



Co-creating frugal innovation at the bottom of the pyramid

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ABSTRACT

Frugal innovation, characterised by affordable, cost-effective, resource-efficient solutions, has become increasingly significant for addressing the needs of the Bottom of the Pyramid (BoP) in emerging markets. It necessitates concerted efforts by key stakeholders with the shared goal of co-creating new solutions to enhance the quality of life at the BoP. However, the exploration of co-creation in devising affordable solutions for the underserved BoP market is limited in the literature. This study explores how entrepreneurs collaborate with key stakeholders to co-create frugal innovations for the BoP customers in an emerging market. We employed a multiple case study approach to address the research question. Analyzing data from 12 start-ups, including 43 interviews, our findings revealed the collaboration mechanisms in the frugal innovation process addressing BOP needs. We also demonstrate how start-ups form collaborative networks co-create frugal innovations, overcoming multiple constraints by utilising shared resources, knowledge, and capabilities. Furthermore, we reveal the key outcomes of frugal innovations. The findings advance the frugal innovation literature by incorporating co-creation as a strategic approach to addressing innovation challenges at the BoP. We extend both co-creation and frugal innovation literature by stressing the significance of co-creation in identifying problems, understanding complex scenarios, and devising affordable solutions.

1. Introduction

In the last two decades, emerging markets have gained significant attention in the global economy. However, a considerable portion of this population do not have access to basic services such as healthcare, energy, and education (Pralhad and Ramaswamy, 2004; Gupta and Kanungo, 2022). We identify this portion of the population at the bottom of the pyramid (BoP) market which makes an invisible market of over billion people living on less than 2\$ per day (Pralhad, 2012). The orientation toward addressing these services within these markets has instigated a reevaluation of innovation priorities among firms operating therein (Hossain, 2020). Consequently, emerging markets have become fertile grounds for innovation owing to their considerable market size, escalating demands, and their potential to evolve into centers of innovation (Adomako et al., 2024a,b; Jha et al., 2016).

As the trajectory of growth persists within emerging markets, firms

are increasingly transitioning from conventional innovation practices which are expensive, target rich customers with no or less social impact (Pisano, 2015), toward cost-effective and more inclusive innovation approaches, thereby giving rise to newer innovation paradigms such as frugal innovation (Adomako et al., 2024a,b; Pisoni et al., 2018). Frugal innovation refers to the process of creating quality, affordable solutions with limited resources (Dabić et al. 2023; Hossain et al., 2016). Enhanced product functionality, reduced cost and serving low-income customers lie at the core of the concept. Frugal innovation requires collaboration between key stakeholders at different stages of production who share the same aspiration to assist poor (Chakravarty, 2022; De Marchi et al., 2022; Shahid et al., 2023). As such co-creation has become a key paradigm shaping frugal innovation activities (Tesfaye and Fougère, 2022). It involves diverse stakeholders collaborating to design, develop, and refine products, or services to generate new value (Frow et al., 2015; Karami and Read, 2021). Co-creation and frugal

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innovation together hold significant promise for addressing resource constraints, promoting inclusivity, and driving inclusive development (Bhattacharjya et al., 2023; Pansera and Owen, 2018; Tesfaye and Fougère, 2022) in societies confronted with resource scarcity (Adomako et al., 2024a,b; Cunha et al., 2014; Sahasranamam et al., 2024).

Despite growing recognition of frugal innovation as a means to address the needs of BoP markets, extant research has largely examined its antecedents, outcomes, and contextual drivers in isolation (e.g., Adomako et al., 2024a,b; Brem et al., 2023; Hossain, 2018). In parallel, the co-creation literature has emphasized joint value creation among multiple stakeholders (e.g., Frow et al., 2015; Payne et al., 2008), yet has paid limited attention to how such interactions unfold under the severe resource constraints and institutional complexities characteristic of BoP contexts. This separation has resulted in a fragmented understanding of how resource-constrained innovation is actually accomplished in practice. Specifically, we lack insight into the micro-level mechanisms through which entrepreneurs mobilize, align, and recombine heterogeneous stakeholders' resources and motivations to develop affordable, contextually embedded solutions in emerging markets (Welter and Baker, 2021). Existing studies acknowledge the importance of collaboration but remain largely silent on *how* and *why* such collaborative arrangements translate into viable frugal innovations (e.g., Lacoste, 2016; Tesfaye and Fougère, 2022). This gap is theoretically consequential because it limits our ability to explain how innovation emerges under conditions of scarcity, where traditional firm-centric and resource-abundance assumptions do not hold. Without understanding these generative mechanisms, theory remains ill-equipped to account for how entrepreneurs orchestrate distributed resources and navigate institutional constraints to produce inclusive innovations.

Addressing this gap, we ask: How do entrepreneurs mobilize and orchestrate diverse stakeholders to co-create frugal innovations for BoP markets in emerging economies?

By unpacking the underlying mechanisms of co-creation in resource-constrained settings, our study contributes to a more processual and interaction-based understanding of frugal innovation and extends co-creation theory into contexts characterized by scarcity, institutional complexity, and inclusion challenges. First, focusing on BoP customers allows us to offer a deeper understanding of frugal innovation as a collaborative process enabled by like-minded stakeholders. As such, we extend the frugal innovation literature (e.g., Adomako et al., 2024a,b; Ernst et al., 2015; Hossain, 2018) by integrating the concept of co-creation to explore collaborative innovation mechanisms at the BoP. Exploring the distinct characteristics of frugality – enhanced product functionality, reduced cost and serving low-income customers – our study underscores how key stakeholders collaborate in shaping these aspects of frugal innovation for low-income people. Second, we reveal various co-creation mechanisms through which frugal innovations meet the needs of BoP customers in emerging markets by emphasising the shared commitment among key stakeholders with aspirations to serve these communities. Although a body of literature has discussed the salience of collaborative practices to BoP-related innovations (e.g. Angeli et al., 2022; Dembek et al., 2018; Reyens et al., 2016; Rocchi et al., 2022), our study specifically highlights 'how' and 'why' such collaborations occur, expected outcomes and motivations of the different stakeholders involved. This effort underscores the role of co-creation in identifying issues, understanding complex situations, and developing affordable solutions, thereby deepening our understanding of frugal innovation.

2. Theoretical background

2.1. Frugal innovation

Frugal innovation, emerging as a response to resource constraints and a catalyst for inclusive development, has garnered substantial

attention within academic and business spheres (Adomako et al., 2024a, b; Gibbert et al., 2014). Frugal innovation addresses social and environmental challenges (Shahid et al., 2023) through affordable, eco-friendly and quality products tailored for low-income customers who are usually overlooked in mainstream innovations (Foster and Heeks, 2013). At its core, frugal innovation seeks to achieve more with fewer resources, striving to make high-quality products and services accessible to a broader population (D'Angelo and Magnusson, 2020). Originating mainly from environments characterised by limited resources, such as emerging markets, frugal innovation challenges conventional views that often prioritise substantial investment and advanced technologies in the innovation process (Li et al., 2022). While frugal innovation can be disruptive sometimes, it's not necessarily disruptive by nature. As such we distinguish the term from disruptive innovation as an innovation that results in formation of a new value network and a new market and eventually disrupts an existing value network and market (Christensen et al., 2015). However, like disruptive innovation, frugal innovation includes innovations that improve a product or service in ways that the market may not expect.

Various scholars have proposed frameworks emphasising simplicity, affordability, and sustainability as defining characteristics of frugal innovation (Chatterjee et al., 2021; Hossain, 2018, 2021; Lim and Fujimoto, 2019; Ploeg et al., 2021). Frugal innovation underscores the importance of understanding local needs and leveraging contextual insights to develop solutions that are effective and affordable to the BoP customers. While some defined the BoP using a per capita income at or below US\$1500 or US\$2000 per annum based on "purchasing power parity", others refer to the poverty threshold of one or two US dollars per day customers (Kolk et al., 2014).

Frugal innovation has been explored from different perspectives, including the role of institutions (Ananthram and Chan, 2021), societal and operational pressures (Levänen et al., 2022), product development processes (Brem et al., 2020), measurement scale for frugal innovation capabilities (Rossetto et al., 2023), role of intermediaries (Hyvärinen et al., 2024) and social impact (Park et al., 2022). Several driving factors underpin frugal innovation, and a comprehensive understanding of these factors are crucial for contextualising its application (Hossain et al., 2023; Pineda-Escobar, 2025). Economic constraints, particularly prevalent in emerging markets, necessitate the exploration of such innovations (Shahid et al., 2023). The role of co-creation in frugal innovation development warrants further investigation.

2.2. Co-creating frugal innovation

Co-creative innovation emphasises the collaborative generation of value by involving multiple stakeholders in the innovation process (Beverland et al., 2024; Karami and Read, 2021; Payne et al., 2008). Co-creative innovation contrasts with the traditional linear innovation (Lacoste, 2016) as it involves the active participation of diverse stakeholders in the innovation process (Prahalad and Ramaswamy, 2004). Co-creation of new artefacts builds on the constructionist view of entrepreneurship emphasising the importance of collective understanding of future and resource sharing to actualise it. In this view, like-minded stakeholders come together to collectively shape new opportunities by leveraging their resources (Karami and Read, 2021; Sarasvathy, 2001).

On the other hand, frugal innovation revolves around the creation of high-quality, affordable solutions with limited resources (Dabić et al., 2022), which essentially relies on resource sharing by like-minded stakeholders who integrate social benefit into their offerings (Shahid et al., 2023). Successful frugal innovations entail engaging a broader set of actors, including end-users, suppliers, and other external partners, who care about inclusivity and serving low-income people (Tefaye and Fougère, 2022). The motivation behind co-creating frugal innovation often arises from the recognition that diverse resources enhance the affordable innovation process. Co-creative entrepreneurs seek to tap

into the collective intelligence of various stakeholders, leveraging their insights to develop solutions that are not only cost-effective but also aligned with customers' needs (Mačiulienė and Skaržauskienė, 2016; Onsongo et al., 2023; Wang et al., 2020).

While co-creating frugal innovation holds promise, the intricacies of managing diverse stakeholders and the potential for power imbalances in the co-creation process require careful navigation (Lacoste, 2016). Additionally, the need for a nuanced understanding of contextual factors is crucial as pronounced in recent research (Welter and Baker, 2021). Serving low-income customers in emerging markets requires a clear understanding of customers' needs and liabilities, institutional hurdles, local communities, existing businesses in the market etc. (Shahid et al., 2023). Gaining this type of contextual information requires close cooperation with different stakeholders in these markets to make sense of customers' needs and different ways of serving them with affordable solutions. A deeper exploration of the contextual factors associated with co-creating frugal innovation can enrich our understanding of this evolving paradigm (Pineda-Escobar, 2025).

3. Methodology

3.1. Study context

We chose an emerging market as the research context. Our choice of Pakistan as a research context includes three reasons. First, the country faces numerous socio-economic challenges, such as limited access to resources, infrastructure deficiencies, and a large low-income population (Azam et al., 2020; Chaudhry, 2017). These conditions create opportunities for innovative solutions that are cost-effective, resource-efficient, and tailored to local needs. Second, Pakistan has a growing ecosystem of entrepreneurs, startups, NGOs, and government initiatives focused on fostering innovation and entrepreneurship (Sher et al., 2020). This collaborative ecosystem has the potential to facilitate partnerships and knowledge-sharing among diverse stakeholders, which is essential for effective co-creation of frugal innovations (Chakravarty, 2022). Third, Pakistan is home to a significant population of BoP consumers (Heuer et al., 2020), who have limited purchasing power and access to essential goods and services. Co-creating frugal innovations in this context can address the specific needs and constraints faced by BoP consumers.

3.2. Case selection

We used purposive sampling to select cases which were experiencing the phenomenon of theoretical interest (Campbell et al., 2020). Table 1 presents an overview of the selected case firms. This qualitative study employs the well-established multiple case study approach (Eisenhardt, 1989; Yin, 2018), which is effective in studying underexplored areas of theoretical significance. For the initial selection of cases, two of the authors based in the local context conducted rigorous desk research to identify such local start-ups that were mainly focused on serving the underprivileged segments of the customers in their respective markets with innovative products. Initially, 19 potential cases of frugal innovation were shortlisted based on this desk research coupled with the advice of six local experts consisting of entrepreneurship mentors and the managers of leading incubation centers in Pakistan. Eventually, out of these 19 cases only 12 were selected for the purpose of this study based on the following five parameters: they were (1) serving the low-end of the market; (2) pursuing product innovation; (3) being technology-enabled, (4) having strong growth potential (5) and represented contextual variation including differences in sector (e.g., healthcare, clean energy, housing, education). This ensured exposure to a broad range of frugal innovation settings and potential co-creation configurations. The final sample was comprised of 12 case studies, which is consistent with other inductive studies that are typically based on a similar number of cases (Powell and Baker, 2014; Shepherd et al.,

Table 1
Summary of data.

No.	Case	Primary data			Secondary data
		Informants	No.	Duration (minute)	No.
1	Bioniks	Co-Founder	2	66	147
		Co-Founder & CEO	1	40	
2	Brighterlite	Founder & CEO	2	108	14
3	Byonyks	Founder & CEO	2	160	89
		CTO	1	35	
		Head, HR	1	45	
		CMO	1	30	
4	Daisy	International expert	1	20	14
		Founder	3	181	
5	Economia	Head, marketing	3	149	47
		Co-Founder & CEO	3	138	
6	EzShifa	Co-founder & CEO	2	90	104
		Co-founder & CTO	1	140	
		Franchisee	1	40	
7	Girly Things	Founder & CEO	1	80	48
8	Jaan Pak	Founder & CEO	2	107	43
9	Jaguar	Founder & CEO	2	79	174
10	Jolta	Founder & CEO	3	120	169
		CTO	1	45	
11	Modulus	CEO	4	225	38
		Tech COO	1	120	
12	PakVitae	Co-founder & CEO	4	320	92
		Co-founder & CFO	1	130	

Note. CEO- chief executive officer, CTO- chief technology officer, CMO- chief medical officer, COO- chief operating officer. Secondary data includes social media post, press release, blogs, news articles & videos.

2020). After iterative discussions among three researchers, we developed a detailed, unstructured questionnaire for the interview. Furthermore, we tailored some questions to address the unique aspects of each case.

3.3. Data collection

Data was mainly collected through unstructured interviews, field observations and secondary documents (see Table 1). The key informant approach was utilised, and founders and senior managers who constituted the "single most knowledgeable and valid information sources" were interviewed (Kumar et al., 1993). Altogether 43 in-depth interviews were conducted including seven in-person and 36 over Zoom. The interviews were jointly conducted by three researchers in three rounds. In the first step, founders from two of these ventures were interviewed, and the second step involved a preliminary analysis and reflection of their interview transcripts by the authors. Two of the authors made three on-site visits. These visits consisted of guided tours by the senior managers of these facilities, during which photos and extensive field notes were taken. This was followed by the second round of interviews, where 16 more interviews were conducted comprising founders, employees, and customers of the next four cases. In the third step, eight more interviews were conducted with the present six cases of the previous two rounds and 13 interviews with six new cases. The language of all interviews was primarily Urdu, with phrases or words of English being frequently used by the respondents. The authors regularly reflected on their interview notes and emergent data after every interview.

All interviews were subsequently reviewed, transcribed, and

converted into English for further analysis and were given a final review by two separate researchers. Interview data was then triangulated (Gibbert et al., 2008) based on the available information and the secondary information obtained from publicly available forums such as blogs, newspaper articles, and company press releases. This was supplemented by more secondary data for each case from their respective websites, LinkedIn, and Facebook pages. Additionally, around 2428 min of video of TV interviews featuring founders, customer reviews, and product descriptions were viewed and transcribed. The triangulation process of data from multiple sources was undertaken to increase the reliability of the study (Gibbert et al., 2008).

3.4. Data analysis

The data analysis approach used in this study is inductive in nature, which has its roots in the philosophical discipline of pragmatism (Gioia et al., 2013; Locke, 2007). An inductive approach was useful to assess the imperative ideas expressed by the respondents in relation to the available literature on co-creation and frugal innovation. Data Analysis was performed using the NVivo software to code and organise extensive qualitative data. The interview data was coded into various themes that pertained to the research questions, which resulted in the emergence of trends, patterns, and relationships within the data. Fig. 1 illustrates the data structure. This allowed the authors to grasp a deeper understanding of the co-creative processes of innovation and how they enabled frugal innovation development in each case. The transcripts were coded and

then compared in an iterative process going back and forth between data and emergent themes (Locke, 2000). A total of 32 first-order codes were formed. For instance, the statements such as “Instead of publishing advertisement and spending money, we self-create news” and “all of us who are working in this organization are volunteers” were combined to form the first-order code of ‘Integrating soft resources for cost reduction.’ Similarly, comments such as “we are keeping design simple so that cost is less” and “As a manufacture we don't want to put our hands into everything” were pooled to form a first-order code of ‘Stakeholder collaborations for product simplicity’.

Next, axial coding was performed (Gioia et al. 2013) to identify the relationship between different first-order constructs to consolidate them into second-order theoretical categories to progress the analysis to a higher level of abstraction. Ultimately, 8 s-order categories were formed. In the next step, core concepts regarding co-creation and frugal innovation from the literature were aligned with the second-order categories to create higher-level aggregated dimensions around three core elements of frugal innovation, namely, enhanced functionality, cost reduction, and serving low-end market. The last step comprised of conceptualising the connection between these aggregate dimensions and how they interacted to form a logical framework of co-creating frugal innovation (Fig. 2). We have developed a comprehensive understanding of co-creation as tabulated in Appendix A including some key factors, namely co-creation partners and their motivations and roles along with outcomes of co-creating frugal innovation.

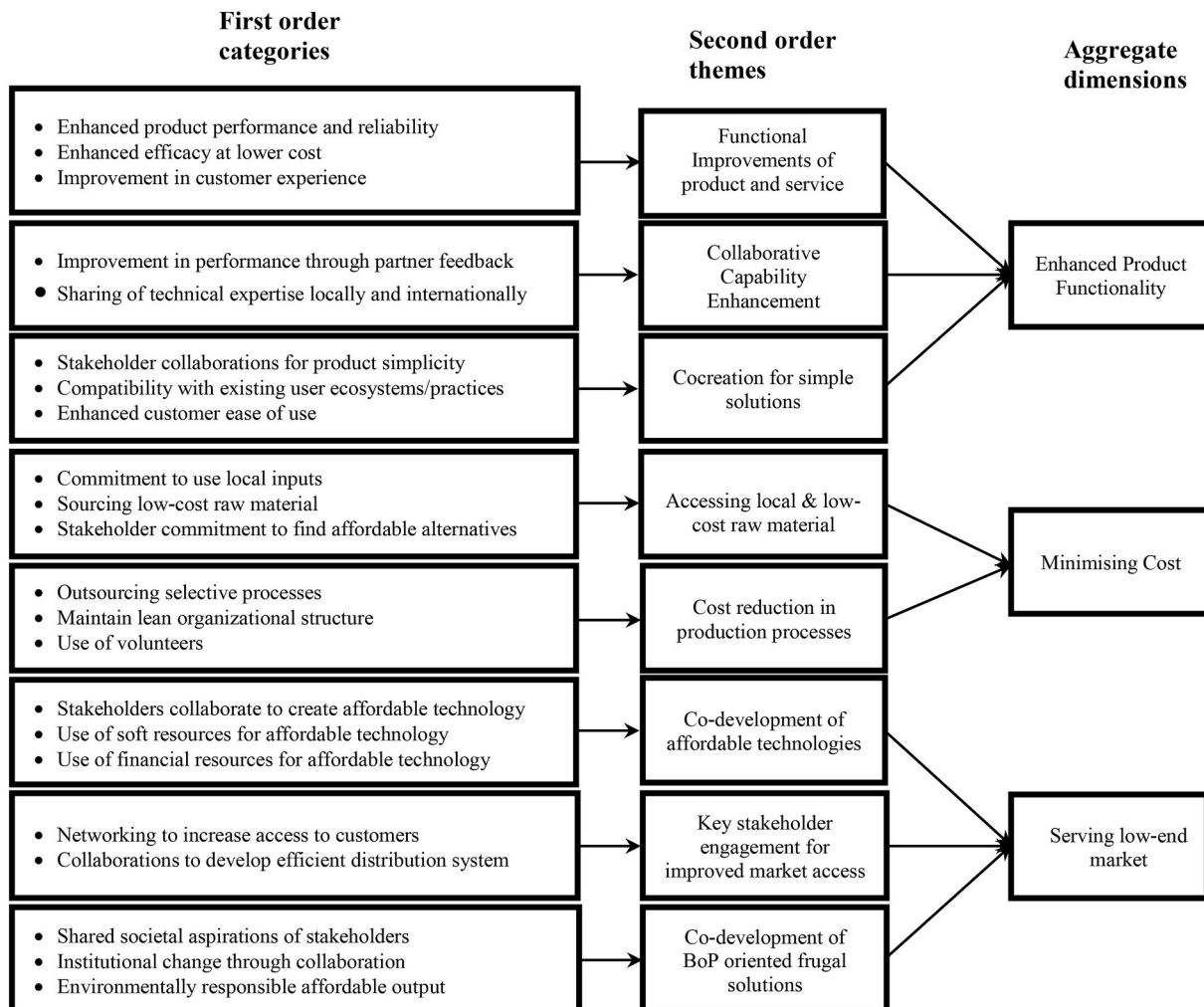


Fig. 1. Data structure.

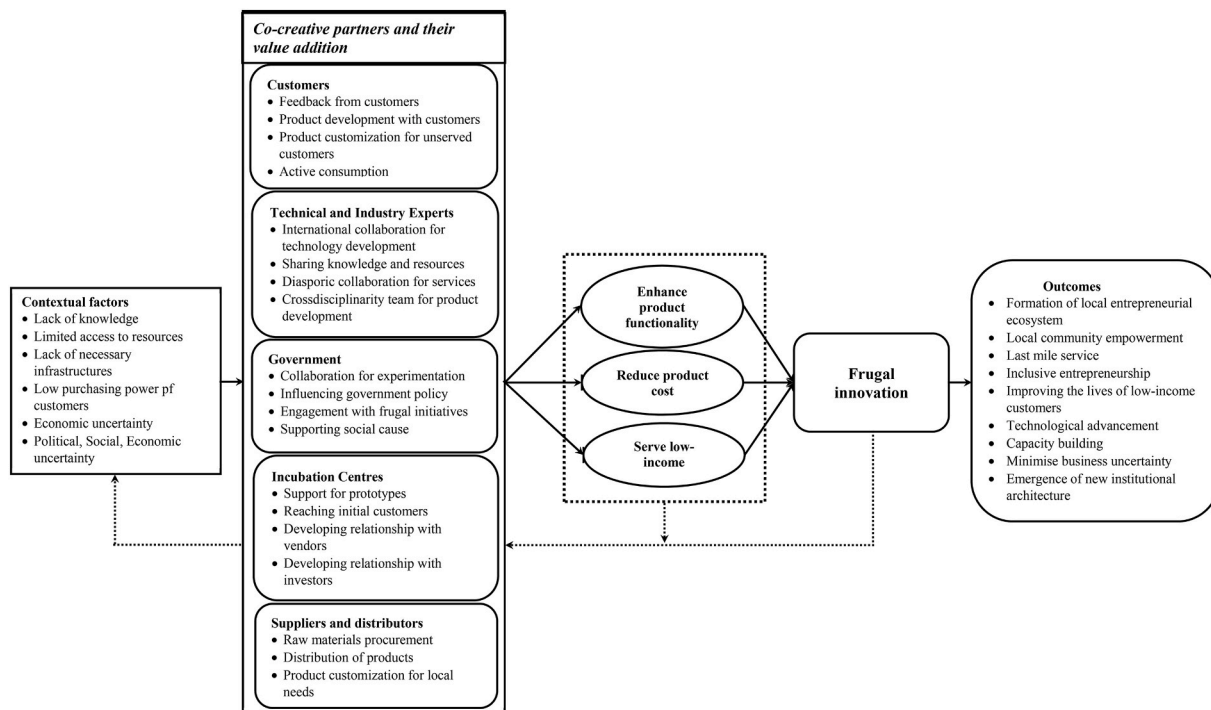


Fig. 2. Co-creating frugal innovation process.

4. Findings

Fig. 1 illustrates the comprehensive data structure, embodying the theoretical constructs derived from the empirical evidence through a rigorous, iterative process. Our analysis identified three overarching dimensions: enhanced product functionality, minimising cost, and catering to the needs of the BoP customers. The aggregate dimension of enhanced product functionality encompasses a spectrum of second order themes, namely functional improvement of product and services, collaborative capacity enhancement, and co-creation for simple solutions. The second aggregate dimension, cost minimization, involves strategies such as the utilization of local and economic materials, coupled with initiatives aimed at the reduction of production costs. The final aggregate dimension of serving low-income customers delineates the strategies employed by firms to collaboratively develop cost-effective technologies, engage key stakeholders to gain market access and co-developing BoP-oriented solutions. We provide a detailed exposition of our findings in the ensuing subsections.

4.1. Enhanced product functionality

As a result, of the efforts of the actors, new frugal outputs were created that show marked improvements in product performance compared to alternative products available in the market. For the users of Jolta's electric bike, for example, improved mileage, low maintenance cost and better affordability of the bike were key product improvements. Likewise, the health benefits and sustainable nature of the sanitary pads developed by Daisy offered women a new solution for their hygiene problems hitherto unavailable in the market at a comparable price as described by the owner:

“Women really prefer this over other products because it feels softer, more natural and absorbs better ... we use biodegradable materials, and we try to make it environmentally friendly. And see that our products don't have the chemicals that would damage the health of the women like other products.” (Founder of Daisy)

For ModulusTech, it was the affordability, short construction time, and sturdiness of their housing solutions which made their product better than existing alternative. Similarly, EzShifa, provided a reliable healthcare access at affordable rates to people in remote locations that otherwise lacked access to trained doctors.

“The objective of the main box is primary health care. What it does is that the poor can easily avail the basic health care facilities and consult a GP doctor through the machine installed. Then the GP refers you to other doctors on an as needed basis.” (Founder of EZShifa)

Economia and Jaguar both created sustainable transportation solutions using electric vehicle technology while keeping the needs of the local customer at the forefront of their innovations. This enabled these companies to create customized solutions that were much better suited, more cost effective and reliable for local needs compared to imported technologies. The targeted nature of these innovations led to greatly enhancing the customer experience for their users. Economia understood that the lower income users in Pakistan use bikes to transport large families as well as household goods. Most imported solutions rely on installing hub motors in the rear which makes load balancing difficult and compromises performance. They instead opted to install a mid-drive system that replaces the engine with an electric motor that connects to existing transmission while keeping the gears and clutch functional. The founder of Economia explained:

“Our customers often travel with family members or carry household goods—sometimes three people on a single bike, which is common in Pakistan. Hub-motor electric bikes cannot manage this kind of load, but our system performs reliably under these conditions. We have even demonstrated this by riding with three passengers while climbing a bridge. This load-handling capability is something other manufacturers currently cannot offer.”. (Founder of Economia)

Founders in the study addressed high levels of technological, market, and institutional uncertainty involved in developing frugal innovations for BoP markets through continuous engagement with users and stakeholders. Across cases, entrepreneurs described deploying pilot projects,

minimum viable products, and trial installations to test assumptions in real-world settings. This iterative learning-by-doing enabled firms to identify usability issues, adapt technologies to local contexts, and reduce adoption barriers among low-income users. Additionally, actively incorporating the suggestions of users and experts enabled improvement in product functionality. This joint problem solving was clearly evident in the case of Jaan Pak who after extensive user feedback realized that imported stove technologies were not meeting the culinary needs of their local customers and worked with a local fabricator to come up with a stove design that offered lower combustion temperatures to meet local cooking needs that suited Pakistani cooking better than advanced stoves. In the case of ModulusTech, incubation support facilitated connections with a corporate client that provided funding as well as a testing opportunity in an extreme environment, allowing the startup to conduct early trial runs, gather performance feedback, and iteratively refine its prefabricated housing solution. As explained by the founder of ModulusTech:

“Nest I/O gave us the opportunities, and access we needed. Through their network, we secured our first customer—a coal mining project in the Thar desert—which allowed us to test our product in extremely challenging conditions. That trial helped us improve the product significantly.”
(Founder, ModulusTech)

Collaborative engagement with local and international technical experts and institutional stakeholders enabled the startups to enhance their innovation capacities beyond internal resource constraints through continuous knowledge sharing and joint problem-solving. This collaborative capacity enhancement strengthened design capabilities, accelerated learning, and enabled the refinement of core technologies, ultimately resulting in more robust, reliable, and higher-performing frugal products. The founders of EzShifa mobilized the Pakistani diaspora mainly based in North America and the UK, collaborating with many international doctors of Pakistani origin to provide digital consultations through their kiosks to patients living in remote areas of Pakistan (see Table 2 for more evidence). The founder of Byonyks had spent several years working in the American medical sales industry and mobilized his professional network to gather like-minded people who invested their skills, capital, and capabilities to develop a painless and affordable dialysis solution for the low-income segment. These collaborations included leading industrial experts, healthcare professionals, and scientists based in the USA and the UK. The technical skills and knowledge of these international collaborators coupled with the contextualized understanding of the local market by the founder helped them co-create an affordable local alternative for dialysis instead of importing expensive preexisting international solutions.

“I bought in friends Mike, Eric and Dr. Frank Rudolph and before coming to Pakistan I talked to them and said I need you to come to Pakistan with me and my kids and help me build the product to save life. They helped to build the company, product and all.” (Founder of Byonyks)

In a similar vein, Jaguar relied heavily on local talent and academic networks to refine their product development activities as expressed by their founder:

“We hired technicians and university experts from different universities and brought them here to develop our R&D lab. After experimentation, they developed the product on-site.”

In certain cases, co-creation also manifested itself in shaping the firm's growth strategy through the role of mentors and network partners in guiding where and how the founders chose to expand. Instead of only giving technical advice, these co-creation partners became part of the process of deciding what a sustainable growth path should look like. As a

Table 2
Exemplar quotations for enhanced functionality.

Improvement of Product and Service	Collaboration for Enhanced performance	Cocreation for Simple Products
<p>ModulusTech <i>Our structure is more sustainable and takes less time. It's one of the fastest building methodologies in the world. So, our prototype can stand in 3 h which has a room.</i> (Founder of ModulusTech)</p>	<p>Daisy <i>Every time we prepare a new design for the product I would kind of try it out on different people, right so I'd ask different people to use the product and then tell me what they think about it and then also compare it to the previous design that I had.</i> (Founder of Daisy)</p>	<p>Byonyks <i>Peritoneal dialysis is comparatively simple so that the patients can do it themselves, it is a very simple process, you can do it at home after 2 weeks of training.</i> (Patient of Byonyks)</p>
<p>Byonyks <i>The beauty of the device is that it is much cheaper than the alternatives available abroad product which is 20-25 lacs (\$1300 - \$1600) but this one will be 3-4lacs (\$1900 - \$2600) ... So far there has been no adverse effect, and it is for patients who don't have any chance of surviving and for those who can't rely on hemo dialysis either.</i> (Founder of Byonyks)</p>	<p>Jolta Electric <i>We wanted people to use the bike and give feedback ... We started BLDC manufacturing in Pakistan; we collected raw material from local and international suppliers from wherever we got.</i> (Founder of Jolta Electric)</p>	<p>Jolta Electric <i>Initially we used the same design (as CD70) due to cost effectiveness, there is already an after sale for parts in this design (in the Pakistani market). If people won't be able to find the damaged parts, then it is a loss for them.</i> (Founder of Jolta Electric)</p>
<p>PakVitae <i>A simple filter that can be attached to any pump or tap which is better quality and cheaper than live straw. We modulated our filter in a multipurpose fashion so that it can be placed on anything.</i> (Founder of PakVitae)</p>	<p>Pak Vitae <i>We wrote to different experts online, wrote to factories. Read different research papers. We would make these combinations and send to factories to make a sample ... We met a professor, working on nano tubes. We modified that and used it.</i> (Founder of PakVitae)</p>	<p>Modulus Tech <i>The windows and doors etc, are standardised. Even the wall sections are standardised to keep it affordable, but we can change the map.</i> (Founder of ModulusTech)</p>

result, the startup's strategy developed through ongoing discussions between the founder and their network, especially around the need to build strong revenues before focusing on wider social impact. As the founder of Bioniks explained,

“So when you are designing a growth plan, it's really important to discuss it with your mentors and your network to identify potential markets and the key decisions you need to make. For example, we were trying to grow our business in more underdeveloped countries, but our mentors told us that first you need to build strong revenue, and then you can focus on the helping part later. So now we have decided to build our startup in the US, and then we will move toward the countries that are actually in need of these prosthetics”.

The founders of the firms studied in this research created networks that could enhance the user-friendliness of the products for customers at the BoP with less technology literacy. EzShifa's healthcare kiosk for example, not only provided quality primary healthcare facilities in remote locations but the process was further aided through the provision of a trained assistant at each location that could assist the BOP patients in availing the facility. This staff was provided by the franchisees of the business and helped patients overcome barriers regarding language and technology literacy and ensured their problems were correctly communicated to the medical practitioners and the medical assistance was properly understood by them. In a similar vein the following quote from the founder of Brighterlite; that provides affordable off-grid solar

solutions to combat electricity shortage in rural areas, demonstrates how they used packaging to facilitate user understanding for their product.

“We designed the product in one simple package, with instructions in Urdu and local languages, so people don’t need technical knowledge.” (Founder of Brighterlite)

Similarly, the water filters developed by PakVitae were designed keeping in view the ease of their integration with conventional taps already being used by households in Pakistan. These were detachable water filters that could easily latch onto an existing water tap and hence required minimal adaptation on the part of the user. The antibacterial nature of the product enhanced its longevity and required minimal up-keep. The simplicity inherent to PakVitae’s product design was an outcome of their collaborations with international scientists and some local academicians who they collaborated with during the initial phases of product development.

“If there is no ease for people, they won’t do it. If it’s more time consuming, there is less usage. I thought of the solution in 2018 and started to research. Fundamentally our approach was to make membrane anti-bacterial.” (Founder of PakVitae)

In the case of both Jolta and Jaguar, while the founders developed a proprietary electric kit for their bikes with the aid of their industrial connections in China, they kept the overall shape and design of the bike extremely simple and adhered to convention. They did not innovate much around the design of the product as such, owing to their focus on product simplicity. While the dealers of their bikes helped Jolta to understand customer preferences, vendors helped them with the overall design of their electric bike as well as assisted them with the designing and manufacturing of its sub-components. These collaborative efforts ultimately led to a locally made, affordable, simple, and environmentally friendly alternative of the gasoline bike. As stated by a founder of Jolta Electric while commenting on the importance of their collaboration with vendors:

“Initially, we used the same design due to cost effectiveness. Our suppliers and dealers said there are already after-sales services and spare parts for the existing bikes. So, we used the same design and just added our electric kit to it. We manufacture motors and batteries in-house. All the other components are supplied by vendors”. (Founder of Jolta)

Similarly, as commented by the founder of Jaguar while explaining the design of their electric bikes:

“The design is that of the traditional petrol bike, and we have kept that because the spare parts are readily available in Pakistan. Any consumer, even from the furthest areas of Pakistan, can repair it at a very cheap cost.” (Founder of Jaguar)

4.2. Minimising cost

Cost reduction emerged as a central aggregate dimension underpinning the feasibility and scalability of frugal innovations in resource-constrained contexts (see Table 3). Rather than being treated as a downstream outcome, cost reduction was actively pursued through deliberate design, sourcing, and organizational choices made early in the innovation process. In all cases, the co-creation process began with the commitment of the firms to use local raw materials as much as possible. They reduced costs in production by outsourcing and through organizational processes. Together, these mechanisms enabled ventures to offer affordable solutions while maintaining functional adequacy for bottom of the pyramid users. In doing so, the objective of the founders was not only to reduce costs and ensure supply reliability, but also to promote the local economy. It led these firms to build partnerships with local vendors and suppliers, gaining commitment for the provision of reliable and cheaper raw material. Most of the founders in our study created feedback loops with their raw material suppliers which ensured

Table 3
Exemplar quotations for reducing cost.

Accessing local and low-cost raw material	Cost Reduction in production processes
<p>Byonyks <i>We use local companies for the mixture of sugar, salt and water needed for dialysis, and are making these liquids locally, so the price of the liquid is half as compared to the imported ones. (Founder of Byonyks)</i></p> <p>EzShifa <i>The manufacturing of kiosk is in Pakistan ... There is basically most of the stuff assembled in Pakistan as we want to create that industry in Pakistan. Most stuff we use is off the shelf like screens and devices, but they are medically approved. (Founder of EzShifa)</i></p> <p>Daisy <i>I get the material from either Lahore or the outskirts of Lahore. Like, for every part, for every material, we have to go to different markets. The materials that I use are local so that saves up on any transport costs. I only pay for the quality of it. (Founder of Daisy)</i></p>	<p>ModulusTech <i>We worked on some utilities, flatpack system that is the intermesh and assembly methodology ... it is the man to machine ratio and how we industrialise, how it takes less time to set up the houses, how you can ship the houses, more sets in the same shipping, we optimised the material use, so less material is used. (Founder of ModulusTech)</i></p> <p>PakVitae <i>Fundamentally we use 4 times less membrane, so cost is less. Membrane cost is less, body size, bottle size, everything is less. Manufacturing time is less, and cost is reduced ... When we went to China, the membrane making factories were not very good. So, we upgraded the machines of the factories where our membrane is produced. So, they charge us less. (Founder of PakVitae)</i></p>

continuous exchange of technical knowledge and market information resulting in the capacity building of both the suppliers and the start-ups. Long-term partnerships with vendors, for example, were a key aspect of a frugal product development, especially for ModulusTech, Daisy, Jolta, Jaguar, JaanPak and PakVitae, since the performance and cost of their final products relied heavily on the quality of the material as well as the feedback provided by their vendors. As stated by the founder of Jolta:

“90% parts are made locally. There was already a market for parts, so we just started. For the kit 90% parts are available and only 10% are imported from China and Korea. There was already a market, and we just added our electric bike to it.”

A similar sentiment was expressed by the founder of Economia who designed and manufactured the motor and kit for their EV bikes locally. 95% of their electric bike based on indigenous components except for lithium-ion batteries. The founder expressed his views on why use of local components was key in creating a frugal solution:

“When you have local technology, you save foreign exchange and reduce inventory time from three to four months to just ten to fifteen days. Importing parts makes the product financially unfeasible for local manufacturing. (Founder of Economia)

In the case of Jaan Pakistan, the founders initially experimented with importing internationally available clean cookstoves to Pakistan. However, these solutions proved both functionally unsuitable and economically unviable for low-income households. Imported products quickly exceeded the purchasing power of target users once taxes and logistics costs were accounted for. This prompted a strategic pivot toward developing an indigenous solution using locally available materials and fabrication capabilities. They experimented with using secondhand materials but scraped this idea because it was compromising the quality of the product showing that cost reduction through local sourcing was not pursued at the expense of product integrity. By working with domestic fabricators in Lahore and sourcing materials such as mild steel sheets locally, Jaan Pakistan was able to avoid import-related costs while maintaining greater control over production expenses.

“We considered using second-hand materials from the market, but that was meddling with standardization ... so we couldn’t use oil containers or barrels. We had to use new sheet metal ... mostly mild steel, 16-gauge mild steel sheets, and we found a local fabricator in Lahore.” (Founder of JaanPak)

Collaborations with local vendors, fabricators, and ecosystem actors supported experimentation with cost-efficient materials and designs. These stakeholders were not passive suppliers but active contributors to the process of identifying feasible material substitutes and production methods that balanced cost with functional performance. The founders of ModulusTech frequently consulted their vendors while designing their prefabricated housing solutions to optimize the architectural and manufacturing aspects of their product. The team shared their design problems with their vendors who were able to suggest better materials depending on the project's needs and specifications.

"We push them for ideas, and they visit us and take interest in our project. They do add extra machinery or extra resources for our product as well. Maybe keep it in warehouse for extra time. They see the long business partnership not as a one-time order. They are sold on our vision and purpose." (Founder of ModulusTech)

Additionally, firms pursuing frugal innovation came up with innovative combinations of internal and external resources to achieve frugality in their respective products. It involved decisions around keeping only the most fundamental aspects of production in house, bringing in consultants for specific tasks and limited time, streamlining procurement, and designing technologies that were cost-effective through the entire cycle of manufacturing and delivery.

"We work with outsourcing parties. We have a better cost margin better than the market. Membrane manufacture in China and RND is in Singapore, but we are shifting labor to Pakistan to reduce cost. In Pakistan we are doing free membrane development and testing in Comsats." (Founder of PakVitae)

Similarly, for Bioniks, cost reduction primarily occurred through process-level frugality rather than material substitution and modularizing its manufacturing processes. As explained by their founder:

"We've broken down our manufacturing process into smaller chunks so we can focus on major things rather than manufacturing the whole prosthetic by ourselves."

Similarly, a simple product design and an optimum mix of in-house and outsourced components by Byonyks made the production of their dialysis machine very cost-effective. As commented by the founder of Byonyks:

"My charity is to bring the price of the product low so that people can buy it, and my frugality was in the selection of the components and raw materials I challenged one of the finest mechanical engineers, and we put together our first machine in just USD 750".

Lean organisational structures were mainly composed of multi-taskers, performing a myriad of functions for the organization. Founders and early team members frequently wore multiple hats, simultaneously engaging in product development, field testing, customer acquisition, and fundraising. This reduced overhead costs and allowed firms to allocate scarce financial resources toward core activities such as prototyping and market experimentation. Lean structures also facilitated faster decision-making, enabling firms to adapt production and design choices in response to user feedback without incurring bureaucratic delays. Several startups relied heavily on interns, volunteers, and rotating roles rather than permanent staff, particularly during early stages. For example, GirlyThings operated with a small core team supplemented by interns who supported packaging, social media, and delivery functions, allowing the venture to continue operations despite limited financial resources. Similarly in the case of Bioniks the integration of technology and automation reduced human labor and allowed them to maintain a lean and flat organizational structure.

"It's mostly a flat hierarchy ... everybody can come directly to us if they have any innovation or idea ... we try to integrate a lot of technology and

keep the human effort minimum. And that is the only reason why we are able to reduce the cost." (Founder of Bioniks)

The use of volunteers, interns, and fellows also played a critical role in reducing operational costs, particularly during the nascent stages of venture development. Several founders described deliberately engaging students and early-career individuals who were motivated by learning opportunities, social impact, or field exposure rather than financial compensation. In Jaan Pakistan, large cohorts of interns supported extensive field research, community engagement, and early testing efforts. This enabled the firm to conduct geographically dispersed experimentation and data collection that would otherwise have been prohibitively expensive. Furthermore, as evident in the case of Daisy, while the use of social media and word-of-mouth as main promotional channels helped the start-up to significantly reduce their marketing cost, their use individual volunteers for product distribution enabled them to keep the logistical cost low.

"One of the major saves in cost is that all of us who are working in this organization are volunteers. We don't take anything at all and just channel it back into the organization." (Founder of Daisy)

While reliance on volunteer and intern labor introduced challenges related to continuity and skill variability, founders viewed this trade-off as necessary for survival in the absence of substantial funding. Importantly, this approach aligned with a broader ethos of frugality and effectuation, where ventures leveraged available human and social resources to compensate for financial limitations.

4.3. Serving low-income customers at BoP

We found that the integration of innovative technologies served as a central enabler of frugal innovation across nearly all cases examined in this study. In most of the cases, the primary source of innovation was proprietary technology, developed by the founders in collaboration with a diverse set of stakeholders. The development of this proprietary technology was an outcome of multifaceted co-creation processes, starting from the formalization of commitments between different stakeholders, including founders, local and international partners, customers as well as government and non-government agencies that chose to collaborate for the development of a new and unique solution. Through these co-creative activities, stakeholders contributed not only technical expertise but also financial and physical resources, collectively supporting the technology development efforts of these firms.

The founder of Daisy worked with Indian companies and used their insight to come up with a unique technology of sanitary pads that were biodegradable, chemical-free, and organic as compared to the synthetic products that were available in the market.

"I reached out to a few companies in India who were doing something similar for advice to see what materials they were using. I think that they really helped me kind of design the product. I used that as inspiration to find alternatives that were present in Pakistan." (Founder of Daisy)

EzShifa collaborated with doctors, who provided key insights regarding primary healthcare and combined it with their own skills in software design as well as hit and trial to create a kiosk that provided virtual healthcare services at affordable rates in remote locations. Similarly, the founders of Bioniks collaborated with medical experts for their prosthetics technology development as shared by their founder:

"We had a lot of doctors on board so that they were giving us their feedback regarding how we can work on that. And they were elaborating about the muscles, movement, and neural network. We have all those technological players around us."

PakVitae, meanwhile, garnered support from local researchers and international scientists working in the field of hollow fiber membranes to co-create the antibacterial hollow fiber membrane technology for its

Table 4
Exemplar quotations for serving the BoP customers.

Co-development of affordable technology	Stakeholder engagement for market access	Co-development of frugal solution for BoP
<p>ModulusTech We made an intermesh technology. It's like we optimize the man to machine ratio ... We work like an auto mobile structure; different people make different structures and then we bring it all together. (Founder of ModulusTech)</p>	<p>ModulusTech "We saw private mortgage companies who were focused on providing mortgage to needy people, so we contacted them. Now we are buying land and building houses privately. From direct sale model we are becoming developers and providing land to the mortgage company." (Founder of ModulusTech)</p>	<p>ModulusTech We do mortgage system. Household income is more than 40,000 per month. We work with private mortgage system companies. We provide mortgage and arrange it for them in affordable housing. (Founder of ModulusTech)</p>
<p>PakVitae He (South Korean Membrane maker) was the most helpful person; he helped us change our design and perfect our membrane ... The machine only made fiber, and the bodies were made by Chinese mold companies ... We started with quotations and then asked companies for samples and ran our experiments and then fixed the product. (Founder of PakVitae)</p>	<p>Byonyks From the beginning we have made contacts with doctors, and we have products and patients that we are evaluating and right from the beginning we are making connections from across the globe to ensure that we have a good network of doctors. (Founder of Byonyks)</p>	<p>Byonyks One of our doctors is working for 3 years and we have never paid a dollar to him. Even in America there is a volunteer group who are working passionately. (Founder of Byonyks)</p>
<p>Jolta We worked on core parts and travelled to China and Korea to study technology and core components. (Founder of Jolta Electric)</p>	<p>PakVitae "A long relationship with the retailers, like have a personal family relationship with the owner. He will keep it on the main shelf even if it doesn't sell." (Founder of Pak Vitae)</p>	<p>EzShifa He (Dr. Abbas from UK, running a charity clinic in Mianwali signed the kiosk right away too. He is giving 2 h per day and viewing his patients through the kiosk and managing the clinic and doctors through it. (Founder of EzShifa)</p>

water filters (See Table 4 for more evidence). As expressed by a co-founder of PakVitae:

"He (Singaporean professor) was a membrane scientist, and he went out of his way to help us. He taught us many things about membrane technology and gave us access to a lab in Singapore for prototyping. He also invited us to Singapore and introduced us to the founder of a similar start-up at his university. All of this was a breakthrough for us!"

Apart from soft resources, stakeholders also contributed financial resources to further the frugal innovations for BoP customers due to their shared vision of solving pressing problems. Startups mobilized stakeholder-provided financial resources including grants, angel investments, subsidized testing services, soft loans, and early-stage competition funding to enable the development of affordable technologies. These financial inputs allowed firms to prototype, test, and iterate without transferring high R&D risks to end users. PakVitae, ModulusTech and JaanPak all received competition funding to accelerate product development. Whereas Bioniks, Daisy as well as Modulustech received grants from local and international organizations as well. Pak-Vitae also received free testing services from Pakistan Council of Scientific and Industrial Research for \$9000.

"We won the Grand Challenges Canada grant for \$100,000 ... then the Dubai Expo Live Impact Award ... another \$50,000 during the pandemic." (Founder of JaanPak)

"Save the Child Foundation gave us some funding ... to design machinery and do camps." (Founder of Daisy)

Another factor that made it possible for these businesses to serve low-end markets was their use of partnerships with certain external stakeholders who helped them distribute their products to customers living in remote areas. The key point here was recognising key stakeholders who could join the venture providing maximum value with less cost. Indeed, the quality of frugal innovation directly relied on the quality of the stakeholders. Daisy, for example, leveraged their partnership with a local NGO not only to address social taboos around menstrual hygiene by conducting educational camps for local women, but also leverage its network to sell their sanitary pads to women living in extremely remote areas of Sindh and Baluchistan through this collaboration.

"We offer really subsidised amount to NGOs. We sell for 150 PKR on the online website and then the profits go into subsidies. And then when we give them to NGOs, for 100 rupees per packet." (Founder of Daisy)

Brighterlite used stakeholder partnerships with a local telecom provider (Telecom) to optimize payment collection and financial efficiency. This was key since they were trying to provide energy solutions to remote villages which comprised a hard-to-reach population. Easypaisa is a local digital financial solution used by low income and low literacy users that enables them to make payments through their mobile devices and does not require bank accounts and has achieved widespread adoption given the high mobile penetration and large unbanked population in Pakistan.

"We collaborated with Telenor for integrating EasyPaisa, which made it possible for customers to pay digitally, reducing collection costs and making payments seamless."

In the case of ModulusTech, it was their partnership with certain private mortgage companies that was extremely pivotal for their success. These mortgage companies, under a special arrangement, provided loans to low-income families to purchase of portable houses from ModulusTech. As described by its founder:

"We partnered with one of these mortgage companies who find people in remote areas willing to buy a house. They give them loans and we build the house".

EzShifa used a franchising model to reach communities living in very remote areas of Pakistan. Following a franchising model, they offered local individuals the opportunity to become partners by installing their healthcare kiosks in different locations. The franchisee would find a suitable location for its installation and manage its daily operations. Meanwhile, EzShifa would provide marketing support to the franchisee and ensure the availability of doctors for at least 50 digital consultations in a day. Onboarding local partners enabled EzShifa to minimize their fixed costs and increase the operational efficiency of their healthcare solution.

"We have a franchising model; we sell them a kiosk in one time at 300,000 and we do the marketing and all too ... We ask the person to make the entrance fee, but we take 40% of it. and we will manage the doctors and book them in accordance with the demanded time slots." (Founder of EzShifa)

The evidence from all twelve cases points towards an initial phase of commitment formation between various actors in the ecosystem

including the founders, government agencies, non-government organizations, and vendors that join forces because of mutually shared intentions guided by social aspirations. Founders in multiple cases emphasized personal sacrifice and frugality as a means of signaling credibility and moral legitimacy to their partners. This signaling included foregoing salaries, working with volunteer teams, and accepting delayed returns in order to demonstrate commitment to the venture's mission. Such practices encouraged doctors, engineers, suppliers, and local partners to contribute expertise and resources on a pro-bono or symbolic basis. This was explained by the founder or *GirllyThings*:

"Sometimes you don't pay yourself and you keep trying because you don't have enough money. (Founder of GirllyThings)"

In the case of *ModulusTech*, this involved the shared aspiration of the founders who wanted to solve the Syrian humanitarian crisis by creating affordable housing for low-income customers. In this entrepreneurial pursuit, they were supported by a local incubation center in prototype designing and reaching initial customers willing to pay for their products. They utilised their engineering knowledge to develop a basic but efficient assembly and packing methodology known as *intermesh* and harbored key relationships with various vendors that could provide essential housing components to create a new highly affordable and local housing solution.

Across cases, collaboration with diverse stakeholders contributed to incremental institutional change by reshaping how frugal innovations were recognized, supported, and governed within existing ecosystems. Through engagement with public agencies, regulatory bodies, incubators, donors, and large corporate actors, startups were able to challenge dominant assumptions about appropriate technologies for BoP contexts and gain legitimacy for locally developed solutions. Rather than formal policy reform, institutional change occurred through cumulative shifts in practices, norms, and expectations, allowing frugal solutions to be developed, tested, and disseminated within previously restrictive institutional environments.

In the case of *Economia*, collaboration with public research institutions and government ministries enabled regulatory approvals, pilot deployments, and minister-level endorsement for electric vehicle retrofitting, contributing to the gradual legitimization of EV technologies within an otherwise weakly regulated institutional environment. Similarly, the success of the frugal solution created by *ModulusTech* garnered them government attention and support as evidenced below:

"We got attention from policy makers, investors, and governments ... the new government announced that he wants to work with startups, and he announced an agenda to work on housing." (Founder of ModulusTech)"

Similarly, the efforts of *JaanPak* led to normative change, their free trials shaped future dissemination practices and led to NGOs and donors accepting locally developed cookstoves as valid alternatives to imported gold standard technologies.

Furthermore, affordability was achieved alongside deliberate efforts to minimize social and environmental externalities through product and process design. Sustainability was directly embedded in to the design of frugal solutions, such as reducing material waste, limiting pollution, and avoiding environmentally harmful substitutes. These design choices enabled startups to deliver low-cost products that addressed essential needs while reducing negative environmental impacts relative to conventional alternatives. *Daisy* created biodegradable pads that reduced environmental waste, *ModulusTech* reduced the environmental pollutants and water wastage of traditional construction process through their *intermesh* technology where as both *JaanPak* and *Brighterlite* created environmentally friendly alternatives for kerosene burning stoves and lamps.

5. Discussion and conclusion

Our findings yield several insights into the co-creative process underlying frugal innovation. First, frugal innovation emerges through sustained collaboration among diverse stakeholders such as government actors, customers, suppliers, and technical experts who jointly mobilize resources and knowledge to address the needs of Bottom of the Pyramid customers (Frow et al., 2015; Payne et al., 2008). Second, co-creation functions as a mechanism for overcoming resource scarcity and institutional constraints, enabling entrepreneurs to enhance product functionality, reduce costs, and improve market access (Hossain et al., 2016; Welter and Baker, 2021). Third, these collaborative processes generate broader outcomes beyond the focal innovation, including ecosystem development, community empowerment, capacity building, and reduced uncertainty. Together, our findings show that frugal innovation is shaped by the integration of functionality, cost minimization, and serving low-income customers, and unfolds through an iterative, non-linear, and adaptive co-creation process (Hossain et al., 2016).

5.1. Theoretical implications

This study adds fresh theoretical perspectives to the frugal innovation discourse, by uniquely integrating the concepts of co-creation and frugal innovation, providing a richer understanding of the process of innovation at the BoP. More specifically, we considered a specific portion of emerging market population with low income as a BoP market. While prior research has acknowledged the collaborative nature of frugal innovation (Bhattacharjya et al., 2023; De Marchi et al., 2022), this study is among the first to deeply explore the co-creative mechanisms that underpin its development, particularly in an emerging market as a BoP market. Unlike previous studies that primarily see frugal innovation as a result of internal organisational efforts, this integration of the two theoretical perspectives shows that frugal innovation is an intrinsically collective process that requires active collaboration of multiple stakeholders who aspire to serve BoP markets. Our findings show that entrepreneurs in emerging markets provide more affordable technological innovations with some frugal elements (Chakravarty, 2022). We demonstrate how co-creating frugal innovation process enables stakeholders to identify issues, make sense of complex situations, and collectively develop affordable solutions.

By contextualising co-creation within resource-constrained settings, the study advances the co-creation literature by showcasing how collaborative mechanisms function as enablers of frugal innovation, allowing stakeholders to overcome resource limitations through leveraging shared aspirations and partnerships, motivated by the intention to serve BoP people. We elucidate specific co-creation mechanisms – such as collaborative product development, stakeholder engagement, and the integration of local knowledge – through which frugal innovations are developed to cater the needs of the BoP customers. Our research demonstrates how start-ups form collaborative networks, and how those networks provide access to essential resources, knowledge, and capabilities that might otherwise be inaccessible due to institutional limitations. While prior studies have touched on the BoP context (e.g., Gobble, 2017; Hossain, 2018; Park et al., 2022), this work uniquely focuses on the co-creative frugal innovation mechanisms at the specific context of emerging markets' BoP. This theoretical approach enables us to contextualise co-creative frugal innovation as an interesting phenomenon in emerging markets. The involvement of different like-minded stakeholders in a co-creative process of innovation is shown to reduce cost, enhance the performance of frugal solutions, resulting in improved product functionality and reduced costs. As a result, our study challenges the traditional linear model of innovation by showcasing the iterative and inclusive nature of co-creating frugal innovations (Hossain, 2018).

This study also advances the co-creation literature by integrating it with the frugal innovation literature considering contextual aspects

which provides a deeper understanding of a specific context where addressing issues requires a collaborative approach acknowledging the increasing importance of context in research (Shirokova et al., 2023; Welter and Baker, 2021).

Furthermore, this research illustrates that co-creative entrepreneurship enables essential mechanisms for tackling societal and economic issues in underprivileged communities (Hossain, 2021; Levänen et al., 2022), thereby broadening the theoretical perspective of co-creation and frugal innovation in the contexts where resource limitations and affordability are critical factors.

5.2. Managerial implications

This study offers several implications for managers. First, frugal solutions offer a powerful pathway to tap into the vast potential of the BoP market, fostering inclusive growth while ensuring financial sustainability. Such markets typically may not appear promising for large firms due to low profit margins but can offer profitable business opportunities given their sheer size. To capitalise on the potential of such markets, however, it is imperative for managers to build solutions that are not only affordable but also accessible for BoP customers. Larger firms can broaden their market reach and promote inclusive development by emulating the frugal solutions developed by startups to cater low-income customers. For example, as demonstrated by case firms, developing simplified, easy to use and adaptable products can assist larger firms penetrate the low-end of the markets. Moreover, although the BoP typically depicts low-income customers in emerging markets, frugal solutions hold value for low-income customers in developed countries, too. Managers should explore frugal innovations to better serve these markets and broaden potential customer base. For instance, affordable sanitary pads could be invaluable for low-income customers in Western countries. This highlights the wider applicability and impact of frugal solutions beyond traditional BoP markets. Technologies can play a key role in enabling frugal innovation for managers, which can be leveraged to enhance the functionality, accessibility, and affordability of their solutions.

Undertaking of frugal innovation, however, is not a standalone challenge. As an approach to frugal innovation, co-creation is proven to be an effective process to build affordable innovative solutions despite low profit margins while maintaining financial sustainability. Utilising local knowledge and engaging with local experts and stakeholders particularly in the product development process can allow managers to understand the unique needs, constraints, and aspirations of BoP customers. Moreover, it is only through these co-creative efforts that firms can successfully gain access to local resources and BoP markets. For instance, firms can collaborate with local suppliers to identify low-cost raw materials and reduce production costs, as well as leverage the platforms of local NGOs to access marginalised populations and remote areas, as evidenced in our study. By fostering collaboration and knowledge-sharing through co-creation, managers can tap into a wealth of insights and resources in BoP markets, leading to solutions that are both affordable and accessible for the customers, while being profitable for the business. Incorporating international experts into the co-creative process can be particularly useful for firms to overcome gaps related to domain and technical knowledge needed for frugal innovation.

Despite price reductions and enhanced functionality, scaling up frugal innovations poses a significant challenge. Most frugal solutions tend to be confined to limited geographical territories. Hence, formal institutional efforts to identify, support, and scale up such solutions are pivotal. In a broader perspective, frugal innovation provides an alternative path towards more inclusive, affordable, and therefore sustainable innovation. Policymakers, therefore, should recognise the far-reaching impacts of co-creative frugal innovation and revise regulatory

institutions to support such endeavors.

5.3. Limitations and future research avenue

This study has several limitations which pave ways for future research. The current research uses a few carefully selected frugal innovation cases from Pakistan. Future research could examine more regional cases to better understand the dynamics of frugal innovation. A broader stakeholder perspective can help explaining the process of co-creating frugal innovation in a more nuanced manner. Future research could also provide benchmarks by comparing conventional mainstream innovations with frugal innovations to provide a better picture of frugality in different aspects and stages of innovation.

While the current study focused on the development of frugal solutions, future research may also study the diffusion of such solutions within and across different markets and the role of co-creative activities in facilitating this diffusion. Specific diffusion mechanisms (e.g., social networks and institutional support) or barriers to diffusion (e.g., regulatory hurdles and consumer perceptions) in this regard remain under-explored. Longitudinal studies could offer better insights about the lifecycle of frugal innovations from inception to adoption and how the role of different stakeholders evolve over time. Geographically, this study covers only Pakistan, future research may explore other south Asian countries, Africa and South America. Similarly, considering Western customers from the BoP stratum would enhance the contextual diversity of our findings. This study mostly includes early-stage companies while studying more mature companies may reveal new insights into different organisational contexts.

Our study opens many avenues for cross-disciplinary research on frugal innovation and co-creation. Social capital theory and network competence can be used to examine how businesses in institutionally constrained environments build collaborative networks and co-creative value. Also, the integration of our study's findings with socio-cultural theories such as Marxist Theory and Social Constructivism may also provide rich theoretical implications. Our study also emphasises the integration of the institutional theory into innovation discourse to dig deeper into the context of emerging markets in future research. This theory can explain how institutional arrangements in emerging markets affect start-ups' frugal innovation strategies (e.g. co-creation) at the BoP.

CRediT authorship contribution statement

Mokter Hossain: Conceptualization, Data curation, Formal analysis, Writing – original draft, Writing – review & editing. **Masoud Karami:** Conceptualization, Data curation, Supervision, Writing – original draft, Writing – review & editing. **Muhammad Shehryar Shahid:** Conceptualization, Data curation, Investigation, Methodology. **Nomah Javed:** Conceptualization, Data curation, Investigation, Writing – original draft, Writing – review & editing. **Samuel Adomako:** Conceptualization, Supervision, Writing – original draft, Writing – review & editing.

Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript. We have no financial, personal, or professional affiliations that could be perceived as influencing the work presented in this study. All authors have reviewed and approved the final version of the manuscript and affirm that no competing interests could affect the research, analysis, or conclusions drawn in this paper.

Appendix A. Case summary and their co-creating characteristics

Case (year established)	Products	Co-creation Partners	Partner Motivations	Co-creative Role	Outcomes of Co-creating Frugal Innovation
Byonyks (2017)	Bloodless home-based dialysis machine Products under development: <ul style="list-style-type: none"> • Different models of the dialysis machine and complimentary mobile application • Insulin delivery kits 	1. Founders	Personal desire of the founder to serve the underprivileged BOP customers.	Used his experience of working in the international medical industry to bring relevant local and international partners on board in the form of medical experts, engineers, and volunteer patients.	<ul style="list-style-type: none"> • Patented peritoneal dialysis technology. • DRAP (Drug Regulatory Authority of Pakistan) approved medical device. • 100% in-house designing of both mechanical and electronic components. • Use of seasoned nephrologists and other doctors as ambassadors for the product. • Equity sharing model for international technical experts. • Costs about 1/10th of the price of imported equivalents. • Very lean physical infrastructure. • Considerable reliance on from individuals and voluntary groups in the US and UK.
		2. Patients	To attain an affordable solution for dialysis that is painless and more convenient to use.	Volunteered to get the operation of dialysis delivery, obtained training tested the basic features of the product and gave their input for improvements like changing the temperature of the liquid vials.	
		3. Doctors	Provide better care for patients suffering from dialysis and increase their life expectancy.	Provided technical medical input for product creation and helped spread words in the medical community.	
		4. Employees	Contribute to delivering a frugal product to patients that are out of traditional dialysis options and create a product in the BOP customer segment that has been ignored by bigger companies.	Worked on marginal salary so most resources can be spent on research and development.	
		5. Technical Expert	Create a cost friendly dialysis solution that is one of a kind and serves people in the low-income market of Pakistan.	Used their skills to develop and prototype the product and create a solution that is 1st/10th of the price of the alternatives, effectively disrupting the hemodialysis market.	
Daisy (2016)	Eco-friendly and health- friendly sanitary napkins Products under development: <ul style="list-style-type: none"> • A range of sanitary napkins with different specifications 	1. Founder	Remove that Menstrual taboo and lack of female hygiene particularly in BOP females in Pakistan while keeping environmental consciousness in mind.	Performed market research and gathered information from international companies to prototype the product	<ul style="list-style-type: none"> • Use of local raw materials. • Very low manufacturing cost due to low mechanization. • Low fixed cost due to outsourced manufacturing. • No profit charged on products sold through NGOs. • Sanitary napkins and hygiene camps for females living in underprivileged areas to educate them on menstrual health. • Local production and manufacturing team employed from the outskirts of the city, leading to self-employment opportunities for people in remote areas. • Product design partnership with similar Indian start-ups. • Biodegradable Sanitary Pads – Made from non-toxic, chemical-free materials, including rayon and wood pulp, offering an eco-friendly alternative to conventional pads. • Affordable & Accessible Menstrual Products – Aimed at providing cost-effective menstrual hygiene to low-income women and NGO-run health camps. • Period Poverty Awareness & Education – Conducted social media campaigns and workshops on menstrual health, hygiene, and myth-busting in Pakistan. • Employment for Underprivileged Women – Created a micro-enterprise model where women from low-income backgrounds were employed in pad assembly.
		2. Volunteers/Employees	Deliver eco-friendly and organic menstrual health products to Pakistani women especially BOP underprivileged females.	Volunteered their time to contact NGOs, conduct menstrual hygiene camps, build a website, transport the product and run business operations and logistics	
		3. Customers	Obtain an essential product that is eco-friendlier and better for their health and hygiene.	Tried out different versions of the product and gave feedback for improvement	
		4. NGOs	Provide a necessity-based product for menstrual hygiene to underprivileged women.	Helped spread awareness about menstrual health through hygiene camps and distributed the product free of cost to needy parties	
		5. Donor Agency	Support a nonprofit organisation that is creating awareness regarding menstrual health and creating eco-friendly products that are affordable for BOP customers in a developing country.	Provided a large donation to the business due to their social impact and environment friendly nature of business to subsidise their product and create inventory	
		6. Eco-Friendly Business Partners	Promote the sale of biodegradable and environment friendly products.	Provided free space to feature and sell the product on their website.	
		7. Women from Low-Income Backgrounds (Pad Makers)	Employment opportunities and financial independence	Assembled pads, enabling local and cost-effective production	
		8. Social Media & Online Communities	Interest in eco-friendly products and period hygiene education	Helped expand reach, created a social impact brand, and encouraged customer engagement	
		9. Friends & Family (Early Donors)	Support a social cause and help establish an impact-driven business	Provided initial funding through donations and personal contributions	

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Case (year established)	Products	Co-creation Partners	Partner Motivations	Co-creative Role	Outcomes of Co-creating Frugal Innovation
EzShifa (2018)	<p>Technology-enabled kiosk for medical consultation [Apna Doctor] for the remote areas of Pakistan.</p> <p>Products under development:</p> <ul style="list-style-type: none"> • Kiosks with integrated power bank, ultrasound, and ECG machine • Vital screening technology using AI and computer vision, allowing non-contact health monitoring through a camera. • Expansion of Apna Doctor Kiosk, with enhanced remote diagnostic features. 	<ol style="list-style-type: none"> 1. Founders 2. Government 3. Franchisees 4. Industry Experts 5. Doctors 6. International Investor 7. Investors & Angel Funders (Adnan Siddique, Baqir Naqvi, Others) 8. NUST (National University of Science & Technology) 9. Local & International NGOs (Green Star, Amjad Saqib's Organization, Others) 10. Schools & Educational Institutions 11. Social Media & Digital Marketing Team 12. End Users (Patients, Families, Remote Communities) 	<p>Self-realization of poor primary healthcare facilities in remote areas of Pakistan.</p> <p>Provide primary health care facility in newly launched rest areas. Generate business income and provide access to quality medical advice in remote areas.</p> <p>Create social welfare by facilitating the provision of top-of-the-line primary healthcare in a convenient fashion in remote areas at an affordable price point. Provide medical advice to patients that were not accessible without this and manage system remotely with ease.</p> <p>Generate business income and create social value by providing reliable medical solutions remotely.</p> <p>Support scalable, tech-driven healthcare solutions</p> <p>Advance AI-driven health screening technology</p> <p>Deploy telehealth kiosks for low-income communities</p> <p>Improve health screening in children</p> <p>Drive awareness and engagement for telehealth solutions</p> <p>Access affordable telehealth services</p>	<p>Used their technical skills to prototype the product that could operate on any bandwidth and used their contacts to onboard doctors. Installed the product on government sponsored rest areas for travelers. Created a clinic to house the product and hired an attendant, gave them basic training regarding how to facilitate the process for customers and provided feedback to founders on how to improve the kiosk like adding available timings of doctors on the system.</p> <p>Provided insight on how to keep production costs low and spread awareness about products in remote areas through their network to increase adoption.</p> <p>Provided their input in terms of product design like adding ultrasound features, installed in their offices for remote consultation and volunteered their time for free to provide health advice to BOP needy customers in remote areas.</p> <p>Provided investment to the company to create more inventory and continue R&D.</p> <p>Provided financial backing and strategic guidance</p> <p>Partnered in R&D for vital screening through computer vision</p> <p>Provided network access, funding support, and distribution channels</p> <p>Partnered to install Ez Screening systems in schools</p> <p>Built EzShifa's digital brand, promoted services, and acquired users</p> <p>Provided feedback on usability, affordability, and service improvement</p>	<ul style="list-style-type: none"> • Social Media Engagement & Advocacy – Established Daisy's presence on Instagram to connect with customers, donors, and NGOs, ensuring direct customer interaction and product education. • Retail Partnership with DAWAM – Enabled the commercial sale of biodegradable sanitary pads via eco-conscious retail channels. • Partnerships with doctors in the USA and UK. • Use of a franchising model for product distribution. • Costs 1/4th of the fee charged by a private hospital doctor. • Simple to set up, easy to use, and limited training required to operate the kiosk. • Use of local raw material. • 100% in-house development of software. • SaaS-based platform with enhanced protection against hacking. • AI-backed system to facilitate the doctor with the diagnosis of patient's data. • HIPAA (Health Insurance Portability and Accountability Act) compliant technology. • Paperless and online medical consultation. • Apna Doctor Kiosk – A telehealth kiosk that connects patients in remote areas to doctors in major cities for low-cost remote consultations. • Hawa Kiosk – A mother-child healthcare kiosk with ultrasound screening, addressing maternal healthcare challenges in underserved areas. • Ez Screening – A school-based health screening system for detecting vision issues, psychological health, and early-stage diseases in children. • Expansion to Global Markets – Deployed telehealth kiosks in Nigeria and UAE and in discussions with Afghanistan for further expansion. • Cost-Effective Healthcare Model – Reduced the cost of teleconsultations to PKR 100, making healthcare accessible to low-income communities. • Scalability & Automation – Implemented automated customer support and sales processes, reducing operational costs and improving efficiency. • Health Services for Crisis Situations – Provided medical support in flood-affected regions through temporary telehealth setups.

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Case (year established)	Products	Co-creation Partners	Partner Motivations	Co-creative Role	Outcomes of Co-creating Frugal Innovation
Jolta Electric (2021)	Electric motorbikes: <ul style="list-style-type: none"> • Jolta E-bike JE 70D • Jolta E- bike • JE-70D (SE) • JE-Scooty • JE-Cycle Products under development: <ul style="list-style-type: none"> • Jolta Electric Care 	<ol style="list-style-type: none"> 1. Founder 2. Employees 3. Vendors 4. Customers 5. Government 	<p>Personal environmental consciousness of the founder, aspiration to create local infrastructure, upskill labor and generate employment.</p> <p>Learn new skills and obtain training.</p> <p>Become part of the EV value chain in transport sector.</p> <p>Obtain an ecofriendly and affordable transport solution for daily commute.</p> <p>Create an environment friendly solution for transport and encourage electric vehicle usage to reduce carbon footprint.</p>	<p>Used his experience of working with Chinese companies to create a factory and train employees to prototype different versions of the EV battery inhouse.</p> <p>Received training to learn how to make batteries in house and innovate in assembly methodology.</p> <p>Provided local parts to help generate prototype body.</p> <p>Provided feedback for product design to improve prototype like adding a back seat on the body where children can sit.</p> <p>Approved the electric vehicle policy that allowed registration and manufacturing of electric bikes in Pakistan.</p>	<ul style="list-style-type: none"> • Local & International Partnerships – Collaborated with NGOs, governments, and universities to increase deployment and funding opportunities. • Costs 1/2 of the price of imported Chinese equivalents. • Significantly improved mileage (80Kms in PKR20) which means the lower operating cost. • Low manufacturing cost due to conventional product design. • Electric motorbikes to promote an affordable mode of transportation for low-income segments. • Eco-friendly and noiseless alternative to conventional motorbikes. • Strategic use of the existing networks of vendors and dealers in the motorbike industry of Pakistan. • 100% in-house designing, manufacturing, and assembling of the kit leading to the creation of business opportunities for local small and micro businesses. • Patented electric conversion kits with dry or lithium-ion battery. • Patented intermesh technology for prefabricated houses. • More energy-efficient and low carbon footprint. • 100% in-house technology development. • Partnership with non-financial institutes for the provision of a mortgage to low-income customers. • Construction cost is 1/3rd of the comparable products due to intermesh technology. • Less usage of structural material as compared to imported equivalents. • More energy efficient houses • Low carbon footprint. • Solar-powered housing solutions. • Low packaging and shipping cost due to flat-pack technique. • Low fixed cost. • Optimization of product design and time in the manufacturing process. • Flat-Pack homes with prefabricated sustainable housing units that can be assembled in under 3 h. • Transitioned from low-environmental impact designs to fully net-zero energy homes. • Customised housing for different regions including housing for urban slums, refugee camps, and commercial use.
Modulus Tech (2016)	Prefabricated sustainable and affordable housing: Community houses -B2B office structures. Products under development: <ul style="list-style-type: none"> • Backyard housing Eco tourist pods 	<ol style="list-style-type: none"> 1. Founders 2. Vendors 3. Competitors 4. Customers 5. Incubator 6. International Investor 7. Universities & Student Interns 8. Corporate Partners & Real Estate Developers 	<p>To solve the Syrian global crisis that resulted in homelessness of displaced people</p> <p>Generate business income.</p> <p>Collaborate to come up with sustainable solutions and improve their own product.</p> <p>Obtain an affordable housing option that is customizable, of good quality and is ready to inhabit instantly.</p> <p>Creation of sustainable eco-friendly products that generate social welfare as well as business activity.</p> <p>Generate business income by investing in a sustainable and scalable business idea.</p> <p>Conduct R&D and field testing for innovative net-zero housing solutions</p> <p>Expand reach of sustainable housing solutions</p>	<p>Used their technical skills to design the intermesh technology and flat packing technique.</p> <p>Provided all basic parts of the house and delivered them to remote areas for assembly.</p> <p>Gave feedback to improve prototype.</p> <p>Shared helpful advice regarding unit economics to improve product distribution and collaborated with the business to jointly undertake large projects. Some competitors also became manufacturers for the business.</p> <p>Gave insights and feedback to improve products in terms of design, generate new product iterations and develop frugal innovation in the form of ecotourism products.</p> <p>Provided seed money, helped land first customer, and provided the business with vital insight and contacts.</p> <p>Provided the business with funding to scale up and set up a factory, add new products to their portfolio and increase exports. They also provided technical advice for product improvement and helped create a new revenue stream by initiating a mortgage system for the bottom 40% customers.</p> <p>Conducted product trials, design optimizations, and market research</p> <p>Incorporated Modulus Tech's flat-pack homes into larger housing projects</p>	<ul style="list-style-type: none"> • Patented intermesh technology for prefabricated houses. • More energy-efficient and low carbon footprint. • 100% in-house technology development. • Partnership with non-financial institutes for the provision of a mortgage to low-income customers. • Construction cost is 1/3rd of the comparable products due to intermesh technology. • Less usage of structural material as compared to imported equivalents. • More energy efficient houses • Low carbon footprint. • Solar-powered housing solutions. • Low packaging and shipping cost due to flat-pack technique. • Low fixed cost. • Optimization of product design and time in the manufacturing process. • Flat-Pack homes with prefabricated sustainable housing units that can be assembled in under 3 h. • Transitioned from low-environmental impact designs to fully net-zero energy homes. • Customised housing for different regions including housing for urban slums, refugee camps, and commercial use.

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Case (year established)	Products	Co-creation Partners	Partner Motivations	Co-creative Role	Outcomes of Co-creating Frugal Innovation
		9. Local & International NGOs (UN, Development Banks, Grant Organizations) 10. Government	Promote sustainable and social housing projects Provide affordable housing to low-income individuals.	Provided grants and funding for large-scale affordable housing initiatives Became a facilitator by making policies that allowed private mortgage companies to finance houses for low-income individuals that was used as a new revenue stream by the business.	<ul style="list-style-type: none"> Scalable off-grid housing solutions with homes designed to function independently of traditional energy and water grids. Water & Energy efficient building design by integrating rainwater harvesting, solar panels, and natural cooling systems
Pak Vitae (2017)	Detachable water filters: -Point-of-use (POU) water filters Products under development: <ul style="list-style-type: none"> Water dispenser bottle with pre-installed filter The athlete water bottle with preinstalled filter 	1. Founders 2. Academic Expert 3. Government Research Agency 4. Incubator 5. International and Local Investors 6. International Technical Experts 7. Mentors & Advisors 8. Academic Institutions & Researchers 9. Manufacturers (China) 10. Distributors (Muller & Phipps) 11. Marketing & PR Agencies (Leo Burnett, Adcom, etc.)	Personal suffering of the founder from Diarrhea after drinking contaminated water and need to solve this problem for BOP customers in an affordable, scalable manner. Enable effective use of his academic research and create a product with real utility for customers Create products that improve the standard of living of people and offer unique solutions to fundamental problems. Accelerate business ideas that have a scalability potential and create products which can benefit customers. Generate business income and sell a product that has mass appeal. Harness technical expertise in improving a product that improves the standard of living of people in an underdeveloped country at an affordable cost. Provide strategic advice on investment, business growth, and product-market fit Support research and development through knowledge exchange and collaboration Business opportunity in producing high-demand water filtration systems Profitability through distributing an essential and high-demand product Engage in raising awareness and branding for a social impact product	Used their technical skills and research to generate a Nano filter that could be used as an add-on to any water source for filtration. Allowed the business to use his proprietary hardware production base machine to create initial prototypes of the product. He also provided capital to help the founders travel to international competitions where they made invaluable contacts for the business. PCSIR allowed the business to conduct free testing in their facility Incubator provided seed funding to the business to create inventory and run operations Provided funding to generate products, undertake research and development and run business operations. Helped make R&D lab in Singapore. Created the antibacterial polymer for the product and helped in improving product functioning and quality. Guided product development, funding decisions, and helped navigate business challenges Assisted in securing intellectual property rights (82 patents filed globally) and product innovation Provided production facilities and ensured large-scale manufacturing capabilities Provided supply chain support and ensured the product reached end consumers Helped shape brand identity and executed marketing campaigns to drive product adoption	<ul style="list-style-type: none"> Patented antimicrobial hollow fibre membrane technology. Water filters with no electricity consumption. Replaces the use of plastic water bottles. 100% in-house technology development. Filtration capacity of up to 16 nm; filters 60 L/h. Superior lifespan of the filter with no maintenance cost. Substantially less unit manufacturing cost. Very lean organisation with a headcount of only 14 employees. Low fixed cost. The parent company is registered in Singapore to facilitate trade and fundraising. Detachable water filters and point-of-use water purifiers for the low segments of the market. Enhanced access to clean drinking water due to the superior lifespan of the filter with no maintenance cost in rural areas. Affordable & Durable Water Filtration Technology – Developed cost-effective, long-lasting water purification systems. Adapted Filtration Systems for Remote & Underdeveloped Areas – Designed technology suited for areas with limited access to clean water. Large-Scale Production Capabilities – Partnered with manufacturers in China for mass production. Patent-Protected Water Filtration Innovations – Secured 82 patents globally, ensuring product uniqueness and market protection. Distribution Network for Market Penetration – Established partnerships with M&P, Muller & Phipps, and other distribution firms to expand reach. Brand Development & Awareness Campaigns – Leveraged marketing and PR agencies to enhance public visibility and social impact messaging.

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Case (year established)	Products	Co-creation Partners	Partner Motivations	Co-creative Role	Outcomes of Co-creating Frugal Innovation
Bioniks (2012)	<p>Sensor-enabled prosthetic arms and legs</p> <p>Products under development:</p> <ul style="list-style-type: none"> • Lower-limb prosthetics with advanced mobility features, including sweat-proof technology and improved neural control systems. • Exoskeleton technology, aimed at providing mobility assistance. 	<ol style="list-style-type: none"> 1. Doctors & Healthcare Institutions 2. Engineers & Technical Experts 3. Patients & Users 4. Investors & Grant Providers (AKDN, European Union-backed grant) 5. Universities & Research Institutions 6. Employees & Interns 7. Mentors & Social Networks 8. Manufacturers & Suppliers 	<p>Provide better prosthetic solutions to amputees</p> <p>Advance prosthetic technology for improved accessibility</p> <p>Gain access to functional and affordable prosthetics</p> <p>Support impact-driven healthcare innovation</p> <p>Enhance biomechanical and prosthetic research</p> <p>Enhance biomechanical and prosthetic research</p> <p>Gain experience in prosthetic design and manufacturing</p> <p>Provide strategic guidance and market insights</p>	<p>Medical expertise on patient needs, clinical feedback, and guidance on muscle movement and neural networks (Dr. Javed Arshad, Dr. Iqtidaar Tawfiq, Dr. Dilshad Qureshi, Dr. Abdullah Janjaffar)</p> <p>Bioniks' R&D team designed and optimised bionic arms with embedded sensors, plug-and-play technology, and tele-rehabilitation features</p> <p>Provided feedback on prosthetic usability, comfort, and functionality, which informed product design improvements</p> <p>Provided financial resources to sustain operations and research</p> <p>Assistance with their R&D and product development</p> <p>Team members, including interns, contributed to R&D, product development, and business growth</p> <p>Helped Bioniks refine business strategy, expand globally, and prioritise financial sustainability over immediate expansion to underserved markets</p> <p>Supplied affordable raw materials and optimised prosthetic production processes</p>	<ul style="list-style-type: none"> • Affordable prosthetics in the form of bionic arms and legs designed to be cost-effective for low-income patients. • Technologically advanced prosthetics with embedded neural sensors, allowing movement through muscle signals. • Designed to be plug-and-play making them useable without medical intervention eliminating the need for extensive medical supervision. • Enhanced longevity & durability due to sweat-proof, durable materials to withstand long-term usage, especially in hot climates. • Customization for young children & adults because prosthetics were tailor-made based on patient size, needs, and growth factors. • Rapid Production & Delivery due to short lead time and quick home delivery, ensuring patients receive prosthetics without long waiting periods. • Designed for instant use upon delivery, allowing patients to regain mobility quickly. • Availability of aesthetic & functional customization because prosthetics were available in various designs, colors, and personalised features. • Lightweight & Comfortable design that ensured ease of use for individuals of all ages, minimising discomfort or strain. • Locally Produced & Sustainable because prosthetics were manufactured using locally sourced materials, reducing costs and ensuring accessibility. • Discreet home delivery service allowed women to order menstrual products privately, reducing social discomfort. • Bloodstain remover innovation through a custom-developed formula designed for stain removal, responding to customer needs. • Biodegradable & reusable napkins created through experimenting with eco-friendly menstrual products for sustainability.
GirlyThings (2019)	<p>Biodegradable sanitary pads</p> <p>Products under development:</p> <ul style="list-style-type: none"> • Menstrual pads with wings • Sustainable and reusable scented napkins 	<ol style="list-style-type: none"> 1. Founder (Tanzila) 2. Suppliers & Manufacturers (China, USA, Local) 3. E-commerce & Logistics Team 4. Customers (Women & Girls, especially with disabilities) 5. Social Media Networks (Facebook, Instagram, etc.) 	<p>Address accessibility issues for menstrual healthcare products, particularly for disabled women</p> <p>Expand market for menstrual health products and partner with startups</p> <p>Ensure quick and discreet delivery of menstrual products</p> <p>Access menstrual products without social stigma or physical barriers</p> <p>Promote menstrual health awareness and drive product sales</p>	<p>Developed the idea, imported products, designed packaging, and introduced innovation (e.g., bloodstain remover)</p> <p>Provided menstrual health products, biodegradable napkins, and packaging materials</p> <p>Managed online operations, packaging, and last-mile delivery</p> <p>Provided feedback on usability, privacy concerns, and delivery experience</p> <p>Enabled customer engagement, marketing campaigns, and feedback collection</p>	<ul style="list-style-type: none"> • Discreet home delivery service allowed women to order menstrual products privately, reducing social discomfort. • Bloodstain remover innovation through a custom-developed formula designed for stain removal, responding to customer needs. • Biodegradable & reusable napkins created through experimenting with eco-friendly menstrual products for sustainability.

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Case (year established)	Products	Co-creation Partners	Partner Motivations	Co-creative Role	Outcomes of Co-creating Frugal Innovation
		6. Grant Providers & Award Organizations (NGOs, American NGO, Startup Competitions)	Support social entrepreneurship in female health and hygiene	Provided financial grants and recognition for impact-driven innovation	<ul style="list-style-type: none"> E-commerce platform for menstrual healthcare which created a direct-to-consumer model that bypassed retail stores. Accessible menstrual products for women with disabilities which addressed mobility barriers by ensuring delivery to their homes. Menstrual healthcare awareness campaigns that used social media to normalise conversations around menstrual hygiene. Partnerships for mental healthcare add-ons that explored mental health support services as an extension of menstrual health. Price parity with market by ensuring cost competitiveness with major brands. Incubation & startup recognition by securing grants and awards, increasing visibility and credibility.
		7. NIC (LUMS Incubation Center)	Support innovative startups in Pakistan	Provided office space and networking opportunities	
Economia (2009)	EV retrofitting kits for motorcycles Products under development: <ul style="list-style-type: none"> Hydrogen fuel cell electric vehicles, intended for long-range travel with quick refueling. Graphene-based battery technology, in early R&D for improved battery efficiency. 	1. Universities & Research Institutions (FIP programs, Top Pakistani Universities) 2. Government Bodies (Engineering Development Board, PSQCA, NHCE, Ministry of IT, Science & Technology) 3. Investors & Business Partners (Local & International) 4. Pakistani Military & Government Organizations (Pakistan Navy, Air Force, Police, Delivery Riders Program) 5. Engineering & Manufacturing Experts 6. Automotive Suppliers & Component Manufacturers 7. Concept Science & Technology (Joint Partner, Global Network) 8. Local Mechanics & Small Businesses	Conduct research and test feasibility of electric vehicle (EV) designs Promote local EV production, reduce fuel imports, and curb pollution Support innovative EV technology and enter the emerging EV market Deploy sustainable patrol vehicles and support electric mobility solutions	Provided academic input, tested prototypes, and suggested design improvements Evaluated technical standards, provided policy approvals, and facilitated EV adoption initiatives Provided financial backing and strategic guidance, though some funding deals failed Procured EVs for patrol use and delivery operations	<ul style="list-style-type: none"> Retrofitting kit for motorcycles that converted existing fuel-based bikes into electric vehicles to lower costs and pollution. Mid-Drive transmission system that enabled better load balancing and hill climbing, unlike standard hub-motor EVs. Affordable EV conversion solution that drastically reduced fuel costs from PKR 7-10/km to PKR 0.20-1/km, making it financially viable for daily commuters. Custom-designed motors that used N48 magnet technology, consuming 30% less energy while delivering higher torque. Locally manufactured EV components with nearly 95% of components are produced in Pakistan, reducing dependency on imports. Hydrogen fuel cell EV prototype under development, expected to enable long-range travel with quick refueling. Graphene battery R&D with plans to manufacture locally produced graphene-based batteries for long-lasting EV performance. Scalable EV training & services network of mechanics across Pakistan trained to install and maintain EV conversion kits, creating jobs and local expertise.

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Case (year established)	Products	Co-creation Partners	Partner Motivations	Co-creative Role	Outcomes of Co-creating Frugal Innovation
Jaguar (2003)	Affordable electric motorcycles and scooters Products under development: • Three-wheeler electric vehicles, expanding beyond motorcycles and scooters. • Locally manufactured lithium-iron phosphate batteries, reducing dependency on imports.	1. Founder (Chaudhry Mohamed Hassan Asad) 2. R&D Team (Local Engineers & University Graduates) 3. Chinese Suppliers & Technical Advisors 4. Government & Regulatory Bodies (Engineering Development Board, Ministry of IT, Science & Technology) 5. Dealership Network & Company Outlets 6. Customers (Middle-Class Commuters, Women, Rural Users) 7. Military & Government Sectors 8. Pakistani Universities & Technical Institutions 9. Corporate Partners & Industry Networks	Restart and scale electric vehicle (EV) production in Pakistan for affordability and sustainability Develop high-performance EV technology using local expertise Provide high-quality EV components and manufacturing guidance Promote local EV industry growth and meet environmental goals Expand customer accessibility to EVs Access affordable, low-maintenance electric motorcycles Integrate electric vehicles into public services Train local EV engineers and researchers Strengthen supply chain and EV ecosystem	Led business expansion, product development, and strategic decision-making Designed battery systems, tested bike efficiency, and optimised motor performance Supplied lithium-iron phosphate batteries, motors, and chargers, while offering manufacturing best practices Set licensing requirements, tested and approved vehicle models Distributed Jaguar EVs across 40+ cities, with new company-owned outlets for direct sales Provided feedback on usability, durability, and real-world performance Used Jaguar EVs in government initiatives, including a women's scooty program Supplied skilled graduates and collaborated on technology research Helped in scaling production, ensuring the availability of spare parts	<ul style="list-style-type: none"> Partnership with military & public sector with initial EV fleet deployed for Navy, Air Force, and Police patrols to test technology viability. Smart financing model for EV adoption with plans for revolving funds to allow users to pay for conversions through fuel savings over 6-12 months. Affordable electric motorcycles & scooters with five EV models designed for budget-conscious Pakistani riders, using existing petrol bike frames for cost efficiency. Fast-charging lithium-iron phosphate batteries which provided a 10-year battery life with under 2-h charging time, the fastest among local competitors. Error detection & digital display system with integrated self-diagnosing system to identify mechanical issues without visiting a mechanic. Extended warranty & after-sales service with a 5-year warranty with doorstep servicing across Punjab, Sindh, and KPK. Government-supported women's scooty initiative which led to the adoption of electric scooters in female mobility programs, improving accessibility. Locally manufactured & assembled EVs with 95% of components being sourced from China but assembled locally, ensuring availability of spare parts. Energy cost savings for users because the EVs were 90% cheaper than petrol bikes, reducing daily commuting expenses. Shifted from dealership-based sales to company-owned retail outlets, with the first store opened in Lahore. Scalable EV production facility with expanded manufacturing & warehouse space, anticipating further growth. Market awareness & cultural adaptation by overcoming public skepticism about EVs by using familiar petrol bike designs and promoting cost savings. Affordable solar home systems that were low-cost, off-grid solar energy solutions designed for rural communities.
Brighterlite (2012)	Off-grid solar home systems Products under development:	1. Norwegian Investors (Eric & others)	Support renewable energy solutions for underserved communities	Provided financial investment and strategic direction	<ul style="list-style-type: none"> Affordable solar home systems that were low-cost, off-grid solar energy solutions designed for rural communities.

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Case (year established)	Products	Co-creation Partners	Partner Motivations	Co-creative Role	Outcomes of Co-creating Frugal Innovation
	<ul style="list-style-type: none"> Larger solar home systems, with increased battery storage for businesses and community-level electrification. 	<ol style="list-style-type: none"> Government of Pakistan (Punjab, KPK, Sindh) Telenor (Telecom Partner) German & Norwegian Technology Providers Chinese & Thai Manufacturers Local Communities & Customers Employees & Local Teams Banks & International Funds (World Bank, Asian Bank, Norwegian Government) Mentors & Business Networks 	<ul style="list-style-type: none"> Provide off-grid energy solutions to rural areas Increase mobile service usage by integrating energy solutions with mobile payments Develop reliable solar power solutions Cost-effective production of solar components Access to affordable electricity in rural areas Work in solar energy and support product distribution Finance scalable energy projects Guide business strategy and market expansion 	<ul style="list-style-type: none"> Engaged in discussions about implementing the project in remote areas Integrated EasyPaisa payment system for "pay-as-you-go" solar power Supplied technology and expertise in solar power and battery storage Produced solar panels, batteries, and system components Provided feedback on usability and demand for solar products Assisted in sales, installations, and customer service Provided funding support and facilitated international investment Advised on financial sustainability and strategic growth 	<ul style="list-style-type: none"> Pay-As-You-Go (PAYGO) solar technology integrated with Telenor EasyPaisa, allowed users to activate their solar systems through mobile payments. Scalable product range with three different solar energy kits (L4, L9, and L16) designed for varying energy needs. <ul style="list-style-type: none"> L4: One panel, one battery, and two lights. L9: Includes a mobile charger and additional lights. L16: Includes a TV, ceiling fan, pedestal fan, and multiple lights. Energy access for remote areas provided sustainable electricity to villages without grid connections. Plug-and-Play installation with a simple setup requiring no technical expertise, with clear Urdu-language instructions. Battery backup system provided 8-10 h of energy storage to ensure power availability at night. Locally manufactured components where panels and batteries were sourced and assembled using Chinese, Thai, and German technology. Smart power management system which automatically disconnected power when payment wasn't made, ensuring financial sustainability. Solar-Powered appliances are designed to run lights, fans, mobile chargers, radios, and televisions, improving daily life. Adaptation for local market needs which adjusted product features based on customer feedback to ensure reliability and usability. Supreme stove was a locally developed clean cookstove optimised for high fuel efficiency and lower emissions. Developed four distinct customised regional cookstove variants to match local cooking habits: <ul style="list-style-type: none"> GB Stove (Gilgit-Baltistan) – Designed for large, wide cooking utensils. Double Supreme Stove (AJK, KPK, GB) – Taller model suitable for cooking and heating. H1 & H2 Heaters (KPK, GB, AJK) – Heater-focused cookstoves for colder climates. Standard Supreme Stove (Punjab, Sindh) – First product iteration designed for general use.
Jaan Pak (2014)	<p>High-efficiency clean cookstove</p> <p>Products under development:</p> <ul style="list-style-type: none"> Smart cookstove models with integrated sensors, designed to monitor fuel usage and optimize efficiency. 	<ol style="list-style-type: none"> Founder (Khizr Imran) 	<p>Address the high cost and inefficiency of cooking and heating fuel in off-grid communities</p>	<p>Developed the idea, secured funding, led product development, and conducted market research</p>	<ul style="list-style-type: none"> Supreme stove was a locally developed clean cookstove optimised for high fuel efficiency and lower emissions. Developed four distinct customised regional cookstove variants to match local cooking habits: <ul style="list-style-type: none"> GB Stove (Gilgit-Baltistan) – Designed for large, wide cooking utensils. Double Supreme Stove (AJK, KPK, GB) – Taller model suitable for cooking and heating. H1 & H2 Heaters (KPK, GB, AJK) – Heater-focused cookstoves for colder climates. Standard Supreme Stove (Punjab, Sindh) – First product iteration designed for general use.

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Case (year established)	Products	Co-creation Partners	Partner Motivations	Co-creative Role	Outcomes of Co-creating Frugal Innovation
					<ul style="list-style-type: none"> • 51 iterations of stove Design by undertaking extensive testing and refinement process for maximising efficiency. • Fuel efficiency & cost Savings through reduced fuel consumption, cutting household fuel costs by up to 40%. • Lower carbon emissions as each stove avoided 0.3 to 2 tons of CO₂ emissions per year, making it eligible for carbon credit programs. • Transitioned from community-based adoption to digital and TV marketing, increasing reach and creating a scalable sales model • Explored financial subsidies, loans, and installment plans to improve affordability and create a microfinance-based adoption model • Partnerships with Local Manufacturers by establishing standardised local production in Lahore, ensuring quality and cost control. • Used extensive customer feedback from off-grid communities to refine product designs and undertake field research-driven innovation • Raised £15,000 through online crowdfunding, expanding production and awareness.

Data availability

Data will be made available on request.

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