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Measuring frugal innovation capabilities: An initial scale proposition

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ABSTRACT

This paper proposes an initial scale to measure the frugal innovation capabilities within organizations. Our scale comprises three major dimensions: (1) focus on core functionalities, (2) substantial cost reduction, and (3) shared sustainable engagement. We adopted the frugal innovation efficiency-driven perspective based on both the resource-based and the capability-based views. From primary survey data of 1,097 companies in three countries (Brazil, India, and the USA), we developed a reliable and valid scale to measure frugal innovation capabilities comprising ten features with clear psychometric properties. We also contribute to the innovation research literature by revisiting its main texts and proposing a concept of frugal innovation capabilities. In doing so, we introduce an initial measuring instrument. Such an initiative represents an advance in the literature to better understand the development of frugal innovation, guiding the exploration of frugality-based advantages. It enables managers to identify the organizational capabilities that are needed to increase the odds of developing frugal innovations. This is a first attempt to measure the concept of frugal innovation capabilities. There is much room for the exploration of its other dimensions.

1. Introduction

Among its manifold results, the COVID-19 pandemic, in addition to directly affecting every single person around the world, has also shown us the importance of saving resources and the need to invest in the search for affordable solutions that can keep businesses alive in prolonged times of crisis (Corsini et al., 2021; Harris et al., 2020). The overload of patients in health care systems worldwide worsened the lack of respiratory support devices in hospitals for the treatment of COVID-19 patients. A global race for the development of alternative solutions to ventilators that were more accessible, efficient, and could be produced on a large scale was started (Harris et al., 2020). This surge in demand led companies such as NASA (National Aeronautics and Space Administration) to develop low-cost devices in just 37 days (Good, 2020; McFall-Johnsen and Woodward, 2020) and later share their production license, allowing this solution to reach other countries, such as Brazil, India, and China, among others. In addition to NASA, several other companies worldwide developed similar solutions (Good et al., 2020; Harris et al., 2020). The result was the development of a device produced at a significant cost reduction, focused on its core functionalities, and with a shared sustainable engagement, meeting an essential social demand, creating partnerships and collaboration to save lives.

The case mentioned above is a very good example of a frugal innovation. Frugal innovations are specially developed by companies, which Bhatti et al. (2018) describe as efficient-driven frugal innovation. This type of frugal innovation is the main phenomenon analyzed in this article. Frugal innovation usually refers to innovative solutions that significantly reduce the total cost of ownership/usage while meeting or exceeding prescribed quality standards (Zeschky et al., 2011b). From this value proposition, frugal innovation extends to unserved customer groups while ensuring "affordable excellence," which does not necessarily mean cheap products but products that offer good value (Pisoni et al., 2018; Tiwari et al., 2016b). It also does not mean frugal innovation products are makeshift, grassroots contraptions or somehow improvised. In contrast, these innovations emerge from companies and are aligned with Rao's (2017a) concept of advanced frugal innovations

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(AFIs), which comprise original solutions that seek to reconcile the dilemma between advanced technological innovations and resource efficiency for creating low-cost products. Hence, it offers a high perception of use-value and sustainability for more inclusive consumption (Rao, 2013; 2017a; b, 2019) and could be applicable in different contexts in emerging economies and developed consumer markets (Rao, 2013; Shankar and Narang, 2019).

Due to the specific characteristics of frugal innovation, we believe that its development process requires companies to possess specific capabilities. Thus far, the literature has explained this process as being focused only on grassroots movements (Brem et al., 2020) instead of on a broad firm-level reach. Furthermore, Brem et al. (2020) did not aim to identify the capabilities needed to set up frugal innovations. Indeed, studies on frugal innovation and even those focusing on resources (Asakawa et al., 2019) and capabilities (Lim et al., 2013) fail to point out how to develop such capabilities at the firm level. Consequently, the following question remains: what are the capabilities needed in a company for developing frugal innovation? This paper aims to develop and validate an initial scale to provide a proper answer to this question. Our findings result from the analysis of primary survey data from 1,097 companies in three countries (Brazil, India, and the United States). This analysis led to a scale comprising a set of the following three main capabilities: (1) focus on core functionalities, (2) substantial cost reduction, and (3) shared sustainable engagement.

Understanding the main capabilities that allow frugal innovation development brings meaningful contributions to the innovation management literature and practice. First, the capabilities for achieving frugal innovation complement the frugality-based advantage idea (Asakawa et al., 2019), supporting the operationalization of frugal innovation. Second, these three capabilities offer an approach to identifying, developing, and managing frugal innovation at the firm level (Bhatti et al., 2018; Rao, 2017a). This advance meets the needs of studies that explore frugal innovation by providing a valid and reliable measurement tool (Hossain, 2018a; Pisoni et al., 2018; Tiwari et al., 2016b). Incidentally, with the evolution of the frugal innovation approach, other capabilities may arise to complement the three main capabilities we propose here. Finally, identifying and measuring these three capabilities can assist managers in developing or improving their frugal innovation process to gain frugality-based advantages. Managers can assess the company's competence regarding their readiness to focus on core functionalities, pursue substantial cost reduction, and promote shared sustainable engagement. This assessment allows managers to identify the areas within their companies to allocate efforts and enhance capabilities.

2. Frugal innovation

Frugal innovation advocates the idea of being innovative while simultaneously saving resources (Pisoni et al., 2018). At first, frugal innovation was viewed as an innovative approach to generating new applications, and it even allowed the creation of previously unexplored or unserved markets in the promising low-end market segment (e.g. Farooq, 2017; Leliveld and Knorringa, 2017; Tiwari et al., 2016b; Weyrauch and Herstatt, 2016a). Some of these researchers suggest attributes that consist of developing products and services for substantially lower costs, offering limited features, ease of use, and good value-for-money, with a focus on low-income customers (Agarwal and Brem, 2012; Bhatti, 2012; Brem and Ivens, 2013; Economist, 2009; Zeschky et al., 2011b). However, the development of the literature showed that frugal innovation is not only for the bottom of the pyramid (Hossain, 2018a; Pisoni et al., 2018; Tiwari et al., 2016b). Companies from developed countries are adopting frugal innovations to reach unserved resource-constrained markets or those customers worried about waste excess (Rosca et al., 2017b).

Frugal innovation is different from "makeshift contraptions" or improvised solutions such as Jugaad innovations, which have temporary roles and can evolve into other types of innovations or not but are not planned or developed by companies with clear commercial purposes despite being able to become commercial products later on (Agarwal et al., 2017; Hossain, 2016). Grassroots innovation, in addition to emerging from individuals or a community, in and takes advantage of grassroots capabilities and local/regional enablers to meet their needs (Hossain, 2016, 2018b). Frugal innovations emerge from companies or entrepreneurs who want to deliver value through affordable solutions (Camargo and Rossetto, 2018; Tarraço et al., 2018).

As we are analyzing FIs developed by companies, it is important note that Rao (2017a, 2017b, 2018, 2019), in his set of studies, spotted a new class of frugal innovations, and coined the term "advanced frugal innovation" (AFI), which consists of "the application of cutting-edge science and engineering" to achieve robust functioning. By introducing AFI as a class of FI, Rao (2017b, 2019) indicates that AFIs are realized through the "methodical application of scientific principles, as opposed to their grass-roots brethren, which are usually created on a makeshift basis" (Rao, 2017a, 2019). The concept studied here is more aligned with AFI; however, from an evolutionary perspective of innovation (Figueiredo, 2002), not all FI is in the advanced stage of development, as described by Rao. Similar to other traditional innovations, most companies are in the basic stage of innovation development, while others are in the intermediate stage, and a small percentage of companies reach the advanced stage. This means that frugal innovation is developed by firms with an innovation process (basic, intermediate or advanced).

To help set frugal innovation apart from the traditional concept of innovation as well as other variations, such as resource-constrained innovations, we present Appendix I. Following the efficiency-driven perspective of Bhatti et al. (2018), this article assumes that frugal innovation is based on the firm level since it differs from other perspectives that focus on individual-, community-, or sectoral-levels. Our aim here is to help organizations develop the best approach to solve resource constraints and innovation challenges. Cases such as Mettler Toledo (Zeschky et al., 2011b), Tata Motors (Rao, 2017b; Ray and Ray, 2011), Renault-Nissan, Siemens, PepsiCo (Economist, 2014), General Electric (Govindarajan and Ramamurti, 2011; Rao, 2017b), and Procter & Gamble (Economist, 2011) suggest that firms view the implementation of frugal innovation as either an efficiency-driven solution to obtain a competitive advantage (e.g. see Hossain, 2017) or a frugality-based advantage (Asakawa et al., 2019).

In this way, companies need to develop specific capabilities when implementing frugal innovation because of the differentiated logic from that of traditional innovations (Bernardes et al., 2019). First, frugal innovation is a response to resource constraints; it is not based on unlimited resource availability. The scarcity of resources could be the result of inputs, income, or infrastructure (Asakawa et al., 2019). Second, frugal innovation may be focused on a new market or an existing one not yet explored (Asakawa et al., 2019). Keeping in mind core functionalities, cost reduction, and sustainable contingencies (Weyrauch and Herstatt, 2016a; Zeschky et al., 2011a). In the face of a scarce resource situation, a firm should renew its innovation strategy using frugal innovation principles; otherwise, it is fated to start its innovation process from scratch (Lim et al., 2013; Rao, 2013). This means that the frugal innovation demands that certain particularities in the innovation development process be adopted (Bhatti et al., 2018; Hossain, 2020). In other words, it is expected that companies develop and manage specific capabilities in the development of frugal innovations.

Finally, based on the definitions in the literature (Weyrauch and Herstatt, 2016a; Zeschky et al., 2011a), we understand that the process of developing frugal innovation should focus simultaneously *on (1) the essential functionalities and performance of the offering, meeting or exceeding the prescribed quality standards; (2) a substantial reduction in usage and/or property costs, minimizing the use of material, financial and organizational resources throughout the value chain; and (3) the employment of shared sustainable engagement to* support *environmental and social*

sustainability. This means that the following three main requirements (assumed here as capabilities), which occur simultaneously, constitute the requirements to characterize that which we call frugal innovation: focus on core functionalities, substantial cost reduction, and shared sustainable engagement.

3. Capabilities for the development of frugal innovation

Capabilities are the articulated set of tangible and intangible resources and organizational routines oriented to a specific purpose (Helfat and Peteraf, 2003). Taking into consideration the perspective based on the RBV – Resource-Based View (Barney, 1991), the process of developing frugal innovation is the result of a heterogeneous trajectory of articulated resources and routines in the constitution of core functionalities, cost reduction, and shared sustainable engagement capabilities. When a company manages to simultaneously coordinate these three capabilities, it can develop frugality-based advantages (Asakawa et al., 2019). The reunion of capabilities within frugal innovation can create value when answering questions regarding input, income, and infrastructure constraints (Asakawa et al., 2019). Frugality-based advantages may not be easy to develop because the structuration of an innovation strategy that combines cost reduction, core functionalities, and shared sustainable engagement is not a trivial task. It may be challenging to replicate the process because managing innovation strategy capabilities takes substantial effort, time, and experimentation. The dependency trajectory for a firm's frugal innovation approach demonstrates the difficulty in generating such capabilities. Finally, the firm needs to develop these capabilities. It is not something that can be acquired in the market. It is nonreplaceable because of this development effort; each company organizes the exploration of the capabilities and executes the strategies of frugal innovation in a heterogeneous way (Lim et al., 2013).

However, before discussing each of the capabilities, the following question needs to be answered: why are these the three capabilities needed for the development of a frugal innovation? To answer that, we followed the recommendations of Podsakoff et al. (2016) by reviewing the literature on the conceptual definitions of frugal innovation and its construct dimensions, and we organized the attributes of the three capabilities found *a priori* in the selected literature (Table 1). In cases where different characteristics are treated in the literature as similar or equivalent, we have grouped them to correspond to the same attribute or variable. For example, the focus on core functionalities naturally indicates that the innovation had a basic design with fewer features or had a reduction in the number of characteristics. Therefore, all cases present in the literature that indicate defeaturing or basic design also considered these characteristics as ones that contribute to keeping the focus on core functionalities and are represented in the proposed scale as CORE 1. Likewise, Table 1 depicts all the literature review papers analyzed whose

Table 1
Categories and attributes that emerged from the literature review papers on frugal innovation from Wos 1.

CAPABILITIES *(a priori dimensions)*		ATTRIBUTES *(a priori categories/items)*	Reviewed Papers ID																					
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Sum
Core functionalities	CORE 1	Core functionality/Defeaturing/Basic Design		■			■			■	■	■	■	■	■	■	■	■	■	■	■	■		15
	CORE 2	Easy to use		■	■					■	■	■	■	■	■	■	■	■	■		■	■		14
	CORE 3	Durability/Robustness	■	■	■			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		18
Cost reduction	COST 1	Good value product/Value proposition	■		■		■	■	■	■	■	■	■	■	■		■	■	■		■	■		16
	COST 2	Substantial cost reduction/Affordability	■				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	18
	COST 4	Rearrangement of operational processes					■				■			■	■		■	■	■			■	■	9
	COST 3	Saving organizational resources					■			■	■		■		■		■	■	■			■	■	10
Shared Sustainable Engagement	SSE 1	Socioenvironmental consumption/needs			■	■	■			■	■	■	■	■	■		■	■	■	■	■	■		15
	SSE 2	Collaboration/cooperation/open innovation/cocreation	■								■		■		■		■	■	■		■	■	■	10
	SSE 3	Sustainable production		■						■	■	■		■	■		■	■	■		■	■	■	12
Emerging categories *which we do not highlight in our model*			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Sum
Emerging Dimension of Analysis from the Literature Review Papers on Frugal Innovation in the last ten years.		Improved efficiency along the value chain			■					■					■		■	■			■			6
		BOP Focus (as market)					■																	1
		Mindset, processes, and outcomes						■																1
		Resilience												■										1
		Scientific (engineering) perspective																		■				1
		Others																■				■	■	3

ID	Reviewed Papers
1	Tiwari and Herstatt (2012a)
2	Rao (2013)
3	Pansera (2013)
4	Nari Kahle et al. (2013)
5	Brem and Wolfram (2014)
6	Soni and Rishikesha (2014)
7	Nair et al. (2015)

ID	Reviewed Papers
8	Khan (2016)
9	Rosca et al. (2017a)
10	Agarwal et al. (2017)
11	Hossain (2017)
12	Farooq (2017)
13	Hossain (2018a)
14	Reinhardt et al. (2018)

ID	Reviewed Papers
15	Rosca et al. (2017b)
16	Pisoni et al. (2018)
17	Albert (2019)
18	Rao (2019)
19	Hossain (2020)
20	Niroumand et al. (2021)
21	Iqbal et al. (2021)

Note: Tiwari and Herstatt (2012a), 2. Rao (2013), 3. Pansera (2013), 4. Nari Kahle et al. (2013), 5. Brem and Wolfram (2014), 6. Soni and Rishikesha (2014), 7. Nair et al. (2015), 8. Khan (2016), 9. Rosca et al. (2017a), 10. Agarwal et al. (2017), 11. Hossain (2017), 12. Farooq (2017), 13. Hossain (2018a), 14. Reinhardt et al. (2018), 15. Rosca et al. (2017b), 16. Pisoni et al. (2018), 17. Albert (2019), 18. Rao (2019), 19. Hossain (2020), 20. Niroumand et al. (2021), 21. Iqbal et al. (2021).
Source: The authors, based on the literature review paper results

authors present the characteristics of the frugal innovation they mentioned. The last column (Total) indicates the number of occurrences of such characteristics in those papers. It is worth noting that these characteristics appear in at least 9 (nine) of these papers. In Table 1, we breakdown each capability into defined attributes. In doing so, we reviewed the literature and identified the occurrence of these attributes and their frequency (see the methodological procedures in Appendix II). Our proposed scale may be easily confirmed by the literature review, as well as by the interviews described in Sections 4.1 and 4.2, by the face and content validation described in Section 4.3, and finally by the results of the research presented in the subsequent sections. Some attributes identified less frequently in the literature are indicated below as emerging categories that have not been addressed for frugal innovation.

Although frugal innovation has several definitions, as identified in some recent reviews (Hossain, 2018a; Pisoni et al., 2018), the following three dimensions of capabilities are recurrent: concern about the cost in response to resource constraints; a focus on the essential, without unnecessary or superfluous features; and shared sustainable engagement. First, frugal innovation is described as having a low-offer price or considerably lower initial cost (Agarwal and Brem, 2012; Bound and Thornton, 2012; Economist, 2010; Radjou and Prabhu, 2014b; Zeschky et al., 2011b) in the definition provided by Tiwari and Herstatt (2012a), who reinforced the idea in 2014 (Tiwari et al., 2014) and 2016 (Tiwari et al., 2016b). Second, frugal innovation includes a focus on the essential and/or functional elements of the offer (e.g. Agarwal and Brem, 2012; Economist, 2012; Radjou et al., 2012; Tiwari et al., 2016b; Zeschky et al., 2014). Moreover, Weyrauch and Herstatt (2016a, 2016b) note a "concentration on core functionalities." The third capability is shared sustainable engagement (Pisoni et al., 2018; Rosca et al., 2017b; Tiwari et al., 2016b) through local cooperation (Hossain, 2013, 2018a; Tiwari and Herstatt, 2012b) and going beyond social and environmentally sustainable concerns (Basu et al., 2013; Brem and Ivens, 2013; Farooq, 2017; Geels et al., 2015; Kuo, 2017; Rosca et al., 2017b; Tiwari et al., 2016b). The goal is to achieve the fullness of resource savings, optimizing the delivery of results associated with the integration of the business environment and creating shared value for every player in the game while embracing open innovation as a way to achieve frugal innovation (Basu et al., 2013; Brem and Ivens, 2013; Farooq, 2017; Geels et al., 2015; Kuo, 2017; Rosca et al., 2017b; Tiwari et al., 2016a).

3.1. Focus on the core functionality capability

The "focus on core functionality" capability is prevalent in the literature. The emphasis is on developing products in such a way that their functionalities are essential to and compatible with the socioeconomic context of the markets (Hart and Christensen, 2002; Prahalad and Hart, 2002; Soni and Rishikesha, 2014). The focus on core functionalities has been mentioned by many authors using a variety of descriptions, such as the following: "good enough, "limited features" (Agarwal and Brem, 2012; Hossain, 2020), "easy to use" (Hossain, 2018a; Pansera, 2013; Santos et al., 2020),"affordable" (Albert, 2019; Pisoni et al., 2018; Winterhalter et al., 2017), "keep it simple," "cut corners, making exceptions to some of the requirements" (Andel, 2013; Farooq, 2017), "reducing complexity," "seek to minimize the use of extensive resources" (Barclay, 2014), "does not have sophisticated technological features," "core benefits," "eliminating unessential functions," "maintain quality," "maximize value" (Brem and Wolfram, 2014; Khan, 2016; Tiwari and Herstatt, 2012a), "robustness," "defeaturing" (Kumar and Puranam, 2012; Nair et al., 2015; Rao, 2013; Soni and Rishikesha, 2014), and "instead of adding ever more bells and whistles, they strip the products down to their bare essentials" (Wooldridge, 2010).

These features emerge in the literature as product design (e.g., simple, defeatured, affordable) (Agarwal et al., 2017; Rosca et al., 2017a, 2017b), product functionality (e.g., easy to use, reduced complexity, and eliminating nonessential functions) (Reinhardt et al., 2018), or product performance (e.g., maintain quality, good enough, and maximize value), which could be considered unique dimensions subsumed as attributes of "core functionalities." Additionally, in this study, we consider performance as part of the focus on core functionalities and performance, where performance assumes a broad meaning comprising both functionalities (e.g., simplicity, defeatured, easy to use, reduced complexity, affordability, maintained quality, good enough, value maximization, etc.), and engineering aspects (e.g., shape, size, durability, flavor, smell, color, texture, etc.) (Rosca et al., 2017b; Weyrauch and Herstatt, 2016b).

Thus, we propose the "focus on core functionalities" capability as a firm's effort to bring the following dimensions together: a product with basic functions and good performance that is sought after by consumers and is designed to be "easy to use" and "durable."

3.2. Substantial cost reduction capability

The definition of frugal innovation, as adopted by Zeschky et al. (2011b), suggests an orientation toward low-cost, resource-constrained innovation (Ray and Ray, 2010) or cost innovation (Williamson, 2010). Examples such as those from Galanz, General Electric, Haier, and Tata illustrate the typical course of frugal innovation and how firms adapt themselves to offer substantial cost reductions (Zeschky et al., 2011b). Firms studied by Zeschky et al. (2011b) and others (e.g. Hossain, 2017) used a similar approach to organize their frugal innovation activities. Many of these firms had varying interests in engaging in frugal innovation; however, all firms in their studies were motivated by increasing pressure from low-cost competition, which forced them to develop offers to meet the needs of their consumers with scarce resources. The pressure from low-cost competition is not exclusive to emerging countries (Rao, 2013). It also affects developed markets (Angot and Plé, 2015; Rao, 2013) as consumers become more value-oriented, especially in the wake of recent economic crises (Albert, 2019).

It is difficult to specify the extent of the cost reduction effect of a frugal innovation because of the variety of descriptions in the literature (Hossain, 2018a, 2020; Hossain et al., 2016; Tiwari and Herstatt, 2012a; Weyrauch and Herstatt, 2016b). Many terms such as "low cost," "affordable cost," "minimum cost," "significantly lower costs," or "dramatic cost reduction" indicate the importance of considering cost reduction as a frugal innovation dimension (Brem and Wolfram, 2014; Nair et al., 2015; Soni and Rishikesha, 2014). Moreover, it is difficult to precisely determine a threshold level to consider as a "cost reduction," or a "low-cost level" because a reduction in cost depends mainly on each context, but unavoidably, there should exist a resource-constraint situation that requires affordable products to fill the needs of people with limited resources (Rao, 2013; Weyrauch and Herstatt, 2016a, b). In more developed countries, a substantial cost reduction could result in a significant reduction in the final price, so firms could offer good value (Pisoni et al., 2018; Rosca et al., 2017b; Santos et al., 2020) to those consumers who want premium brands but at lower prices (Pansera, 2013).

Thus, we propose that the "substantial cost reduction" capability is a firm's efforts to offer a "good-value product," with "organizational resources arranged" to provide "substantial cost reductions" in operational and organizational processes, enabling the firm to transfer these savings to final consumers.

3.3. Shared sustainable engagement capability

Shared sustainable engagement integrates socioenvironmental sustainability and collaboration between actors into a shared value proposition. Specifically, socioenvironmental sustainability is defined in the literature as the consideration of social (Albert, 2019; Khan and Melkas, 2020; Kuo, 2015; Silveira, 2016; Tiwari et al., 2016b) and environmental (Farooq, 2017; Kuo, 2017; Rosca et al., 2017a) consumption and sustainable production (Basu et al., 2013; Brem and Ivens, 2013; Khan,

2016; Le Bas, 2016; Levänen et al., 2016; Molina-Maturano et al., 2020a; Rosca et al., 2017a). Frugal innovation for emerging markets and developed economies has been guided by the new social aspirations of sustainability and frugality based on a new behavioral pattern that attributes value to conscious consumption and local needs. Albert (2019) identifies a long list of potential contributions of frugal innovation and its positive connections with sustainability, social needs, and eco-environmental concerns from a literature review. Khan and Melkas (2020) also provide strong evidence of the social dimension of frugal innovations and point out how social benefits can be promoted by frugality.

Many potential actions identified by Albert (2019) and Khan and Melkas (2020) are strongly linked to engagement actions toward solving social-environmental needs, driving social equity, and empowering and enabling the BoP (bottom of the pyramid) market. This scenario contributes to greater inclusiveness, promotes a low carbon footprint, contributes to wellbeing and livelihood development, and promotes the UN's SDGs (Sustainable Development Goals). This approach seems to be an ideal model to create green products, promote the inclusion of marginalized low-income people, contribute to global sustainability, create value from waste, encourage reaching for self-sufficiency, and find new purposes, among other benefits (Albert, 2019; Khan, 2016).

Howard (2011) identified a wave of "frugal innovations," describing them as low-cost, ingenious, and rapidly produced while creating a low carbon footprint (Hossain, 2017, 2018a, 2020). More recently, frugal innovation has shown its potential to play a major role in dealing with the growing social-environmental sustainability challenges of the world (Brem and Agarwal, 2017; Brem and Ivens, 2013; Rosca et al., 2017b). Summarizing this literature, Pisoni et al. (2018) describe the frugal ecosystem as indispensable for the development of frugal solutions that meet the social-environmental and sustainable needs of customers through environmental and sustainable operational processes in partnership with local companies (Santos et al., 2020).

The collaboration is summarized in partnership aspects that involve coproduction (Annala et al., 2018; Belkadi et al., 2016) and open innovation (Hartley, 2015; Hossain, 2013; Knorringa et al., 2016; Tiwari and Herstatt, 2012b). A company promotes shared sustainable engagement at the managerial level through the implementation of open management platforms (company or product) defined by a set of assets organized in a common structure from which it can develop and produce a flow of byproducts in connection with suppliers and user communities (Autio and Thomas, 2013; Chesbrough et al., 2014). In this way, we understand that microentrepreneurial ecosystems geared to frugal innovation are those that constitute profitable and sustainable business strategies whose objectives are centered on the collaboration between the producer, user communities and stakeholders to develop and market new goods or services cocreated with values and attributes for frugal and sustainable-shared needs (Albert, 2019; Khan, 2016; Pansera and Owen, 2015). Evidence has been gathered through cases from agriculture, sustainable development, and the water sector in Mexico, reinforcing the social role of frugal innovations and the role they play in promoting social welfare (Molina-Maturano et al., 2020a, 2020b).

Socioenvironmental sustainability and collaboration are important for sharing sustainable engagement, but there are some critical points related to shared value that need to be addressed. An example of a fully shared sustainable engagement vision can be found in Pansera and Owen (2015) with Graamen Shakti in Bangladesh. The main argument is that resource-constrained innovation is inherently eco-friendly because it seeks to reduce the use of energy, resources, and raw materials not only in the final product but also in its entire value chain. Such strategies depend on the construction of mechanisms of engagement between the actors that allow local constraints to be overcome by creating an environment with a new awareness of value-orientation toward social and environmental sustainability. The value shared is not central to the firm and surpasses the capitalist orientation that a sole company can generate a frugal solution to solve the problems of resource constraints. In addition, the question of the multiple values shared view is reinforced by Baskaran and Mehta (2016), who show how the cultural and context variables in constrained-resource situations create differentiated perspectives about innovation.

In summary, Pansera (2018) brings a reflection about resource constraints and value into the frugal literature. In general, the frugal literature sees Global South countries as constrained resource countries. However, Pansera (2018) shows that this is not the best association. The question is the unequal shared resources in great part created by the dysmorphia of the capitalist system. At the same time, the frugal literature gives firms, especially large-sized companies, or MNCs the role of solving the resource constraints problem. Pansera (2018) indicates that the result could be more firm profit, but not necessarily solve the resource constraint situation. The logic of value is only directed to the central firm and not to the other firms, society, and institutional and political regimes. Because of these points, in our view, we restrict ourselves to designating value as shared. The question of value for us is essential and makes sense, but we believe that firms are not yet oriented to the actual stage of frugal innovation.

Thus, we propose the concept of "shared sustainable engagement" as a firm's effort to foster partnerships with members of its nearby microenvironment. These local partnerships allow the firm to optimize its financial efficiency and functional capabilities in order to achieve solutions that meet the social-environmental needs of consumers by increasing environmental sustainability in their production, innovation, and operational processes, thereby achieving greater benefits from open innovation processes.

4. Research design and scale development procedures

As the concept and use of capabilities become understood, we propose a scale for frugal innovation made up of three main capabilities. The process of the development and validation of the scale is systematized in Fig. 1. The process started with the conceptualization of the construct, where item generation was performed, refinement conducted, and selection made for utilization in the next steps.

Next, a judging committee made up of academics, experts, and managers who contribute to face and content validity was engaged. Then, the model specification was undertaken with its respective detailing (Mackenzie et al. (2011). Subsequently, we conducted a scale evaluation and refinement process for questionnaire development and data gathering and analysis with appropriate multivariate statistical techniques (Devellis, 2003; Hair et al., 2009).

In the validation process, we gathered five datasets from three different countries, aiming to ensure that the proposed scale is structured appropriately to construct a reliable and valid instrument (Churchill, 1979; Mackenzie et al., 2011). To complete the process, norms for the use and application of the capabilities for frugal innovation scale proposed here are recommended.

4.1. Develop a conceptual definition of the construct (step 1)

First, based on the recommendations of Mackenzie et al. (2011), we carried out a literature review of previous theoretical and empirical research on frugal innovation, followed by a literature review on the meanings of the related constructs. In this way, we established the conceptual domain of frugal innovation by generating a broad list of definitions found in the literature.

From the literature review and the conceptual definition (see Appendices I and II), we conducted preliminary research using an inductive approach with subject matter experts to validate the definition and minimize any conceptual mistakes or meaning errors. To achieve this aim, we executed three in-depth interviews with senior professors of innovation from Switzerland, the UK, and Brazil, all specialized in frugal innovation. For each interviewee, we presented the following three questions: (1) What does frugal innovation mean to you? (2) What are

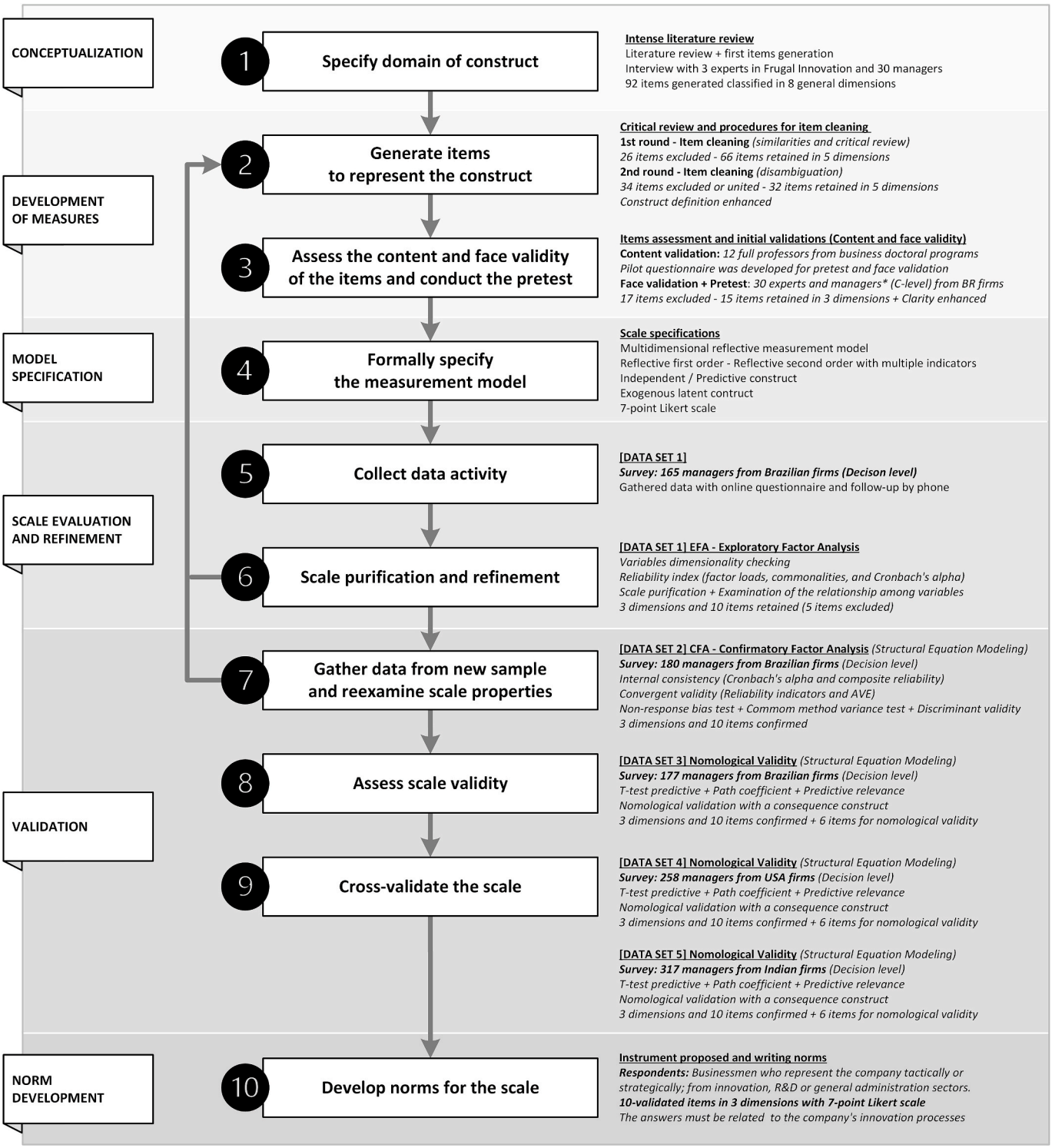

Fig. 1. Research design and methods: Frugal Innovation Scale development process.
Source: The authors, based on Churchill (1979) and Mackenzie et al. (2011).
Note: *The 30 experts and managers (C-level and Decision Level) participants in the pretest and face validation were from companies oriented to frugal innovation.

the main dimensions of frugal innovation? (3) In your opinion, how can frugal innovation be measured? The results were crucial to establishing the constructs and to generating the items for the next step.

To validate the results, we conducted in-depth interviews with 30 managers (C-level and decision level managers from Brazilian manufacturing companies that have been involved with the innovation processes and oriented to frugal innovation) using the same procedures as before. This was followed by a qualitative content analysis of the answers with a simple categorization. This step was crucial to validate and complement item generation in the next step.

4.2. Generate items to represent the construct (step 2)

With the insights provided by the experts and managers in the

previous step and after reviewing the existing literature, 92 general items related to frugal innovation were generated. These 92 raw items were initially classified into eight general dimensions based on a literature review (functionality, performance, cost, sustainability, perceived value, utility, collaboration, and environment). The first round of item cleanup was conducted to eliminate similarities. Additionally, after a critical review, 26 items were considered noncontributory or similar and were eliminated, and the remaining 66 items were categorized into 5 overall dimensions (functionality, performance, cost, sustainability, and collaboration).

A second cleaning round was conducted to eliminate any ambiguity or difficulty in understanding the meaning. After this review, 34 of the 66 items were found to be similar or ambiguous and were eliminated, leaving 32 items distributed in the same 5 previous dimensions. The remaining 32 items were rewritten and paraphrased to maintain their original meaning but improve the clarity and understanding of the items. These 32 items advanced to the next step for content assessment, face validity, and pretesting.

4.3. Assess the content validity of the items (step 3)

At this point, each item was rewritten and transformed into a statement with the aim of being as simple and precise as possible, allowing them to be used as statements to be answered. Items with more than one meaning were split, and redundant items were eliminated. Next, we created an assessment tool that started with a brief presentation of the instructions and a clear definition of the concept. Then, we asked the raters to analyze each of the 32 items to obtain content validity and the descriptive capacity of all items. The 32 items from the prior step representing the capabilities for achieving frugal innovation were then presented. Each item was followed by two scales used to assess the statements. The first is a five-point scale used to assess the adequacy of each statement to represent the capabilities of frugal innovation, ranging from (1) being "very inadequate" to five (5) being "very adequate." The second scale was a five-point assessment scale used to evaluate the clarity of each statement, indicating how clear and comprehensible each statement is, ranging from one (1) being "very poor" to five (5) being "very good." Each statement was presented with both scales, where we asked respondents to indicate to what degree each statement adequately represented the provided definition. A blank space was included below each statement to allow raters to provide comments and suggest modifications to better represent each of the 32 statements.

4.3.1. Multidimensionality assessment

For the multidimensionality assessment, the raters were presented with another form to help them classify the 32 items into unique dimensions, where they were asked to assign each item to a corresponding dimension with no suggestions or stimuli. Twelve professors from doctoral programs from different universities who had sufficient knowledge of the domain and the intellectual ability to determine the correspondence between items and the theoretical definitions were invited to rate the items (Mackenzie et al., 2011). To avoid a rater overburdening effect, the 32 items were split into two interview sessions and applied on different days (16 each) (Mackenzie et al., 2011). As recommended by Mackenzie et al. (2011), a heuristic process of one-way repeated-measures ANOVA was then used to assess whether an item's mean rating on one aspect of the construct's domain differs from its ratings on other aspects of the construct's domain. The assessment of the averages identified the items with higher scores and lower scores. We dropped all items scoring less than 3.8 and followed with a qualitative assessment of the comments and recommendations given to enhance the items for the in-development measurement instrument. This content validation step provided input, which was used to rewrite and reformulate some statements. The results aided the assessment of the items, causing 17 items to be eliminated, resulting in 15 items classified into three (3) dimensions. The same three "*a priori* dimensions" identified in our preliminary literature review that are described in Section 3 and are presented in Table 1 emerged, confirming the same scale dimensions and serving as an additional validation of the scale dimensions.

4.3.2. Face validity and pretest procedure

Based on the judgment of our academic and expert committee, the 15 items in three dimensions showed good content validity and multidimensional validation, and we developed the questionnaire for data collection. Initially, 30 people representing the target population (managers at the decision level) were surveyed with a questionnaire consisting of 15 items; minor modifications were made to enhance clarity. In addition to these 15 items, respondents were asked demographic questions, such as the firm sector, firm size (number of employees), and respondent's job title, to characterize the sample.

Thirty people whose firms were involved in innovation processes and new product development agreed to complete the questionnaire and provide feedback. Five people were experts (market consultants and innovation specialists), and 25 people were decision-level managers with diverse backgrounds from Brazilian manufacturing firms oriented to frugal innovation (see Appendix III for the sample's description). All 30 people were contacted by phone to schedule a 20-40-min face-to-face meeting. This process served to improve face validity and as a pretest. The results provided a few minor adjustments, allowing us to enhance the clarity of the items. All 15 items in three dimensions were retained as a result of this process, validating the items and dimensions.

4.4. Specification of the measurement model (step 4)

With the valid set of items, a measurement model that captures the frugal innovation concept and the relationships between its indicators and its dimensions was specified. Based on the literature review (Churchill, 1979; Mackenzie et al., 2011), the scale was conceptualized as a second-order multidimensional construct (at the firm level) composed of three dimensions characterized as the first-order construct with multiple reflective indicators.

Brazil was selected as the first country to be surveyed for the following reasons. First, Brazil is an emerging country with the presence of all the usual conditions of other emerging countries, such as institutional voids, a resource-constrained environment, and a considerable number of consumers living at the bottom of the pyramid. Second, the entrepreneurial environment of Brazil leads many entrepreneurs to create affordable solutions, making it a promising place to find companies in which to develop frugal innovations, even unconsciously. To validate the measurement instrument proposed, India was chosen as the second country to be surveyed because it is recognized as the cradle of frugal innovation. India shares many characteristics with Brazil, as mentioned before, contributing to comparative purposes and validation. The US was selected as the third country to be surveyed to obtain results from a developed country. The results from the US contribute to the discussion about whether frugal innovation occurs only in emerging markets or if it also occurs in developed countries and was chosen because of the convenience of data collection. The same approach was selected to provide results enabling us to compare the results among countries and check possible differences that may help to obtain a better understanding of the frugal innovation phenomena.

4.5. Data collection and sampling (step 5)

The first dataset was gathered from a secondary database from a leading market data company. The dataset used comprises a universe of 2,714 Brazilian product and service companies from all manufacturing industries. This list was reduced by selecting companies that have product development activities. A digital version of the questionnaire was built and contact information for the selected companies was entered into a mailing database. An item randomization feature was included in the questionnaire to avoid carryover effects (Macfie et al.,

1989).

The system allowed e-mail tailoring for each person, including personalization of name and position in the company. After three days, respondents were contacted by phone to clarify any issues they might have regarding the study. This helped to reinforce the request to complete the survey.

From the 2,440 e-mails sent to respondents, 313 responses were received; however, cases with incomplete answers, respondents not meeting the target profile, and outliers were excluded. The first dataset then consisted of 165 observations (n = 165), with a response rate of 7.1%. It is important to note that the focus of respondents was at least C-level managers (owners, presidents, or CEOs) or decision-level managers (directors or high-level managers with some power to make decisions) aware of product/service development processes (see Appendix IV for the sample's description). Due to the nature of the required respondent profile (they are very busy), the data-gathering process required significant effort and explains the high rate of incomplete questionnaires and the average response rate of 8% across all surveys. Potential respondents had to stop during the process for justifiable reasons and had no time to resume or complete the questionnaire. Further considerations are provided at the end of Section 6.1.

4.6. Scale purification and refinement (step 6)

4.6.1. EFA - exploratory factor analysis (first dataset – 165 Brazilian firms)

To filter the first dataset, exploratory factor analysis (EFA) was conducted to verify the appropriateness of the 15 items for capturing the following three dimensions: COST (substantial cost reduction), CORE (focus on core functionalities), and SSE (shared sustainable engagement) as first-order dimensions.

Principal component analysis with a varimax rotation was used to simplify factor interpretation since this method maximizes the sum of load variances demanded by the factorial matrices (Hair et al., 2009). The first results with the 15 items did not show satisfactory factor loadings, and five items were eliminated following a series of analyses (CORE_4: significant reduction of the product final price; SSE_4: sustainability (environmental/social) of the product; SSE_5: efficient and effective solutions to meet the economic needs of customers; SSE_6: efficient and effective solutions through local partnerships; COST_5: solutions that provide resource savings to our buyer).

With ten remaining items, the results showed an adequate fit. Table 2 shows the results of the EFA with item loadings on the three dimensions (factors) as expected and reliability measures and discriminant validity. These results were considered acceptable for proceeding to the next step.

5. Results

5.1. Gathering data and reexamination of scale properties (step 7)

5.1.1. CFA – confirmatory factor analysis (second dataset −180 Brazilian firms)

As the three first-order dimensions for the frugal innovation construct were supported in its final format, the structure (10 items) was tested with confirmatory factor analysis (CFA) using SPSS AMOS software.

This second dataset comprised multiple secondary data source providers, such as leading market data companies and the annual report from EXAME Magazine (one of the most respected business-related publications in Brazil), which lists the largest and best companies with open capital or public data, ranked by their results (revenue, growth, and ESG). This database resulted in a sample of nearly 1,000 manufacturing companies in Brazil. The target company profile was similar to those of the first dataset. From a universe of 1,000 companies in Brazil, companies with either product or service development activities from all industries were contacted, and an e-mail invitation was then sent to a specific person from the same profile (managers at the C-level or Decision-level) in each company.

Following similar procedures from the previous survey, an online questionnaire was developed with the same parameters used previously. An introductory text was provided on the objectives and guidelines of the research, and then questions were added for screening and classification, considering the positions held and the area of activity in the respondent's company. This filter allowed only C-level or decision level managers to answer the questionnaire. We obtained 253 responses, and after excluding all cases with incomplete answers and outliers, 180 responses remained as the final sample (n = 180), with a response rate of 18.8%.

Table 3 shows the fit of the model. All items presented substantial loadings on their respective dimensions. All factor loadings were above 0.6, except for two items (COST_1 and SSE_3), which were above 0.5 and were considered acceptable (Hair et al. (2009). These results were considered adequate to move forward to the next step, where another round of data collection was undertaken for a CFA with a focus on nomological validity.

5.2. Assessment of scale validation (step 8)

5.2.1. Third dataset – 177 Brazilian firms

In this round, we assessed companies from a different secondary data provider to obtain companies different from those included in the earlier

Table 2
First Brazilian Dataset - Reliability measures and discriminant validity and exploratory factor loads.

	Constructs/Items	Component			AVE	CR	α	Discriminant Validity		
		1	2	3				CORE	COST	SSE
CORE	CORE_1 (Core functionality)	**.814**			.546	.781	.709	**.734**		
	CORE_2 (Easy to use)	**.772**								
	CORE_3 (Durability)	**.617**								
COST	COST_1 (Good value products)		**.503**		.557	.828	.809	.536	**.731**	
	COST_2 (Cost reduction)		**.866**							
	COST_3 (Economic manufacturing)		**.874**							
	COST_4 (Process rearrangement)		**.680**							
SSE	SSE_1 (Socioenvironmental satisfaction needs)			**.705**	.579	.805	.779	.555	.558	**.760**
	SSE_2 (Sustainable production)			**.797**						
	SSE_3 (Partnership in the production process)			**.781**						

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
Rotated component matrix: Rotation converged in 6 iterations.
Note. The results obtained from the analysis with the diagonal of the anti-image matrix showed a value above 0.500, KMO.882, Bartlett's test ($p < .001$), and explained variance of 67.72%.
Reference values: AVE >0.5; CR > 0.70; Cronbach's Alpha >.7.

two samples. The database offered a universe of 4,283 Brazilian manufacturing companies. Again, the companies offered products or services from all manufacturing industries and engaged in product or service development activities. Of this initial sample, 4,242 manufacturing companies matched the target profile. Again, we sent e-mail invitations to specific people in each company who met the target profile (C-level or decision level managers). Responses were received from 267 managers, of which 177 contained valid answers without outliers (n = 177), for a response rate of 4.4%.

Additionally, in this new round of data, the nomological validity of the capabilities for the frugal innovation scale were examined along with the operational performance scale already validated in the literature (Calantone et al., 2002). Respondents were asked to indicate their opinions regarding how their production unit performed on a global basis concerning the competition in their industry and generally, on a scale ranging from one ("Lower than the industry average") to seven ("Higher than the industry average"). The items used were (1) compliance with product specifications; (2) delivery time performance; (3) flexibility to change product specifications; (4) flexibility to change the product; (5) unit cost of production; and (6) speed to introduce new products (Calantone et al., 2002). The final model tested is shown in Fig. 2. Testing the relationship between the two constructs and examining whether frugal innovation has a positive association with the operational processes of firms helps empirically determine whether the capabilities for achieving frugal innovation contribute to operational performance and to the scale validation process, thus assuring its nomological validity.

The reliability and validity indicators of the constructs and fit index are presented in Table 3. It performs the nomological validation and validates the frugal innovation scale. The association between capabilities for achieving frugal innovation and operational performance is significant, with a path estimate of 0.581, an R^2 of 0.103, and a *t*-test of 3.522 ($p < .001$).

5.3. Cross-validation of the scale (Step 9)

5.3.1. Fourth dataset – 258 US firms

Despite the stability of the capabilities for a frugal innovation measurement model, two additional data-gathering processes were undertaken with new samples in two countries to confirm the original results and to increase generalizability across cultures and economies.

The fourth dataset included data from 258 US manufacturing firms. We collected data from US firms following the same process as used for the previous surveys, this time employing an international research database provider of US firm data. We obtained a universe of 4,937 US manufacturing companies available in their records. Again, we selected companies with both product and service development activities from all manufacturing industries. This resulted in 4,885 US manufacturing companies with the target profile available. We sent e-mail invitations to a specific person in each company who met the profile (C-level or decision level managers). From this population, 273 responses were received, with 258 completely answered questionnaires and without outliers (n = 258), for a response rate of 5.4%. Table 3 shows that the indexes and the association between frugal innovation and operational performance are significant, with a path estimate of 0.696, an R^2 of 0.643, and a *t*-test of 7.875 (p < .001), providing evidence that frugal innovation leads to operational performance enhancement in US firms.

5.3.2. Fifth dataset – 317 Indian firms

The fifth dataset included data on 317 Indian manufacturing firms.

Table 3
Statistical results of each survey.

2nd Brazil Dataset: Reliability measures and discriminant validity (1st Confirmatory Factor Analysis)

Constructs	AVE	CR	Cronbach's Alpha	Discriminant Validity			Goodness-of-fit index	
				CORE	COST	SSE		
CORE	.500	.749	**.723**	**.734**			X^2 = 67.499*	NFI = .915
COST	.555	.829	**.812**	.517	**.704**		GFI = .928	CFI = .952
SSE	.513	.756	**.741**	.521	.500	**.710**	AGFI = .876	RMSEA = .079
							TLI = .933	SRMR = .0576

3rd Brazil Dataset: Reliability measures and discriminant validity (1st SEM + Nomological)

Constructs	AVE	CR	Cronbach's Alpha	Discriminant Validity				Goodness-of-fit index	
				CORE	COST	SSE	PERF		
CORE	.565	.795	**.776**	**.750**				X^2 = 164.52*	NFI = .903
COST	.614	.862	**.853**	.583	**.777**			GFI = .898	CFI = .959
SSE	.577	.802	**.794**	.588	.568	**.757**		AGFI = .892	RMSEA = .061
PERFOR	.643	.915	**.913**	.621	.600	.605	**.800**	TLI = .951	SRMR = .0523

4th US Dataset: Reliability measures and discriminant validity (2nd SEM + Nomological)

Constructs	AVE	CR	Cronbach's Alpha	Discriminant Validity				Goodness-of-fit index	
				CORE	COST	SSE	PERF		
CORE	.525	.767	**.757**	**.725**				X^2 = 198.098*	NFI = .923
COST	.642	.877	**.871**	.577	**.801**			GFI = .914	CFI = .960
SSE	.586	.809	**.807**	.611	.553	**.766**		AGFI = .883	RMSEA = .062
PERFOR	.619	.907	**.905**	.627	.568	.601	**.787**	TLI = .952	SRMR = .041

5th India Dataset: Reliability measures and discriminant validity (3rd SEM + Nomological)

Constructs	AVE	CR	Cronbach's Alpha	Discriminant Validity				Goodness-of-fit index	
				CORE	COST	SSE	PERF		
CORE	.623	.832	**.827**	**.789**				X^2 = 217.227*	NFI = .939
COST	.604	.859	**.857**	.613	**.777**			GFI = .914	CFI = .966
SSE	.678	.863	**.863**	.649	.639	**.823**		AGFI = .883	RMSEA = .061
PERFOR	.637	.913	**.911**	.628	.618	.655	**.798**	TLI = .959	SRMR = .035

Reference values: AVE >0.5; CR > 0.70; Cronbach's Alpha >.7; *(p < .001).
Source: Elaborated by the authors

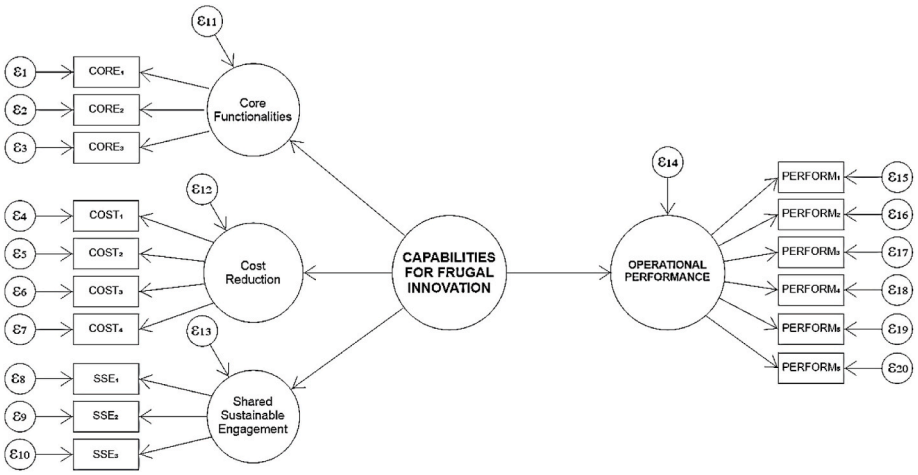

Fig. 2. Research structural model for nomological network validation (BRAZIL, INDIA, and the US.).
Source: Elaborated by authors with SPSS AMOS software

We again used an international research database provider to obtain a list of Indian firms, which was provided to us through a database containing a universe of 5,742 manufacturing companies. Again, companies from all manufacturing industries that have product or service development activities were selected for the sample. This left 5,674 companies that matched the target profile. E-mail invitations were again sent to a specific person in each company (C-level or decision level managers). Responses from 323 managers were received, with 317 completely answered questionnaires as a final sample for this data collection without outliers (n = 317), for a response rate of 5.7%. Table 3 shows acceptable indexes and that the association between the capabilities for achieving frugal innovation and operational performance is significant, with a path estimate of 0.848, an R^2 of 0.649, and a *t*-test of 10.213 ($p < .001$), providing evidence that frugal innovation leads to operational performance enhancement in Indian firms.

Appendix V shows the common method variance details (Harman's test) and measurement test of invariance across the three country samples.

6. Discussion

In this section, we present the final instrument to measure the capabilities of frugal innovation and the definitions of its three capabilities. We also provide a set of norms to guide managers and researchers on the application of the proposed measurement tool, highlighting the caveats for its adoption and limitations.

6.1. Measurement instrument, proposed norms (step 10), and capabilities for achieving frugal innovation

The capabilities for achieving frugal innovation are measured using a seven-point Likert-type scale designed with firms as the unit of analysis (firm-level).

Table 4 presents the final measurement model. We recommend that

Table 4
Capabilities for the frugal innovation measurement scale (factor loadings[c] across studies, AVE[a], and Cronbach's Alpha[b]).

Think about the main product line of the company and indicate the level of agreement of the company with the following statements: (1 = Strongly disagree to 7 = Strongly agree).		1 Round EFA Brazil (N = 165)	2 Round CFA Brazil (N = 180)	3 Round SEM+N Brazil (N = 177)	4 Round SEM+N USA (N = 258)	5 Round SEM+N India (N = 317)
In the last three years, in the Development of products/services, your company has assigned great importance to ….						
FOCUS ON CORE FUNCTIONALITIES (Cronbach's Alpha: .758)		AVE .54	AVE .50	AVE .56	AVE .52	AVE .62
CORE_1	core functionality of the product rather than additional functionality	.814	.727	.750	.669	.769
CORE_2	ease of product use	.772	.775	.813	.792	.822
CORE_3	the question of the durability of the product (does not spoil easily)	.617	.610	.687	.707	.775
SUBSTANTIAL COST REDUCTION (Cronbach's Alpha: **.840**)		AVE .55	AVE .55	AVE .61	AVE .64	AVE .60
COST_1	solutions that offer "good-value" products*	.503	.527	.616	.826	.758
COST_2	significant cost reduction in the operational process	.866	.749	.848	.829	.804
COST_3	savings of organizational resources in the operational process	.874	.874	.891	.851	.795
COST_4	rearrangement of organizational resources in the operational process	.680	.786	.752	.689	.750
SHARED SUSTAINABLE ENGAGEMENT (Cronbach's Alpha: **.796**)		AVE .57	AVE .51	AVE .57	AVE .59	AVE .63
SSE_1	efficient and effective solutions to customers' social/environmental needs	.705	.763	.744	.745	.775
SSE_2	environmental sustainability in the operational process	.797	.784	.835	.800	.881
SSE_3	partnerships with local companies in the operational process	.781	.584	.692	.751	.811

Note: The AVE values presented are rounded to 2 places after the decimal. [b] The Cronbach's alpha value indicated in each dimension is the average value for the Cronbach's alpha calculated based on each of the five datasets. [c] EFA (exploratory factor analysis); CFA (confirmatory factor analysis); SEM (structural equation modeling); N (nomological validity); AVE (average variance extracted).
Note 2: The response rates were as follows: Dataset 1 = 8,3% response rate; Dataset 2 = 18.8% response rate; Dataset 3 = 4.4% response rate; Dataset 4 = 5.4% response rate; and Dataset 5 = 5.7% response rate. (Average response rate over all datasets = 8.3%).
Source: The authors based on outputs from IBM SPSS AMOS v.22.

the data be collected from individuals who hold tactical or strategic positions, preferably engaged in firm activities linked to new product development, innovation processes, product creation, product design, engineering, manufacturing, or R&D and at the managerial decision level who are able to provide answers from the company's perspective. It is important to make clear to respondents that by answering the scale questions, they represent the firm's perspective and not their individual point of view on the subject. Independent of the firm's size, it is important to highlight the scope of the study and ensure that respondents answer based on the "innovation process" of the company, even if these "innovation" processes or their innovation culture are not clear or consolidated in the company.

The final scale of the capabilities for achieving frugal innovation allows us to introduce our final definitions of each capability. In Section 3, we provided initial definitions that guided our field research and were used to develop and validate the scale.

The final scale gives us a basic configuration of each capability and allows the improvement of the definitions. In this way, we present the final definitions of the three capabilities for achieving frugal innovation:

A focus on the core functionality capability is a firm's effort to bring together the dimensions that offer the basic functions of a product that is designed to be easy to use and durable. The definition of the core functionality capability remains very similar to that initially proposed, where the three variables used to measure the capability express the main terms of the definition. We removed the words "good performance" and "sought by consumers" from the definition because they do not reflect the final attributes.

A substantial cost reduction capability is a firm's efforts to offer a good-value ("good value for money") product with organizational resources arranged to provide a lower cost compared to standards in operational and organizational processes. Here, we change the definition of the aspect of transferring the savings to final consumers. We note that the question of good value remains in the variables but not in the transfer of savings.

Finally, the ***shared sustainable engagement capability is a firm's effort to promote the collaborative innovation process along with members of the company's microenvironment, allowing for the provision of solutions that meet the social and environmental needs of all parties engaged.*** The remaining items that describe this variable involve collaboration and socioenvironmental practices. However, the idea of multiple views of innovation and shared value does not remain in our scale process. This is an important point that we discuss further in the contributions, limitations, and suggestions for future studies.

Nevertheless, there are some observations and limitations related to implementing the scale presented here. The first observation concerns the capabilities of the frugal innovation concept itself. Due to being a relatively new phenomenon that is still growing, the proposed scale comprises three dimensions, and its ten items are not intended to fully or definitely represent or measure the phenomenon of frugal innovation, as neither this phenomenon nor the proposed scale are conclusive. However, our results demonstrate that these are the central dimensions and attributes that best represent the phenomenon at present.

In the implementation of the scale, it is important to observe some limitations in our process and challenges for future application of the scale.

One limitation is the trend of obtaining a low response rate, which reflects the challenge of collecting data from companies. The usual response rate for online surveys is approximately 5%–30%, with 10% being the most typical response rate for unrestricted respondents (Evans and Mathur, 2005). Different from surveys applied to consumers, in which it is easier to obtain a higher response rate, the more restricted the target profile is, the lower the response rate obtained (Fan and Yan, 2010). The difficulty lies in reaching the right people with the desired profile (managers at the command or decision level) who are available and/or are willing to contribute to the research process (Shih and Fan, 2008). Furthermore, higher level managers are naturally busy and do not have much time to spend answering questionnaires, which leads to a high rate of incomplete questionnaires (Kongsved et al., 2007). Our average response rate over the five surveys was 8%; however, we advise future researchers to give special attention to the data collection processes to prevent lower response rates, even more so, when questionnaires are conducted online. We recommend proceeding by making initial contact, followed by phone calls and reminders. The lower response rate is a challenge to be faced by researchers and scholars in the future, and these actions can help overcome it.

Another aspect that represents a limitation is the time-consuming process and energy usually needed in a scale development process, which is quite complex and involves many steps, such as interviews, validation, data collection, and analysis. This study took approximately four years to complete five rounds of data collection in three countries, and a long time span might influence the results, even more so considering the rapid changes in the worldwide context. It is assumed that economic, environmental, political, social, and technological factors might change abruptly in different contexts. We recommend that managers and researchers use a transparent data collection strategy. We suggest running this scale by testing some control variables related to economic, environmental, political, social, and technological factors.

The last aspect representing a limitation is the profile of the survey respondents answering the questionnaires addressed to their companies. The measurement instrument proposed and validated in this work was developed to identify or measure their current capabilities of companies to develop frugal innovations. Since the study uses a firm-level scale, the respondents assume an essential role in answering the questionnaire insofar as they provide their perceptions about their company and answer on behalf of it. That is why selecting managers at the command or decision level is essential. However, the answers or perceptions about the company may vary, constituting a limitation of this research when only one respondent in a company contributes as a respondent. To improve the results or avoid bias from single respondents, we suggest carefully analyzing the sample and trying to obtain answers from more than one manager in each firm, or at least in part of the sample with a focus on the largest companies when a perception may vary internally. Another suggestion is to split the sample and proceed with some common method bias tests that can be performed to assure the results.

7. Conclusions

In this section, we present the main contributions of this work, pointing out the applications of the scale proposed here. In sequence, we present the theoretical contributions and their implications for the literature on frugal innovation and the advancement of related theories. Then, we present the managerial implications arising from this work and how managers and entrepreneurs can make decisions and benefit from applying the scale proposed here to identify existing capabilities for the development of frugal innovations and/or which capabilities should be developed. Finally, we present the study's limitations and some suggestions for future studies to guide future researchers' steps on using the capabilities for achieving frugal innovation.

7.1. Theoretical implications

The article presented a scale to measure the capabilities for achieving frugal innovation based on ten items divided into the following three capabilities: focus on core functionalities, substantial cost reduction, and shared sustainable engagement. The main objective was achieved by developing a scale based on several psychometric procedures to ensure the appropriable dimensionality, reliability, and validity of the construct.

The main contributions of the paper lie in the identification and proposition of a scale to measure organizational capabilities for achieving frugal innovation. On the one hand, this contributes to the efficiency-driven perspective (Bhatti et al., 2018) of frugal innovation

and opens door for further developments in advanced frugal innovations (Rao, 2017a). This contribution responds to an existing gap in the scientific literature on the subject of frugal innovation. Most studies are based on descriptive narratives, ethnographic studies, and case studies, placing particular interest on the more classic approaches of Jugaad and Gandhian innovation (Radjou and Prabhu, 2014b; Radjou et al., 2012). Despite being fundamental for the advancement of the theory, these studies pay little attention to the dimensions of science, technology, and engineering for a broader understanding of the nature of frugal innovation processes in companies (Rao, 2017a). By developing the constructs and validating a scale for frugal innovation capabilities, we contribute to the consolidation and advancement of this theoretical field (Cheng and Shiu, 2012), paving the way for specific advancements on AFIs in the future.

On the other hand, the scale presented contributes to the debate on the capabilities that anchor frugal innovations. It contributes to the debate on innovation strategies based on the theoretical perspective on resources and capabilities. It allows us to think about the capabilities for frugal innovation as operational capabilities (Helfat and Winter 2011) or technological capabilities (Figueiredo, 2002). In this way, the capabilities complement some studies devoted to enhancing the role of resources (Asakawa et al., 2019) and capabilities (Lim et al., 2013) for frugal innovation. In addition, understanding these capabilities opens the discussion to the role of other capabilities for achieving frugal innovation and the importance of the discussion about the creation, development, and reconfiguration of these capabilities (Helfat and Winter 2011).

We emphasize the importance of the three capabilities resulting from the managerial perception of frugal innovation that emerges from the development and validation scale process. However, we recognize that they are not exhaustive, and there is space for other capabilities to be identified and used in the future. As we said, the literature and concept of frugal innovation are in their infancy and still evolving (Hossain, 2018a). Our scale of the capabilities for achievement of frugal innovation opens possibilities for new capabilities to be identified according to the evolution of the concept and its use by firms. For example, the question of shared value and rethinking the ends of frugal innovation (Pansera, 2018) opens an avenue for a new orientation of the firm innovation strategy and, consequently, the efforts for developing new capabilities.

Finally, considering that you cannot improve what you cannot measure, we contribute to responding to calls for instruments to measure the frugal innovation approach (e.g. Brem and Agarwal, 2017; Farooq, 2017; Hossain, 2017; Pisoni et al., 2018; Radjou and Prabhu, 2014a), contributing to an extensive list of studies that allude to the advantages of frugal innovation but are based only on case studies (e.g. Annala et al., 2018; Bianchi et al., 2017; Devi and Kumar, 2017; Hossain, 2017; Kuo, 2017; Winterhalter et al., 2017). We developed and validated the capabilities for the frugal innovation scale and showed positive effects on the firm's operational performance. These results offer possibilities for researchers and scholars to create new studies exploring the relation between frugal innovation and other constructs independent of capabilities. For example, the integration of multinational management literature and constructs of transference of innovation and knowledge management, along with the construct of the capabilities for frugal innovation, could be essential to increase the understanding of reverse innovation (Malodia et al., 2019; Shankar and Narang, 2019). Another path for future studies consists of developing a focused scale to identify and measure advanced frugal innovations (Rao, 2017a; b, 2018), contributing to a wide range of authors and processes that need to be understood and measured from managerial, engineering, and scientific points of view.

7.2. Managerial implications

Managerial contributions emerge from this research, offering a better understanding of the capabilities for setting up frugal innovation, which can help managers improve their efforts.

Firms must understand where they stand on the different capabilities for achieving frugal innovation to define how to improve their overall frugal innovation processes. To this end, the scale provides a self-assessment tool in the form of an index measuring overall capabilities for achieving frugal innovation (composed of substantial cost reduction, focused on core functionalities, and shared sustainable engagement). Firms may place different degrees of emphasis on the three capabilities when implementing their frugal innovation strategies. This type of assessment can provide early and quick feedback to firms. If a firm finds itself deficient in any dimension, it can conduct a more detailed analysis and take necessary corrective actions.

The scale of capabilities for achieving frugal innovation provides managers with a valuable tool to assess their firms' strengths and weaknesses in developing frugal innovation. Moreover, the proposed scale makes it possible to compare a firm's capabilities for frugal innovation to that of other firms, thereby providing a basis for determining where additional investments should be made to upgrade and improve its implementation as a whole.

Finally, a critical view for managers (especially of large-sized companies and multinationals) is the absence of multiple shared values in the discourse. Understanding the meaning of innovation (Baskaran and Mehta, 2016) and the purpose (Pansera, 2018) for all engaged, even according to political and economic contexts, might be a future value proposition.

7.3. Future research directions

First, it is important to note that the three capabilities proposed here only represent an initial attempt to explain the capabilities for achieving frugal innovation at the firm level. Then, we recommend improvement of the measuring instruments used. Several studies on frugal innovation have been emerging with increasing frequency, bringing new contributions, perspectives, and some improvements that can clear the path toward new dimensions or items to be incorporated into the concept/construct of the capabilities for achieving frugal innovation in the future. Some factors can help emerging new capabilities in the future, such as a) the evolution of the innovation management field (Hossain, 2018a); b) market changes in terms of inputs, income, and infrastructure (Asakawa et al., 2019); and c) other perspectives based on efficiency-driven, social-driven, user-drive, or challenge-driven frugal innovations (Bhatti et al., 2018).

A promising path may be the creation of new analytical dimensions and constructs through cross-section research, refining the advanced organizational and productive processes of frugal innovation with specific intertemporal and sectorial cuts - industry and services - considering the intensity of the activities of R&D, technological application, and knowledge base complexity. Digital transformation poses new challenges for understanding a new analytical mindset driven by data science and artificial intelligence with the emergence of a type of smart economic innovation. From this perspective, we make a theoretical contribution to complement this scale through its own constructs to understand how ecosystems integrated as business objectives can drive frugal innovation. It will be fundamental to understand how business strategy decisions redefined by market changes and competitive pressure stimulate the implementation of frugal innovation projects.

Another fruitful field is to develop studies promoting a deep understanding of the shared-sustainable-engagement elements toward establishing a frugal innovation ecosystem concept. Considering how companies need to develop their capabilities simultaneously to implement frugal innovations, they need to determine ways to create or even engage themselves in their ecosystem to promote partnership, share costs and risks to have an environment able to support their innovation activities to promote a substantial cost reduction along the value chain, optimizing processes and enabling their capabilities to innovate in a

frugal way. New studies that contribute to understanding frugal innovation and its role in and for the ecosystem (local and global) are welcome.

Finally, it might be promising to develop studies that include in the new scale dimensions that consider innovative consumption patterns and environmental and institutional regulations of the market. This may elucidate the dynamic differences in the formation of competencies and resources for economic innovation.

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Declaration of competing interest

We declare for the purposes we have no conflicts of interest to declare.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.technovation.2022.102674.

References

Agarwal, N., Brem, A., 2012. Frugal and reverse innovation: literature overview and case study insights from a German Mnc in India and China. In: Katzy, B., Holzmann, T., Sailer, K., Toben, K.D. (Eds.), 18th International Conference on Engineering, Technology and Innovation, p. 11.

Agarwal, N., Grottke, M., Mishra, S., Brem, A., 2017. A systematic literature review of constraint-based innovations: state of the art and future perspectives. IEEE Trans. Eng. Manag. 64, 3–15. https://doi.org/10.1109/TEM.2016.2620562.

Albert, M., 2019. Sustainable frugal innovation: the connection between frugal innovation and sustainability. J. Clean. Prod. 237, 117747 https://doi.org/10.1016/j.jclepro.2019.117747.

Andel, T., 2013. Frugal price: virtue or vice? Journal 68, 4. https://www.mhlnews.com/powered-vehicles-and-forklifts/article/22049554/andel-and-handling-frugal-price-virtue-or-vice.

Angot, J., Plé, L., 2015. Serving poor people in rich countries: the bottom-of-the-pyramid business model solution. J. Bus. Strat. 36, 3–15. https://doi.org/10.1108/jbs-11-2013-0111.

Annala, L., Sarin, A., Green, J.L., 2018. Co-production of frugal innovation: case of low cost reverse osmosis water filters in India. J. Clean. Prod. 171, S110–S118. https://doi.org/10.1016/j.jclepro.2016.07.065.

Asakawa, K., Cuervo-Cazurra, A., Annique Un, C., 2019. Frugality-based advantage. Long. Range Plan. https://doi.org/10.1016/j.lrp.2019.04.001.

Autio, E., Thomas, L.D.W., 2013. Innovation ecosystems: implications for innovation management? In: Dodgson, M., Gann, D.M., Phillips, N. (Eds.), The Oxford Handbook of Innovation Management. Oxford University Press, UK, p. 35.

Barclay, C., 2014. Using frugal innovations to support cybercrime legislations in small developing states: introducing the cyber-legislation development and implementation process model (CyberLeg-DPM). Inf. Technol. Dev. 20, 165–195. https://doi.org/10.1080/02681102.2013.841630.

Barney, J., 1991. Firm resources and sustained competitive advantage. J. Manag. 17, 99–120. https://doi.org/10.1177/014920639101700108.

Baskaran, S., Mehta, K., 2016. What is innovation anyway? Youth perspectives from resource-constrained environments. Technovation 52–53, 4–17. https://doi.org/10.1016/j.technovation.2016.01.005.

Basu, R.R., Banerjee, P.M., Sweeny, E.G., 2013. Frugal innovation: core competencies to address global sustainability. J. Manag. Global Sustain. 1, 63–82. https://doi.org/10.13185/JM2013.01204.

Belkadi, F., Gupta, R.K., Vlachou, E., Bernard, A., Mourtis, D., 2016. Linking modular product structure to suppliers' selection through PLM approach: a frugal innovation perspective. In: Harik, R., Rivest, L., Bernard, A., Eynard, B., Bouras, A. (Eds.), Product Lifecycle Management for Digital Transformation of Industries: 13th IFIP WG 5.1 International Conference. Springer International Publishing, Columbia, SC, USA, pp. 227–237.

Bernardes, R.C., Borini, F., Figueiredo, P.N., 2019. Innovation in emerging economy organizations. Cadernos EBAPE. BR 17, 1–2. https://doi.org/10.1590/1679-395120190184.

Bhatti, Y., Basu, R.R., Barron, D., Ventresca, M.J., 2018. Frugal Innovation: Models, Means, Methods. Cambridge University Press, Cambridge.

Bhatti, Y.A., 2012. What Is Frugal, what Is Innovation? towards a Theory of Frugal Innovation. SSRN - Social Science Research Network.

Bianchi, C., Bianco, M., Ardanche, M., Schenck, M., 2017. Healthcare frugal innovation: a solving problem rationale under scarcity conditions. Technol. Soc. 51, 74–80. https://doi.org/10.1016/j.techsoc.2017.08.001.

Bound, K., Thornton, I., 2012. Our Frugal Future: Lessons from India's Innovation System. Nesta London.

Brem, A., Agarwal, N., 2017. Frugal innovation-past, present, and future. IEEE Eng. Manag. Rev. 45, 37–41. https://doi.org/10.1109/EMR.2017.2734320.

Brem, A., Ivens, B.S., 2013. Do frugal and reverse innovation foster sustainability? Introduction of a conceptual framework. J. Technol. Manag. Growing Econ. 4, 31–50. https://doi.org/10.15415/jtmge.2013.42006.

Brem, A., Wimschneider, C., de Aguiar Dutra, A.R., Vieira Cubas, A.L., Ribeiro, R.D., 2020. How to design and construct an innovative frugal product? An empirical examination of a frugal new product development process. J. Clean. Prod. 275, 122232 https://doi.org/10.1016/j.jclepro.2020.122232.

Brem, A., Wolfram, P., 2014. Research and development from the bottom up-introduction of terminologies for new product development in emerging markets. J. Innovat. Entrepreneur. 3, 9. https://doi.org/10.1186/2192-5372-3-9.

Calantone, R.J., Cavusgil, S.T., Zhao, Y.S., 2002. Learning orientation, firm innovation capability, and firm performance. Ind. Market. Manag. 31, 515–524. https://doi.org/10.1016/s0019-8501(01)00203-6.

Camargo, F.A., Rossetto, D.E., 2018. Jugaad innovation. In: Bernardes, R.C., Borini, F.M., Rossetto, D.E., Pereira, R.M. (Eds.), Innovation in Emerging Markets. Senac, São Paulo, p. 368.

Cheng, C.C., Shiu, E.C., 2012. Validation of a proposed instrument for measuring eco-innovation: an implementation perspective. Technovation 32, 329–344. https://doi.org/10.1016/j.technovation.2012.02.001.

Chesbrough, H., Kim, S., Agogino, A., 2014. Chez Panisse: building an open innovation ecosystem. Calif. Manag. Rev. 56, 144–171. https://doi.org/10.1525/cmr.2014.56.4.144.

Churchill, G.A.J., 1979. A paradigm for developing better measures of marketing constructs. J. Market. Res. 16, 64–73. https://doi.org/10.1177/002224377901600110.

Corsini, L., Dammicco, V., Moultrie, J., 2021. Frugal innovation in a crisis: the digital fabrication maker response to COVID-19. R D Manag. 51, 195–210. https://doi.org/10.1111/radm.12446.

Devellis, R.F., 2003. Scale Development: Theory and Applications. 2 ed. Sage publications, Inc., Thousand Oaks.

Devi, W.P., Kumar, H., 2017. Frugal Innovations and Actor–Network Theory: A Case of Bamboo Shoots Processing in Manipur, India. European Journal of Development Research, pp. 1–18. https://doi.org/10.1057/s41287-017-0116-1.

Economist, T., 2009. Health care in India: lessons from a frugal innovator. Journal 67–68.

Economist, T., 2010. The power of disrupt: business innovations from emerging markets will change the rich world too. Journal 395, 16–18.

Economist, T., 2011. First Break All the Rules: the Charms of Frugal Innovation. The Economist, pp. 3–5.

Economist, T., 2012. Asian innovation: frugal ideas are spreading from East to West. Journal.

Economist, T., 2014. Under the radar: innovation envolves in asia. In: Vaithaeeswaran, V. V. (Ed.), A Report from the Economist Intelligence Unit. The Economist Intelligence Unit, Shangai, China, p. 29.

Evans, J.R., Mathur, A., 2005. The value of online surveys. Internet Res. 15, 195–219. https://doi.org/10.1108/10662240510590360.

Fan, W., Yan, Z., 2010. Factors affecting response rates of the web survey: a systematic review. Comput. Hum. Behav. 26, 132–139. https://doi.org/10.1016/j.chb.2009.10.015.

Farooq, R., 2017. A conceptual model of frugal innovation: is environmental munificence a missing link? Int. J. Innovat. Sci. 9, 320–334. https://doi.org/10.1108/IJIS-08-2017-0076.

Figueiredo, P.N., 2002. Does technological learning pay off? Inter-firm differences in technological capability-accumulation paths and operational performance improvement. Res. Pol. 31, 73–94. https://doi.org/10.1016/S0048-7333(01)00106-8.

Geels, F.W., Mcmeekin, A., Mylan, J., Southerton, D., 2015. A critical appraisal of sustainable consumption and production research: the reformist, revolutionary and reconfiguration positions. Global Environ. Change 34, 1–12. https://doi.org/10.1016/j.gloenvcha.2015.04.013.

Good, A., 2020. NASA Develops COVID-19 Prototype Ventilator in 37 Days, NASA JPL. NASA, Passadena, California.

Good, A., Inclán, B., Rydin, M., 2020. Brazilian Partnership to Begin Producing NASA-Designed COVID-19 Ventilator, Benefits for You. NASA, Passadena, California.
Govindarajan, V., Ramamurti, R., 2011. Reverse innovation, emerging markets, and global strategy. Global Strat. J. 1, 191–205. https://doi.org/10.1002/gsj.23.
Hair, J.F., Black, W.C., Babin, B.J., Anderson, R.E., Tatham, R.L., 2009. Multivariate Data Analysis. Prentice hall, Upper Saddle River, NJ.
Harris, M., Bhatti, Y., Buckley, J., Sharma, D., 2020. Fast and frugal innovations in response to the COVID-19 pandemic. Nat. Med. 26, 814–817. https://doi.org/10.1038/s41591-020-0889-1.
Hart, S.L., Christensen, C.M., 2002. The great leap: driving innovation from the base of the pyramid. MIT Sloan Manag. Rev. 44, 51–56. https://sloanreview.mit.edu/article/the-great-leap-driving-innovation-from-the-base-of-the-pyramid/.
Hartley, J., 2015. Eight and a half propositions to stimulate frugal innovation in Public Services. In: Wanna, J., Lee, H.-A., Yates, S. (Eds.), Managing under Austerity, Delivering under Pressure: Performance and Productivity in Public Service. ANU Press, Australia, p. 18.
Helfat, C.E., Peteraf, M.A., 2003. The dynamic resource-based view: capability lifecycles. Strat. Manag. J. 24, 997–1010. https://doi.org/10.1002/smj.332.
Helfat, C.E., Winter, S.G., 2011. Untangling dynamic and operational capabilities: strategy for the (N)ever-Changing world. Strat. Manag. J. 32, 1243–1250. https://doi.org/10.1002/smj.955.
Hossain, M., 2013. Adopting Open Innovation to Stimulate Frugal Innovation and Reverse Innovation. SSRN - Social Science Research Network.
Hossain, M., 2016. Grassroots innovation: a systematic review of two decades of research. J. Clean. Prod. 137, 973–981. https://doi.org/10.1016/j.jclepro.2016.07.140.
Hossain, M., 2017. Mapping the frugal innovation phenomenon. Technol. Soc. 51, 199–208. https://doi.org/10.1016/j.techsoc.2017.09.006.
Hossain, M., 2018a. Frugal innovation: a review and research agenda. J. Clean. Prod. 182, 926–936. https://doi.org/10.1016/j.jclepro.2018.02.091.
Hossain, M., 2018b. Grassroots Innovation: the State of the Art and Future Perspectives. https://doi.org/10.1016/j.techsoc.2018.06.008. Technology in Society.
Hossain, M., 2020. Frugal innovation: conception, development, diffusion, and outcome. J. Clean. Prod. 262, 121456 https://doi.org/10.1016/j.jclepro.2020.121456.
Hossain, M., Simula, H., Halme, M., 2016. Can frugal go global? Diffusion patterns of frugal innovations. Technol. Soc. 46, 132–139. https://doi.org/10.1016/j.techsoc.2016.04.005.
Howard, M., 2011. Will frugal innovation challenge the west? Journal 3, 1. https://www.marketingsociety.com/sites/default/files/thelibrary/june-2011_17.pdf.
Iqbal, Q., Ahmad, N.H., Halim, H.A., 2021. Insights on entrepreneurial bricolage and frugal innovation for sustainable performance. Bus. Strat. Dev. 4, 237–245. https://doi.org/10.1002/bsd2.147.
Khan, R., 2016. How frugal innovation promotes social sustainability. Sustainability 8. https://doi.org/10.3390/su8101034.
Khan, R., Melkas, H., 2020. The social dimension of frugal innovation. Int. J. Technol. Manag. 83, 160–179. https://doi.org/10.1504/IJTM.2020.109234.
Knorringa, P., Peša, I., Leliveld, A., van Beers, C., 2016. Frugal innovation and development: aides or adversaries? Eur. J. Dev. Res. 28, 143–153. https://doi.org/10.1057/ejdr.2016.3.
Kongsved, S.M., Basnov, M., Holm-Christensen, K., Hjollund, N.H., 2007. Response rate and completeness of questionnaires: a randomized study of internet versus paper-and-pencil versions. J. Med. Internet Res. 9, e25. https://doi.org/10.2196/jmir.9.3.e25.
Kumar, N., Puranam, P., 2012. Frugal engineering: an emerging innovation paradigm. In: Ivey Business Journal, March/April 2012. Richard Ivey School of Business Foundation, Western University, pp. 14–16.
Kuo, A., 2015. Creating social value through frugal innovation. In: Tsai, S.D.H., Liu, T.Y. C., Li, S.J., Hu, J. (Eds.), Social Enterprise, Network and Grassroots Case Studies. World Scientific Publishing Company, Singapore, pp. 53–70.
Kuo, A., 2017. Harnessing frugal innovation to foster clean technologies. Clean Technol. Environ. Policy 19, 1109–1120. https://doi.org/10.1007/s10098-016-1304-y.
Le Bas, C., 2016. Frugal innovation, sustainable innovation, reverse innovation: why do they look alike? Why are they different? J. Innovat. Econ. Manag. 9–26. https://doi.org/10.3917/jie.021.0009, 2016/3.
Leliveld, A., Knorringa, P., 2017. Frugal Innovation and Development Research. The European Journal of Development Research. https://doi.org/10.1057/s41287-017-0121-4.
Levänen, J., Hossain, M., Lyytinen, T., Hyvärinen, A., Numminen, S., Halme, M., 2016. Implications of frugal innovations on sustainable development: evaluating water and energy innovations. Sustainability 8, 4. https://doi.org/10.3390/su8010004.
Lim, C., Han, S., Ito, H., 2013. Capability building through innovation for unserved lower end mega markets. Technovation 33, 391–404. https://doi.org/10.1016/j.technovation.2013.06.010.
Macfie, H.J., Bratchell, N., Greenhoff, K., Vallis, L.V., 1989. Designs to balance the effect of order of presentation and first-order carry-over effects in Hall tests. J. Sensory Stud. 4, 129–148. https://doi.org/10.1111/j.1745-459X.1989.tb00463.x.
Mackenzie, S.B., Podsakoff, P.M., Podsakoff, N.P., 2011. Construct measurement and validation procedures in Mis and behavioral research: integrating new and existing techniques. MIS Q. 35, 293–334. https://doi.org/10.2307/23044045.
Malodia, S., Gupta, S., Jaiswal, A.K., 2019. Reverse innovation: a conceptual framework. J. Acad. Market. Sci. https://doi.org/10.1007/s11747-019-00703-4.
McFall-Johnsen, M., Woodward, A., 2020. NASA's Cheap, Simple Ventilator Just Got Emergency Approval from the FDA. It Could Prevent Shortages in a 2nd Wave of COVID-19 Cases. Business Insider. Business Insider, NY.
Molina-Maturano, J., Bucher, J., Speelman, S., 2020a. Understanding and evaluating the sustainability of frugal water innovations in México: an exploratory case study. J. Clean. Prod. 274, 122692 https://doi.org/10.1016/j.jclepro.2020.122692.
Molina-Maturano, J., Speelman, S., De Steur, H., 2020b. Constraint-based innovations in agriculture and sustainable development: a scoping review. J. Clean. Prod. 246, 119001 https://doi.org/10.1016/j.jclepro.2019.119001.
Nair, A., Guldiken, O., Fainshmidt, S., Pezeshkan, A., 2015. Innovation in India: a review of past research and future directions. Asia Pac. J. Manag. 32, 925–958. https://doi.org/10.1007/s10490-015-9442-z.
Nari Kahle, H., Dubiel, A., Ernst, H., Prabhu, J., 2013. The democratizing effects of frugal innovation: implications for inclusive growth and state-building. J. Indian Bus. Res. 5, 220–234. https://doi.org/10.1108/JIBR-01-2013-0008.
Niroumand, M., Shahin, A., Naghsh, A., Peikari, H.R., 2021. Frugal innovation enablers, critical success factors and barriers: a systematic review. Creativ. Innovat. Manag. 30, 348–367. https://doi.org/10.1111/caim.12436.
Pansera, M., 2013. Frugality, grassroots and inclusiveness: new challenges for mainstream innovation theories. Afr. J. Sci. Technol. Innovat. Dev. 5, 469–478. https://doi.org/10.1080/20421338.2013.820445.
Pansera, M., 2018. Frugal or fair? The unfulfilled promises of frugal innovation. Technol. Innovat. Manag. Rev. 8 https://doi.org/10.22215/timreview/1148.
Pansera, M., Owen, R., 2015. Framing resource-constrained innovation at the 'bottom of the pyramid': insights from an ethnographic case study in rural Bangladesh. Technol. Forecast. Soc. Change 92, 300–311. https://doi.org/10.1016/j.techfore.2014.10.004.
Pisoni, A., Michelini, L., Martignoni, G., 2018. Frugal approach to innovation: state of the art and future perspectives. J. Clean. Prod. 171, 107–126. https://doi.org/10.1016/j.jclepro.2017.09.248.
Podsakoff, P.M., MacKenzie, S.B., Podsakoff, N.P., 2016. Recommendations for creating better concept definitions in the organizational, behavioral, and social sciences. Organ. Res. Methods 19, 159–203. https://doi.org/10.1177/1094428115624965.
Prahalad, C.K., Hart, S.L., 2002. The Fortune at the Bottom of the Pyramid. Strategy & Business First Quarter. https://doi.org/10.22215/timreview/1148.
Radjou, N., Prabhu, J., 2014a. 4 CEOs who are making frugal innovation work. Harv. Bus. Rev. 2014. https://hbr.org/2014/11/4-ceos-who-are-making-frugal-innovation-work.
Radjou, N., Prabhu, J., 2014b. Frugal Innovation: How to Do More with Less. The Economist, New York.
Radjou, N., Prabhu, J., Ahuja, S., 2012. Jugaad Innovatio: Think Frugal, Be Flexible, Generate Breakthrough Innovation. Wiley & Sons.
Rao, B.C., 2013. How disruptive is frugal? Technol. Soc. 35, 65–73. https://doi.org/10.1016/j.techsoc.2013.03.003.
Rao, B.C., 2017a. Advanced frugal innovations [Leading edge]. In: IEEE Technology and Society Magazine 36, pp. 53–54. https://doi.org/10.1109/MTS.2017.2763453.
Rao, B.C., 2017b. Advances in science and technology through frugality. IEEE Eng. Manag. Rev. 45, 32–38. https://doi.org/10.1109/EMR.2017.2667219.
Rao, B.C., 2018. Science is indispensable to frugal innovations. Technol. Innovat. Manag. Rev. 8 https://doi.org/10.22215/timreview/1148.
Rao, B.C., 2019. The science underlying frugal innovations should not be frugal. R. Soc. Open Sci. 6, 180421 https://doi.org/10.1098/rsos.180421.
Ray, P.K., Ray, S., 2010. Resource-constrained innovation for emerging economies: the case of the Indian telecommunications industry. Engineering management. IEEE Transactions on 57, 144–156. https://doi.org/10.1109/TEM.2009.2033044.
Ray, S., Ray, P.K., 2011. Product innovation for the people's car in an emerging economy. Technovation 31, 216–227. https://doi.org/10.1016/j.technovation.2011.01.004.
Reinhardt, R., Gurtner, S., Griffin, A., 2018. Towards an adaptive framework of low-end innovation capability – a systematic review and multiple case study analysis. Long. Range Plan. 51, 770–796. https://doi.org/10.1016/j.lrp.2018.01.004.
Rosca, E., Arnold, M., Bendul, J.C., 2017a. Business models for sustainable innovation – an empirical analysis of frugal products and services. J. Clean. Prod. 162, S133–S145. https://doi.org/10.1016/j.jclepro.2016.02.050.
Rosca, E., Reedy, J., Bendul, J.C., 2017b. Does Frugal Innovation Enable Sustainable Development? A Systematic Literature Review. European Journal of Development Research, pp. 1–22. https://doi.org/10.1057/s41287-017-0106-3.
Santos, L.L., Borini, F.M., Oliveira Júnior, M.d.M., 2020. In search of the frugal innovation strategy. Rev. Int. Bus. Strat. 30, 245–263. https://doi.org/10.1108/RIBS-10-2019-0142.
Shankar, V., Narang, U., 2019. Emerging market innovations: unique and differential drivers, practitioner implications, and research agenda. J. Acad. Market. Sci. 48, 1030–1052. https://doi.org/10.1007/s11747-019-00685-3.
Shih, T.-H., Fan, X., 2008. Comparing response rates from web and mail surveys: a meta-analysis. Field Methods 20, 249–271. https://doi.org/10.1177/1525822x08317085.
Silveira, F., 2016. Frugal e Social Innovation: Due casi di studio italiani, Dipartimento di Economia Aziendale. Università Degli Studi di Verona, Vicenza, p. 153.
Soni, P., Rishikesha, T.K., 2014. Frugal innovation: aligning theory, practice, and public policy. J. Indian Bus. Res. 6, 29–47. https://doi.org/10.1108/JIBR-03-2013-0025.
Tarraço, E.L., Guedes, C., Rossetto, D.E., 2018. Frugal innovation. In: Bernardes, R.C., Borini, F.M., Rossetto, D.E., Pereira, R.M. (Eds.), Innovation in Emerging Markets. Senac, São Paulo, p. 368.
Tiwari, R., Fischer, L., Kalogerakis, K., 2016a. Frugal Innovation in Scholarly and Social Discourse: an Assessment of Trends and Potential Societal Implications. Fraunhofer MOEZ Leipzig and Hamburg University of Technology in the BMBF-ITA project, Leipzig and Hamburg, p. 29.
Tiwari, R., Herstatt, C., 2012a. Assessing India's lead market potential for cost-effective innovations. J. Indian Bus. Res. 4, 97–115. https://doi.org/10.1108/17554191211228029.

Tiwari, R., Herstatt, C., 2012b. Open Global Innovation Networks as Enablers of Frugal Innovation: Propositions Based on Evidence from India. Hamburg University of Technology, Technology and Innovation Management. Working Paper. http://d-nb.info/1048573494.

Tiwari, R., Kalogerakis, K., Herstatt, C., 2014. Frugal Innovation and Analogies: Some Propositions for Product Development in Emerging Economies. Hamburg University of Technology, p. 10.

Tiwari, R., Kalogerakis, K., Herstatt, C., 2016b. Frugal Innovations in the Mirror of Scholarly Discourse: Tracing Theoretical Basis and Antecedents. R&D Management Conference, Cambridge, UK.

Weyrauch, T., Herstatt, C., 2016a. Frugal Innovation: what Is it? Criteria for Frugal Innovation. R&D Management Conference, Cambridge, UK.

Weyrauch, T., Herstatt, C., 2016b. What is frugal innovation? Three defining criteria. J. Frugal Innovat. 2, 1. https://doi.org/10.1186/s40669-016-0005-y.

Williamson, P.J., 2010. Cost innovation: preparing for a 'value-for-money' revolution. Long. Range Plan. 43, 343–353. https://doi.org/10.1016/j.lrp.2009.07.008.

Winterhalter, S., Zeschky, M.B., Neumann, L., Gassmann, O., 2017. Business models for frugal innovation in emerging markets: the case of the medical device and laboratory equipment industry. Technovation 66–67, 3–13. https://doi.org/10.1016/j.technovation.2017.07.002.

Wooldridge, A., 2010. First break all the rules: the charms of frugal innovation. Journal 3–5.

Zeschky, M.B., Widenmayer, B., Gassmann, O., 2011a. Frugal Innovation in Emerging Markets, 54. Research-Technology Management, pp. 38–45. https://doi.org/10.5437/08956308X5404007.

Zeschky, M.B., Widenmayer, B., Gassmann, O., 2011b. Frugal Innovation in Emerging Markets: the Case of Mettler Toledo, 54. Research-Technology Management, pp. 38–45. https://doi.org/10.5437/08956308X5404007.

Zeschky, M.B., Winterhalter, S., Gassmann, O., 2014. From cost to frugal and reverse innovation: mapping the field and implications for global competitiveness. Res. Technol. Manag. 57, 20–27. https://doi.org/10.5437/08956308x5704235.