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Frugal Innovations in Water Sector

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Abstract:

Water stands as arguably the most deeply interconnected and fundamental resource on our planet. Nonetheless, billions confront challenges related to water, spanning from inadequate access to water and sanitation services to obstacles impacting livelihoods and socio-economic activities. The Sustainable Development Goals (SDGs) recognize the multifaceted role of water in development and urge the involvement of the private sector in addressing these diverse developmental hurdles. This research explores the potential of frugal innovations as a method for the private sector to address water-related development challenges. Our analysis, drawn from a case study and literature review, suggests that frugal innovations hold promise in this regard due to their emphasis on affordable, straightforward solutions. However, we also acknowledge potential drawbacks associated with frugal innovations in the water sector. While these innovations theoretically promote sustainability, issues related to scalability and institutional frameworks may arise. These issues stem from the significant role of water in various natural and human-made processes, as well as the intricacies of global production-consumption value chains. Enhancing the sustainability impact of these innovations necessitates a broader understanding of the underlying value chains and their diverse connections with water. Taking a holistic perspective on water can mitigate business risks associated with water while enhancing individual well-being.

Keywords: —Water, Sustainable Development Goals, frugal innovations, sustainability, value chains

I. Introduction

Water stands as one of the most vital ingredients for human life, health, and wellbeing, as well as for ecosystems, making it a key element for sustainable development. However, billions of people contend with water scarcity; at least 1.8 billion individuals rely on drinking water sources contaminated with fecal matter, 2.4 billion lack access to basic sanitation, and the majority of wastewater is discharged without proper treatment. The indispensability of water and its multifaceted role across various activities can easily be overlooked when one is not directly confronted with these challenges. Yet, for those affected by water-related challenges, the implications can be numerous and severely impede development and wellbeing. Moreover, water poses a growing concern for businesses throughout their value chains. In 2015, The World Economic Forum ranked water crises as the number one global risk in terms of impact.

Addressing these extensive water challenges demands new solutions. Beyond addressing individual-level challenges, such as ensuring access to safe water, there's a pressing need to delve deeper into water's interconnected role within both human-made and natural systems. Solutions implemented in one part of the world can exert burdens on water resources or users elsewhere due to the intricate value chains associated with modern-day, globalized production patterns. Therefore, there's a call for solutions, whether existing or innovative, on various levels. Conversely, global networks and novel innovations may assist in transforming these challenges into opportunities for businesses and for economic and human development more broadly. The private sector is increasingly called upon to help tackle the key development challenges, as global partnerships are emphasized and business-led solutions and technologies are called upon by the Sustainable Development Goals (SDGs) launched in 2015. Concurrently, circular economy and sustainable production and consumption, included in the SDGs, aim towards sustainable societies, environment, and growth. This brings more emphasis on the sustainability of the entire value chain and related processes, instead of solely the final outcome. In the water sector, this means broadening the view from mere water supply and sanitation (WSS) to broader aspects of water resources use and management. Frugal innovations have been proposed as a potential approach for serving resourceconstrained consumers in emerging and developing markets, as well as in the lowgrowth Western markets. This is due to their notion of affordability, acceptable quality, and no-frills structure. The objectives of Sustainable Development Goals (SDGs) resonate with these innovations, and they are often perceived as sustainable. However, existing research has largely focused on the outcomes of frugal innovation, such as end products, rather than rigorously examining the sustainability implications throughout value chains.

This article explores the potentials and pitfalls of frugal innovations as a means for the private sector to address water-related development challenges in developing country contexts. Our case study examines a multinational company's (Ahlstrom) frugal innovation process related to a low-cost water treatment solution in Tanzania. The case study concentrates on the early phases of product and business development, analyzing it through the SWOT (Strengths, Weaknesses, Opportunities, and Threats) framework. The aim of the article is to understand the potentials and pitfalls of frugal innovations in the water sector and sustainable development, and to provide recommendations for both companies

developing frugal innovations and other organizations (e.g., international development organizations, donors, and legislative bodies) involved in innovation processes.

II. Materials and Methods

The purpose of the literature review and case study is to examine the current state of the frugal innovation field and its relationship with the Sustainable Development Goals (SDGs), particularly in relation to the water sector. The literature review provides context for the article by summarizing prominent approaches and identifying gaps in the emerging fields of frugal innovation, sustainable development (with a focus on SDGs), and water. The case study offers a practical perspective on one potential path for the development of frugal innovation, serving as a means for private sector involvement in water sector development and, more broadly, sustainable development. The literature review focused on key literature regarding frugal innovation, including peer-reviewed articles, as well as primary publications and documentation on the SDGs and the water sector. Additionally, the review of the SDGs and the state of water resources drew from databases and assessments conducted by international organizations, such as the United Nations. The case study material is based on an experimental product and business development process, which began in the fall of 2015 as a joint effort of Aalto University and Ahlstrom. The focus of the case lies on the creation of a frugal water innovation—a novel type of water filter—targeting consumers within the low-income context of Tanzania. This case study adopts an exploratory approach utilizing a qualitative analysis design. This methodology was selected for several reasons: the relatively ambiguous nature of frugal innovations' concepts and development processes; the highly exploratory nature of the entire project; and the complexities stemming from the context of a developing country, including the unavailability of reliable data [17,18]. The action research tradition serves as a framework for this case, facilitating dialogue between practitioners (the case company) and researchers, as well as active researcher involvement in product and business model development within the new market area. The research methods employed in this case study encompassed literature review, meetings and interviews, observations, and key-informant interviews. Interviewees during the field research period in Tanzania included households, entrepreneurs, companies, public sector actors, donor organizations, and students. Key informants consisted of local individuals, entrepreneurs, company representatives, as well as selected officials and experts. Observations were conducted within communities, local residences, and commercial activities in Tanzania. Workshops involving Tanzanian university students were also utilized to gather, structure, and analyze data. An interdisciplinary research team, guided by the first author, conducted the research. Significant points from each interview, meeting, workshop, and observation were documented by the research team and

compiled at the conclusion of the field research period.

III. Setting the Context: Water, SDGs, and Frugal Innovations

A. Water Sector

The focus of the case lies on the creation of a frugal water innovation—a novel type of water filter—targeting consumers within the low-income context of Tanzania. This case study adopts an exploratory approach utilizing a qualitative analysis design. This methodology was selected for several reasons: the relatively ambiguous nature of frugal innovations' concepts and development processes; the highly exploratory nature of the entire project; and the complexities stemming from the context of a developing country, including the unavailability of reliable data [17,18]. The action research tradition serves as a framework for this case, facilitating dialogue between practitioners (the case company) and researchers, as well as active researcher involvement in product and business model development within the new market area. The research methods employed in this case study encompassed literature review, meetings and interviews, observations, and key-informant interviews. Interviewees during the field research period in Tanzania included households, entrepreneurs, companies, public sector actors, donor organizations, and students. Key informants consisted of local individuals, entrepreneurs, company representatives, as well as selected officials and experts. Observations were conducted within communities, local residences, and commercial activities in Tanzania. Workshops involving Tanzanian university students were also utilized to gather, structure, and analyze data. An interdisciplinary research team, guided by the first author, conducted the research. Significant points from each interview, meeting, workshop, and observation were documented by the research team and compiled at the conclusion of the field research period.

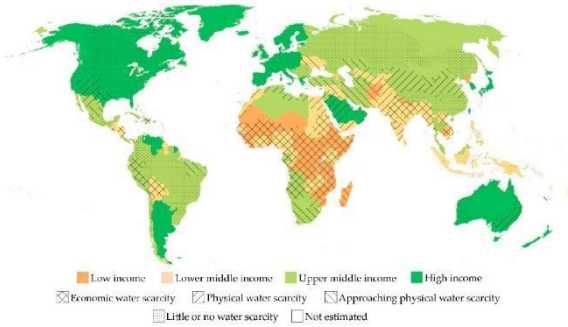

Figure 1. Water scarcity and countries by income class

Similarly to the hydrological cycle, water is flowing through the value chains of humanmade processes. Water is present and used throughout these value chains, from the extraction of raw materials, to the production and utilization of products and services, and all the way to their disposal or reuse. To illustrate the intertwined nature of water and these activities, the diagram below shows the connections and embeddedness of the hydrological cycle and key value chains (fig.2)

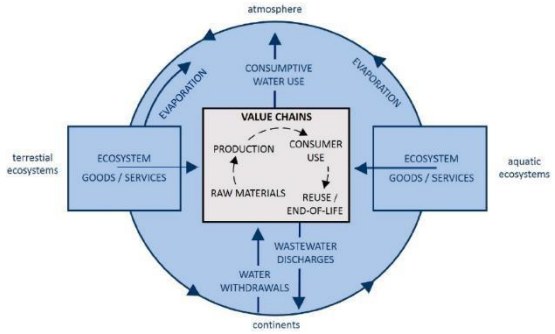

Fig-2. Hydrological cycle and its linkage to industrial value chains

The agriculture-based food production chain is the most water-intensive, accounting for about 70% of global freshwater withdrawals and 90% of consumptive water use. Water is vital not only for growing crops but also for agricultural inputs and processing. Industrial processes and energy generation also heavily rely on water, constituting around 20% of global freshwater withdrawals. Domestic water use, about 10% globally, directly affects people's health and wellbeing. However, access to safe water varies, with some regions lacking proper treatment. Ensuring safe water supply requires diverse equipment and technologies. Water, though consumed locally in many activities, flows globally through commodities, impacting various sectors and products along their value chains.

B. Sustainable Development Goals (SDGs)

The year 2015 marked the transition from the Millennium Development Goals (MDGs) to the Sustainable Development Goals (SDGs), emphasizing collective action across sectors to address global challenges. Unlike the MDGs, the SDGs take a comprehensive approach to water, recognizing its significance beyond supply and sanitation. They promote integrated water management and its connections to various challenges and ecosystems. The SDGs offer opportunities for the water sector by encouraging private sector involvement in sustainable development through innovations and technologies. This is particularly crucial in developing countries where public sector resources are limited. To meet SDG targets by 2030, there's a need for affordable water technologies, private sector engagement, and an integrated approach to water and related value chains. However, supportive governance at local and global levels is crucial to ensure the sustainability of private sector engagement, given water's vital role in well-being and livelihoods.

C. Frugal Innovations

In the water sector, the most well-known frugal innovations have focused on providing safe water to consumers. Tata’s Swach and Hindustan Unilever’s Pureit are examples of these; both are point-of-use water treatment devices for household use. Swach and Pureit are more energy efficient than existing solutions, as they do not require electricity or running water to function. However, according to external testing, the microbiological purification efficacy of Swach does not reach international standards. Here, the efficacy is considered to be good enough, as water quality is measurably improved. External research has shown that Pureit reaches international standards for

microbiological purification efficacy, and no additional measures for microbiological treatment are required. Both Swach and Pureit offer a replaceable purification "bulb" or "kit" after every 1500 or 3000 liters, depending on the model. Swach combines rice husk waste with a coating of silver nanoparticles to filter water, and no chemicals are utilized in the purification process. The Swach solution can be regarded as more reusable and material efficient than boiling with solid fuels, but it should be noted that there is no evidence of recycling initiatives for Swach or Pureit purifiers or their components, such as filters. Due to the generated wastes, both are considered to have a negative impact regarding material efficiency, reusability and recyclability.

Tata Swach (Water)

Tata Swach, developed by Tata Chemicals of India, is a gravity-driven "table top" water purification device for households, and it does not require electricity or running water. It was launched in India in 2009 as one of the world's most inexpensive water purifiers. The treatment technology is based on rice husk ash and nanotechnology. The technology is incorporated in a replaceable "bulb", which comes with a lifetime of 1500 liters and 3000 liters. Tata Chemicals of India claims that non-electric Tata Swach is effective at eliminating bacteria and viruses from water for safe drinking. Tens of millions of Tata Swach purifiers have been sold, but it seems that it is still too expensive to reach the extreme poor people of the low-income market segment

Hindustan Unilever Pureit (Water)

In 2008, Hindustan Unilever (HUL) launched the Pureit Classic water purifier in India. Pureit is a gravity-driven "table-top" water filtration system that does not require electricity or running water to function. The technology consists of a four-stage purification process, which includes a microfiber mesh for the removal of larger particles, a carbon filter for the removal of certain protozoan parasites, a chlorine dispenser "Germkill Kit" for disinfection and a carbon polisher to remove excess chlorine and chlorination by-products. The replaceable "Germkill Kit" is claimed to meet the strict international criteria of the U.S. Environmental Protection Agency (USEPA) for the removal of harmful viruses and bacteria. Like Tata Swach, Pureit has been sold to millions of middle-income or high-income customers in the low-income market segment.

The water solutions release users' time when compared to boiling water. Both Swach and Pureit release time for the users as the systems purify the water "on their own". Thus, time is not wasted in collecting fuel for boiling or keeping an eye on the boiling. However, it should be emphasized that because the water treatment efficacy of Swach is insufficient, one should also deploy other methods, such as boiling, to attain water safety to the fullest. Pureit and Swach are significantly less expensive than the majority of the existing water purification solutions on

the market. The climate impacts of the water treatment solutions are indirect. However, boiling water, especially with solid fuels, results in carbon emissions. Moreover, making firewood causes deforestation in the areas where the renewability of forest ecosystems does not match the increasing demand for wood. Consequently, both Swach and Pureit are considered more climate neutral than the existing solutions.

IV. Case—Development of a Frugal Water Treatment Solution for Low Income Market

A. Background—Research and Development Process and Its Outcome

Our case study offers insights into the research and development journey of a frugal water treatment innovation, a collaborative effort between the multinational corporation Ahlstrom and Aalto University. Ahlstrom, headquartered in Finland, operates globally in the business-to-business sector, producing fiber-based materials for diverse applications such as filters, medical fabrics, and food packaging. With approximately 3300 employees across 22 countries and net sales of EUR 1.1 billion in 2015, Ahlstrom partnered with Aalto University to explore new applications of its advanced materials in a developing country context, specifically in Tanzania. Water sources and treatment methods in Tanzania exhibit significant diversity and inconsistent quality. Apart from piped water supplied by water utilities, households acquire water from boreholes, shallow wells, rivers, streams, and informal vendors. Household water treatment techniques include boiling, cloth filtration, purification tablets, ceramic filters, and more advanced technologies. Consequently, the costs associated with water extraction and treatment vary widely. However, many households in Tanzania lack access to safe water or fail to treat their water adequately. Moreover, microbial contamination, fluoride, and salinity pose significant challenges to water quality in Tanzania. A diverse team from Aalto University, led by the primary author, collaborated with Ahlstrom to research and develop a frugal innovation and business model. They focused on initial product and business model development, resulting in a prototype household water filter using Ahlstrom's technology. Further refinement and testing are ongoing through external ventures. Key parameters for the water filter included cost-effectiveness, profitability, and stakeholder benefits, with considerations for pricing, quality, functionality, and sustainability. Positioning decisions were based on opportunities identified in research conducted in Finland and Tanzania. Ideas were rapidly developed and evaluated based on affordability, accessibility, and predefined design parameters rather than Ahlstrom's usual process. Field research informed prototype evaluation, which followed conventional innovation steps but with less formality. The user-centered approach used participatory methods to understand local needs and preferences, with agile adaptation to emerging findings.

B. Strengths, Weaknesses, Opportunities, and Threats of the Frugal Innovation Process

In this segment, we employ a SWOT analysis to examine the principal strengths and weaknesses (internal to Ahlstrom and this process), as well as the opportunities and threats (external, derived from the operational environment) associated with this frugal innovation process. One of the primary strengths of the water filter lies in its strategic positioning within the water supply chain, coupled with its mode of application, and its ability to maintain low production and operational costs. Initial assessments conducted in Dar es Salaam revealed that the operational expenses of the filter are significantly lower—up to seven times less—than traditional household-scale water treatment methods involving boiling water with charcoal [16]. This strategic positioning not only facilitates the provision of safe water at a reduced cost but also generates revenue for the company. Moreover, the filter serves as a plug-in accessory to commonly available utensils in Tanzanian households, operates without electricity, and boasts a smaller footprint compared to similar point-of-use water filtration solutions such as Tata Swach and Unilever Pureit. The underlying technology embedded within the filter is cost-effective at the current scale of utilization, and the manufacturing costs for the product remain low, allowing for a margin for both the producer and its partners. Additionally, the strategy to leverage existing distribution networks through local partners streamlines the process of reaching end-users and target market segments.

Before initiating the project, Ahlstrom's technology was recognized for its potential in resource-constrained settings due to its affordability and ability to eliminate bacteria and viruses from water without requiring electricity. However, there was a lack of understanding on how to effectively and efficiently implement the water treatment technology in such contexts. The agility and proximity to the intended end users during the research and development phase facilitated the identification of an appropriate positioning for the filter in the target market and a thorough comprehension of the local environment, desires, and needs.

Nevertheless, the filter has its limitations and may be inaccessible to the poorest individuals unless subsidized, as it represents an additional expense alongside purchased water, and the initial investment is relatively high for those in the lowest income brackets. Since the product focuses solely on household water treatment, it relies on existing and functional water extraction and supply processes. Achieving economies of scale in terms of providing safe water with such household devices may be more challenging compared to centralized largerscale solutions. As a consumer product with replaceable parts, the innovation generates waste, posing a challenge in areas like the study location and other developing countries where waste management and recycling systems are often inadequate and overseen by a mix of formal and informal entities. The innovation includes materials

such as plastic and alumina nanofibers, which can harm the environment if not disposed of properly.

To mitigate potential negative environmental impacts, which could have socio-economic repercussions, plans are underway for a return scheme for the replaceable parts to ensure proper recycling and disposal. At the global, regional, and national levels, significant opportunities arise from prevailing megatrends, physical and economic challenges, and the inadequate state of Water, Sanitation, and Hygiene (WSS) services, leading to a demand for water treatment and service solutions. Household-level water treatment solutions offer an alternative to traditional centralized systems, which may struggle to meet the needs of rapidly growing and urbanizing areas, as well as households outside these centralized systems. Despite the rapid economic growth in many African and Asian countries, financial resources remain scarce, making the relative affordability of the developed water filter advantageous. In the specific context of the study in Tanzania, ranked among the top 10 countries with the highest number of people lacking access to safe drinking water, there is a significant need and potential for affordable water treatment solutions. The Sustainable Development Goals (SDGs) add further pressure to improve water supply and sanitation and are likely to attract additional investments in the sector. On a local level, key threats include competition, counterfeit products, corruption, and market entry challenges. In Tanzania, large companies with established brands dominate the consumer market, making it difficult for new players to enter. Institutional challenges related to WSS and broader water resource management, coupled with insufficient investments in other waterdependent sectors, make development and investment in the water sector unreliable. Additionally, legal and political risks, lack of infrastructure, and human resources are commonly cited challenges in such markets. Looking beyond frugal innovation to the global-level value chains, other sustainability-related threats become apparent. The components of the innovation are sourced globally, as is common in modern business operations. Therefore, tracking practices and quantities of water consumption and use (water footprint) or potential risks posed to water, the environment, and humans along the entire value chain presents challenges.

V. Discussion *A.*

Potentials

The case study has illuminated two significant potentials of frugal innovations concerning sustainable development and the water sector:

1. A broader perspective on water and its associated challenges can create opportunities for businesses and expand their scope of operations. Embracing a frugal innovation mindset allows companies to explore new avenues for organizing products and business development processes,

enabling them to respond effectively to water-related challenges faced by less affluent communities. For instance, Ahlstrom, in our case study, identified opportunities for their technology beyond its traditional applications in industrial processes. Collaborating with partners, they researched and developed new applications for a previously untapped market segment. Particularly in low-income settings, which often grapple with multiple development challenges, the demand for aff ordable solutions is high. Recognized by prominent sustainable business advocacy organizations, such as [7], the potential of business-driven solutions in addressing sustainable development challenges is significant. Frugal innovation's advantage in this expanding water market lies in its characteristics: affordability, quality, and suitability to local environments.

2. Frugal innovation processes frequently necessitate a thorough reconsideration of existing operational practices due to their emphasis on affordability. The effectiveness of frugal innovations often hinges on grasping the local context, as they strive to achieve a significant cost reduction while ensuring suitability for the specific local environment. Consequently, frugal innovations can inspire companies to explore novel approaches within their product development and design processes, and potentially alter organizational mindsets and revamp current operating frameworks.

The case study highlights innovative approaches such as unconventional partnerships and flexible operational strategies outside traditional corporate frameworks. Ahlstrom's agile product development model prioritized partnerships over internal R&D, reducing initial investment costs and financial risks. Frugal innovation processes led to new locallybased research centers. Frugal innovations deliver affordable solutions of satisfactory quality, benefiting low-income users and advancing sustainable development at individual and household levels. These solutions often replace inefficient or harmful practices with environmentally, socially, and economically superior alternatives, such as replacing charcoal or firewood for water boiling to mitigate greenhouse gas emissions, deforestation, and health risks.

B. Drawbacks

Frugal innovations in the water sector present both sustainability and institutional challenges. Sustainability issues arise from neglecting social, environmental, and economic implications across the value chain. While frugal innovations target local needs, production often occurs in global chains, leading to cost-driven practices that conflict with sustainability goals. For instance, sourcing from low-cost countries like China may involve environmental and social concerns. Additionally, extraction of raw materials can exacerbate water scarcity. Addressing these challenges requires a shift towards centralized solutions rather than individual household devices. Institutional

challenges stem from the water sector's heavy public sector involvement. Frugal innovations often focus on specific aspects, like household water quality, without considering broader institutional contexts. This can hinder the development of comprehensive solutions driven by the public sector. Understanding and addressing these institutional gaps is crucial for effective private sector engagement in emerging markets.

C. Way Forward: Envisioning a Broader View for Water-Related Frugal Innovations

Our research results, drawn from both literature analysis and the case study, suggest a necessity to grasp and consider the broader context of water-related frugal innovations, particularly if they are to be in harmony with the objectives outlined for sustainable development. To facilitate discourse on this matter, we have created a diagram intended to illustrate the interrelationships among frugal innovation value chains, water, and sustainability (Figure 3).

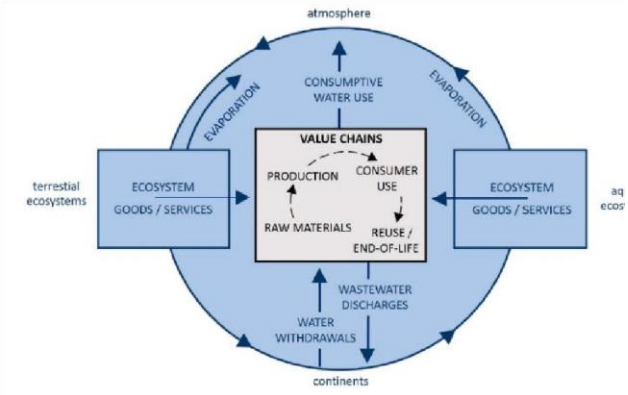

Figure 3. Diagram for scaling-up sustainability impact of frugal innovations in the water sector, combining water sector (spheres) with the frugal innovation value chain (dashed arrows).

Our visualization highlights two main concerns: water and frugal innovation value chains. It emphasizes the need for a holistic approach on local to global scales. The key message is that sustainability evaluation of frugal innovations should cover entire value chains, not just end products, including considerations for end-of-life phases like reuse and recycling. Addressing these complexities in global supply chains will likely involve gradual phases, starting with areas where frugal innovators have direct influence, such as improving end-of-life product aspects, then focusing on production and raw material sustainability.The diagram illustrates the diverse aspects of water usage and management, emphasizing that interventions focusing solely on water supply or sanitation overlook its intricate links to food, energy, and other sectors. By broadening perspectives, particularly in considering water supply and sanitation holistically, connections between frugal innovation and various stakeholders can be enhanced, potentially leading to greater sustainability impacts. Frugal innovation value chains involve multiple actors and scales, spanning from raw material extraction to end-of-life solutions, often involving collaboration between public, private, civil society, and academic sectors. While private sector innovation drives technological advancements, the public sector plays a

crucial role in creating an enabling environment and ensuring inclusivity and alignment with broader sectoral goals. Engagement between private sector innovators and public sector stakeholders is essential from the outset, acknowledging the latter's leadership in overall water sector development. Despite challenges, this broadened perspective offers opportunities for businesses to expand their offerings across value chains and water spheres, as exemplified by companies like Grundfos diversifying into water kiosks, payment systems, and remote monitoring services.

D. Limitations

This article discusses a case study on an experimental product and business development process, cautioning that its findings are indicative and should guide future studies. Frugal innovation, the focus here, is still evolving, and definitions may change. Due to the nature of the case study, quantitative data and analytical methods face challenges, leading to the use of qualitative analysis. However, integrating quantitative analysis would enhance the study. Future research should include comprehensive quantitative analysis, such as value chain examination, cost comparisons, market size assessment, and consumer preference surveys. Broader investigations into the sustainability of value chains beyond frugal innovations are also recommended to understand their contributions and challenges.

VI. Conclusions

The article explores frugal innovations in water and sustainable development, emphasizing their potential benefits for resource-constrained consumers and profitability for companies. It expands the analysis beyond product outcomes to entire innovation processes, considering global value chains. Through a case study and literature review, it highlights strengths, weaknesses, opportunities, and threats of frugal innovations in water. Frugal innovation approaches can lead to new opportunities and mindsets, emphasizing the importance of understanding local contexts and constraints. However, sustainability deficiencies like unsustainable manufacturing and waste generation stem from prioritizing extreme affordability and overlooking value chains and usage environments. Institutional shortcomings also exist, necessitating collaboration and guidelines for frugality and sustainability in innovation processes, potentially through existing platforms like the World Business Council for Sustainable Development or the UN Global Compact. The article suggests a broader view of value chains and water resources, integrating sustainability considerations throughout, to enhance business opportunities and sustainability impacts.

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Acknowledgment *(Heading 5)*

The preferred spelling of the word “acknowledgment” in America is without an “e” after the “g”. Avoid the stilted expression “one of us (R. B. G.) thanks ...”. Instead, try

"R. B. G. thanks...". Put sponsor acknowledgments in the unnumbered footnote on the first page.

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