

What facilitates frugal innovation? – A configurational study on the antecedent conditions using fsQCA



Hui Fu^a, Min Xu^a, Yingyu Wu^{b,*}, Weiqing Wang^a

^a School of Business, Sun Yat-sen University, 501Zhongkai Road, Haizhu District, Guangzhou 510225, PR China

^b School of Business, Zhongkai University of Agriculture and Engineering, Guangzhou, Guangdong, PR China

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ABSTRACT

Frugal innovation, a new paradigm suitable for start-ups to promote innovation with restrained resources, has proliferated over the past decade. However, a comprehensive analysis of the factors affecting frugal innovation during the entrepreneurial process is lacking. To fill this gap, this study explores the antecedent conditions of frugal innovation, based on the Timmons model and configurational perspective through a fuzzy set Qualitative Comparative Analysis of 132 start-ups in China. Resources, entrepreneurial opportunities, and top management teams are key factors in an entrepreneurial process. Our study findings indicate that frugal innovation cannot be achieved through one of these factors independently. Further analysis indicates that the combined effects of resources, entrepreneurial opportunity, teams, and digital technologies facilitate frugal innovation; particularly, four configurations are observed to enhance it. These include the "sustainable leadership-centric and resource-enhanced configuration" (F1), the "cognitive flexibility-centric and market response-enhanced configuration" (F2), the "digital technology and resource double-centric configuration" (F3), and the "multiple centric configuration" (F4). Moreover, complementary or substitutional relationships exist among resource bricolage, external relational embeddedness, resource activities, and market activities.

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Introduction

Emerging economies remain the backbone of global economic growth, despite their enterprises facing declining external market demand, rising business costs, and insufficient innovation budgets and capabilities (Zahra, 2022). How these enterprises survive and innovate effectively, using restrained resources, has attracted the attention of scholars and entrepreneurs. Frugal innovation (FI), a new paradigm suitable for startups to promote innovation and technological catch-up with limited resources (Wooldridge, 2010), is particularly significant for emerging economies. FI is caused by the gap between the unsatisfied demand for low-priced products from the bottom of the pyramid and the weak economic foundation of emerging markets (Hart & Christensen, 2002). This enables enterprises to design products and services from scratch at low cost (Dabić, Obradović, Vlačić, Sahasranamam & Paul, 2022). Therefore, disclosing the conditions (and their combinations) that facilitate corporate FI in emerging economies and how they interact are of great significance.

To analyze and reveal how FI is initiated, it is necessary to define the prerequisite conditions. Previous studies have investigated the

antecedents of FI from different perspectives, i.e., leadership theory (Iqbal, Ahmad, Li, Li & Dnes, 2022), social networking theory (Wei & Iqbal, 2022), knowledge management perspective (Shehzad, Zhang, Le, Jamil, & Cao, 2022; Q. Iqbal, Ahmad & Li, 2021). A comprehensive analysis reveals that factors significantly stimulate frugal innovation, including firm-level resource constraints (Ploeg, Knoben, Vermeulen & van Beers, 2021), bricolage capability (Santos, Borini & Pereira, 2020), sustainable leadership (Iqbal et al., 2022), internal and external sources of knowledge (Dost, Pahi, Magsi & Umran, 2019), managerial ties (Wei & Iqbal, 2022), and market and technological turbulence (Shehzad, Zhang, Le, Jamil, & Cao, 2022).

Previous research has focused primarily on analyzing individual influencing factors, rarely integrating them for a holistic perspective. To deepen the research on frugal innovation, our study combines existing literature and the Timmons model with innovative practices in emerging markets. The Timmons model focuses on the complex interactive entrepreneurial and innovation process (Timmons, Spinelli & Tan, 2004). Existing studies on this model primarily consider three different elements—resources, opportunities, and teams—which are the antecedents of any entrepreneurial process. FI is a complex process wherein multiple factors interact with, and influence each other, and a "configurational perspective" is suitable for uncovering causal complexity among multiple factors in complex decision-making processes (Leppänen, George & Alexy, 2023). From a

* Corresponding author at: Zhongkai University of Agriculture and Engineering, 501 Zhongkai Road, Haizhu District, Guangzhou, 510225, PR China.
E-mail address: wuyingy3@zhku.edu.cn (Y. Wu).

configurational perspective, multiple influences are interdependent and can be combined to achieve the common purpose of influencing decision outcomes. Thus, based on the Timmons model, our study explores the complexity of FI from a novel holistic viewpoint and defines the relationships between the conditions and FI of enterprises, in terms of sets rather than variables.

The fuzzy-set qualitative comparative analysis (fsQCA) method proves valuable for this research as it allows for the consideration of various conditions and their combinations, particularly with a smaller research sample size (Ragin, 2008). While quantitative research methods, such as linear regression models, have been beneficial for examining one-to-one correspondence effects on the FI of a single factor, such as bricolage (Q. Iqbal, Ahmad & Halim, 2021), resource constraints (Bhatti, 2014), market demand (Soni & T. Krishnan, 2014), and organizational culture (Ananthram & Chan, 2021), they are constrained by modeling and analysis software, and are one-sided. For instance, in correlational theorizing, a linear relationship is expressed as "the more of X, the more of Y" (Delbridge & Fiss, 2013). However, in today's VUCA environment, many enterprises increasingly participate in complex social networks through globalization and digitalization. Simple "net effects" or linear research conclusions cannot accurately explain the reality of frugal innovation in global contexts because they overlook the systematic synergistic impact of these related elements. Qualitative research methods, such as case studies, also have limitations in exploring the integrated impact of multiple factors in the innovation process. The inductive case-study approach, typically employed by scholars to study processes, often confines itself to theoretical descriptions and derivations, lacking an analysis of the relationships and interactions between conditions across multiple cases, leading to less specific and targeted research conclusions (Agarwal & Brem, 2012). fsQCA can effectively combine quantitative and qualitative research methods, allowing feature interaction studies through grouping, theory construction, and derivation, providing tools for studying complex systems with multi-factor interactions.

In summary, we used a configurational perspective based on the Timmons model and embarked on an fsQCA approach to reveal the net and interactive effects of multiple factors that work together, and to explore which factors play a more important role and the kinds of complementary or alternative relationships existing among them. The remainder of this paper is organized as follows. Section 2 provides a concise overview of the relevant literature and explores the factors and mechanisms affecting frugal innovation by combining the process perspective, outlining the research questions, and the antecedents and configurations of frugal innovation. Section 3 describes the sample and methodology used in our study, i.e., the analysis of a sample of 132 small and medium-sized enterprises (SMEs) to examine these configurations within the context of digital economy. Section 4 presents and discusses the results obtained from our analysis, explores the role of different factor groups in forming FI through fsQCA, and systematically deconstructs the determinants of the FI. In Section 5, we draw the conclusions and offer theoretical and practical implications based on the findings. Section 6 discusses the limitations of the study and provides suggestions for future research directions.

This study makes several theoretical contributions to the literature. First, based on Timmons' model, we develop a novel interactive model of the FI formation process and provide a systematic and complete theoretical analysis framework for studying and promoting frugal innovation. Second, we expand the literature on FI by analyzing processes from a new process-based perspective. Third, we use fsQCA to study the factors influencing the formation configuration of FI, focusing on four elements: resource activities, market opportunities, top management teams (TMTs), and digital technology. The findings will help researchers gain more accurate insights into entrepreneurship and FI, and may be applicable to enterprises in emerging markets.

Literature review and research framework

Frugal innovation

Frugal innovation has traditionally evolved from "frugal engineering" to describe the pattern of behavior of Renault-Nissan Alliance's low-cost innovations under resource constraints (Hossain, Simula & Halme, 2016). Researchers have identified FI as a resource-scarce solution, designed and implemented, despite financial, technological, material, and other constraints; it involves the use of fewer resources to develop sustainable, affordable, and accessible products (Hossain et al., 2016; Shehzad, Zhang, Le, Jamil & Cao, 2023). This usually involves finding simple, cost-effective, and non-traditional methods to meet the needs of specific markets or user groups, especially in resource-constrained environments. Frugal innovation emphasizes efficiency, affordability, and doing more with less, while still delivering valuable outcomes by leveraging available resources. Frugal innovation is fundamentally different from traditional innovation models (see Table I). Radjou sees FI as a new business model to achieve "high value-add and low cost," thereby being an important way to meet the needs of bottom-of-the-pyramid consumers (Radjou, Prabhu & Ahuja, 2012). Weyrauch and Herstatt focus on the essence of FI, summarizing it as "cost saving," with "core function focus," and "performance excellence" (Weyrauch & Herstatt, 2017). FI can create value via product, service, process, or business model innovation, providing efficiency in integrating new technologies and delivering products that are significantly cheaper and sufficient to meet customers' basic needs (Hossain et al., 2016). Previous research has used innovation activities or activity levels in process studies to explain FI. Malik and Aggarwal identify FI as uniquely contextualized Emerging Market Multinational Companies' capabilities to readily use materials and existing resources to manufacture products and services (Malik & Aggarwal, 2012). Based on the product-oriented perspective, Agarwal et al. define FI as products and services that are "good enough" to overcome resource constraints, and affordable to a wide range of consumers (Agarwal, Grottke, Mishra & Brem, 2016).

Owing to the recent global economic slowdown, people have become increasingly concerned about providing solutions to reduce poverty and utilizing limited resources to drive innovation and technological catch-up. Previous studies have discussed several types of innovations aimed at serving underserved customers (Hossain, 2020). Social innovation, such as reverse, grassroots, inclusive, and frugal innovation, refers to innovations that originate in emerging markets (Govindarajan & Ramamurti, 2011; Agarwal & Brem, 2017; Brem, Wimschneider, de Aguiar Dutra, Cubas & Ribeiro, 2020; Mortazavi, Eslami, Hajikhani & Vaatanen, 2021; Prabhu & Jain, 2015; Zeschky, Widenmayer & Gassmann, 2011). Following the guidelines of Marina Dabić et al. (2022)), this study categorizes these low-cost innovations into eight types and selects relevant articles for analysis, as shown in Table II. The primary difference between frugal and other

Table I
Frugal Innovation Model vs. General Innovation Model.

	General innovation model	Frugal innovation model
Place of occurrence	Developed countries	Emerging Economies
Resource input	Large quantity	Limited
Product price	Expensive	Cheap
Population served	Affluent groups	Population with weak purchasing power
Innovation process	Strategy -oriented	Flexibility-oriented
Diffusion direction of innovation results	From developed to developing countries	From emerging economies to developed countries
Typical cases	Apple and GlaxoSmithKline	Transsion Mobile Phone and Tata Nano EV

Table II
Literature related to poverty alleviation.

Type of Innovation	Definition and key characteristics	Reference
Reverse innovation	Reverse innovation is defined as a transfer of ideas from emerging to developed markets. It is characterized by products and services initially meant for low-cost countries becoming acceptable in developed countries.	Govindarajan & Ramamurti, 2011; Zeschky et al., 2011
Constraint-based innovation	These are innovations conceived under the extreme resource constraints existing in EMs. It is characterized by the utilization of the fewest resources to meet the widest market needs at affordable prices.	Agarwal & Brem, 2017
Grassroots innovation	These innovations are primarily designed to reduce or eliminate drudgery and are created by local people using local resources. It is characterized by local civilians becoming inventors and using their social networks for commercialization.	Hossain, 2020
Jugaad innovation	Jugaad is the "the art of overcoming harsh constraints by improvising an effective solution, using limited resources" and is defined as "an attempt to maximize the ratio of value to resources" using the principles of frugality (low cost), flexibility, and inclusivity. It is characterized by improvised quality and used by people in India.	Prabhu & Jain, 2015; Radjou et al., 2012
Inclusive innovation	Inclusive innovation is a form of innovation that was crafted to develop mechanisms for companies and other actors. It is characterized by not only serving the needs of lower-income people affordably, but also building their capabilities, and enhancing their empowerment and welfare	Mortazavi et al., 2021
Bottom of the Pyramid (BoP) innovation	Entrepreneurship at the bottom of the pyramid is a new way to exert the bottom vitality and tackle poverty. It is characterized as used by people at the Bottom of the Pyramid (BoP).	Brem et al., 2020
Frugal innovation	A resource-scarce solution (i.e., product, service, process, or business model) that is designed and implemented despite financial, technological, material or other resource constraints, whereby the outcome is significantly cheaper than competitive offerings (if available) and is good enough to meet the basic needs of customers. It is characterized by being specifically designed in emerging markets and driving sustainable development.	Hossain et al., 2016; Marina Dabić et al., 2022

innovations is that FI is specifically designed for emerging markets or resource-scarce environments; therefore, it can reduce the use of scarce or expensive resources, thereby developing profitable solutions at an affordable price (Asakawa, Cuervo-Cazurra & Annique Un, 2019). Another unique characteristic of FI is that it can drive sustainable development (Hossain, 2020).

As any innovation model is always influenced by social, economic, and environmental characteristics, previous research related to the antecedents of FI argues that the rise of frugal innovation is mainly driven by three forces: the market, environment, and technology. Given that resource and market limitations are the main obstacles to FI, enterprises must seek opportunities in highly uncertain emerging markets and overcome core rigidities in competition through resource allocation to achieve FI. Emerging market environments provide a unique context for innovation, which is an important prerequisite for FI. Sharma and Iyer argue that FI stems from resource scarcity and advocates using limited resources to meet the needs of low-income customer groups (Sharma & Iyer, 2012).

Frugal innovation is a form of innovation that aligns with the sustained growth of emerging markets and the increasingly severe scarcity of resources. Kantabutra and Avery (2011) examined the sustainable business practices of a large listed Thai enterprise, the Siam Cement Group (SCG), and found that enterprises in Thailand and other less-developed countries aim to sustain their organizational success by focusing on long-term perspectives, people's priorities, innovation, and uncertainty. Based on the upper echelon theory (UET), Iqbal et al. (2022) investigated the mechanism of sustainable leadership-environmental performance and found that frugal innovation partially mediated the impact of sustainable leadership on environmental performance. From a technology-driven perspective, Dost et al. (2019) discussed the significant effects of internal and external knowledge sources on FI, revealing that these are strengthened by the moderation of technological turbulence. Market turbulence enhances the influence of external knowledge sources and weakens that of internal knowledge sources on FI.

Despite the considerable number of studies on "frugal innovation," some interesting and potentially important issues are identified in our review of previous research. First, existing FI research has predominantly adopted either an antecedent-oriented or process-oriented perspective, often treating FI as a 'single' step. Further exploration and definition of the nonlinear relationships between the

influential factors on FI represent future research opportunities. Second, the proposed variables of the factors influencing the FI were random and scattered. Moreover, previous research has mostly focused on the net effect of each antecedent variable on FI, without exploring the basic conditions and specific contexts in which each factor operates. Therefore, to understand the primary reasons for the success of FI, an integrated analytical framework for the antecedents is needed to help us understand these factors and their synergetic effects.

An extension of Timmons' model of frugal innovation

Timmons' model, developed by Timmons in 1974, has traditionally been regarded as a framework for analyzing the entrepreneurial process (Timmons et al., 2004). The model views entrepreneurship as a highly dynamic balanced process, driven by the synergy of three key factors, i.e., resources, entrepreneurial opportunities, and TMTs, and entrepreneurial growth as an adaptation and balance of these three elements (Zhang & Yang, 2006). As suggested, an entrepreneurial opportunity is initially the core factor in creating a new venture, while resources provide the necessary support for the entrepreneurial process and serve as the basis for developing and utilizing opportunities. TMTs are decision makers who adjust enterprises' activities to balance entrepreneurial opportunities and resources. Innovation and entrepreneurship are often considered as integrated development processes with the same roots. Digital transformation is the focus of enterprises in today's digitalized environment (Li et al., 2023). Thus, from the process-based perspective of "status-transformation-result," this study extends the Timmons model to the context of FI and suggests that resources, entrepreneurial opportunities, TMTs, and digital technology are important antecedents of FI. This paper presents the configurations of causally interrelated structures of sets of factors.

(1) Resource

The integration of internal and external resources is an important process to achieve innovation, which is reflected in the internal resource "bricolage" (Halme, Lindeman & Linna, 2012) and external relational embeddedness (Isaac, Borini, Raziq & Benito, 2019). Bricolage refers to using the resources at hand and combining them to solve new problems or create opportunities and innovations (Baker & Nelson, 2005). Scholars consider bricolage an important action

strategy to achieve FI because it enables declining enterprises to utilize the resources at hand, thus resolving for their resource constraints in technology, personnel, and materials and facilitating product, technological, and business model innovation (Hoskisson, Wright, Filatotchev & Peng, 2013). The knowledge-management perspective proposes that a significantly frugal innovative outcome stems from a rich knowledge base and diverse knowledge portfolios through heterogeneous knowledge-sharing mechanisms (Iqbal & Piwowar-Sulej, 2023; Wang & Li, 2023).

External relational embeddedness refers to the external relationships established by enterprises and other institutions, such as with governments, universities, research institutions, and relevant associations (Isaac et al., 2019). Social networking theory claims that managerial ties enable firms to access external knowledge, technology, and resources, which, in turn, acquire knowledge and allocate resources from the external environment to stimulate frugal innovation (Wei & Iqbal, 2022; Asai, K. & Wang, H., 1996). Frugal companies thrive in environments characterized by notable institutional gaps and limited resources. However, within these environments, the interconnected relationships among ecosystem participants are leveraged to create cost-effective and sustainable solutions that address institutional gaps and overcome constraints (Curley, Donnellan & Costello, 2013). Frugal innovation activities are embedded in social relations, and external relational embeddedness often functions as a substitution mechanism for enterprises to improve their operational and innovation efficiency. Specifically, links with governments help enterprises better understand and obtain policy information and funding support; universities and research institutions help them obtain technical knowledge; and relevant associations or other enterprises help them obtain market information and enhance cooperation (Zhang et al., 2023).

Thus, this study argues that enterprises in emerging economies can creatively allocate all available internal and external resources to create cost-effective products and services, meet cost-sensitive consumer demand, and achieve high FI levels.

(2) Entrepreneurial Opportunity

Opportunities drive entrepreneurship. Entrepreneurship involves creating or seizing opportunities and exploiting them, regardless of whether the company has sufficient resources. Previous research findings indicate that situational factors, including market (Shehzad et al., 2022) and technological (Q. Iqbal et al., 2021) turbulence, significantly impact a firm's FI. Thus, *market responsiveness* and *opportunity iteration* are key factors for uncovering and responding to market opportunities. *Market responsiveness* refers to the ability of an enterprise to perceive and grasp potential market opportunities (Chang, Gong, Way & Jia, 2013). On the one hand, rapid market responsiveness enables companies to perceive consumer needs quickly and innovate products or services by improving their marketing adaptability and developing market-appropriate products and services to cope with the complex and volatile market environment. On the other hand, market responsiveness enables enterprises to sharply capture growth spaces and allocate resources in risky and uncertain emerging markets, loosening the shackles of insufficient resources.

Opportunity iteration refers to the process through which enterprises continuously improve their products and services to meet market demand based on market dynamics (Jimenez, 2017). Innovation is a dynamic process of continuous adjustment and trial and error; the rapid iterative cycle of enterprises can continuously optimize products, businesses, and processes, thus achieving the effect of innovation (Ketchen, Ireland & Snow, 2007). The higher the level of opportunity iteration, the faster an enterprise innovates; this provides a first-mover advantage (Eisenhardt & Martin, 2000), thereby reducing the cost of innovation.

(3) Top management teams

Frugal innovation has been examined not only in terms of its unique process, but also in terms of the mindset, beliefs, and philosophy of its innovators (Bhatti and Ventresca, 2013). The Upper Echelons Perspective suggests that the strategic direction of each enterprise is determined by its TMT (Hambrick & Mason, 1984). The impact of the TMT on innovation likely results from managers' cognitive and behavioral styles, as reflected in their cognitive flexibility and sustainable leadership. *Cognitive flexibility* refers to individuals having alternative choices for any cognitive activity and being confident about future uncertainty (Yao & Li, 2023). Frugal innovators are known for their ability to think and act (Agarwal et al., 2017; Radjou et al., 2012), as they possess the ability to transform resource constraints into opportunities (Radjou et al., 2012). TMTs with high cognitive flexibility are more innovative because they can flexibly shift their thinking patterns, weigh ideas, and solve problems from multiple perspectives. Moreover, the cognitive flexibility allows the team to shift their attention to the ever-changing market environment and allocate resources to meet market demand, freeing them from resource constraints.

Sustainable leadership embodies managers' concerns about the social and environmental benefits of corporate production, while balancing current and long-term interests. Leadership theory suggests that sustainable leadership promotes frugal innovation by instilling values, resource management practices, long-term perspectives, and commitment to social and environmental responsibility within an organization (Iqbal et al., 2022). For example, based on semi-structured interviews, observations, and internal and external documentation, Avery (Avery, 2006) proposed a sustainable leadership grid to analyze a large Thai listed company, the Siam Cement Group (SCG), and suggested that the company prioritizes values, including social responsibility, environmental stewardship, and ethical business practices. These values closely align with the principles of frugal innovation, which include affordability, resource efficiency, and inclusivity (Kantabutra & Ketprapakorn, 2020; Kantabutra & Thepha-Aphiraks, 2016). Frugality, which is considered a rational virtue, aims to maximize long-term satisfaction while maintaining a healthy equilibrium among different types of needs. Similarly, sustainability, like frugality, advocates a well-balanced approach that encompasses financial, social, and ecological objectives. Therefore, frugal innovation is frequently linked to sustainability because of its emphasis on minimizing the utilization of resources, both material and financial (Brem & Ivens, 2013; Weyrauch & Herstatt, 2017). The core principle of FI, "doing more with less," makes companies emphasize intensive production methods, eliminating unnecessary complex functions and pursuing simple and practical innovation, which can be considered a sustainable innovation approach (Wood & Mckinley, 2017). In a resource-constrained environment, the realization of frugal innovation relies on the adoption of a conservation-oriented mindset and strong support from top management with sustainable leadership (Santos et al., 2020). Leadership support, combined with a participative organizational culture, cultivates an innovative mindset within the organization (Zhou, Hu & Shi, 2015). Leaders drive innovation by setting benchmarks and encouraging continuous improvement (Lander & Heugens, 2017). Sustainable leaders prioritize the creation of long-lasting value for all stakeholders, emphasizing the judicious utilization of resources for relevant activities (Albert, 2019). Prior studies have found that sustainable leadership influences organizational citizenship behavior toward the environment through a green organizational climate, and that person-organization fit strengthens this relationship (Iqbal & Piwowar-Sulej, 2023). The pro-environmental characteristics of sustainable leadership encourage managers to reduce complexity and simplify the use of corporate resources to drive sustainable and resource-efficient innovation. Organizations with a green climate often prioritize innovation in sustainability

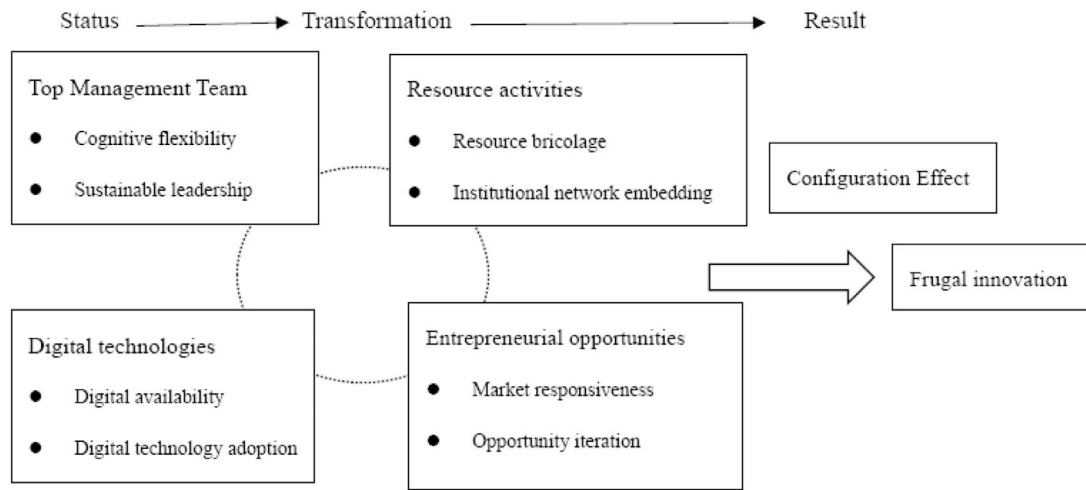


Fig. 1. Conceptual model for frugal innovation process.

practices. Frugal innovation is a form of innovation that aligns with these objectives by seeking creative, cost-effective solutions to sustainability challenges. Thus, we propose the pro-environmental characteristics of sustainable leadership to encourage managers to reduce complexity, simplify the use of corporate resources, and promote FI.

(4) Digital technology

Digital technology combines information, computers, interactions, and connection technologies (Nambisan, 2017), bringing together customers, partners, and developers, and fostering the creation of expansive markets that benefit from substantial economies of scale and enhanced efficiency. The characteristics of digital technology - editable, addressable, and perceivable - may be cost-effective for the enterprise products. The digital level of an enterprise can be estimated through *digital technology adoption* and *digital affordance*. *Digital technology adoption* can effectively assist enterprises in capturing, analyzing, and processing various data in the production process, acquiring a large amount of market information data with important potential value, and reducing the cost of searching and collecting information data for enterprises (Nambisan, 2017). Additionally, the communication function of digital technology may re-engineer business processes and generate internal innovations within enterprises (Nambisan, 2017).

Digital affordance refers specifically to the possibilities offered by digital technologies to actors (Nambisan, Wright & Feldman, 2019), including cumulative and variant affordance. Cumulative affordance is based on the addressability of digital technology, which can characterize the data and information of enterprise manufacturing and sales operations in binary numbers and homogenize them using digital technology, facilitating communication and collaboration between enterprises and other subjects under the same standards, reducing costs, and realizing innovation. Variability affordance is based on the editable nature of digital technologies, which can transform and reintegrate digital formations in different industries for different needs, while coupling loose traditional technological components into different layers, expanding innovation reach and generation, and facilitating high-level innovation realization.

Configurational conceptualization of frugal innovation

Our discussion identified potential combinations of various antecedent conditions and their intersections that may affect FI. The stimulation and generation of FI is a multifaceted, dynamic, and complex process influenced by the synergy and interaction of related factors.

As argued previously, we propose that FI may result from a wide range of perceptions, including resource bricolage and external relational embeddedness, market responsiveness and opportunity iteration, managerial cognitive flexibility and sustainable leadership, digital technology adoption, and digital affordance. Following contingent theory, we believe that the integration and interaction of these factors are the primary reasons for the success of FI.

Referring to our conceptual framework, Fig. 1 highlights the combinations of antecedent conditions that drive FI. Configurations may include combinations of these factors, leading to the following proposition.

A company's market responsiveness and opportunity iteration are important drivers to identify and transform entrepreneurial opportunities and influence the specific needs of its resources. A company's resource bricolage and external relational embeddedness constitute the resource and capability base of the innovation process and influence the feasibility of and difficulty in realizing market opportunities. At the same time, the TMT and digital technology empower the company to match the "resource-market" needs effectively, draw resources from internal and external sources continuously, and adjust them dynamically to the market environment to achieve innovation through feedback under constantly changing conditions. TMTs and digital technology elements are the existing support bases for corporate innovation, while resources and entrepreneurial opportunities are transformational keys for companies to deliver innovation performance.

Research methodology

fsQCA

fsQCA is useful for studying complex social phenomena for several reasons. First, fsQCA can study complex social phenomena that often involve relationships among multiple factors that are difficult to identify using simple linear logic (Furnari et al., 2021). Second, fsQCA is more suitable for outcomes and predictor variables on a fuzzy scale (continuous) than on a dichotomous scale (binary). Third, fsQCA offers various configurations, including necessary and sufficient conditions. The FI of enterprises in emerging economies is characterized by contextual complexity, subject diversity, and a multiplicity of levels, and the antecedent conditions are multiple and concurrent (Agarwal et al., 2016). We used fsQCA to better investigate how multiple antecedent conditions (resource activities, opportunities, teams, and digital technologies) affect FI. Different triggering paths can be analyzed by comparing the similarities and differences between different

Table III
Descriptive statistics.

Name	Choice	Number	Percentage (%)
Respondent position	Founder	31	23.48
	General manager	72	54.55
	Executive team member	29	21.97
Years of operation	Less than 5 years	18	13.64
	5–10 years	83	62.88
	More than 10 years	31	23.48
Industry	Manufacturing	59	44.7
	Service	59	44.7
	Wholesale and retail	14	10.61
Enterprise size	0–50 employees	70	53.03
	50–100 employees	41	31.06
	More than 100 employees	21	15.9

configurations, leading to the results. Using fsQCA, different paths that generate high levels of FI can be compared and analyzed.

Sample and data

As this study focused on exploring the mechanisms driving the FI of enterprises in emerging economies, the sample selected comprised SMEs in the PRD (Pearl River Delta) region of China. The sample includes only private enterprises because state-owned or foreign-owned corporations are often strong and do not suffer from a lack of resources, and their corporate innovation behavior does not fall into the category of FI.

The sample collection method included both online and offline channels. The questionnaires were collected by email or offline entrepreneurial activities (such as the entrepreneurial "creation and venture" education courses). The questionnaire had to be completed by the founder or senior management officials of a company because they possess a more in-depth understanding of the operations. A total of 171 questionnaires were collected, 132 of which were valid, with a validity rate of 77%. The sample size was greater than 100 and defined as a large sample size.

The characteristics of the samples are listed in Table III. Most enterprises (76.52%) had been in operation for less than 10 years. Those with 100 employees or fewer, accounted for 84.09% of the total. The companies belonging to the manufacturing and services industries accounted for 89.4% of the total. Respondents were mainly general managers, accounting for 53.03% of the total sample.

Measurement and calibration

Measurement

Based on the previous discussion, the factors influencing FI were classified into four elements—resources, TMT, entrepreneurial

opportunities, and digital technologies—involving eight independent variables. Each variable is measured using a 5-point Likert scale.

- (1) Resources are reflected in two dimensions: *resource bricolage* and *external relational embeddedness*. To measure resource bricolage, the scale developed by Senyard, Baker and Davidsson (2009)), which measures the flexible deployment of resources and new uses of the old resources of the enterprise, was applied. External relational embeddedness consists of the breadth and depth of the ties of an enterprise with the government and other organizations in the external environment.
- (2) Entrepreneurial opportunities were measured using *market responsiveness* and *opportunity iterations*. Market responsiveness refers to an enterprise's execution of market opportunities and its acuity towards consumer and competitor actions. According to Harms and Schwery (2020), opportunity iteration can be estimated by the extent to which enterprises can accurately align their limited resources with core market needs, and how quickly they can iteratively update their products or services based on market demand feedback.
- (3) The TMT was evaluated based on cognitive flexibility and sustainable leadership. To measure cognitive flexibility, Dennis and Van der Wal's (2010) perspective, which refers to individuals' thinking patterns and behavioral choices in the face of dilemmas, was employed. Based on the study proposed by Dalati (2017), sustainable leadership was measured by whether managers could consider the demands of their stakeholders and take a comprehensive, long-term view of a company's development.
- (4) Digital technology was estimated using digital affordances and technology adoption. *Digital affordance* was measured by the affordability of digital technology to the enterprise and its likelihood of achieving its goals, as Chatterjee et al. proposed (Chatterjee, Moody, Lowry, Chakraborty & Hardin, 2020). According to Chen and Tsou (2007), *digital technology adoption* is determined by whether an enterprise has implemented any adjustments to introduce digital technology in terms of strategy, organizational structure, and employee training.

Calibration

As a key step in fsQCA, the data must first be calibrated to membership value grades at continuous intervals between zero and one. The three calibration points require the specification of full non-membership in a set (lower threshold), full membership (upper threshold), and a crossover point of maximum ambiguity regarding membership (Ragin, 2009). Therefore, this qualitative anchor evaluation process draws on the identification of the 5th (lower threshold), 95th (upper threshold), and 50th percentiles (crossover point) of each condition or outcome. The descriptive statistical characteristics of each variable and calibration point are listed in Table IV.

Table IV
Descriptive statistics and calibration anchor.

Variable	Calibration anchor			Descriptive statistics			
	Upper threshold	Crossover point	Lower threshold	Min. value	Max.	Mean	SD
Frugal innovation	4.8	4.49	4.2	4.1	4.9	4.474	0.161
Resource bricolage	4.8	4.4	3.9	3.4	4.8	4.335	0.292
External relational embeddedness	4.63	4.17	3.65	3.333	4.663	4.168	0.345
Market responsiveness	4.67	4.5	3.8	3.667	5	4.352	0.298
Opportunity iteration	4.64	4	3.65	3.6	4.8	4.062	0.304
Cognitive flexibility	4.63	4.4	3.88	3.6	4.71	4.351	0.251
Sustainable leadership	4.72	4.55	3.95	3.8	4.909	4.419	0.253
Digital affordance	5	4.1	3.8	3.1	5	4.255	0.381
Digital technology adoption	4.75	4.2	3.75	3.5	4.75	4.241	0.341

Table V
Analysis results of necessary conditions.

Condition		Frugal innovation		~ Frugal innovation	
		Consistency	Coverage	Consistency	Coverage
Resource bricolage	Condition	0.733089	0.755100	0.430496	0.468002
	Non-condition	0.483510	0.445802	0.774727	0.753905
External relational embeddedness	Condition	0.800405	0.767491	0.444408	0.449756
	Non-condition	0.426160	0.420878	0.770257	0.802879
Market responsiveness	Condition	0.610604	0.666072	0.486412	0.560011
	Non-condition	0.596652	0.523972	0.709959	0.658038
Opportunity iteration	Condition	0.720367	0.709736	0.517999	0.538646
	Non-condition	0.531735	0.511060	0.720862	0.731240
Cognitive flexibility	Condition	0.858705	0.763014	0.469873	0.440657
	Non-condition	0.370507	0.398386	0.747300	0.848073
Sustainable leadership	Condition	0.697664	0.765487	0.453910	0.525645
	Non-condition	0.567674	0.496203	0.797492	0.735729
Digital affordance	Condition	0.772096	0.713254	0.530156	0.516902
	Non-condition	0.477048	0.490317	0.705901	0.765757
Digital technology adoption	Condition	0.761601	0.748271	0.442372	0.458723
	Non-condition	0.449081	0.432799	0.757244	0.770244

Note: "~" represents the "non" of logical analysis.

Data analysis

Analysis results of necessary conditions

The first step in testing the "net effect" of an individual condition is to conduct a necessary condition analysis to reveal the degree to which individual causal conditions are necessary for high and very high performance. A causal condition obtaining a score of 0.90 or higher can be considered necessary for the outcome of interest and should be eliminated from the configurational analysis (Ragin, 2009). As shown in Table V, the level of consistency for all conditions and non-conditions was less than 0.9, indicating that the eight antecedent conditions were not necessary for FI.

Configurational sufficiency analysis

Configurational sufficiency analysis aims to reveal the influence of combining individual causal conditions for FI (Andrews, Beynon & McDermott, 2019). The consistency threshold for confrontational analysis was set to 0.75. The frequency threshold was set to 1 and the PRI consistency threshold was set to the minimum acceptable standard of 0.70. The specific configuration results are listed in Table VI. The configurations that produced high FIs were above the consistency threshold of 0.75. Meanwhile, the overall coverage was 0.70,

indicating that the configurations had good explanatory power for generating a high level of FI.

As shown in Table VI, we found four different configurations associated with high performance, which echo the complex antecedent conditions of FI, as shown in previous research and practice. According to the core and peripheral conditions of each configuration, this study names the configurations as the "sustainable leadership-centric and resource-enhanced configuration" (F1), the "cognitive flexibility-centric and market response-enhanced configuration" (F2), the "double centric configuration" (F3), and the "multiple centric configuration" (F4).

(1) Configuration F1: Sustainable leadership-centric and resource-enhanced configurations, wherein sustainable leadership is a core condition and resources are a peripheral condition. Configuration F1 indicates that enterprises with sustainable leadership as the core condition and resource bricolage and external relational embeddedness as peripheral conditions, can produce high FI (F1a-d). We found no evidence that entrepreneurial opportunities and digital technology alone are sufficient for high performance. The high-performing configuration F1 is explained as follows. On the one hand, the high level of sustainable leadership of managers is due to direct participation in resource actions (Martin & Anderson, 1998), a capability that enables enterprises to utilize resources intensively in the face of scarcity, improve resource allocation

Table VI
Sufficiency analysis results for frugal innovation.

Condition		F1				F2	F3				F4
		F1a	F1b	F1c	F1d	F2	F3a	F3b	F3c	F3d	F4
Digital technology	Digital technology adoption	⊗		●	⊗	⊗	●	●	●	●	●
	Digital affordance	●	⊗	⊗	⊗	⊗	●	●		●	⊗
Top management team	Cognitive flexibility	⊗	●		●	●	●	●	⊗	●	●
	Sustainable leadership	●	●	●	●	●			●	●	⊗
Resource	Resource bricolage	●	●	●	⊗	⊗	●	●	●		⊗
	External relational embeddedness	●	⊗	⊗	●	⊗	●	●	●	●	●
Entrepreneurial opportunities	Market responsiveness	⊗	⊗	⊗	⊗	●	⊗		●	●	●
	Opportunity iteration	⊗	⊗	⊗	●	●		●	●	●	●
Raw coverage		0.34	0.46	0.19	0.41	0.16	0.13	0.19	0.15	0.14	0.17
Unique coverage		0.02	0.03	0.01	0.00	0.01	0.01	0.04	0.01	0.02	0.04
Consistency		0.97	0.95	0.98	0.95	0.99	0.98	0.99	0.99	0.99	0.97
Overall solution coverage		0.70									
Overall solution consistency		0.95									

Note: ● means the presence of core conditions; ● means the presence of peripheral conditions; ⊗ means that the absence of core condition; ⊗ means that the absence of peripheral condition; blank means the antecedent condition can exist or not.

efficiency, and achieve resource bricolage effects. On the other hand, enterprises quickly explore favorable external resources through the institutional network embedding effect to meet constantly alternating resource demands, thus helping them overcome resource constraints. With deepening resource application capability and application scenarios, managers can create a rational layout and optimal combination of resources based on the consideration of local policy inclinations, advantageous industries, and competitors, and continuously acquire shared resources from a close and stable institutional network. The absence or "irrelevance" of market opportunity in configuration F1 indicates that, with sustainable leadership, the company can achieve mutual support between different resource combinations to form a resource synergy, regardless of the level of digitization and market opportunity the company is at. The "low level of marketization" feature of configuration F1 makes it more likely to occur when the external environment is stable and consumer demand is explicit.

- (2) Configuration F2: Cognitive flexibility-centric and market response-enhanced configurations, where cognitive flexibility is a core condition and market response is a peripheral condition. Configuration F2 demonstrates that enterprises with cognitive flexibility as the core condition and market responsiveness and opportunity iteration as peripheral conditions are sufficient to achieve high FI. According to Configuration F2, enterprises can improve their FI when the TMT possesses high cognitive flexibility and a strong understanding of the environment. The team can grasp and evaluate external situations and internal resources simultaneously, and respond quickly to changes in the market. Specifically, they can scan and identify the corresponding opportunities in the market situation to cash in on the complexity, match their own resources, and guide enterprises to respond effectively to market choices to achieve FI in the face of resource constraints and weak digitalization. Resource and digital technology in F2 are absent, suggesting that despite a lack of resources, enterprises in emerging economies with high levels of market flexibility and opportunity iteration are adept at improving and updating their original technologies in response to market and user needs and achieving FI.
- (3) Configuration F3: Double-centric configuration, wherein digital technology and resources are core conditions. We found high-performance configurations with digital technology adoption and external relational embeddedness (F3a-d). Configuration F3 shows that companies with high digital technological capabilities can reduce enterprise transaction and production costs by embedding institutional networks across geographic and organizational boundaries, integrating the resource actions of different subjects and boundaries, and achieving internal and external resource synergies. Moreover, enterprises can reduce R&D costs through the powerful computing, connecting, and communication functions of digital technology by collaborating with external institutions to exchange, absorb, utilize, and combine resources and knowledge to achieve high FI levels.

Furthermore, external relational embeddedness is a peripheral condition of configuration F1 and a core condition of Configuration F3. This is caused by digital technology adoption as a core condition in Configuration F3, whereas in path F1, digital technology does not exist or exists only as a peripheral condition. We find strong evidence that the digital technology condition is an important factor in generating external relational embeddedness, which is at the core of configuration F3.

- (4) Configuration F4: Multiple-centric configuration, wherein four factors are present as core conditions. Configuration F4 states that enterprises with digital technology adoption, cognitive flexibility,

external relational embeddedness, and market responsiveness as core conditions and opportunity iteration as a peripheral condition can generate high levels of FI. As a key strategic resource for corporate innovation, digital technology can drive interaction and network effects of stakeholders by laying out a dense network of relationships and enabling companies to find channels to resolve technical barriers to products in different market segments (Monaghan, Tippmann & Coviello, 2020). At the same time, with cognitive flexibility, the TMT can accurately gauge consumers, realize real-time interaction with them, and collect their feedback to make rapid iterations of product technologies to achieve FI. Digital technology can also facilitate knowledge exchange between enterprises and partners by reducing inter-industry and spatial differences, and collaboratively building complementary assets to generate value symbiosis.

Comparative analysis of different paths

Compared to the other configurations, F1 has the highest coverage rate, which means that most companies enhance their FI levels through this path. A comprehensive analysis of enterprises with a high level of FI reveals that, first, in most cases, the cognitive flexibility and sustainable leadership of enterprise managers positively affect FI, indicating that in emerging economies, the cognitive and behavioral styles of the TMT are key to achieving FI. Second, when level of digitization of an enterprise is low, the level of market responsiveness and opportunity iterations play key roles in achieving a high level of FI. Third, when managers' cognitive and behavioral styles are similar, resources and entrepreneurial opportunities can become effective substitutes for each other. This process helps increase FI, whether by breaking through resource constraints through resource bricolage and external relational embeddedness, or by cashing in on entrepreneurial opportunities through market responsiveness and opportunity iteration.

Robustness check

We ran three additional fsQCA-specific analyses to ensure robust results, including adjustment consistency, PRI, and frequency thresholds (Skaaning, 2011). First, the consistency threshold was from 0.75 to 0.80. The key findings remained the same and showed differences only between the core and periphery in the partially missing conditions of path F2. Second, the PRI consistency thresholds were from 0.7 to 0.75. The results showed that the number of configurations was reduced from four to two. However, the core elements are digital technology and managers, which are consistent with the original configurations. Third, we set a frequency threshold for the two cases of each configuration. However, the lowest frequency before adjustment was > 2. This implies that at least two cases or samples followed a specified configuration. Thus, adjustment of the frequency threshold did not affect the study results. More details on the robustness test can be found in Appendices C1–C3.

In summary, the configuration results before and after adjusting the threshold indicated a perfect subset relationship, and the results (consistency and coverage score) were highly consistent. Therefore, the results of this study are robust.

Discussion

Conclusions and discussion

Compared to developed countries, markets in emerging countries are characterized by scarce resources, expanding population bases, and prominent sustainability issues, while experiencing rapid economic growth. New innovative models and methods are required to

meet the constantly increasing consumption needs of a vast number of middle- and low-income groups. As a form of innovation that creates more value with less investment, frugal innovation is highly aligned with the sustainable development goals (SDGs) and affordable consumption patterns of emerging markets. Research on economic development in EMs focuses on identifying the antecedents that promote FI.

This study conducts a preliminary exploration of frugal innovation based on the environmental characteristics of emerging markets, and proposes the Timmons framework model, based on the differentiation of concepts and induction of characteristics. We employ fsQCA on a sample of 132 start-ups to explore the drivers of FI: resources, entrepreneurial opportunities, TMT, and digital technology.

Consistent with our expectations, we find that only a single element of enterprise resources, such as entrepreneurial opportunities, the TMT, and digital technology, has a significant influence on FI. Sustainable leadership, digital technology adoption, and external relational embeddedness play universal roles in generating high FI levels. This suggests that individual conditions exert a weak net effect on frugal innovation, and that the factors enhancing it are multifaceted, aligning with the nature of aggregation. Scholars label configurations for better interpretation in some presentations of fsQCA methods (Furnari et al., 2021); in our study, we found four configurations: sustainable leadership-centric and resource-enhanced (F1), cognitive flexibility-centric and market response-enhanced (F2), double-centric (F3), and multiple-centric (F4). Among them, "sustainable leadership-centric and resource-enhanced configuration" has the highest coverage and is the main path for enterprises to improve FI.

Finally, we determine the equivalence of multiple combinations to achieve FI and the substitutional relationships between these four factors. The sustainable leadership-centric configuration (F1) and cognitive flexibility-centric configuration (F2), given that the cognitive styles and behaviors of enterprise managers are similar, resources and entrepreneurial opportunity seem to be substitutes, lead to specific considerations. In low-resource contexts with market constraints, enterprises can enhance FI by seeking breakthroughs from either of them.

Theoretical contributions

Based on these findings, we present insights into studies on Timmons' entrepreneurial process model, the FI literature, and the configuration of antecedent conditions.

First, the study extends the application of the Timmons model to the field of innovation by developing a conceptual model for the FI process based on it. Timmons' model is particularly useful for explaining the entrepreneurial process. While previous research used Timmons' model to discuss entrepreneurs and start-ups in mature enterprises and economies, our study proposes a process model to effectively explain the current state of frugal innovation in enterprises in emerging economies. Moreover, although scholars have repeatedly found the importance of opportunity (Beltagui, Sesis & Stylos, 2021), resources (Piwowar-Sulej & Iqbal, 2022), and teams (Q. Iqbal et al., 2021) in Timmons' model of enterprise innovation, these net effects have been verified using linear regression. Our study scrutinizes the (joint) effect of different conditions, incorporates digital technologies into the conceptual model, and reveals the synergistic configurations of the four factors, offering a fine-grained understanding of FI by focusing on the mechanisms of interaction between factors.

Second, our study provides new insights into the "status-transformation-result" process of FI. Previous studies have interpreted the identification and definition of FI, however, few have explored the important role of its process. Scholars have found a strong influence of sustainable leadership (Q. Iqbal et al., 2021) and entrepreneurial bricolage (Ying, Wang & Liu, 2022) on FI; however, the systemic

effects of these factors on FI have not been fully revealed. An integrated view of FI that combines the technological and market aspects should be developed. Therefore, this study adopts a process-based perspective to analyze the influencing factors, empirically explore the relationship between multiple antecedent conditions and FI, and gain insights into the combination of factors influencing FI.

Finally, as a novel approach to revealing conjunctural causation, the configurational perspective allows scholars to study the sufficiency and necessity of relevant conditions and combinations of these conditions for the outcomes of interest (Leppänen et al., 2023). From this perspective, this study provides an in-depth QCA approach to study how frugal enterprises in emerging economies generate innovation. Unlike the regression method used in existing research to test the influence of single factors (Senyard et al., 2009), our study uses the perspective of configuration to analyze the combined effects of different factors on the process of FI and expands the application of the QCA approach in the field of innovation. Four types of FI configurations are found, further illustrating that the process of FI is a concurrent mechanism of multiple factors and confirming the view that "innovation is a dynamic process driven by resources, opportunities, and teams" (Kirkley, 2016).

Practical implications

Our findings have several practical implications to support enterprises that seek to enhance their FI.

First, based on the "sustainable leadership-centric and resource-enhanced configuration" (F1) and "cognitive flexibility-centric and market response-enhanced configuration" (F2), TMTs with sustainable leadership or high cognitive flexibility are key to explaining the presence of FI. The configuration results indicate that enterprises with sustainable TMT leadership can achieve FI through the efficient and creative allocation of resources that are obtained from internal and external sources, and completing resource accumulation and aggregation. Additionally, the results suggest that TMTs with high cognitive flexibility can quickly identify and capture innovation opportunities in emerging markets. Therefore, **managers** must revitalize resources, quickly transform capacity, maximize the synergistic effects of different resources, and maintain sufficient flexibility and connectivity in emerging market operations to respond quickly to dynamic changes in the market environment.

Second, the evidence of "digital technology and resource double-centric configuration" (F3) shows that, with the empowerment of digital technology, enterprises are no longer constrained by time and space. They can establish the interface of communication and feedback among stakeholders; form a network structure; realize the rapid flow of management, technical, and marketing knowledge in the network; reduce information, R&D, and transactional costs; and lower risks to innovation. Therefore, **enterprises** should follow the trend of the digital economy, actively carry out digital transformation, establish a dense relationship network, and utilize the linkage effect of the network.

Third, the "multiple-centric configuration" (F4) emphasizes the role of multiple stakeholders. Thus, **policymakers** should encourage companies to systematically explore and allocate innovation assets with breadth and depth by establishing links with multiple stakeholders, using multiple technology combinations, connecting diverse customer groups, identifying and utilizing the value-added space of innovation resources, and adding value to products to improve innovation levels.

Limitations and future research

We hope to address the limitations of our study in future studies. First, our sample consisted of 132 questionnaires from the Pearl River Delta region of China, which may have limited the generalizability of our results to other settings. Further, most of our sample consisted of

small and medium enterprises. Our findings need to be tested for generalizability to other emerging economies and large enterprises. Therefore, future exploratory analyses should be conducted at the national level, focusing on other industries.

Second, using cross-sectional data from a questionnaire, our study focused only on the static relationship between each influencing factor and FI. In reality, innovation usually occurs over a long period; hence, it is difficult to observe and measure. Therefore, longitudinal studies are required to observe this effect over longer periods. Key factors also change during innovation. Further research could also explore the evolutionary mechanisms of multiple factors influencing FI by considering the dynamic changes in various factors over time.

Third, we explored the antecedent conditions of FI and focused on factors, such as resources, entrepreneurial opportunity, and top management team, which are based on the theoretical analysis framework of the Timmons model. Additionally, we also considered digital technology, as "digitization" has fundamentally transformed many industries. However, we also overlooked some factors, such as heterogeneous knowledge sharing, organizational networking, political ties, and market turbulence, which previous studies concluded, are vital factors in spurring frugal innovation. Further research is needed to understand how these factors affect FI.

Declarations of competing interest

The authors declare that they have no known competition financial interests or personal relationships that could have appeared to influence the work reported in this paper. Some or all data, models, or code that support the findings of this study are available from the corresponding author upon reasonable request.

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