed as a second-order reflective-reflective construct. The five interrelated first-order dimensions that make up the construct (Means Orientation [MO], Affordable Loss [AL], Partnership Orientation [PO], Leveraging Contingencies [LC], and Control Orientation [CO]) represent separate but related ways of expressing a generalised logic of effectual reasoning. All five first-order dimensions represent different expressions of effectuation's broader logic; therefore, they should not be conceptualised as separate formative constructs but as reflections of an underlying cognitive framework that guides entrepreneurial behaviour. This perspective is consistent with Sarasvathy's (2001) foundational theorisation of effectuation as a non-predictive approach to decision-making based on available means, affordable loss, stakeholder involvement, and learning and adaptation over time.

Recent research has reinforced this interpretation. Research indicates that the five principles of effectuation are not independent mechanisms but instead reflect interdependent behaviours associated with a common cognitive schema (Braun & Mauer, 2022; Johnson & Hörisch, 2022; Roach et al., 2016). Therefore, we employ a reflective-reflective hierarchical component model (HCM) using the two-stage approach in PLS-SEM, consistent with the recommendations of Hair et al. (2024). The hierarchical model enables several first-order reflective dimensions to represent a unified latent construct, namely, the general effectual mindset.

Formative specifications were considered initially, but they turned out to be inconsistent with the conceptual ideas associated with effectuation. In formative models, indicators are conceptualised as causal precursors that collectively define the construct; therefore, changes in an indicator may alter the meaning of the construct (Jarvis et al., 2003). This interpretation conflicts with the theory of effectuation, where each indicator measures or expresses an individual element of reasoning that supports effectuation rather than defining the reasoning style. For instance, an individual does not cease to exhibit effectual reasoning simply because they score lower, or fluctuate in, one of its underlying dimensions, such as Affordable Loss or Leveraging Contingencies. Rather, several of these tendencies may co-occur to reflect a common pattern of reasoning regarding how entrepreneurs act in uncertain environments.

Research has provided both theoretical and empirical support for the reflective conceptualisation of Effectuation. Prior studies suggest that all dimensions of Effectuation are related and combine into a single cognitive construct (Braun & Mauer, 2022; Chandler et al., 2011). Conversely, a formative model of Effectuation would imply that each dimension contributes independently to defining the construct, which is inconsistent with conceptualising Effectuation as a coherent cognitive

and behavioural logic. Therefore, modelling Effectuation as a reflective-reflective construct is consistent with its theoretical conceptualisation as an integrated reasoning process reflected through combinations of principle-related behaviours.

Data analysis procedure

Data analysis was conducted using Partial Least Squares Structural Equation Modelling implemented in SmartPLS 4.1 (Ringle et al., 2024). The analysis followed a multi-step procedure involving measurement model assessment, structural model evaluation, mediation and moderation testing, and common method bias assessment.

Because all hypotheses were derived from established theory and specified a priori as directional, statistical significance was evaluated using one-tailed bias-corrected bootstrapping with 5000 bootstrap subsamples. Consistent with current PLS-SEM recommendations, one-tailed significance testing is appropriate when directional hypotheses are specified a priori and the objective is to test theoretically predicted relationships rather than exploratory associations (Hair et al., 2024).

The first step involved evaluating first-order reflective constructs to assess indicator reliability (Cronbach's alpha/internal consistency reliability and composite reliability), convergent validity (average variance extracted [AVE]), and discriminant validity using a heterotrait-monotrait ratio (HTMT), with HTMT values below 0.85. The second step generated latent variable scores for the five first-order constructs, which were then used to identify indicators of the second-order reflective construct, Effectuation. Finally, the second-order reflective construct was evaluated against standard reflective assessment criteria: CR $\geq$ 0.70 and AVE $\geq$ 0.50.

To assess mediation, we used a one-tailed, bias-corrected bootstrapping approach with 5000 resamples to evaluate the indirect paths from Effectuation to CVC via OIC and SOLC, both independently and in serial sequence (Zhao et al., 2010). The moderating role of Paradox Mindset was tested using an interaction term approach in PLS-SEM. Additionally, moderated mediation was assessed by examining the conditional indirect effects across different levels of the moderator and by evaluating the Index of Moderated Mediation (IMM) following the SmartPLS 4.1 procedure for first-stage moderated mediation models using bootstrapped interaction-specific indirect effects and bias-corrected bootstrap confidence intervals.

To estimate the moderating effects of Paradox Mindset, interaction terms were constructed using the two-stage approach implemented in SmartPLS 4.1. This approach was selected because Effectuation was modelled as a reflective–reflective higher-order construct using the disjoint two-stage procedure, thereby ensuring methodological consistency between the higher-order construct estimation and the moderation analysis. The interaction terms were estimated using standardised latent variable scores obtained from the first-stage estimation, consistent with current PLS-SEM recommendations while avoiding the complexity associated with product-indicator estimation (Hair et al., 2024). Significant interaction effects were subsequently interpreted using the simple slope plots generated automatically by SmartPLS 4.1.

We implemented procedural remedies by ensuring respondent anonymity and psychologically separating the predictor and criterion constructs within the survey design (Podsakoff et al., 2003). Statistically, common method bias (CMB) was assessed using multiple complementary approaches. First, full collinearity variance inflation factors (VIFs) were all below the recommended threshold of 3.3 (Kock, 2015). Second, Harman's single-factor test indicated that no single factor accounted for >50% of the total variance (Podsakoff et al., 2003). Third, a marker-variable assessment (Chang et al., 2020) was conducted using the theoretically unrelated item 'I like the colour blue', which bears no conceptual relationship to Effectuation, Open Innovation Capability, Sustainability-Oriented Learning Capability, Paradox Mindset, or Circular Value Creation. The inclusion of the marker variable did not produce any meaningful changes in the model's explanatory power (R^2), suggesting that common method variance was unlikely to have materially influenced the study findings. Taken together, these procedural and statistical assessments do not indicate severe common method bias. Nevertheless, because the study relies on cross-sectional data collected from a single respondent per organisation, the possibility of residual common method variance cannot be completely ruled out and therefore remains a limitation of the study.

Derivation of fuzzy rules and explainability assessment using the TP model transformation

To complement the PLS-SEM analysis and enhance interpretability, a Tensor Product (TP)-based fuzzy rule extraction procedure was applied following Sudár et al. (2025). First, the latent variable scores produced by the PLS-SEM model were organised into a multi-dimensional data tensor representing the five latent constructs (Effectuation, OIC, SOLC, PM, and the method factor M1). The non-equidistant coordinate grids along each dimension, as well as the aggregation approach used to obtain a single value per grid point (ultimately operationalised as the mean of the CVC scores for the nearest observations), were optimised using a genetic algorithm to balance precision and generalisability. In this first optimisation stage, the genetic algorithm operated with a population size of 35 chromosomes, evolved over 10 generations and searched over (i) the number and placement of non-equidistant grid coordinates in each dimension, (ii) the aggregation operator used to obtain a single value per grid point (i.e., nearest observation, mean, median, or distance-weighted sum), and (iii) the number of nearest observations aggregated per grid point. Fitness was defined as the R^2 score between the CVC values reconstructed from the resulting TP model (discretised and interpolated between discretisation coordinates) and the observed CVC scores. The best configuration – a 5-by-2-by-5--by-4-by-4 grid combined with mean-based aggregation over the five nearest observations, obtained following eight generations – achieved a fitness of $R^2 = 0.70$, with no further fitness improvement observed over the final generations of the search.

It should also be noted that the method factor M1 corresponds to the marker-variable-based method factor obtained during the common method bias assessment (based on the theoretically unrelated marker item described in Section 3.7 on Data Analysis). Extending the marker-variable logic (Chang et al., 2020) to the rule-based setting, M1 was deliberately retained as an input dimension of the TP model so that the rule extraction could also serve as an additional diagnostic: because the marker item is by design theoretically unrelated to all substantive constructs in the model, any systematic contribution of M1 to the extracted rules would be attributable to common method variance rather than to substantive relationships. Retaining M1 as an explicit dimension therefore allows for the possibility that method variance – if present – becomes visible in the rule structure, rather than being silently absorbed into the substantive dimensions. As reported in the Findings section, no such systematic contribution was observed, consistent with M1's intended role as a control dimension rather than as a substantive construct.

Subsequently, the tensor was decomposed using Higher-Order Singular Value Decomposition (HOSVD), retaining two ranks (weighting functions) in each dimension (De Lathauwer et al., 2000). The decision to retain two singular values was supported by the singular value spectra, which were strongly dominated by the first two components in every dimension. The resulting rank-2 approximation reconstructed the aggregated data tensor with an R^2 of 0.93, and the originally observed CVC scores – again, through interpolation between the discretisation coordinates – with an R^2 of 0.69. The resulting weighting matrices were then transformed into the Close-to-Normal (CNO) canonical form (Baranyi, 2013), ensuring that each weighting function – that is, each column in the weighting matrices – exhibited at least one dominant peak that could be interpreted as a normalised fuzzy membership function. Based on the peak locations across the dimensional weighting functions

and the resulting core tensor, a compact set of seven Takagi-Sugeno fuzzy rules was derived, capturing the primary associative patterns among key latent variables and CVC (Sudár et al., 2025).

In this latter step, thresholds for identifying membership peaks and other accuracy-explainability trade-offs were likewise optimised using a genetic algorithm. The algorithm operated with a population of 18 chromosomes evolved over 15 generations, with the fitness of each candidate configuration computed as the average of five independent rule extraction trials. The search space comprised (i) the 'alpha-cut' threshold above which weighting function values were treated as 'dominant peaks' and hence considered as forming the antecedent fuzzy sets, (ii) the minimum share of observations that a rule was required to cover in order to be retained, (iii) the number of samples from within the support of the antecedent fuzzy sets that were used to generate the rule consequents, and (iv) the maximum number of antecedent sets per dimension (search range: 2–6). Fitness was again defined as the R^2 between the rule-based reconstruction and the observed CVC scores. The search converged to a fitness of $R^2 = 0.45$, with the winning configuration emerging after seven generations. Of the 72 candidate rules defined over the resulting antecedent sets, only those with non-negligible empirical support (a coverage weight of at least 0.001, i.e. rules actually instantiated by observations in the sample) were retained, yielding the seven-rule set reported in the Findings section. Since this retention threshold differs from the one applied internally during the genetic algorithm search, the fitness of the final rule set is somewhat lower ($R^2 = 0.30$; see also Findings) – a trade-off we consider acceptable in favour of a compact and interpretable rule-base. Alternative high-fitness configurations explored during the search gave rise to rule sets exhibiting the same qualitative structure – with distinct combinations of antecedent levels consistently mapping onto low, intermediate and high levels of CVC – indicating that the extracted rules are robust to moderate variations in the extraction settings.

This procedure provides a transparent rule-based representation of the structural patterns uncovered by the PLS-SEM model, offering an exploratory, complementary interpretability layer that maps how value ranges within the latent constructs emerge together with circular value creation. Because this representation is derived from the same latent variable scores – and the same sample – as the PLS-SEM model, rather than from independent validation data, it should be read as an interpretability aid to structural results rather than as independent corroboration of them.

Findings

Measurement model assessment

The measurement model was evaluated in line with current PLS-SEM recommendations by examining indicator reliability, internal consistency reliability, convergent validity, and discriminant validity (Hair et al., 2024). Indicator reliability was assessed using standardised outer loadings, while internal consistency reliability was evaluated primarily using rho_A and Composite Reliability (CR), supplemented by Cronbach's alpha for completeness. Convergent validity was assessed using the Average Variance Extracted (AVE), with values above 0.50 indicating that each construct explained more than half of the variance in its indicators. Discriminant validity was established using the Heterotrait–Monotrait ratio (HTMT), with statistical inference assessed through bootstrapped bias-corrected confidence intervals. Discriminant validity was considered satisfactory when the confidence intervals did not include the value of one.

According to Table 2, all items in each construct had acceptable loadings (between 0.63 and 0.89), providing evidence of adequate indicator reliability (Hair et al., 2024). All CR (between 0.83 and 0.94) and α (between 0.72 and 0.93) values exceeded the minimally accepted threshold of 0.70, suggesting adequate or satisfactory reliability for each construct (Table 2, Hair et al., 2024; Nunnally & Bernstein, 1994). The study further evaluated rho_A coefficients, which were above the minimum threshold of 0.70 to provide greater precision in estimating the reliabilities of the constructs assessed through reflective measurement models (Dijkstra & Henseler, 2015). The results reported in Table 2 show that each AVE exceeds the recommended cut-off of 0.50, hence confirming the existence of convergent validity. During indicator purification, item E-MO1 was removed because its standardised loading did not meet the recommended threshold. Its removal improved the psychometric properties of the Means Orientation dimension while preserving its conceptual coverage.

Discriminant validity was assessed using both the Heterotrait–Monotrait criterion and the inferential procedure recommended by Franke and Sarstedt (2019), which is considered a more reliable criterion than the Fornell–Larcker approach (Henseler et al., 2015). As shown in Table 3a, all HTMT ratios were below the recommended threshold of 0.90. To provide a more rigorous assessment, bias-corrected bootstrap confidence intervals were subsequently examined (Table 3b). The higher-order measurement model satisfied the inferential criterion

Table 2
Outer loadings, cronbach's alpha (α), CR, and AVE for first-order constructs.

LOC – Items	FL	VIF	α	rho_a	CR (rho_c)	AVE
CVC1	0.84	2.35	0.88	0.88	0.91	0.68
CVC2	0.81	2.03				
CVC3	0.81	1.92				
CVC4	0.86	2.44				
CVC5	0.80	1.90				
E-AL1	0.74	1.75	0.83	0.84	0.88	0.60
E-AL2	0.82	2.26				
E-AL3	0.73	1.71				
E-AL4	0.77	1.71				
E-AL5	0.80	1.83				
E-CO1	0.68	1.46	0.80	0.81	0.86	0.56
E-CO2	0.83	1.96				
E-CO3	0.71	1.46				
E-CO4	0.79	1.75				
E-CO5	0.71	1.45				
E-LC1	0.67	1.41	0.85	0.85	0.89	0.62
E-LC2	0.82	2.04				
E-LC3	0.83	2.14				
E-LC4	0.79	1.76				
E-LC5	0.82	2.13				
E-MO2	0.78	1.58	0.72	0.74	0.83	0.54
E-MO3	0.63	1.33				
E-MO4	0.80	1.73				
E-MO5	0.72	1.20				
E-PO1	0.70	2.05	0.79	0.79	0.85	0.54
E-PO2	0.67	1.99				
E-PO3	0.76	1.67				
E-PO4	0.73	1.61				
E-PO5	0.80	1.99				
OIC1	0.75	1.58	0.87	0.87	0.91	0.66
OIC2	0.79	1.87				
OIC3	0.82	2.13				
OIC4	0.86	2.53				
OIC5	0.86	2.47				
PM1	0.80	1.85	0.84	0.85	0.89	0.61
PM2	0.73	1.63				
PM3	0.78	1.80				
PM4	0.85	2.11				
PM5	0.76	1.81				
SOLC1	0.87	3.12	0.93	0.93	0.94	0.77
SOLC2	0.88	3.34				
SOLC3	0.86	2.87				
SOLC4	0.89	3.35				
SOLC5	0.88	2.89				

CVC: Circular Value Creation, Eff: Effectuation, E-AL: Effectuation – Affordable Loss, E-CO: Effectuation – Control Orientation, E-LC: Effectuation – Leveraging Contingencies, E-MO: Effectuation – Means Orientation, E-PO: Effectuation – Partnership Orientation, OIC: Open Innovation Capability, PM: Paradox Mindset, SOLC: Sustainability-Oriented Learning Capability, AVE: Average Variance Extracted, CA: Cronbach's Alpha, CR: Composite Reliability, FL: Factor Loading, VIF: Variance Inflation Factor.

Table 3a
Discriminant validity using HTMT ratios.

Panel A: LOC	CVC	E-AL	E-CO	E-LC	E-MO	E-PO	OIC	PM	SOLC
CVC									
E-AL	0.49								
E-CO	0.68	0.65							
E-LC	0.70	0.61	0.88						
E-MO	0.60	0.42	0.58	0.64					
E-PO	0.75	0.48	0.60	0.56	0.64				
OIC	0.82	0.38	0.68	0.68	0.62	0.78			
PM	0.70	0.38	0.67	0.76	0.56	0.62	0.75		
SOLC	0.85	0.38	0.57	0.59	0.64	0.61	0.78	0.68	

Panel B: HOC	CVC	Eff	OIC	PM	SOLC
CVC					
Eff	0.83				
OIC	0.82	0.80			
PM	0.70	0.77	0.75		
SOLC	0.85	0.71	0.78	0.68	

LOC: Lower Order Constructs, HOC: Higher Order Constructs, CVC: Circular Value Creation, Eff: Effectuation, E-AL: Effectuation – Affordable Loss, E-CO: Effectuation – Control Orientation, E-LC: Effectuation – Leveraging Contingencies, E-MO: Effectuation – Means Orientation, E-PO: Effectuation – Partnership Orientation, OIC: Open Innovation Capability, PM: Paradox Mindset, SOLC: Sustainability-Oriented Learning Capability. All HTMT values are below the recommended threshold of 0.90. Inferential assessment was subsequently performed using bias-corrected bootstrap confidence intervals (Table 3b).

Table 3b
HTMT inferential assessment (Bias-Corrected Confidence Intervals).

Construct Pair	HTMT	Upper BCa CI	Inference
E-CO ↔ E-LC	0.878	0.931	Marginally exceeds 0.90
SOLC ↔ CVC	0.846	0.901	Marginally exceeds 0.90
Remaining LOC pairs	<0.90	<0.90	Supported
All HOC pairs	0.676–0.846	0.743–0.893	Supported

CVC: Circular Value Creation, E-CO: Effectuation – Control Orientation, E-LC: Effectuation – Leveraging Contingencies, SOLC: Sustainability-Oriented Learning Capability, LOC: Lower Order Constructs, HOC – Higher Order Constructs, BCa: Bias-Corrected Confidence Interval.

for all construct pairs. Within the lower-order measurement model, the upper confidence limits remained below 0.90 for all but two construct pairs. Specifically, the confidence intervals for Leveraging Contingencies–Control Orientation (0.931) and Sustainability-Oriented Learning Capability–Circular Value Creation (0.901) marginally exceeded the recommended threshold (Table 3b). Given the small magnitude of these deviations, together with satisfactory evidence from indicator reliability, convergent validity, and the theoretically distinct conceptualisation of the constructs, the overall discriminant validity of the measurement model was considered acceptable.

Second-Order construct validation

Effectuation was conceptualised as a reflective–reflective higher-order construct and estimated using the disjoint two-stage approach, consistent with current PLS-SEM recommendations for hierarchical component models (Hair et al., 2024). In the first stage, the five lower-order reflective dimensions of Effectuation – Means Orientation, Affordable Loss, Partnership Orientation, Leveraging Contingencies, and Control Orientation – were estimated independently, and their measurement properties were assessed. The latent variable scores generated in this stage were subsequently used as indicators of the second-order Effectuation construct in the second-stage model. Accordingly, the final structural model was estimated using these second-stage latent variable scores rather than the repeated-indicator specification, ensuring an appropriate estimation of the hierarchical component model.

The second-order construct was evaluated in accordance with the criteria for reflective–reflective hierarchical component models, focusing on the loadings of the lower-order constructs on the higher-order construct together with internal consistency reliability and convergent validity. As reported in Table 4, all five lower-order dimensions exhibited substantial and statistically significant loadings on the second-order Effectuation construct (all $p < 0.001$), providing empirical support for their representation of the overarching effectual reasoning construct. In addition, the higher-order construct demonstrated satisfactory internal consistency reliability (Cronbach's alpha, rho_A, and Composite Reliability) and convergent validity (AVE), thereby confirming the adequacy of the reflective–reflective higher-order measurement model.

Structural model assessment

Once the validity and reliability of the measurement model were confirmed, the next step was to assess the structural model and test the hypothesised relationships between constructs, as suggested by established PLS-SEM methods (Hair et al., 2024), which consider path significance, effect sizes, explanatory power, and predictive relevance.

Prior to interpreting the structural relationships, the researcher examined potential issues related to collinearity among the predictor constructs. The Variance Inflation Factor (VIF) was used to identify the degree of collinearity between predictors; all predictors had a VIF below the conservative value of 3.3, which indicated that collinearity was not an issue and that all predictors provided a unique contribution to the structural path (Diamantopoulos & Siguaw, 2006).

The model's explanatory power was evaluated using the R^2 values for endogenous constructs, which represent the proportion of variance explained by the exogenous predictors. The R^2 values of OIC (0.56), SOLC (0.55), and CVC (0.70) indicated moderate to substantial explanatory power, consistent with accepted benchmarks in

Table 4
Second-order construct assessment.

HOC – Items	OL	CA	rho_a	CR	AVE
LV scores – E-AL	0.69	0.83	0.84	0.88	0.60
LV scores – E-CO	0.84				
LV scores – E-LC	0.85				
LV scores – E-MO	0.74				
LV scores – E-PO	0.76				

LV: Latent Variable, OL: Outer Loading, CA: Cronbach's Alpha, CR: Composite Reliability, AVE: Average Variance Extracted, E-AL: Effectuation – Affordable Loss, E-CO: Effectuation – Control Orientation, E-LC: Effectuation – Leveraging Contingencies, E-MO: Effectuation – Means Orientation, E-PO: Effectuation – Partnership Orientation.

organisational and sustainability research (Hair et al., 2024).

In line with recent PLS-SEM guidelines, predictive performance was assessed using CVPAT and PLSpredict, replacing traditional blindfolding-based approaches (Hair et al., 2024). Results from CVPAT indicated that the PLS-SEM model demonstrated a significant reduction in prediction error compared to the indicator-average benchmark for all constructs (OIC: $\Delta = -0.400$, $t = 6.843$; SOLC: $\Delta = -0.427$, $t = 7.425$; CVC: $\Delta = -0.374$, $t = 7.034$; Total: $\Delta = -0.400$, $t = 8.491$; all $p < 0.001$) demonstrating clear superiority in predictive ability. The results of PLSpredict also show strong predictive relevance, as demonstrated by the positive values of Q^2predict (OIC: 0.545; SOLC: 0.449; CVC: 0.535), with RMSE and MAE values indicating satisfactory prediction accuracy. Collectively, these results provide strong evidence for the model's out-of-sample predictive validity (Hair et al., 2024; Shmueli et al., 2019).

Although PLS-SEM methods focus primarily on predictive capabilities, model fit could still be assessed for analytic completeness. According to previous research (Henseler et al., 2015; Hu & Bentler, 1999), the standardised root mean square residual (SRMR) value of 0.065 is below the recommended cut-off of 0.08, indicating acceptable model fit. The Normed Fit Index (NFI) value of 0.83 provides additional information regarding model fit (Bentler & Bonett, 1980; Sarstedt et al., 2021). Together, these results indicate an acceptable model fit and support the explanatory adequacy of the proposed structural model.

Path coefficients and significance

The hypothesised direct, mediating, and moderating relationships were estimated using bootstrapping with 5000 subsamples, as recommended for robust significance testing in PLS-SEM. Path coefficients (β values), t-statistics, and p-values were computed to assess the magnitude and statistical significance of each relationship.

Results indicated significant positive relationships between Effectuation (Eff) and Open Innovation Capability (H1: $\beta = 0.48$, $p < 0.001$), Sustainability-Oriented Learning Capability (H2: $\beta = 0.22$, $p < 0.001$), and Circular Value Creation (H3: $\beta = 0.28$, $p < 0.01$), supporting H1–H3 (Fig. 2, Table 5).

The mediation results (Table 5) further supported the indirect pathways through OIC (H4a: $\beta = 0.09$, 90% BCa CI [0.04, 0.16]) and SOLC (H4b: $\beta = 0.10$, 90% BCa CI [0.05, 0.15]), as well as the sequential indirect relationship through OIC and SOLC (H4c: $\beta = 0.09$, 90% BCa CI [0.06, 0.14]). Because the corresponding direct relationship between Effectuation and CVC remained significant, these findings indicate partial mediation.

The moderating role of paradox mindset was assessed by estimating an interaction model that included both main and interaction effects (Table 5). Following recommended PLS-SEM procedures, both main and interaction effects were included simultaneously in the moderation model to ensure accurate estimation and interpretation. Following the estimation of the interaction effects, simple slope plots automatically generated by SmartPLS 4.1 were examined to facilitate interpretation of the significant moderation effects at different levels of the moderator. The findings indicate a differentiated pattern of moderation across structural relationships. The interaction between effectuation and paradox mindset was significant and positive for sustainability-oriented learning ($\beta = 0.06$, $p < 0.05$; Table 5), indicating that the positive relationship between Effectuation and Sustainability-Oriented Learning Capability is stronger at higher levels of Paradox Mindset (Fig. 3). In contrast, the interaction effect on Open Innovation Capability was negative but statistically insignificant ($\beta = -0.03$, $p > 0.05$; Table 5), providing no evidence of moderation. Additionally, the interaction between Paradox Mindset and Effectuation was negative and significant for Circular Value Creation ($\beta = -0.06$, $p < 0.05$; Table 5), indicating that the positive relationship between Effectuation and Circular Value Creation is weaker at higher levels of Paradox Mindset. The simple slope plots (Figs. 3 and 4) generated by SmartPLS 4.1 were subsequently examined to visualise and interpret the direction and magnitude of the significant interaction effects across different levels of paradox mindset.

Out-of-Sample predictive assessment

The predictive performance of the proposed model was assessed using both PLSpredict and the Cross-Validated Predictive Ability Test (CVPAT), following current PLS-SEM recommendations (Hair et al., 2024). Table 6 presents the indicator-level prediction results. First, all indicators exhibited positive Q^2predict values, confirming the model's out-of-sample predictive relevance. Second, the prediction errors (RMSE) generated by the PLS-SEM model were generally lower than or comparable to those of the linear model (LM) benchmark across the indicators of Open Innovation Capability, Sustainability-Oriented Learning Capability, and Circular Value Creation, indicating satisfactory predictive performance.

The predictive ability of the model was further evaluated using the Cross-Validated Predictive Ability Test (CVPAT) with the Indicator Average (IA) benchmark. Across all indicators, the PLS-SEM model exhibited significantly lower prediction loss than the IA benchmark, as reflected by consistently negative average loss differences and statistically significant t-values ($p < 0.001$). Collectively, the PLSpredict and CVPAT results demonstrate that the proposed model possesses meaningful out-of-sample predictive ability across all endogenous constructs.

Moderated mediation

Conditional indirect effects were first examined across low (−1 SD), mean, and high (+1 SD) levels of Paradox Mindset (Table 7) to illustrate how the indirect effects varied across the moderator. The indirect effect of Effectuation on Circular Value Creation through Sustainability-Oriented Learning Capability increased from $\beta = 0.070$ at low levels of Paradox Mindset to $\beta = 0.119$ at high levels, indicating that stronger paradoxical thinking is associated with a stronger learning-based pathway. In contrast, the indirect effects involving Open Innovation Capability exhibited comparatively little variation across moderator levels, suggesting a more stable indirect relationship.

To formally assess moderated mediation, the Index of Moderated Mediation (IMM) was evaluated following the SmartPLS 4.1 procedure for first-stage moderated mediation models using the bootstrapped interaction-specific indirect effects together with their bias-corrected bootstrap confidence intervals. As shown in Table 8, the moderated mediation effect (IMM) through Sustainability-Oriented Learning Capability was positive and statistically significant ($\beta = 0.020$; 90% BCa CI [0.010, 0.050]), whereas the moderated serial mediation effect

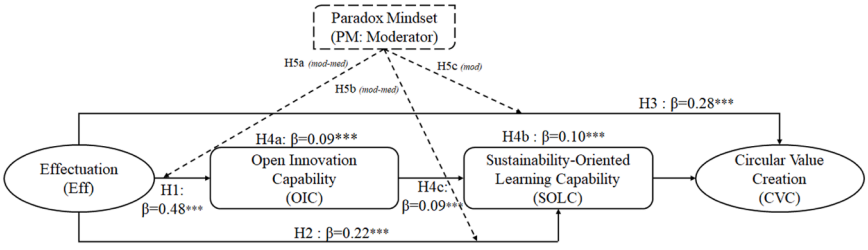


Fig. 2. StructuRAL MOdel.

Table 5
Structural Relationships.

Direct Paths	β	stdev	t-value	p-value	5.00%	95.00%	Status
H1: Eff -> OIC	0.48	0.06	8.67	0.00	0.39	0.57	S
H2: Eff -> SOLC	0.22	0.06	3.38	0.00	0.12	0.33	S
H3: Eff -> CVC	0.28	0.06	4.73	0.00	0.18	0.37	S

Mediation Paths	**β**	**stdev**	**t-value**	**p-value**	**0.05**	**0.95**	**Status**
H4a: Eff -> OIC -> CVC	0.09	0.04	2.62	0.00	0.04	0.16	Partial
H4b: Eff -> SOLC -> CVC	0.10	0.03	3.24	0.00	0.05	0.15	Partial
H4c: Eff -> OIC -> SOLC -> CVC	0.09	0.02	4.20	0.00	0.06	0.14	Partial

Moderation Paths	**β**	**stdev**	**t-value**	**p-value**	**0.05**	**0.95**	**Status**
PM x Eff -> OIC	−0.03	0.03	0.91	0.18	−0.08	0.01	NS
PM x Eff -> SOLC	0.06	0.03	1.92	0.03	0.02	0.11	S
H5c: PM x Eff -> CVC	−0.06	0.03	2.08	0.02	−0.11	−0.02	S

CVC: Circular Value Creation, Eff: Effectuation, E-AL: Effectuation – Affordable Loss, E-CO: Effectuation – Control Orientation, E-LC: Effectuation – Leveraging Contingencies, E-MO: Effectuation – Means Orientation, E-PO: Effectuation – Partnership Orientation, OIC: Open Innovation Capability, PM: Paradox Mindset, SOLC: Sustainability-Oriented Learning Capability, S: Supported, NS: Not Supported.

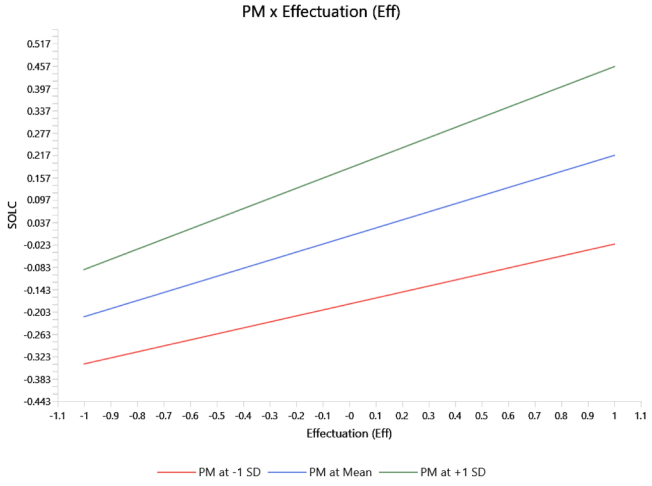


Fig. 3. Interaction plot: PM x Eff -> SOLC.

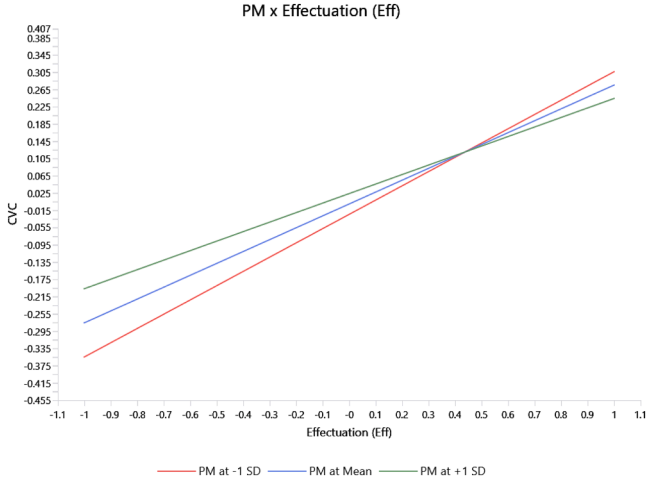


Fig. 4. Interaction plot: PM x Eff -> CVC.

through Open Innovation Capability and Sustainability-Oriented Learning Capability was not significant (β = 0.000; 90% BCa CI [−0.020, 0.000]). These findings indicate that Paradox Mindset strengthens the sustainability-oriented learning pathway linking Effectuation to Circular Value Creation but does not significantly moderate the broader sequential capability-building pathway.

Table 6
Indicator-level predictive assessment using plspredict and CVPAT.

Indicator	Q^2predict	PLS-SEM RMSE	LM RMSE	Average Loss Difference (CVPAT)	t-value	p-value
Open Innovation Capability						
OIC1	0.33	0.85	0.86	−0.36	5.17	<0.001
OIC2	0.30	0.89	0.89	−0.34	4.58	<0.001
OIC3	0.33	0.94	0.90	−0.43	5.20	<0.001
OIC4	0.44	0.76	0.76	−0.47	7.21	<0.001
OIC5	0.39	0.80	0.81	−0.40	5.67	<0.001
Sustainability-Oriented Learning Capability						
SOLC1	0.32	0.87	0.90	−0.36	5.73	<0.001
SOLC2	0.31	0.91	0.93	−0.38	5.60	<0.001
SOLC3	0.35	0.96	0.96	−0.49	6.48	<0.001
SOLC4	0.37	0.90	0.91	−0.47	6.33	<0.001
SOLC5	0.38	0.86	0.87	−0.44	7.17	<0.001
Circular Value Creation						
CVC1	0.30	0.93	0.94	−0.37	5.20	<0.001
CVC2	0.32	0.80	0.83	−0.30	4.60	<0.001
CVC3	0.41	0.75	0.77	−0.39	6.23	<0.001
CVC4	0.34	0.86	0.86	−0.37	5.15	<0.001
CVC5	0.43	0.76	0.76	−0.44	6.30	<0.001

Table 7
Conditional indirect effects (Moderated Mediation).

Path	PM Level	β	p-value
Eff → SOLC → CVC	−1 SD	0.07	0.02
Eff → SOLC → CVC	Mean	0.10	0.00
Eff → SOLC → CVC	+1 SD	0.12	0.00
Eff → OIC → CVC	−1 SD	0.10	0.01
Eff → OIC → CVC	Mean	0.09	0.00
Eff → OIC → CVC	+1 SD	0.09	0.01
Eff → OIC → SOLC → CVC	−1 SD	0.10	0.00
Eff → OIC → SOLC → CVC	Mean	0.09	0.00
Eff → OIC → SOLC → CVC	+1 SD	0.09	0.00

CVC: Circular Value Creation, Eff: Effectuation, OIC: Open Innovation Capability, PM: Paradox Mindset, SOLC: Sustainability-Oriented Learning Capability.

Assessment of fuzzy rules defined over latent scores

Initial (Redundant) and simplified rule set

Because the SEM model identified CVC as the ultimate endogenous construct, all other latent variables were treated as antecedent

Table 8
Index of moderated mediation (IMM): bootstrapped interaction-specific indirect effects.

Moderated mediation pathway	Index (β)	90% BCa CI	Result
H5a: PM × Effectuation → OIC → SOLC → CVC	0.00	[−0.020, 0.000]	Not Supported
H5b: PM × Effectuation → SOLC → CVC	0.02	[0.010, 0.050]	Supported

CVC: Circular Value Creation, Eff: Effectuation, OIC: Open Innovation Capability, PM: Paradox Mindset, SOLC: Sustainability-Oriented Learning Capability.

dimensions, while the CVC latent score served as the consequent dimension in the TP/TS fuzzy model.

Applying the TP/TS rule extraction process resulted in a compact set of seven TS rules. Each rule specifies a combination of latent variable ranges associated with a corresponding CVC score. The rules are presented below, ordered by their consequent value:

(EFF, MED) & (M1, HI) & (OIC, MED) & (PM, LO) & (SOLC, LO) => −0.79
(EFF, MED) & (M1, LO) & (OIC, MED) & (PM, LO) & (SOLC, LO) => −0.52
(EFF, MED) & (M1, LO) & (OIC, HI) & (PM, LO) & (SOLC, LO) => −0.06
(EFF, HI) & (M1, HI) & (OIC, HI) & (PM, HI) & (SOLC, HI) => 0.55
(EFF, MED) & (M1, HI) & (OIC, HI) & (PM, HI) & (SOLC, LO) => 0.58
(EFF, HI) & (M1, HI) & (OIC, MED) & (PM, HI) & (SOLC, HI) => 0.78
(EFF, HI) & (M1, LO) & (OIC, HI) & (PM, HI) & (SOLC, HI) => 1.33

To evaluate how well the rule set approximates the structural relationships in the PLS-SEM model, the consequent values were reconstructed for the original latent variable scores and compared with the observed CVC scores. This yielded an R^2 of 0.30 and a normalised (max-min) RMSE of 0.175, indicating that the rule set captures a moderate portion of the variance in CVC, consistent with the goal of extracting a compact and interpretable rule base rather than achieving maximal predictive accuracy. For reference, the full rank-2 TP model prior to rule sparsification reproduced the observed CVC scores with an R^2 of 0.69; the lower R^2 of the seven-rule set thus reflects the deliberate compression of the model into a compact, human-readable rule base.

To further evaluate internal consistency among the rules, an Ordinary Least Squares (OLS) regression model was fitted using the latent variable values appearing in the rule antecedents (such that 'LO' was replaced with 0, 'MED' with 1 and 'HI' with 2). This model achieved an R^2 of 0.998, confirming high internal coherence within the rule set. However, further analysis revealed substantial multicollinearity: while OIC and PM emerged as the strongest predictors of CVC, the VIF for PM exceeded 3.3, and the VIFs for EFF and SOLC indicated full collinearity with other antecedent variables.

Given these findings – and consistent with the PLS-SEM results, which identified OIC and SOLC as the key mediating variables – the rule set was simplified by retaining only these two latent antecedents. The resulting rule base remained structurally identical but easier to interpret:

Rule 1: (OIC, MED) & (SOLC, LO) => −0.79
Rule 2: (OIC, MED) & (SOLC, LO) => −0.52
Rule 3: (OIC, HI) & (SOLC, LO) => −0.06
Rule 4: (OIC, HI) & (SOLC, HI) => 0.55
Rule 5: (OIC, HI) & (SOLC, LO) => 0.58
Rule 6: (OIC, MED) & (SOLC, HI) => 0.78
Rule 7: (OIC, HI) & (SOLC, HI) => 1.33

An OLS model fitted to this simplified rule set still achieved a high R^2 of 0.914, indicating the rules remained internally consistent even with only two antecedent dimensions. Further, multicollinearity was no longer an issue in the simplified rule set after retaining only OIC and SOLC.

The behaviour of the method factor M1 across rule sets warrants separate consideration. Three observations indicate that M1 did not contribute any systematic explanatory structure to the rules. First, M1 appeared both in its low and high states across rules with low as well as high consequent values – for instance, the rule with the lowest consequent (−0.79) contains M1 at a high level, and the rule with the highest consequent (1.33) contains M1 at a low level, whereas the levels of M1 alternate between low and high even between these two extreme consequents, revealing no consistent direction of association. Second, at a rule level, M1 exhibited a near-zero correlation with the rule consequents ($r = -0.04$) and a small standardised coefficient in the OLS model fitted to the rule set ($\beta = -0.15$). Third, as shown above, removing M1 – together with EFF and PM – left the internal consistency of the rule set essentially intact ($R^2 = 0.914$). While these rule-level observations are necessarily qualitative given the compact size of the rule base, they are consistent with the marker-variable assessment reported in the Data Analysis section and further indicate that common method variance did not meaningfully influence the patterns captured by the PLS-SEM and TP models.

Taken together, the simplified rules reveal a clear and overall positive – though nonlinear – combined influence of OIC and SOLC on CVC. Higher levels of either antecedent are generally associated with higher CVC consequents. The presence of multiple consequents for the same antecedent combination (e.g., Rules 4 and 7) suggests that OIC and SOLC alone do not fully account for all variance captured by the original PLS-SEM model, consistent with their role as mediating rather than exhaustive predictors.

Reflecting the antecedents and consequents back to the indicator variables on the questionnaire

In the previous sections, we derived a fuzzy rule set for the relationship between PLS-SEM scores of mediating variables (e.g., OIC, SOLC) and target variables. To interpret the fuzzy rule consequents in terms of the original measurements, both the antecedent linguistic values and the consequent CVC scores were mapped back onto their corresponding indicator variables. This step was necessary because while the fuzzy rules operate on latent-level values (factor scores), they do not directly convey how each rule relates to the responses on the questionnaire items.

For each fuzzy antecedent set, all responses whose latent variable scores fell within the support region of the corresponding antecedent function were identified. Likewise, for each fuzzy-rule consequent, all observations whose CVC latent score lay within a tolerance window around the rule's output value (set to 25% of the CVC score's standard deviation) were selected. Within these filtered subsets – computed separately for each antecedent and each consequent – the empirical distributions of the associated indicator variables were examined using their quartiles.

This procedure provided an interpretable bridge between the latent-level fuzzy rules and the observed item-level responses, making it possible to characterise what 'low', 'medium' or 'high' levels of each construct look like in practice, and to link the fuzzy rule consequents directly to CVC-related responses. The results of this step are shown in Tables 9–11.

Discussion

The purpose of the research was to examine how the utilisation of effectuation in decision-making is associated with Circular Value Creation, focusing on the role of two important Knowledge-Based Mechanisms (KBMs), Open Innovation Capability and Sustainability-Oriented Learning Capability, in this relationship. The study also sought to

Table 9
Fuzzy antecedent sets (OIC dimension) mapped back onto indicator values.

Indicator(s)	Linguistic variable	count	stdev	min	25%	50%	75%	max
OIC1-OIC5	LOW	2	0.00	1	1.00	1.00	1.00	1
OIC1	MED	16	0.97	1	3	3.5	4	5
OIC2			0.57	2		3	3	4
OIC3, OIC5			0.72	2		3	4	4
OIC4			0.60	3		3	3.25	5
OIC1	HIGH	60	0.46	3	5	5	5	5
OIC2			0.39	4				
OIC3			0.36	4				
OIC4			0.34	4				
OIC5			0.22	4				

Table 10
Fuzzy antecedent sets (SOLC dimension) mapped back onto indicator values.

Indicator(s)	Linguistic variable	count	stdev	min	25%	50%	75%	max
SOLC1	LOW	35	0.87	1	1.00	2.00	2.00	4
SOLC2, SOLC3			0.61			1.00		3
SOLC4			0.61			1.00		3
SOLC5			0.77			2.00		4
SOLC1-SOLC5	HIGH	24	0.00	5	5	5	5	5

Table 11
Fuzzy consequents (CVC dimension) mapped back onto indicator values.

Indicator(s)	Consequent value	count	stdev	min	25%	50%	75%	max
CVC1	-0.79 ± 0.25	36	0.83	1	3.00	3.00	4.00	5
CVC2			0.69	2				
CVC3			0.81	2				
CVC4			0.87	1				
CVC5			0.92	1				
CVC1	-0.52 ± 0.25	39	0.75	2	3.00	3.00	4.00	5
CVC2			0.60			4.00		4
CVC3			0.77			3.00		5
CVC4			0.58			4.00		5
CVC5			0.82			4.00		5
CVC1	-0.06 ± 0.25	67	0.64	2	4.00	4.00	4.00	5
CVC2			0.42	3				
CVC3			0.46	3				
CVC4			0.49	3				
CVC5			0.55	3				
CVC1	$0.55 / 0.58 \pm 0.25$	51/55	0.60	3	4.00	4.00	5.00	5
CVC2			0.76	1				
CVC3			0.47/0.48	4				
CVC4			0.57	3				
CVC5			0.52/0.53	3				
CVC1, CVC5	0.78 ± 0.25	52	0.54	3	4.00	4.50	5.00	5
CVC2, CVC3			0.50	4	4.00	4.00	5.00	
CVC4			0.50	4	4.00	5.00	5.00	
CVC1	1.33 ± 0.25	47	0.25	4	5.00	5.00	5.00	5
CVC2, CVC5			0.28	4				
CVC3			0.0	5				
CVC4			0.20	4				

identify the cognitive conditions under which the relationship between Effectuation and Circular Value Creation varies. The analysis was structured around three research questions (RQ1 to RQ3) and their related hypotheses (H1 to H5c), improving understanding of how entrepreneurial reasoning is associated with KBMs and circular approaches to value creation.

The findings for H1–H3, which address RQ1, indicate significant positive relationships between Effectuation and OIC, SOLC, and CVC. In particular, Effectuation was positively associated with both OIC and SOLC. In addition, Effectuation was positively associated with CVC. Together, these findings are consistent with the premise that Effectuation represents a cognitive orientation associated with collaborative and learning mechanisms relevant to circular approaches to value creation.

Sarasvathy et al. (2001) argue that decision-makers who employ an effectual approach create opportunities through the resources available to them and co-operating with others rather than by predicting the future. This orientation fits within the open innovation paradigm proposed by Chesbrough et al. (2024), which outlines how firms extend their innovation range by collaborating with external knowledge networks.

Futterer et al. (2018) similarly show that firms may establish partnerships prior to development activities and engage in continuous knowledge sharing. In turn, these relationships are associated with opportunities for innovation and the recombination of knowledge relevant to sustainable and circular innovation.

The association between Effectuation and SOLC is consistent with experiential processes of learning, adaptation, and experimentation that are central to effectual decision-making (de Sousa Jabbour et al., 2022).

These findings align with those of Müller and Siebenhüner (2007), who concluded that organisations that use a flexible, open-ended decision--making process are more likely to improve sustainability performance than those that use a fixed, traditional approach, suggesting the relevance of flexible decision-making approaches in contexts involving circular transition.

Effectuation, as a form of entrepreneurial reasoning characterised by iterative experimentation, is consistent with the flexible use and recombination of resources in circular economy contexts. This finding aligns with the views of Coffay and Bocken (2023), who have stressed the importance of co-creating organisations' cognitive experiences with customers in order to embed circular economy principles throughout their business models; it also aligns with those of Sahabuddin et al. (2023), who concluded from their research that firms that view uncertainty as an opportunity rather than solely as a risk may be better positioned to pursue circular value creation. These findings also contrast with more traditional predictive or linear approaches to strategy, which hold that a company's chances of developing and implementing a circular transition will be greatly enhanced if it adopts a formalised, measured approach. Collectively, these findings indicate that Effectuation represents a cognitive orientation associated with the development and utilisation of sustainability-related capabilities and circular value creation. Effectuation therefore provides a useful cognitive perspective for understanding how organisations may respond to uncertainty while pursuing circular innovation.

The findings further complement recent circular economy research suggesting that successful circular transitions depend not only on technological innovation but also on organisational capabilities that facilitate learning, stakeholder collaboration, and ecosystem development. In this regard, the present study positions circular value creation as being associated with complementary innovation and learning capabilities, thereby extending recent work on circular economy ecosystems and capability development (Santa-Maria et al., 2022; Peçanha & Ferreira, 2025; Camilleri, 2025).

RQ2 examined whether Open Innovation Capability and Sustainability-Oriented Learning Capability mediate the relationship between Effectuation and Circular Value Creation, both individually and sequentially. The results supported H4a and H4b, indicating significant partial mediation through OIC and SOLC, respectively, while the significant sequential indirect pathway through OIC and SOLC supported H4c. Overall, these findings indicate that Effectuation is associated with CVC both directly and through distinct capability- and knowledge-based pathways involving OIC and SOLC.

The present findings are also consistent with recent research that highlights that open innovation capability is increasingly viewed as a collaborative organisational capability underpinning circular economy implementation rather than merely a knowledge acquisition mechanism. Recent studies emphasise that inter-organisational collaboration, stakeholder engagement, and knowledge integration constitute critical enablers of circular innovation and value co-creation. Our findings extend this stream of research by positioning Effectuation as an important cognitive orientation associated with collaborative capability development under conditions of uncertainty (Köhler et al., 2022; Calabrese et al., 2024; Camilleri, 2025).

The Knowledge-Based View suggests that organisations develop performance through the effective use of knowledge capabilities rather than merely through strategic intent (Eisenhardt & Santos, 2002; Showkat & Nagina, 2025; Ul-Durar et al., 2023). Effectual reasoning is consistent with the utilisation of knowledge through external alliances and the co-creation of solutions relevant to organisational problem-solving (Jesus & Jugend, 2023). Furthermore, open innovation is associated with external knowledge access and integration, which may complement Sustainability-Oriented Learning Capability.

The sequential mediation findings highlight a relationship in which exploratory external collaboration is associated with subsequent internal sustainability-oriented learning in the context of circular innovation. For example, Eisenreich et al. (2021) found that organisations most often begin their journey of circular innovation through the formation of external partnerships aimed at developing new ideas and technologies, then internally transform those ideas and technologies through the learning and adaptive process. The findings of Mirza et al. (2022) are consistent with this interpretation, indicating that the relationship between open innovation and sustainability transformation may depend on strong learning and absorptive capabilities within organisations.

The sequence detailed here is unlikely to be applicable across all organisations. The relationship between sustainability learning and collaboration is likely to vary depending on whether sustainability has been integrated within an organisation for an extended period. An established internal orientation towards sustainability may also be associated with greater engagement in external collaboration through Open Innovation, suggesting some potential bi-directionality between internal learning and external collaboration. As a result, future research will need to investigate how the interplay between these capabilities may differ between different types of industries or institutional environments. Overall, the findings indicate that SOLC and OIC represent distinct capability-based pathways associated with the relationship between Effectuation and Circular Value Creation. Specifically, effectuation is linked to knowledge flows to external partners followed by internal learning associated with the organisation's capabilities. The combined roles of SOLC and OIC highlight the relevance of both organisational openness and sustainability-oriented learning to circular value creation.

The complementary TP-based fuzzy rule analysis – understood as an exploratory interpretability exercise rather than as independent validation – offers a rule-based perspective that is consistent with the centrality of OIC and SOLC as mediating channels. When the initial set of seven Takagi-Sugeno rules – defined over all five latent dimensions – was simplified by removing the collinear antecedents, OIC and SOLC alone retained an internal consistency of $R^2 = 0.914$, suggesting that these two capabilities carry the bulk of the explanatory structure linking effectuation to CVC. Moreover, the simplified rules reveal a broadly positive yet nonlinear combined association: higher levels of either OIC or SOLC are generally associated with higher CVC, but several rules share the same antecedent combination with different consequents, indicating that OIC and SOLC do not exhaustively account for all variance – consistent with their role as partial mediators rather than sole determinants.

RQ3 examined whether Paradox Mindset moderates the direct and indirect relationships between Effectuation and CVC, as specified in H5a–H5c. The results provide a contextually sensitive understanding of the role of Paradox Mindset in the relationships between Effectuation and CVC. Hypothesis H5a was not supported because the interaction-specific indirect effect for the serial pathway from Effectuation to Circular Value Creation through Open Innovation Capability and Sustainability-Oriented Learning Capability was not statistically significant. Instead, the moderated-mediation analysis indicates that the indirect relationship through Sustainability-Oriented Learning Capability was stronger at higher levels of Paradox Mindset, whereas no significant moderated mediation was observed for the serial capability-building pathway. Specifically, the indirect relationship between Effectuation and Circular Value Creation through Sustainability-Oriented Learning Capability was stronger at higher levels of Paradox Mindset (H5b), while the direct positive relationship between Effectuation and Circular Value Creation was weaker at higher levels of Paradox Mindset (H5c). The interaction-specific indirect effects further indicated that only the moderated mediation through Sustainability-Oriented Learning Capability was statistically significant, whereas the serial moderated mediation through Open Innovation Capability and Sustainability-Oriented Learning Capability was not supported.

The findings suggest that Paradox Mindset plays a selective rather than uniformly positive role in the relationships between Effectuation and circular-transition outcomes. Specifically, the significant positive

moderation of the SOLC pathway is consistent with the findings of Khan et al. (2025), who highlight the role of paradoxical mindsets in enabling individuals to engage with and learn from competing demands and contradictions. Individuals with a paradox mindset may perceive tensions as opportunities for knowledge development by integrating multiple perspectives. Consistent with Smith and Lewis (2011), this finding suggests that engaging with competing yet interdependent demands may enable decision-makers to accommodate tensions rather than resolve them through an either-or choice. Accordingly, Paradox Mindset appears particularly relevant to the learning dimension of circular transformation, where organisations must engage constructively with competing priorities and sustainability-related tensions. In the present context, such paradoxical cognition is associated with a stronger sustainability-oriented learning pathway, suggesting that tensions between operational and sustainability priorities may provide a context for reflective learning and knowledge integration. The significant moderated mediation through Sustainability-Oriented Learning Capability suggests that paradoxical cognition is particularly relevant to the reflective learning processes associated with circular transformation and the constructive engagement with competing priorities. These findings suggest that Paradox Mindset is less relevant to collaborative capability development and more strongly associated with reflective learning and sustainability-oriented knowledge integration under conditions of uncertainty.

In summary, Effectuation represents a cognitive meta-capability associated with circular transitions, while OIC and SOLC represent important pathways through which effectual reasoning is associated with CVC. Paradox Mindset plays a selective role in these relationships, with the sustainability-oriented learning pathway being stronger at higher levels of Paradox Mindset, while its moderating relationship with Open Innovation Capability is not statistically significant. At the same time, the positive relationship between Effectuation and CVC is modestly weaker at higher levels of Paradox Mindset. Overall, these findings position circular transformation as involving an interplay among cognition, organisational capabilities, learning and collaborative processes, and the management of cognitive tensions.

The fuzzy rule analysis provides an additional perspective on these dynamics. By mapping the rule antecedents and consequents back onto the original questionnaire indicators, the analysis reveals the item-level tendencies associated with different levels of CVC. This bridges the gap between latent scores and observable questionnaire responses, providing insights into how ‘low’, ‘medium’ and ‘high’ levels of OIC and SOLC can be interpreted in the context of survey responses, and how they are associated with different levels of circular value outcomes.

Conclusion

The Effectuation construct was conceptualised as a reflective-reflective higher-order construct representing entrepreneurial decision-making. The findings position Effectuation as a cognitive orientation associated with Circular Value Creation, both directly and through knowledge-based capability pathways involving Open Innovation Capability and Sustainability-Oriented Learning Capability. Paradox Mindset plays a selective moderating role in these relationships.

Together, Effectuation Theory and the Knowledge-Based View informed the proposed model and provided a basis for conceptualising Open Innovation Capability and Sustainability-Oriented Learning Capability as mediating constructs in the relationship between effectual reasoning and CVC. The paradox mindset was treated as a type of higher-order cognitive condition that should affect both the direct effects of effectual reasoning and the mediating effects through OIC and SOLC.

In answering RQ1, the findings indicate significant positive relationships between Effectuation and OIC, SOLC, and CVC, supporting H1–H3. In other words, greater use of effectual logic is associated with higher levels of open innovation capability, sustainability-oriented learning capability, and circular value creation. In answering RQ2, the results indicate significant indirect relationships between Effectuation and CVC through OIC and SOLC, both individually and sequentially, supporting H4a–H4c. These findings suggest that effectuation is associated with circular value creation both directly and through capability- and knowledge-based pathways involving open innovation and sustainability-oriented learning. The findings related to RQ3 indicate a more intricate moderating role of paradox mindset. While the hypothesised moderated serial mediation was not supported (H5a), paradox mindset was found to strengthen the Effectuation → SOLC → CVC pathway and modestly weaken the direct Effectuation → CVC link (H5b and H5c supported). This pattern suggests that paradoxical cognition is associated with stronger sustainability-oriented learning under conditions of tension and uncertainty, while modestly attenuating the direct relationship between effectual reasoning and circular value creation.

In summary, the findings position Effectuation as a cognitive meta-capability associated with circular value creation through both learning- and collaboration-oriented capability pathways. The results further indicate that Paradox Mindset plays a selective role in these relationships, being positively associated with the sustainability-oriented learning pathway while modestly attenuating the direct relationship between Effectuation and CVC. Taken together, the findings offer a more nuanced understanding of circular transformation as an interplay among entrepreneurial cognition, organisational capabilities, knowledge processes, and the management of competing tensions.

Theoretical contributions

This research provides several theoretical contributions to our understanding of how entrepreneurial cognition relates to organisational capabilities and circular value creation. Instead of introducing new constructs, this research integrates Effectuation with knowledge-based capabilities, which sheds light on how entrepreneurial cognition is related to circular value creation through different learning and collaborative perspectives.

Furthermore, the results contribute to the circular economy literature. The study advances understanding of CVC by highlighting the importance of entrepreneurial cognition in circular value creation. The results also position Effectuation as a meta-cognitive capability in organisational responses to uncertainty and as a capability-based pathway related to circular transition.

Second, this study contributes to both the knowledge-oriented perspective and open innovation literature as it illustrates that Open Innovation Capability and Sustainability-Oriented Learning Capability may play complementary mediation roles in the Effectuation-Circular Value Creation relationship. The assessed individual and sequential indirect pathways contribute to a better understanding of how effectual reasoning relates to circular value creation through capability- and knowledge-based pathways.

Third, the study informs the usage of Effectuation beyond its well-known area of entrepreneurship and start-ups by examining its role among established companies engaged in circular value creation. The study broadens the understanding of Effectuation in organisations undergoing sustainability- and circular value creation-related uncertainties.

Fourth, the study also contributes to the methodological field by incorporating a procedure for extracting fuzzy rules based on the use of the Tensor Product approach, which complements the PLS-SEM analysis. Takagi-Sugeno rules provide an interpretable description of the structural patterns in the SEM model using latent variable scores. This does not serve as a separate validation of the PLS-SEM estimates but adds an exploratory interpretability perspective, as it describes the mediation of OIC and SOLC by means of rules.

The study further contributes to paradox theory by showcasing the selective role of paradoxical cognition across diverse circular contexts. It was found that paradoxical cognition is positively associated with the sustainability-related learning pathway as long as tension and

uncertainty prevail, while its effect on the Effectuation-OIC relationship is insignificant. This specific practice extends understanding of the concept of paradox mindset, as it implies that the role of paradoxical cognition may change according to the pathways through which effectual reasoning is used.

Managerial and policy implications

Several practical implications emerge for managers responsible for corporate innovation and for policymakers seeking to support established organisations in their transition toward more circular and environmentally sustainable business models. The findings suggest that circular transition may involve not only the integration of new technologies into organisational processes but also managerial approaches to uncertainty and resource constraints. In this context, effectual reasoning may help managers work with available resources, engage internal and external knowledge networks, and pursue circular value opportunities under conditions of uncertainty. Managers may therefore consider complementing predictive planning with iterative experimentation and learning when evaluating sustainability-oriented innovations.

According to the findings, knowledge-based capabilities represent an important link between entrepreneurial cognition and circular value creation. Strengthening open innovation capabilities through joint problem-solving platforms, collaborative partnerships and the transparent sharing of knowledge may be considered by managers to facilitate access to diverse perspectives relevant to circular design and value recirculation. At the same time, developing sustainability-oriented learning capabilities by embedding sustainability training, learning loops, and reflection into organisational processes may help organisations absorb, contextualise, and translate external insights into action. Together, these capability-building practices are consistent with the learning- and collaboration-oriented pathways associated with circular value creation in the present study.

The differentiated role of Paradox Mindset also offers a relevant managerial insight. Because Paradox Mindset was positively associated with the learning-based pathway while modestly attenuating the direct Effectuation–CVC relationship, managers should recognise that greater tolerance for competing demands may not operate uniformly across circular-transition processes. Organisational practices such as cross-functional sustainability teams and structured dialogue around competing priorities may provide useful settings for encouraging reflection, cognitive diversity, and constructive engagement with tensions.

From a policy and ecosystem perspective, this study emphasises the relevance of supporting knowledge networks that connect firms, research institutions and other stakeholders working towards sustainability within a wider circular economy. A policy framework that encourages organisations to carry out open experimentation, share innovative resources and develop sustainability learning platforms may create conditions conducive to capability development at both organisational and ecosystem levels.

Overall, the findings suggest that circular transformation is associated with both structural and cognitive dimensions. Organisations may therefore benefit from combining effectual reasoning, collaborative learning, and constructive engagement with paradoxical tensions when navigating uncertainty in the pursuit of circular and sustainability-oriented innovation.

Limitations and future research directions

The study provides important theoretical and practical insights; however, several limitations should be considered when interpreting the findings. First, the cross-sectional survey design limits causal inference. Although the proposed relationships are grounded in established theory and estimated using a rigorous PLS-SEM framework, the observed relationships should be interpreted as theory-consistent associations rather than definitive evidence of causality. Furthermore, the cross-sectional design does not completely eliminate the possibility of endogeneity arising from omitted variables, reverse causality, or unobserved heterogeneity. Future research could strengthen causal inference by employing longitudinal or experimental research designs and, where the underlying methodological assumptions are satisfied, advanced endogeneity assessment techniques such as Gaussian Copula analysis.

Future studies could further examine how effectual reasoning, knowledge-based capabilities, and circular value outcomes develop over time through iterative learning and strategic adaptation, thereby capturing the temporal dynamics of capability development and potential feedback loops associated with circular transitions.

Another limitation is that all measures in this study were self-reported. Self-reported data may be subject to common method bias and perceptual subjectivity. Although common method bias was addressed through the use of procedural remedies and statistical checks in this study, incorporating multi-source data and/or objective data could enhance the robustness and external validity of future studies. Examples of additional data sources may include performance metrics related to resource recovery, innovation outputs and/or partnerships. Using qualitative triangulation, such as conducting interviews or observing in-depth case examples, would provide insight into the cognitive and cultural components of effectuation in real-world decision contexts.

A third limitation is that this research conceptualised Effectuation as a reflective-reflective second-order construct. Alternative model specifications remain theoretically justifiable. Future research could explore differences between formative-reflective and/or mixed hierarchical models to understand whether the individual elements of effectuation impact learning and collaboration pathways differently. Additionally, growing empirical evidence supports the notion that paradox mindset moderates entrepreneurial reasoning and therefore does not uniformly affect all innovations. Future researchers should investigate additional metacognitive traits (e.g., systems thinking, ambidextrous cognition, or sustainability mindset) to clarify how and when entrepreneurial reasoning links to circular innovation outcomes.

The model, although fairly comprehensive, still offers a narrow perspective on the cognition–capabilities–values relationship across the full extent of the circular economy. Future research should include more mediating variables that may also play a role in shaping circularity when used in combination with effectual reasoning, and include variables such as dynamic capabilities, digital transformation facilitators, and organisational culture. By adding additional mediating variables, researchers may obtain a more complete understanding of how the interaction of cognitive, structural, and technological factors drives circular transitions.

Finally, the TP-based fuzzy rule analysis should be interpreted as an exploratory, complementary interpretability exercise rather than an independent validation of the structural model. Because the fuzzy rules were derived from the latent variable scores produced by the PLS-SEM model and were extracted from the same sample used to estimate that model, they cannot provide out-of-sample corroboration of the structural estimates. Future research could assess the generalisability of the extracted rules by re-estimating them on independent samples, through cross-validation designs, or by relating them to objective indicators of circular value creation.

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CRediT authorship contribution statement

Wang Sheng: Writing – review & editing, Writing – original draft, Validation, Conceptualization. **Ping Zhong:** Writing – original draft, Formal analysis, Data curation. **Adam B. Csapo:** Writing – review & editing, Writing – original draft, Project administration. **Armando Papa:** Writing – review & editing, Software, Resources, Methodology. **Ciro Troise:** Writing – review & editing, Writing – original draft, Supervision, Investigation.

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