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Frugal innovation: Antecedents, mediators, and consequences

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Frugal innovation (FI) describes a phenomenon whereby solutions are developed to serve low-income customers, mainly in developing countries, with affordable products and services that help address pressing social and environmental problems. Despite a decade of academic interest in FI, we still lack an overarching understanding of the various facets of this phenomenon. Based on 48 in-depth interviews for 23 cases, we integrated and validated 10 years of FI scholarship. This study therefore set out to develop a comprehensive framework for FI, one that would identify its antecedents, mediators, and consequences. Such a framework promises a holistic perspective for FI by linking these identified factors to the concept of sustainability. The findings also reinforce the dual contribution that FI makes in terms of both business growth and inclusive growth. Finally, this study discusses the theoretical and practical implications and provides some suggestions for future research on FI.

KEYWORDS
emerging markets, frugal innovation, inclusive growth, low-income customers, sustainability

1 | INTRODUCTION

Over the last decade, studies of frugal innovation (FI) around the world have steadily accumulated (DAngelo & Magnusson, 2020; Lim & Fujimoto, 2019). FI typically involves an affordable but practical product being developed to fulfil a need among low-income customers, generally in emerging markets (Zeschky et al., 2011), thus making it an attractive subject for scholars, practitioners and policymakers alike (Hossain, 2018). What is more, existing firms are increasingly turning to the FI concept when developing strategies for achieving certain economic, social, and environmental goals (Herrera, 2016). In recent studies, scholars have also connected FI to the concepts of sustainability (Levänen et al., 2016; Rosca et al., 2017), inclusive growth (Albert, 2019), and entrepreneurship (Hossain, 2022; Michaelis et al., 2020). Furthermore, studies have explored FI based on different theoretical approaches, such as bricolage and effectuation (Chatterjee et al., 2021; Iqbal et al., 2021; Khanal et al., 2021; Santos et al., 2020). Institutional theory, the resource-based view, the knowledge-based view, network theory, and transaction cost economics have also been used as theoretical perspectives (Dabić et al., 2022).

FI aims to deliver long-term business growth and inclusive growth in parallel (Hall et al., 2012; Khavul & Bruton, 2013). However, prior studies about the antecedents, mediators, and consequences of FI (Hossain, 2020, 2018; Pisoni et al., 2018; Simula et al., 2015) have resulted in scattered findings that are often limited to a specific context. Thus, the FI literature still lacks a comprehensive framework that brings together the various facets of FI and provides a common understanding of this field. With FI growing as a research field as it is explored from different perspectives, it has become imperative to consolidate its antecedents, mediators, and consequences (Cai et al., 2019; Chatterjee et al., 2021; Hossain, 2020; Simula et al., 2015). Such a consolidation will provide a holistic perspective for FI by integrating the prior findings into a common framework, thus helping scholars to target future studies more accurately. This study therefore aims to develop a comprehensive framework for identifying and consolidating the antecedents, mediators, and consequences of FI based on a large number of FI cases from different countries, contexts, and sectors.

We applied an abductive approach for this study, one that involved identifying initial factors in the existing literature, confirming

them through our empirical data, and combining them with the factors that emerged from our own empirical analysis. This approach led to the development of a comprehensive framework based on both the literature and empirical data collected through 48 in-depth interviews with key players for 23 cases of FI. The analysis process involved switching between the data and the literature numerous times, thus helping to consolidate the existing knowledge with new findings from an extensive empirical analysis. We contribute to the FI literature in the following ways: *First*, the developed comprehensive framework unifies the different facets of FI and adds to the literature by highlighting and categorizing the antecedents, mediators, and consequences of FIs. For example, it reveals how various personal, business, and social motivations act as key drivers for FI and demonstrates the mediating influence of constraints in the innovation process. In addition, FI's potential contributions to the three pillars of sustainability are also discussed (Howell et al., 2018; Khavul & Bruton, 2013). *Second*, this study reveals that FI has dual outcomes in terms of achieving both business growth and inclusive growth. FIs are arguably driven by both economic and social motivations, so they often create new markets by developing affordable products that improve people's living conditions and encourage inclusive growth. We therefore argue that given the well-balanced economic, social, and environmental outcomes, FI has the potential to address some of the world's grand challenges, such as sustainable energy generation, affordable healthcare, female empowerment, reduced child labour, and local job creation.

The remainder of this paper is structured as follows: The following section discusses the FI literature. Section 3 then describes this study's context and process for data collection and analysis. Section 4 then presents the findings in the form of a comprehensive framework, while the final section discusses the theoretical and practical implications along with avenues for future research.

2 | LITERATURE REVIEW

2.1 | Frugal innovation

Scholars have studied FI from various perspectives, resulting in multiple definitions and diverse criteria (Rao, 2013; von von Janda et al., 2020) that range from simple to complex (Hossain et al., 2016) and conceptual to functional (Bhatti et al., 2018). FIs are solutions that have been developed under various resource constraints, and they are often significantly cheaper than conventional equivalents, thus serving customers who would otherwise be overlooked (Hossain et al., 2016). FI's definition, however, has evolved from an initial product-oriented form to a market-oriented one before reaching a criteria-oriented definition (Pisoni et al., 2018). An innovation is therefore frugal when it fulfils three criteria, namely, substantial cost reduction, a focus on core features, and optimized performance (Weyrauch & Herstatt, 2017).

An FI is, simply put, affordable, adaptable, and accessible (Bhatti et al., 2018), and it can take the form of a product, service, process, or business model (Hossain, 2018; Knizkov & Arlinghaus, 2020), as well as an innovation process that overcomes extreme resource constraints to provide a solution at a cost advantage (DAngelo & Magnusson, 2020). Constraint-based thinking is also crucial to developing an FI (Agarwal et al., 2021). A recent study also pointed out how to identify frugal candidates for patents (Kronemeyer et al., 2021), while another study extended FI to the concept of *frugal entrepreneurship* (Hossain & Sarkar, 2021). In addition, studies are increasingly embracing new research avenues, such as leadership (Lei et al., 2021), product and process strategies (Rosário & de Lima, 2021), and the FI-development process and how it contrasts with the conventional product-development process (Brem et al., 2020). The development of frugal innovations often encounters challenges, with reluctance from top management, a lack of business acumen, and prototyping difficulties representing the main barriers for FI (Niroumand et al., 2021).

To address societal challenges and remain competitive, firms achieve a lower purchase price by employing FI in emerging markets (Krishnan & Prashantham, 2019). Even western firms are pursuing FI through subsidiaries in low-income countries (Zeschky et al., 2011), but local frugal entrepreneurs are most driven by the frugality construct (Michaelis et al., 2020) when bringing their affordable solutions to market, because their local knowhow and understanding of local markets gives them an advantage in driving FIs and achieving social change (Krishnan & Prashantham, 2019). Many FI proponents suggest it represents a win-win situation, because firms profit from serving low-income customers while alleviating poverty, although some critics argue that it can also act as a means for exploiting inequality (Hossain, 2021; Knorringa et al., 2016). Despite significant efforts to create innovation-friendly operational environments in many sectors, a colossal gap remains between the needs of low-income customers and available solutions (Gupta, 2019). Nevertheless, the emergent FI phenomenon can potentially provide new solutions for customers with limited purchasing power and help address unforeseen problems that society may experience. For instance, FI, is seen as an important tool for dealing with the COVID-19 pandemic (Chatterjee et al., 2021; Corsini et al., 2020; Harris et al., 2020; Miesler et al., 2020; Mishra, 2021; Sarkar, 2020; Vesci et al., 2021).

Factors such as affordability, customer aspirations, and product localization and accessibility are critical if low-income customers are to adopt products. Using the Friedman test, a recent study listed a range of barriers and enablers for FI (Niroumand et al., 2021). It found that paying close attention to local needs, reducing profit margins, collaborating with local organizations, and receiving management support are the main enablers for FI.

Overall, frugality enables firms to utilize new innovation opportunities by adopting a new mindset oriented towards developing affordable products for new markets (Hyvärinen et al., 2016). FIs are often considered to be low-tech, affordable solutions for serving low-income customers, mainly in emerging markets (Tiwari & Herstatt, 2020). However, FI has also been recently explored in relation to sophisticated technologies like artificial intelligence (Govindan, 2022). FIs can be developed by Western multinationals, multinationals in emerging markets, domestic and international

TABLE 1 Key studies of the antecedents, moderators, and consequences of frugal innovation

Category	Description	Example factors identified in the literature
Antecedents	This stream of literature focuses on different motivations for pursuing frugal innovation at personal, business, and societal levels.	Personal drive • Desire to improve general living standards (Agarwal et al., 2016; Agnihotri, 2015; Kim et al., 2020) • Drive for healthier or more sustainable lifestyles (Pisoni et al., 2018; Rao, 2013) Business drive • New opportunities embedded in the frugal innovation phenomenon (Hossain, 2017, 2020) • Need for enhanced idea transfer in complex operational environments (Zeschky et al., 2014) Social drive • Need to address health-related problems (Bhatti et al., 2017; Rosca et al., 2017) • Need to improve environmental sustainability (Pansera & Sarkar, 2016) • Need to develop education systems (Khan, 2016) • Need to fight poverty, hunger, and social injustice (Park et al., 2021)
Mediators	This stream of literature focuses on issues and factors that may either facilitate or hamper the development of frugal innovations.	Scale-up constraints • Lack of skilled labour (Levänen et al., forthcoming) • Rural remoteness (Levänen et al., 2022) Resource constraints • Limited access to raw materials (Sharma & Iyer, 2012) • Limited access to electricity/high energy costs (Numminen & Lund, 2017) Institutional constraints • Inefficiencies in public governance (Ananthram & Chan, 2019) • Lack of access to conventional financial instruments (Hossain et al., 2021; Howell et al., 2018) Innovation task • Experimentation (Brem & Wolfram, 2014; Kroll & Gabriel, 2020) • Utilization of customer feedback (Brem et al., 2020; Levänen et al., 2022)
Consequences	This stream of literature focuses on the economic, social, and environmental implications of frugal innovations.	Economic consequences • New employment opportunities (Leliveld & Knorringa, 2018; Rao, 2013; Rosca et al., 2017) • New business models and forms of entrepreneurship (Basu et al., 2013; Brem & Wolfram, 2014) • More efficient markets (Brem & Ivens, 2013; Khan & Melkas, 2020) Social consequences • Improved access to basic services (Hyvärinen et al., 2016) • Healthier living environments (Levänen et al., 2016; Pisoni et al., 2018) • Female empowerment, improved social equity, and greater inclusion of marginalized people (Basu et al., 2013; Vossenberg, 2018) Environmental consequences • Improved pollution control (Gerybadze & Klein, 2020; Levänen et al., 2016, 2022) • Greener technologies (Gandenberger et al., 2020; Gerybadze & Klein, 2020 • Reduced waste, greater recycling, and value creation from waste (Albert, 2019; Bas, 2020) • Utilization of locally available resources (Hossain et al., 2021; Levänen et al., 2022)

entrepreneurs, and start-ups in a wide range of sectors, such as energy, health, education, ICT, and transportation (Agarwal et al., 2016; Bhatti et al., 2017; Hossain, 2017). Studies of FI mainly focus on Asia, but other recent studies have looked at other regions, such as South America (Borchardt et al., 2020; Gerybadze & Klein, 2020; Wimschneider et al., 2020) and Europe (Kroll & Gabriel, 2020; Skopec et al., 2021).

The literature outlines numerous factors for understanding the FI phenomenon from different perspectives (von von Janda et al., 2020). However, structured knowledge about the methods, approaches, and procedures that support FI development is limited (Weyrauch et al., 2020). To provide a framework that includes the key features of the FI phenomenon, we first identified three literature streams dealing with the antecedents, mediators, and

consequences of FI, and subsequently identified important factors from each of these streams (Table 1).

2.2 | Antecedents, mediators, and consequences of frugal innovation

Antecedents relate to the various motivations for pursuing FI. Prior studies have pointed out numerous such antecedents (Chatterjee et al., 2021; Simula et al., 2015), such as wanting to improve general living standards, have a socio-economic impact, or serve customers at the bottom of the pyramid (Agarwal et al., 2016; Agnihotri, 2015; Rao, 2013). FIs are developed to offer affordable products or services to customers or businesses that have been previously overlooked, possibly enabling a healthier and more sustainable way of life (Pisoni et al., 2018; Rao, 2013). Firms developing FIs typically have an interest in developing business models that make better use of available resources (Hossain, 2017), such as by recycling used components and materials to manufacture new products (Kim et al., 2020). Another important motivation for firms developing a diverse range of FIs is to facilitate the transfer of ideas between different actors in complex operational environments. Multinational firms may also want to increase their presence in emerging markets by establishing new subsidiaries specifically for FI development (Zeschky et al., 2014).

The mediators of FI refer to issues and factors that may facilitate or hinder the development of FIs. Previously identified mediators relate to various factors in the innovation process. Scaling up, for example, is typically hindered by a lack of skilled labour and geographical remoteness when operating in a rural area. Resource constraints, meanwhile, can include limited access to raw materials (Agarwal et al., 2021) and/or energy (Numminen & Lund, 2017), while institutional constraints typically relate to inefficient public governance and poor access to financial instruments (Hartley, 2014; Howell et al., 2018). Both formal and informal institutions can play a crucial role in promoting FIs in emerging markets (Ananthram & Chan, 2019; Prabhu & Jain, 2015) by filling the institutional voids (Gao et al., 2017). Such voids can be filled, for example, by establishing database vendors, certification firms, and technical support organizations (Bhatti et al., 2018). The innovation process is also an important mediator that depends on efficiently using customer feedback (Brem & Wolfram, 2014; Kroll & Gabriel, 2020) and diverse experimentation methods to design and develop suitable solutions (Brem et al., 2020; Levänen et al., 2022). Different customer feedback and experimentation processes may lead to firms employing very different strategies to cope with the challenges they face in the operational environment (Knizkov & Arlinghaus, 2020). The above four mediators are interlinked, such that institutional and resource constraints compound challenges in the operational environment, and scalability becomes even more difficult, thus hindering wide-scale accessibility for the large number of consumers with unmet needs (Bhatti et al., 2018).

The consequences of FI have been discussed from social, economic, and environmental perspectives. From a social perspective (Khan & Melkas, 2020; Molina-Maturano et al., 2020), FI is typically associated with improved access to basic facilities, such as water, energy (Basu et al., 2013; Hyvärinen et al., 2016), and a healthier living environment (Pisoni et al., 2018), but it can also be connected with tackling grand challenges like female empowerment, improved social equality, and the inclusion of marginalized people (Vossenberg, 2018). Overall, FIs can impact society by addressing health issues (Pisoni et al., 2018; Rosca et al., 2018), poor education, and unemployment in addition to fighting poverty, hunger, and social injustice (Khan, 2016; Park et al., 2021; Rao, 2013). From an economic perspective, FI typically involves creating new employment opportunities (Leliveld & Knorringa, 2018; Rosca et al., 2017) and new business and entrepreneurship models (Basu et al., 2013; Brem & Wolfram, 2014), as well as ensuring the efficient functioning of markets, supply chains, and technologies (Brem & Ivens, 2013). From an environmental perspective, FI has been linked with improved pollution control, waste and resource management, fighting deforestation (Albert, 2019; Bas, 2020; Levänen et al., 2016), and generally using greener technologies (Gandenberger et al., 2020; Levänen et al., 2016). In linking the antecedents to the consequences, Pansera and Sarkar (2016), p. 15) noted that for the environmental domain, the aim of sustainability-driven FIs "to generate solutions designed to minimize the impact on the environment combined with the scarcity of material and financial resources leads to the development of more energy- and material-efficient solutions." According to Le Bas (2016), FI encompasses three important end-of-life properties for products, namely, recovering used components for reusability, recyclability, and repairability.

The literature therefore suggests many links between the antecedents and consequences, as well as the roles of mediators. Based on our interpretation of the literature, it seems timely and valuable to outline these relationships in order to describe the FI phenomenon more saliently within a comprehensive framework.

3 | METHODS

Our research sought to develop a comprehensive framework for FI, so to achieve this objective, we applied an abductive approach, as suggested by Steinfield and Holt (2019), and adopted the philosophical stance of critical-realism for interpreting the data (Belfrage & Hauf, 2017; Kilduff et al., 2011). We discuss the research context and processes for data collection and analysis below.

3.1 | Research context

We selected cases from three prior research studies that were conducted by three researchers in Finland, Germany, and the United Kingdom. We compiled case data from these prior research

initiatives to study various geographical settings and sectors and investigate the FI phenomenon comprehensively. The cases were selected based on purposeful sampling (Gao et al., 2017) to better "understand the phenomenon that can be used to inform changes in practice, programs, and policies" (Patton, 1990, p. 295). The case-inclusion criteria were aimed at identifying firms that (a) target developing countries with a large number of low-income customers, irrespective of where they are headquartered; (b) seek to solve pressing problems; and (c) have been widely classified as cases of FI in both academic and managerial discourses. The data for this study therefore derived from 23 cases in four sectors (see Appendix A for case summaries). The cases were geographically dispersed over Africa, Asia, Europe, and South and North America, with them operating in the energy, agriculture, machinery, appliance, and healthcare sectors in various forms, such as for-profit, non-profit, private, and public organizations.

3.2 | Data collection

Data were sourced through interviews, site visits, observations, and archival documents (Table 2), including 48 in-depth interviews ranging in duration from 1 h to a whole day. We used an unstructured questionnaire for 20 interviews and a semi-structured one for the remainder, with the questionnaires being adjusted to the nature of each case, the context, and respondents' cues. Interviews were conducted in either English or the local language, with non-English interview transcripts being translated into English. The interviews focused on the history of the idea, motivations, solutions, stakeholders, development, funding, challenges, and scope for growing the firm in question. The interviewees were key informants in each firm, such as founders and top managers, as well as expert informants like Prof. Anil Gupta, who played a key role in many of the selected Indian cases. Our 20 days of site visits also enabled us to observe various activities first-hand. Most interviews were not recorded to avoid an overly formal interaction and respect the practicalities of the cultural context. Field notes and observations were therefore important tools during the interviews and site visits. Before making contact with representatives of the cases, archival documents were collated from publicly available sources—such as newspaper articles, publications, documentaries, and websites—and studied. Internal documents were also examined, such as company reports, event documents, and presentations. This rich data set from various sources enabled an appropriate degree of triangulation for ensuring the validity of the study (Burton & Obel, 2011).

3.3 | Data analysis

Since we wanted to develop a comprehensive understanding of the factors related to FI, we first took stock of such factors in the extant literature and then performed an empirical analysis based on a large set of empirical data. We employed an iterative abductive analysis approach (Heracleous & Lan, 2012), which has been previously applied in various research fields, such as entrepreneurship (Lounsbury & Glynn, 2001), strategy (Gao et al., 2017), and organizational behaviour (Rindova et al., 2006). The strength of our contribution is premised upon drawing conclusions from the literature, verifying them, and uncovering new insights from a large number of cases that were collected to study the FI phenomenon. We began with an initial understanding of the antecedents, mediators, and consequences that the literature suggests. This initial categorization, as outlined in the literature review, was not intended to be a comprehensive map but rather a starting point for developing an initial template for coding purposes. This therefore helped to legitimize the use of antecedents, mediators, and consequences for our analytical coding process. The initial codes from the literature were then confirmed through the empirical data, and additional codes from the empirical analysis were added to them. Finally, any overlaps and redundancies across the codes were removed to finalize the framework. The iterative process of going back and forth between the data and the literature, as well as triangulation to minimize bias, helped us to enhance the credibility of our findings. In qualitative research, triangulating different data sources and methods enables a study to develop a comprehensive understanding of a phenomenon (Patton, 1999). The phases of data analysis are presented in Table 3, while the process and steps for case analysis are outlined in Table 4.

As part of the data analysis, between June and December of 2020, the authors held nine online meetings to analyse the 23 cases of FI over four phases: (i) the first nine cases, (ii) the next six cases, (iii) the subsequent four cases, and (iv) the remaining four cases. The online meetings lasted between 1 h and 2 h. We also used an online Google Drive spreadsheet to track and share the coding of our respective cases, thus allowing us to review each other's work and the overall analysis in real time. Following the example set by prior research (Behrens & Patzelt, 2018), we structured the data in spreadsheets such that the columns represented the cases and the rows represented the categories. Each of the three authors coded their data individually before discussing it collectively. We first selected nine cases (three for each author). Each author then applied the relevant aggregated knowledge from the existing literature (see Table 1) to individually assess the three respective cases. We later convened and discussed the codes to ensure there was a common understanding and interpretation for each case. After assessing all the categories, we assigned them subthemes before applying the reiteration process (i.e., going back and forth between the literature and data) to help to refine the themes (Eisenhardt, 1989). We then performed a cross-case analysis to identify relationships and patterns between the themes (Strauss & Corbin, 1997).

To develop a framework based on the various cases of FI, we felt that spreadsheets were an effective medium for coding the qualitative data. Indeed, with several authors almost equally engaged with coding activities, online platforms represented an effective medium for a study of this nature. During the coding process, we dropped two cases that were deemed unsuitable for our study due

TABLE 2 Overview of the cases and data

Case	Solution	Sector	Country	Founded in	Org. Type	Informant	Data collection	Interview duration (hour)
Dolphin engimech	Bamboo-stripping and incense-stick-making machines	Machinery/ appliances	India	2004	Social enterprise	1: Inventor and founder	1-day site visit; 1 interview	1
Chetak	Cotton-stripping machine	Agriculture	India	2001	Social enterprise	1: Inventor and founder	1 interview	1
Bright green	Off-grid solar energy	Energy	Bangladesh	2010	Social enterprise	1: CEO	1 interview	1
Grameen Shakti	Off-grid solar energy	Energy	Bangladesh	1996	Social enterprise	1: Manager	1 interview	1
Nuru	Off-grid solar energy	Energy	Rwanda	2008	Social enterprise	1: Country director	1 interview (skype)	1
Boond	Off-grid solar energy	Energy	India	2010	Social enterprise	1: CEO, CTO, technician, field supervisor	1-day site visit; 1 interview	4
Selco	Off-grid solar energy	Energy	India	1995	Social enterprise	1: AGM	1 interview	2
MoM	Baby incubator	Health	UK	2014	For-profit enterprise	1: CEO	1 interview (skype)	1
Embrace	Baby incubator	Health	USA (HQ), India, with sales worldwide	2008	Social enterprise	2: Country representative India and associate director	2 interviews (1 skype)	2
Ksheera	Cookeries	Agriculture	India	2011	Social enterprise	3: Inventor, head of sales and marketing, head of HRM	1-day site visit; 3 interviews	6
Jayashree	Sanitary-pad-making machine	Health	India	2009	Social enterprise	2: Inventor and a social entrepreneur	1-day site visit; 2 interviews	2
MittiCool	Clay refrigerator	Machinery/ appliances	India	1988	Social enterprise	2: Inventor, head of sales and marketing	1-day site visit; 2 interviews	8
Arbutus medical	Surgical drill cover	Health	Canada (HQ), Uganda, Kenya, and sales worldwide	2014	For-profit social enterprise	10: CEO, board member, product Lead, marketing Lead, sales rep, clinician user × 5	5-day site visit; 5 interviews; 1 presentation plus observations	9
Hernia International	Low-cost (mosquito) mesh	Health	UK, Tanzania and with projects worldwide	2008	Charity	9: Team Lead, 4× clinicians, 2× researchers, 2× manufacturing leads	2-day site visit; 5 interviews (2 in person and 3 skype), email exchanges plus observations	6
Brazilian family health strategy	Community health workers	Health	Brazil	1994	Government agency	11: Undersecretary, manager, psychologist, 2× nurse, 3× doctor, technical asst., professor, CHW	3-day site visit; 6 interviews; 2 presentations plus observations	6
GeriCare	Telemedicine for geriatrics	Health	Singapore	2009	Government agency	11: 2x consultant, 3× director, 2× nurse, 3× manager, educator.	3-day site visit; 4 interviews; 1 presentation plus observations	5

TABLE 2 (Continued)

Case	Solution	Sector	Country	Founded in	Org. Type	Informant	Data collection	Interview duration (hour)
The BD Odon device	Assisted birth delivery device	Health	Argentina, UK, USA (HQ)	2005	Large corporation	3: Inventor, clinical lead, trials lead	1-day visit by company to researchers site; 2 interviews; 1 demonstration	3
Heartfile Health Financing	Health emergency payments	Health	Pakistan	2010	NGO	3: Inventor; co-founder, manager	2 interviews (skype) plus email exchange	2
doctHers	Telemedicine GP clinics	Health	Pakistan	2013	Social enterprise	1: Manager	1 interview (skype)	1
Aravind eye care	Cataract surgery	Health	India	1976	Non-profit	2: Executive director, partner	2 interviews (skype)	1
UE Life Sciences	Breast cancer diagnostics	Health	India, USA	2009	SME	1: CEO	1 interview (skype)	3
OneDollarGlasses	Eye glasses	Health	Germany (HQ), worldwide operations	2012	NGO	1: CEO	1-day site visit; 1 interview	1
Ziqitza Health Care	Ambulatory service	Health	India	2005	NGO	2: Ex-CEO and product manager	2 interviews (skype)	1

TABLE 3 The data-analysis phases

Phase	Task	Explanation
1	Identify existing factors related to FI in the literature.	From the existing FI literature, factors in terms of the antecedents, mediators, and consequences of FI were identified (deductive approach).
2	Identify factors related to FI from the empirical data for 23 FI cases.	From the empirical data, factors in terms of the antecedents, mediators, and consequences of FI were identified (abductive approach).
3	Combine the factors identified from the literature (step 1) and empirical data (step 2).	A final and comprehensive framework was developed by removing any overlaps and redundancy across codes (Figure 1).

to their outlier nature. Each of the three authors developed a mind map, and these were discussed together to develop a framework that compiled insights from all three mind maps. Moreover, another author, who was not involved in the framework-development process, provided input for developing the final framework. In the abductive phase, we negotiated which codes to add based on our data and identified existing codes that needed to be revised, merged, or even dropped entirely. We repeated this exercise for four iterations, and each time, we convened to discuss and question our collective cases, such that we iteratively improved our aggregate understanding for the framework's development. Table 3 provides an overview of the phases in the coding process. To develop an initial conceptual framework, we generated a list of a priori first-order codes that were drawn from the literature, with the codes (factors) being broadly categorized as antecedents, mediators, and consequences (Appendix B).

As we had adopted a critical–realist orientation, it was important to check the reliability of the coding process. Following the examples of prior studies (Corley & Gioia, 2011; Shepherd et al., 2020), to ensure the trustworthiness of the data, the three authors critically discussed and debated each other's interpretations of the cases. This helped to form a common understanding and reach consensus during the coding process. Furthermore, the fourth author acted as a neutral reviewer of the data and mediated between the three researchers. In particular, he was not involved in data collection and was therefore less familiar with the cases, so he was better able to critically check the data analysis from an outside perspective. Through our mixed approach to developing and verifying a conceptual framework based on existing studies and analyses of FI cases, we ultimately developed an extensive, integrated, and comprehensive framework for the FI phenomenon.

TABLE 4 Case analysis process

Phase	Author 1	Author 2	Author 3	Author 4	Major data-analysis tasks
1	• Embrace • Milking machine • MittiCool	• Arbutus medical • Brazilian FHS • Hernia International	• Aravind eye care • OneDollarGlasses • UE LifeSciences	Assessed the cases, coding, and constructs as an outsider	• Create an initial coding template from the literature. • Confirm prior codes and add new codes. • Iteratively add further cases for analysis while checking prior cases. • Rename, merge, or remove codes. • Assign first-order codes to second-order constructs and third-order categories. • Refine and finalize the framework.
2	• Boond • Grameen Shakti • Nuru • Selco	• GeriCare	• ZHL		
3	• Chetak • Jayashree • MoM	• BD Odon device	-		
4	• Bright green • Dolphin	• doctHERs • Heartfile Health Financing	-		

4 | FINDINGS

We first present our results for the three themes of our framework, namely, antecedents, mediators, and consequences. The antecedents comprised personal drive, business drive, and societal drive, while the mediators were scalability constraints, resource constraints, institutional constraints, and the innovation task. Finally, the consequences were economic, social, and environmental in nature. Figure 1 illustrates this framework. To distinguish the variables that we initially identified in the literature from those that emerged from our empirical data, the latter are emphasized in italics. The causal relations between the antecedents, mediators, and consequences are represented by solid lines with arrows. However, the variables also interact with each other back and forth in the process, and these are displayed as dotted lines in Figure 1. We here provide inline quotations to support our findings, but an additional set of exemplary quotations can be found in Appendix B.

4.1 | Antecedents

Prior studies have discussed numerous antecedents for FIs at various levels and linked them with typical characteristics of emerging markets, such as high levels of poverty, institutional inefficiency, and a scarcity of resources, among others. The analyses of our selected cases not only confirmed the relevance of the antecedents discussed in the literature—they also revealed other drivers of FIs. We classified the identified antecedents into three broad categories—namely, personal drive, business drive, and societal drive—and these are discussed below.

4.1.1 | Personal drive

Personal drive is common among entrepreneurs, and it can include a desire to improve the health and living standards of people. What is more, the personal and professional experiences of entrepreneurs can play a pivotal role in initiating FIs. For example, Raghava invented his low-cost milking machine due to his personal dissatisfaction with milking his cows by hand. Mansukhbhai Patel of Chetak, the inventor of the cotton-stripping machine, was similarly motivated. In many cases, emotional and social engagements evoked both a dissatisfaction with the status quo and a curiosity about possible solutions, thus inspiring them to develop innovative products. For example, in the cases of UE Life Sciences and ZHL, personal experiences of suffering family members led to dissatisfaction with poor healthcare accessibility in developing countries, resulting in the development of FIs. As Mihir, the CEO of UE Life Sciences, stated, "I really had this sinking feeling that nothing is being done, that no one is really systematically looking to solve this problem. It was a rather sad feeling. And then I intuitively started looking for a solution." In the case of OneDollarGlasses, the innovator witnessed the lack of basic optical services during a personal trip to an African region, and this triggered a desire to explore frugal solutions.

Education and knowledge can aid entrepreneurs in innovating, but depending on the nature of an FI, innovators can have both low and high levels of education. In the case of Aravind, the innovator's medical education and knowledge played a key role in being able to develop a frugal business model for delivering high-quality cataract surgery at an affordable price. Solar energy products, meanwhile, are mainly aimed at supplying energy to underprivileged people, but this also has an environmental benefit by removing the need for kerosene and diesel fuels. What is more, Mansukhbhai Patel developed the cotton-stripping machine to relieve women and children of manual work. For his part, the CEO of MoM was driven to develop an incubator to help the premature babies of vulnerable people to survive, as he expressed: "… a five-minute segment on this program was just showing how many premature births there were just because the stresses of war and how many of them were dying. They were essentially losing a generation, so I thought there's got to be a better way to come up with an affordable portable incubator."

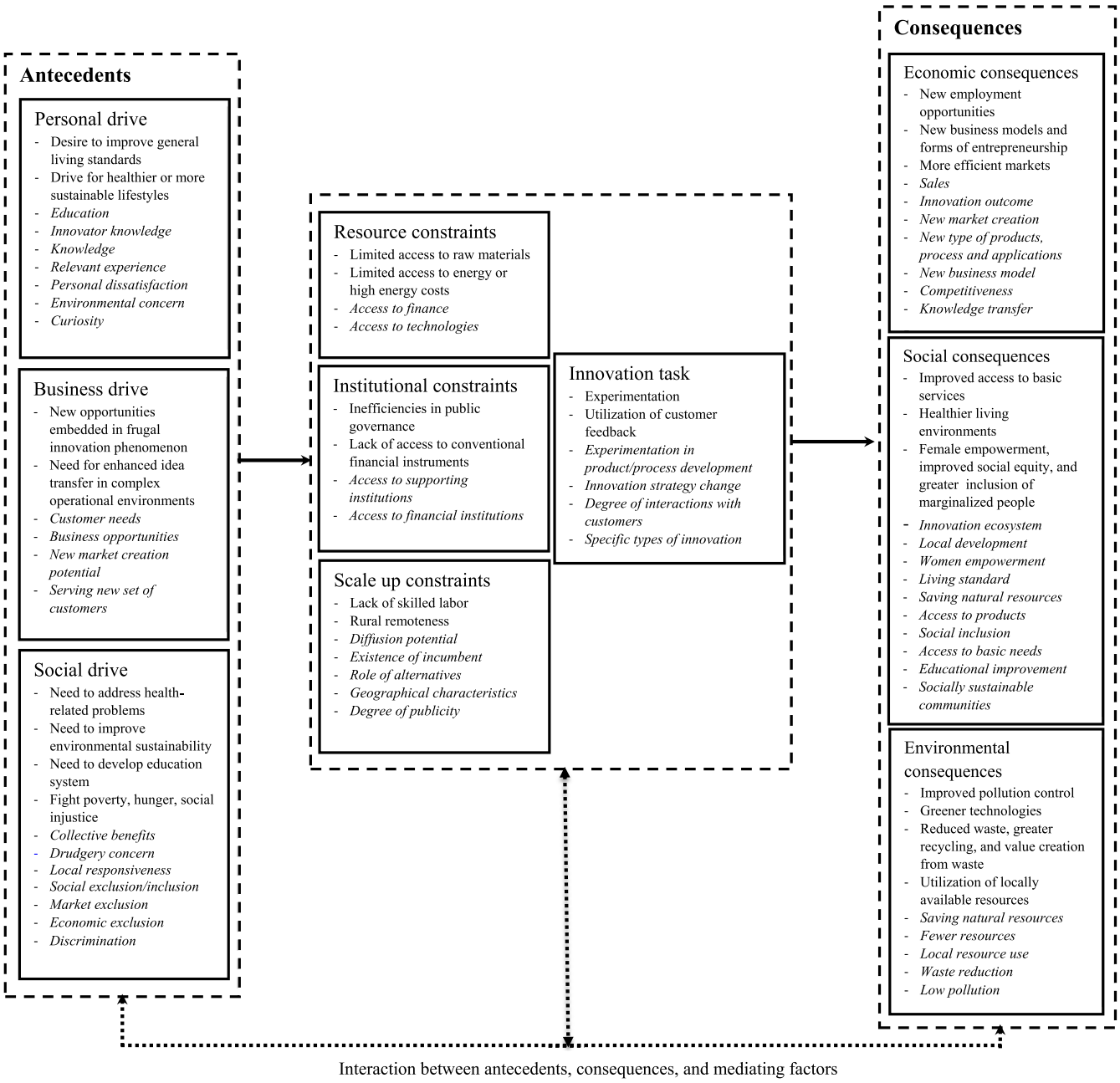

FIGURE 1 A framework of frugal innovation [Colour figure can be viewed at wileyonlinelibrary.com]

4.1.2 | Business drive

FIs can also be driven by a desire to exploit business opportunities, because entrepreneurs strive to create value from new markets and customer segments that were previously not considered commercially viable. For example, Embrace and MoM produce portable incubators for premature babies, but these were specifically developed to meet the needs of families who could not afford, or just lacked access to, hospital incubators, such as those in refugee camps, where no facilities are usually available. Entrepreneurs therefore create new markets with products that differ radically from conventional products in sectors such as agriculture, consumer goods, energy, and healthcare. They serve customers whom mainstream conventional firms have previously ignored because these people simply could not afford their products. In the case of UE Lifesciences, the innovator realized there was a huge business opportunity for developing a low-cost breast-screening device, as Mihir expressed: "It took me a good year to really kind of rise to the realization of this being a case where there was an opportunity to disrupt and there was an opportunity to provide something that did not exist."

Entrepreneurs serve not only their customers' needs but also stimulate other businesses. Many frugal products are based on simple technologies that are easy to replicate, and some frugal innovators encourage others to copy and improve upon their designs to develop

similar products because they lack the capability to serve large or distant markets. Indeed, many entrepreneurs have developed similar "copycat" products and services, such as milking machines, sanitary pad machines, and clay fridges. As Arunachalam said, "copying is allowed because it is a huge country. Thirteen people copied my innovation." Thus, further innovation emerges through a range of derived products to serve the target customers.

4.1.3 | Societal drive

Social motivations are inherent drivers of FIs, and frugal entrepreneurs are often visionaries working to achieve collective benefits by tackling the social evils of drudgery and discrimination and helping to build an inclusive, healthy society. Aravind exemplifies this, because Dr. Govindappa wished to eradicate avoidable blindness by offering high-quality eye-care services that would be affordable and accessible to all, especially for the "last mile" population. Thulsiraj, an executive director at Aravind, stated, "Our customer segment is in a sense a whole community, but then in terms of our proactive approach, it is largely [focused] towards the non-customer, people who need eye care but predominantly are not going anywhere." Similarly, OneDollarGlasses was also primarily driven by the social aspirations of its entrepreneur. Close to a billion people around the world need eyeglasses, but they either lack access to optical services or simply cannot afford them, reflecting a form of social and economic exclusion. In response, Martin, the founder of OneDollarGlasses, set out to explore how flexible spring steel wires could be bent into robust eyeglass frames on-site and at a low cost. A desire to fight poverty, hunger, and social injustice often emerges as a social drive for frugal entrepreneurs.Some frugal products, such as the milking and cotton-stripping machines, automate some tedious manual tasks and thus eliminate aspects of drudgery. Frugal products also offer collective benefits by promoting local responsiveness and enhancing social, economic, and market inclusivity. Greater market inclusion was a powerful motivator for the clinical lead developer of the Odon device: "The idea came to him in a dream, and he believes it was a divine intervention." Thus, entrepreneurs have some key drivers, and these include bringing collective benefits, reducing drudgery, improving local responsiveness, increasing social inclusion, reducing market and economic exclusion, and addressing social discrimination.

4.2 | Mediators

We found four broad classes of mediators between the antecedents and consequences. The innovation task encompasses activities within the innovation process, and mediators can facilitate or hinder the outcomes of it. Three mediators relate to various resource, institutional, and scalability constraints. We labelled these as constraints based on the context in which FIs emerge, but evidence suggests that these so-called constraints can also act as enablers.

4.2.1 | The innovation task

Entrepreneurs need to experiment iteratively to develop their frugal products, and they often consider diverse strategies to bring about the desired change. For instance, the Arbutus drill cover relied on reusable covers for the first 6 years, but it later shifted to disposable covers due to varying regulations in many countries. The original intention was to allow access to safe surgery in a sustainable way, but some sustainability had to be compromised to achieve the main objective. Many of the studied frugal products went through 5–10 years of development and testing. For example, Mansukhbahi began investing in his cotton-stripping machine in 1991, but it only became viable in 1998. Indeed, most grassroots entrepreneurs struggle for many years to develop successful frugal products, as conveyed by Arunachalam: "Yea, you have to wait. I waited for almost one decade. It is not 10 seconds like you buy a chicken."

The entrepreneurs could and did solicit customer feedback for their ventures. In the Brazilian FHS model, citizen feedback was collected regularly, but voting patterns in elections were also a powerful form of feedback in terms of signalling approval or disapproval for government policies. Many of the entrepreneurs enjoyed close interactions with their prospective customers, such as in the cases of MittiCool, Arbutus, and OneDollarGlasses. They developed a range of solutions, and each had its own challenges. For example, the Arbutus, Odon device, and low-cost mesh (LCM) cases needed to go through regulatory approvals following extensive clinical trials. In contrast, the Brazilian FHS, a service innovation that favours social outcomes, did not require regulatory approval, but extensive training was needed for community health workers to make the service widely available. GeriCare faced a similar challenge, as expressed by its lead consultant: "After creating the technological solution, the team discovered that the skilled nursing facility staff did not have the knowledge, physical examination skills, or communication skills required to liaise remotely with the KTPH medical team."

4.2.2 | Resource constraints

The entrepreneurs faced three broad types of challenges when accessing the necessary resources for their ventures. First, they encountered difficulty acquiring essential raw materials and skills. Second, they had trouble securing capital, and third, accessing the necessary technologies was problematic. Where certain raw materials were unavailable, the entrepreneurs devised ways to use locally sourced alternatives or recycle discarded materials. In the case of Embrace, the team needed to use specialized materials that were sourced globally to ensure the effective maintenance of a baby's optimal temperature. Jayashree also needed to import raw materials to India, as conveyed by its CEO: "I import raw materials from the USA, Canada, and Australia. In those places, there are private big industries. They have quality." In many cases, though, importing materials from abroad is unfeasible. For example, the Indian government has implemented

bureaucratic procedures for every step when importing materials from China for solar energy, and this situation has worsened recently due to the India–China border dispute. In other cases, however, alternative solutions were possible due to other atypical resources being locally available. For instance, the Arbutus drill cover enables expensive orthopaedic drills to be replaced with commonly available hardware drills, which are far cheaper, demonstrating how resource constraints can act as catalysts for FIs.

Financial constraints are commonly encountered among consumers and entrepreneurs, and a key strength of the entrepreneurs was their ability to overcome these constraints to create affordable solutions for consumers who could not afford the existing offerings. As Martin from OneDollarGlasses stated, "The most important aspect is the affordability of the solution in developing countries. If they cannot afford the eyeglasses through their daily wages, they will not buy them." Mitticool and Arbutus are other examples where the existing solutions were radically rethought to bring down the cost to an affordable level for low-income consumers. Affordability is therefore a key objective for frugal entrepreneurs. A key problem for Aravind was needing to procure intraocular lenses from abroad, so it set up its own lens-manufacturing facility, thus bringing the price down from $200 to $5 per lens. Nevertheless, it could only achieve this by collaborating with international organizations like the California-based Seva Foundation to acquire the necessary technological capabilities. Aravind also followed a subsidy model, such that it charged affluent consumers more to fund free treatment for almost two-thirds of its poorer patients. Selco energy, meanwhile, developed a business model that allowed consumers to purchase equipment in instalments through microfinancing support.

4.2.3 | Institutional constraints

Entrepreneurs operate in the presence of institutional voids, so the necessary supporting institutions for technology and finance, for example, are lacking. Indeed, supporting institutions—which can provide assistance like start-up incubation, seed grants, business and legal services, and help with regulatory approval—are often unavailable to frugal entrepreneurs in developing countries. To overcome this shortcoming, Arbutus accessed the start-up facilities of the University of British Columbia in Canada. In Pakistan, meanwhile, Norway's Telenor ran a start-up incubator called Velocity that was pivotal to the launch of doctHERs, although a multinational corporation providing incubation in a developing country is a rare occurrence. What is more, entrepreneurs may support each other through locally organized matchmaking by local institutions. For example, Selco provided training and support for Boond, as expressed by the latter's CEO: "I received training from Selco and IIM Ahmedabad to start our business."

Moreover, credit rating agencies, a lack of business loans, and under-developed financial markets can make it more difficult for frugal entrepreneurs to raise capital for their operations. In India, Mansukhbhai Prajapati of Mitticool needed to put his ancestral family home up as collateral to secure a bank loan at an 18% interest rate, resulting in the repayment being four times the original amount due to defaults. Other entrepreneurs sought to secure the necessary funding from international agencies and investors. Heartfile Health Financing in Pakistan, for example, raised international funds through the Clinton Global Initiative, while Embrace raised funds from venture capitalists in Silicon Valley, and Arbutus accessed Canada's social-impact grants. Many of the energy firms were not familiar with raising funds through crowdfunding at the time. In other cases where financing was unavailable, the entrepreneurs chose to partner with larger organizations. For example, after bootstrapping, the inventor of the Odon device licensed the patented device to Beckton Dickinson, a global manufacturer of medical devices. The clinical lead for the Odon device succinctly stated, "The project would not be where it is without the international partnerships."

Perhaps to overcome some of the institutional constraints, Arbutus, Embrace, and Odon pursued a hybrid for-profit/non-profit model to achieve their social and economic objectives. ZHL also benefited from a public–private partnership model, as stated by one of its project managers: "Basically, the government is providing emergency medical services to the citizens free of cost, and ZHL manages and runs these services for the government, and the government pays ZHL to do so." Energy enterprises like Selco and Grameen Shakti have also pursued hybrid models to achieve their desired environmental and economic outcomes. They needed finance, both for their own survival and for improving the purchasing power of their potential customers, so they could afford to buy their solar systems.

4.2.4 | Scalability constraints

Entrepreneurs encounter difficulties in scaling up their ventures. Based on the widespread unmet demand for basic services like housing, healthcare, and education, the potential for scaling up is expected to be high. Entrepreneurs at the grassroots level in India often resonate with the following comment of Arunachalam: "I am not that interested in foreign markets, because India itself is a big country and I am yet to cover a small part of the country … so many challenges." In contrast, Dr. Ravidranath Tongaonkar developed an LCM for use in rural India, but to scale up operations, Tongaonkar needed to work with the global charity Hernia International to diffuse the innovation throughout India and other countries. The Brazilian FHS model, meanwhile, managed to scale up healthcare provision to most of the country thanks to the national government funding and supporting the programme. Both Embrace and MoM encountered difficulties when collaborating with NGOs and international agencies in order to scale up the use of their incubators, as conveyed by MoM's CEO: "I had a trip to Africa and it changed my outlook."

Entrepreneurs recognize the existence of incumbents and alternative solutions. In the case of the LCM, the cognitive bias with which the meshes are viewed makes its global expansion potentially difficult. A researcher involved in evaluating the LCM suggested, "The

challenges remain, but dedicated efforts to publish cohort studies, laboratory studies, and clinical trials can help to mitigate obstacles to uptake." The geographical characteristics of the prevailing environment can also affect how innovations scale up. The Brazilian FHS programme scaled up nationwide, and the United States is exploring using the same model on a smaller scale. The degree of publicity can also impact the potential for scaling up, and many enterprises have benefitted from global publicity, with it helping to accelerate their scale-up activities. For example, the World Health Organization supported the Odon device in achieving global reach. FIs often aim to achieve good economic, social, and environmental outcomes, but different approaches to scaling up lead to varying degrees of achievement.

4.3 | Consequences

The implications of FIs go far beyond those of more traditional product and service innovations. We categorize FIs' outcomes as being economic, social, and environmental in nature, reflecting the three pillars of sustainability.

4.3.1 | Economic consequences

The economic outcomes of FIs are manifold. Such innovations usually have fewer features or use simpler technology than their conventional counterparts. FIs can also be entirely new types of products. For example, off-grid energy services like Selco, Grameen, and Boond are helping thousands of people to raise their living standards. FIs offer different sorts of outcomes, as Arunachalam pointed out: "My machine is different from the traditional machines of large firms." Similarly, OneDollarGlasses offers "clear vision, which is helpful for students in school or adults when they are working," so it has a direct economic impact as well as a social one.

An FI can be a new type of product, process, or application with a fresh business model for serving low-income customers. As frugal products are sold to a new set of customers, they effectively create new markets in developing countries and stimulate new forms of competition. Indeed, other firms and entrepreneurs often come up with similar, competing products. For example, Jayashree sells its products to social enterprises that are mainly run by women, and this has inspired other firms to offer similar products. Thus, low-income customers start enjoying a range of options when buying frugal products. This also creates a platform for transferring knowledge in low-income markets. It also helps prevent the migration of people from the rural areas of developing countries, where jobs may be scarce, to the large cities. For example, Ksheera Enterprises employs local people in its factory for making milking machines, and these workers may well have otherwise moved to a big city to find employment. Indeed, many frugal products create jobs for local people who would otherwise be unemployed, as well as indirect employment through the supply chain up to the point of consumption (e.g., salespeople, delivery agents, etc.). For example, MittiCool employs around 50 full-time local employees, but it also uses many other people for sales and delivery. According to Arunachalam, "Jayashree created a livelihood for 22,000 women in 17 countries through its 2,300 machines." Grameen Energy employs around 2000 people, while Selco employs around 400 people. Most of these people would not be employable in conventional firms.

4.3.2 | Social consequences

FIs foster product awareness in new remote locations, thus developing an innovative ecosystem at the low-income level. As Prof. Anil Gupta points out, "with our three supporting organizations, there is a strong innovation ecosystem to build relationships among the established and aspirant grassroots entrepreneurs." When frugal products originate at the grassroots level, they boost local development because revenues stay at the local level, but even Western firms' frugal products can contribute to local development in target markets. FIs also promote education and knowledge transfer. One Arbutus designer said, "Bioskills workshops have been taught by a local surgeon collaboratively with a surgeon from Vancouver General Hospital since 2013. It is sponsored by our tools, which are then incorporated into the surgical rotation."

Frugal products empower underprivileged people, especially women and children, and increase living standards for marginalized people in developing countries, so they contribute to inclusive development, which is one of the United Nations' sustainable development goals. Frugal products tend to contribute more to sustainable development than conventional products, even if this may not have been the initial motivation. Alongside these products, having sustainable infrastructure with a frugal orientation is important for achieving the SDGs (Ebolor et al., 2022).

While firms profit from offering frugal products, their customers also benefit from getting access to affordable products. Frugal products can transform some tedious manual tasks into a mechanical process. In addition, frugal services like off-grid renewable energy can be a game changer for remote communities, such as by allowing adults to safely work and children to study after nightfall. Thus, FI creates more socially sustainable communities, just as the former CEO of Grameen Shakti expressed: "We aim to bring sustainable light and power to thousands of Bangladeshi villages, thus promoting health, education, and productivity." The Embrace and MoM baby incubators, meanwhile, save the lives of premature babies when their parents cannot access conventional baby incubators. According to one Embrace manager, "We reached over 300,000 premature babies across 22 countries." Similarly, ZHL are offering emergency medical services to the vast population of India. As stated by one of its product managers, "In terms of the impact we have, we have around 1,200 ambulances, and we have served around 3.4 million people across 17 states with around 8,000 people on board."

4.3.3 | Environmental consequences

FIs can have positive environmental effects in many ways. Frugal products contribute to conserving natural resources by using materials more efficiently or avoiding environmentally harmful activities. Many frugal products also take advantage of local and/or recycled materials, thus reducing waste, and they often cause less pollution. According to MittiCool's CEO, "Our products are made of clay, and our clay fridge does not use electricity, so our products are environmentally friendly." Discarded local materials are often used to replace imported raw materials when developing an FI. For example, Arunachalam argues, "We encourage social enterprises to use banana fiber as the raw material to make sanitary pads." This helps reduce the need to import materials while also reducing the locally produced waste. Other cases have also had an indirect positive impact on the environment. For example, the telemedicine provided by GeriCare and doctHERs avoids the carbon emissions that would have resulted from doctors having to physically travel. There can also be some unintended negative effects, however, such as in the case of Arbutus and the Odon device, which had to rely on disposable plastic or rubber covers for their solutions.

5 | IMPLICATIONS AND AVENUES FOR FUTURE RESEARCH

This study has helped to consolidate and reinforce the existing FI literature, as well as build upon prior frameworks (Hossain, 2018; Lim & Fujimoto, 2019). In view of the findings, we now discuss the theoretical and practical implications.

5.1 | Theoretical implications

This study integrates influential factors—namely, the antecedents, mediators, and consequences—into a framework for FI based on empirical findings. On categorizing the antecedents into personal, business, and social categories, this framework reveals three main drivers for pursuing frugal solutions. It also categorizes the mediators into three broad types of constraints encountered during the FI process. Most of the cases we explored had received limited support from formal institutions, which are usually absent, weak, or inadequately resourced. The lack of resources and institutional support essentially forces innovators to mobilize what limited abilities and resources they have at hand to overcome obstacles and arrive at alternative solutions to fill a gap where the existing products and services are either unavailable or inadequate. This, as we have highlighted here, is actually a strength of FI, because the absence of some institutions and resources can often incentivize and facilitate FI activities. Indeed, rather than hindering the innovation process, resource scarcity, a lack of institutional support, and scalability challenges can stimulate innovative activity by compelling innovators to take advantage of the resources at hand and experiment with potential alternatives for securing financial support and commercializing a product.

The importance of the capacity to operate with limited resources has been seen during the recent disruption caused by the COVID-19 pandemic, which forced companies around the globe to adopt FI principles to build more secure, inclusive, and timely solutions (Bhatti et al., 2020; Govindan, 2022). What is more, our framework demonstrates FI's potential for positively contributing to the three major pillars of sustainability, namely, the economy, society, and the environment (Howell et al., 2018; Levänen et al., 2016). FIs not only focus on making better use of resources, because they can also reduce waste and pollution. With governments and companies increasingly focusing on the SDGs, the principles of FI are being adopted to achieve not just financial but also environmental and sustainability benefits. The close link between sustainability and resourcefulness positions FI as a potential strategy for tackling the unprecedented challenges of today, such as climate change and potential future pandemics and economic crises.

This study highlights the dual impact of FI in terms of achieving both business growth and inclusive growth, thus contributing to the literature on dual-business outcomes (Shepherd et al., 2020). FI can serve as an appropriate approach for accomplishing firm growth in an inclusive manner, thus debunking the argument that these two objectives rarely go hand in hand (Shepherd et al., 2020). Driven by both business and social motives, FIs evidently create new markets by fulfilling unmet customer demand, thus benefitting society. Studies related to poverty alleviation argue that even large firms can innovate to achieve business and inclusive growth (Halme et al., 2012). Indeed, FIs are products that are affordable to produce and purchase, so they promote improved livelihoods and inclusive growth. They also generate profit for their firms while also alleviating poverty, a key element of inclusive growth (Bhatti & Prabhu, 2019; Prahalad & Hammond, 2002).

More generally, FI has attracted growing interest as a means for promoting sustainable development (Molina-Maturano et al., 2020). We found that FI helps to address the grand challenges that both rich and poor societies are facing. This links with prior research that has urged management scholars to make their studies more relevant to society (Wickert et al., 2020) and develop business strategies aimed at tackling the grand challenges (George et al., 2016). Frugal solutions represent a means to this end because they contribute to, for instance, sustainable energy generation, female empowerment, and the upskilling of labour. As the management literature and business practices pays more attention to FI, there is considerable scope for it to flourish. Further assessment of the dual impact of FI would benefit from studies set in different contexts and types of organizations, as well as with using different technologies. For instance, integrating FI with recent technological advancements, such as the Internet of Things (IoT) and artificial intelligence, could help achieve operational excellence and lead to companies growing sustainably while creating social value (Govindan, 2022; Park et al., 2021). Just as there has been much interest in FIs spreading from developing to developed markets, from small to large companies, and from local to multinational companies, it would also be worthwhile to explore the shift from using simple and less sophisticated technologies to more complex and highly sophisticated technologies.

The arrows in our framework shown in Figure 1 delineate the links between the antecedents, mediators, and consequences. Antecedents represent the factors that may trigger the FI process, while the consequences reflect the various outcomes (i.e., the *raison d'etre* of the FI process). The mediators, meanwhile, represent the factors that may enhance or diminish the ability of innovators to have a meaningful impact. The degree to which the mediators serve as enablers rather than constraints determines the degree to which the desired consequences materialize. Hence, this directional flow paves the way for future research to explore FI as a process that (i) begins with drivers (personal, business, and social); (ii) involves innovation to transform constraints into enablers; and (iii) ends with outcomes that improve the economy, society, and the environment. This process combines with needs and motivations to achieve a variety of meaningful outcomes by leveraging contextual enablers and agency through innovation. Indeed, our framework suggests there is much more to FIs than simple artefacts (Zeschky et al., 2011), and our framework's emphasis on the innovation task will support efforts by scholars to move beyond FI as a solution to a mindset (Hyvärinen et al., 2016; Prabhu & Jain, 2015) and towards a processual pathway (Knizkov & Arlinghaus, 2020; Kronemeyer et al., 2021) that focuses on how things are done rather than what is being done. FIs as products remain important, but FI as a process has importance for innovators and organizations that wish to draw on FI methods to advance their innovation activities without necessarily developing a frugal product. The focus on the "how" leads us to now discuss some practical insights for innovators and organizations, as well as how policymakers can leverage FI for greater impact.

5.2 | Practical implications

Our comprehensive mapping of the antecedents, mediators, and consequences is useful for practitioners who are considering pursuing FI as a process for developing an FI product or service. Inclusive growth is an important consideration for firms to contribute to society, and we found that FIs contribute to both business growth and inclusive growth for society, so businesses of all sizes can embrace FIs as a means for gaining a sustained competitive advantage. Western firms can benefit from this (Belfrage & Hauf, 2017), as can Western contexts in terms of inclusive social development (Bhatti & Prabhu, 2019). As products with minimal features, FIs are developed to create and capture value by shunning superfluous features, which can result in unwanted products and needless waste. FI as a process can provide the inspiration for large firms to innovate with limited resources. Indeed, the repeated economic downturns in recent decades have resulted in reduced research and development budgets, forcing firms to optimize their resource usage. Spending less to achieve the same desired result improves efficiency and productivity, therefore helping to improve competitiveness.

The dual benefit afforded by FI in reducing costs while improving outcomes represents an attractive proposition for achieving a global competitive advantage. Developing firms pursue this out of necessity due to limited resources and more demanding local customers with limited purchasing power. As they learn, they improve lives, and they grow as they expand into neighbouring markets and eventually even into developed markets (Govindarajan & Ramamurti, 2011). Multinational companies should also do this, as it will help them achieve a sustainable competitive advantage not just in their home markets but also in emerging markets, thus accessing a vast population and facilitating economies of scale. Small firms can also create new markets for underserved customers and thus promote local entrepreneurship, which in turn improves global development. Large firms may then follow suit by convincing new customers to search for affordable solutions. To reap the benefits from FI, though, some organizations will need dual business models that cover both their main products and their frugal alternatives (Winterhalter et al., 2016) in order to cater for a range of market segments. FIs are products and services that serve underserved customers in emerging markets, so they offer value far beyond a quick-fix, improvised solution (Shepherd et al., 2020).

The antecedents, mediators, and consequences outlined in this study will be useful when developing policies to encourage frugal solutions. As innovation and entrepreneurship grow in developing countries, they act as a means for enabling underprivileged people to access basic facilities (Andries et al., 2019), so it is important for policymakers to support them (Allard & Williams, 2020). Indeed, the drivers and outcomes detailed in this study can be integrated into current policies for tackling grand challenges (George et al., 2012) like wealth inequality, climate change, and resource scarcity, because frugal solutions can help solve these pressing issues (Immelt et al., 2009). The dual outcomes of FI also imply that governments and non-profit organizations can work together with commercial enterprises to nurture FIs and address global challenges despite the resource, scalability, and institutional constraints. Emerging markets are currently hotspots for FI ideation and testing, and following successful development, companies are increasingly seeking to diffuse their innovations from emerging and developing markets to developed markets. Hence, policymakers need to continue developing institutions to support innovation activities, including FI, particularly in emerging markets. With the right institutional and policy support, FI activities may flourish more than they currently do. To transform constraints into enablers, the lack of support can be institutionalized when it is deemed to encourage FI activity. However, the smooth spread of FIs from low-income to high-income contexts still faces several barriers (Malodia et al., 2020).

Although FIs are largely triggered by the needs of people in developing countries, developed markets under budgetary constraints are also increasingly pursuing FIs through reverse innovation (Immelt et al., 2009). However, global policy leaders need to level the playing field for the adoption of FIs, regardless of where they were developed (Molina-Maturano et al., 2020) or where they were intended to be used (Skopec et al., 2021). Such measures could include relaxing unnecessary or onerous regulatory hurdles for imported FIs and reducing the number of superfluous features expected, with the focus shifting to a fair balance between outcome and cost to favour greater value for money. This requires an understanding of the context, a

desire to make a difference, and the preparedness and equipment to do so. At a personal level, it is important for innovators to know the field in which they are innovating, either through formal or informal education. The abilities that an innovator needs are also enhanced by having relevant experience in the problem area. At a business level, a close understanding of the customers' needs creates the opportunity to discover new markets with a new set of customers, thus making the FI phenomenon amenable to sustainable growth. At a social level, innovators being personally embedded in the local context means they understand the problems faced by their customers, such as the drudgery of manual labour and inequalities in the market that are exacerbated by social exclusion and discrimination. A thorough understanding of these things requires innovators and organizations to be physically and emotionally close to these needs, such that they not only understand them but are also touched by them enough to trigger an engagement with FI.

5.3 | Limitations and future research avenues

This study has some limitations, and these lead to some new directions for future research. First, this study combined data collected by three researchers who operated independently. Second, our analysis activities used online spreadsheets, unlike other comparable qualitative studies that used specific software for data analysis. Third, our cases operated in several sectors and varied in terms of their size, focus, markets, and customers. Considering the variety of cases, this study is, to an extent, generalizable to the Asian and African contexts, although we recognize that the generalizability of such qualitative research is never entirely guaranteed. Nevertheless, further studies in different contexts and with different cases will help to confirm or dispute our findings.

Given the emergent nature of the concept, there are numerous future research possibilities for FI. We identified the various consequences of FI, and future research could explore the potential trade-offs among the different outcomes. Other than for the BD Odon device, we did not consider any large firms, so addressing this may bring new insights for enriching the FI literature. The way that frugal entrepreneurs mobilize resources to pursue their business ideas is also an interesting research direction. We did examine resource mobilization to an extent, but future studies focusing exclusively on this may help us to understand how frugal entrepreneurs differ from social entrepreneurs.

6 | CONCLUSION

This study has shed further light on the FI phenomenon by developing a comprehensive framework based on identifying the antecedents, mediators, and consequences that prevail in the existing literature and building upon them through empirical study. It positions the consequences of FI in relation to the three pillars of sustainability, namely, the economy, society, and the environment. We also highlighted how FI has dual outcomes in terms of achieving both business growth and inclusive growth, as well as how it may contribute to addressing the grand challenges that the world faces.

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DATA AVAILABILITY STATEMENT

Data are available on request from the authors.

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APPENDIX A: CASE SUMMARY

Case	Description
Dolphin engimech	Dolphin was founded in 2004 as a social enterprise with its bamboo stripping machine and incense (agarbatti) stick making machine. It has subsequently developed several other machines such as Textile Machinery & Part & Hand Tool Kits.
Chetak	Chetak was founded in 2001as a social enterprise to improve the drudgery of workers by developing a cotton stripping machine. It has subsequently developed several other machines in the agriculture sector.
Grameen Shakti	Grameen Shakti was founded in 1996 as a non-profit to provide households solar-home-systems for electricity, improved stoves and biogas for cooking through affordable finance.
Nuru	Nuru was founded in 2008 as an international social enterprise for the distribution of affordable LED lamps that are recharged through a human powered generator
Boond	Boond was founded in 2010 as a for-profit organization with the goal to provide high quality, reliable, customer centric, solar power energy at affordable cost.
Selco	SELCO was founded in 1995 as a for-profit social enterprise to improve living standards of poor households through solar energy based interventions and low smoke cook stoves.
mOm	mOm was founded in 2014 as an affordable, collapsible, and lightweight infant incubator whose mission is to expand access to high-quality healthcare by providing affordable technology solutions that can operate anywhere in the world.
Embrace	Embrace was founded in 2008 as a social enterprise to give premature and underweight babies in the developing world a better chance at life.
Ksheera	Ksheera enterprises was founded in 2011 as a social enterprise to improve the working conditions of the farmers who milk their cows manually.
Jayashree	Jayashree was founded in 2009 to design and sell affordable machinery to produce quality low-cost sanitary napkins targeted at poor rural women.
MittiCool	MittiCool has its roots since 1988 with a mission to reintroduce the science of clay making around the globe. Its flagship product is an earthen refrigerator that works without electricity.
Arbutus	Arbutus was founded in 2014 as a for-profit social enterprise to provide high quality, safe orthopaedic surgical tools to reduce the cost of healthcare globally.
Hernia International	Hernia International was founded in 2008 as a non-profit organization to address the global healthcare problem of hernia. It sends teams of surgeons equipped with low cost (mosquito net) mesh to repair inguinal hernias at a fraction of the cost incurred when using clinical mesh.
Brazilian family health	Since 1994 the Brazilian primary healthcare system has relied on community health workers (CHWs) to reach out to families within a local area, offering home visits and a deep understanding of the community. The programme costs only $50 per person each year.
GeriCare	Begun in 2009, GeriCare at north is a telemedicine initiative in Singapore designed to improve access to specialist elderly care physicians for residents of skilled-nursing facilities. It has delivered system cost savings by preventing unnecessary acute hospital admissions and reducing the need for specialist outpatient consultations.
The BD Odon device	The Odon device was ideated in 2005 by Mr Jorge Odón, a car mechanic from Argentina, WHO then sold licensing rights for the innovation to Becton Dickinson. The device is championed by the World Health Organization (WHO) as a low-cost, simple and easy to use equipment in countries where caesarean sections are either not available or affordable.
Heartfile Health Financing	Heartfile Health Financing (HHF) was developed first in 2010 to provide financial access for high-cost treatment for those who are unable to pay, are likely to spend catastrophically or forgo treatment. HHFs mobile phone-driven process is fully transparent and offers help to patients with dignity.
doctHERs	doctHERs was founded in 2013 to match the under-utilized capacity of female doctors with the needs of female patients via telemedicine. It provides access to affordable, quality healthcare in Pakistan to a subset of the "missing middle" population which is not served by conventional healthcare providers.
Aravind eye care	Aravind eye was founded in 1976 with a mission to end blindness in India. Its main innovations include the local production of affordable intraocular lenses and the use of assembly line systems to standardize care and distribute activities through task-shifting.
UE Life Sciences	UE Life Sciences was founded in 2009 with a vision to be a women's health company commercializing accessible, innovative medical technologies to improve clinical outcomes globally. Its iBreastExam is a US FDA approved device that enables health workers to identify non-palpable breast lumps in just a few minutes, without pain or radiation.
OneDollarGlasses	OneDollarGlasses was founded in 2012 as a non-profit with the goal to establish basic optical care for everyone. Martin Aufmuth invented a system at home in Germany in his basement that allows glasses to be manufactured on site using a simple bending machine, with per glasses material costing around $1.
Ziqitza	Ziqitza Health Care was founded in 2005 with a vision to assist in saving human lives by providing a leading network of fully equipped ambulances across the developing world and be accessible to everyone regardless of their income bracket.

APPENDIX B: THEMES, SUBTHEMES AND EXEMPLARY QUOTATIONS

Themes	Subthemes	Exemplary quotations
Antecedents	Personal drive	"After completing my MBA from INSEAD, I was working in a corporate job, but I left it to do something for the people who are deprived of access to power and work under unhealthy conditions." (CEO, Boond)
	Business drive	"For many, expensive medical tools reduce access to critical surgery, and for the rest they worsen the rising cost of healthcare. We design medical devices which break down barriers to safe surgery. We use frugal innovation to adapt non-medical technology to create devices which deliver maximum value at the lowest cost." (Cofounder, Arbutus)
	Social drive	"With the press machine, I could manufacture 700 earthen pans per day which is many times more than manual making." (Mansukhbhai Prajapati, MittiCool)
Mediators	Resource constraints	"The starting surgery for cataract in the paying side we charge Rs 6000 for what we call as a manual cataract surgery. The same surgery in the free section the patient will have to pay Rs750 for the consumables that have been used in the surgery." (CEO, Aravind) "The only substantive cost we incur is of sterilizing and packaging. Marketing accounts for a 300-400% markup, which we as an NGO do not incur by sourcing low cost mesh inhouse." (President, Hernia International)
	Institutional constraints	"HHF provides financial access to healthcare for the poor in a country where the public system has limited capacity to deliver service. We overcome this constraining factor by linking the public sector with the private sector. However, this can increase cost and ensuring quality remains a challenge." (Founder, Heartfile Health Financing) "Regulatory affairs is quite a tricky and nuanced area as you can see, and these limitations are actually self-imposed by our team since we want to make sure we are doing our best in what is a very grey environment with medical device regulations. (Cofounder, Arbutus)
	Scale up constraints	"The digital platform only incurs lean operational costs and allows for scale up without needing physical presence in the field. Pakistan has an extensive telecommunications infrastructure which allows for mHealth deployment even in rural areas." (Founder, Heartfile Health Financing)
	Innovation task	"We did a lot of rapid prototyping/iterations using dummies – which sped up the process towards current clinical trials." (Clinical lead, The Odon Device) You know educated people cannot think simple. Being uneducated we always give solutions to problems in simple." (Arunachalam, Jayashree)
Consequences	Economic outcome	"BD recognise that the Odon device will not deliver profits similar to their other products, but it is part of their commitment to global health. (Clinical lead, BD Odon device)
	Social outcome	"Aravind employs several locally trained paramedics in their medical services, "each year we take about 400-500 high school girls from villages, put them for two-year training." (Thulasiraj Ravilla, Executive Director, Aravind) "We register the whole family and log them onto our system—the registration is of the family, because we follow the family, as a whole. From there, we'll follow them, see what they need, not necessarily only from the health side of things, but also their education, mental health needs, even seeing what they like to do in their spare time." (Community health worker, Brazil)
	Environmental outcome	"DoctHERs reduces the need to travel to far flung remote areas or even in populated cities, thereby decreasing carbon emissions." (Manager, doctHERs)