Digitalization, Frugal Innovation, and Sustainable Development in the Global South
Opportunities and Challenges of a Frugal Smart Water Pump

van Tuijl, Erwin; Intriago Zambrano, Juan Carlo; Knorringa, Peter

DOI
10.1007/978-3-031-58795-5_4

Publication date
2024

Document Version
Final published version

Published in
The Palgrave Handbook of Sustainable Digitalization for Business, Industry, and Society

Citation (APA)
van Tuijl, E., Intriago Zambrano, J. C., & Knorringa, P. (2024). Digitalization, Frugal Innovation, and Sustainable Development in the Global South: Opportunities and Challenges of a Frugal Smart Water Pump. In M. Ertz, U. Tandon, S. Sun, J. Torrent-Sellens, & E. Sarigöllü (Eds.), *The Palgrave Handbook of Sustainable Digitalization for Business, Industry, and Society* (pp. 63-82). Springer. https://doi.org/10.1007/978-3-031-58795-5_4

CHAPTER 4

Digitalization, Frugal Innovation, and Sustainable Development in the Global South: Opportunities and Challenges of a Frugal Smart Water Pump

Erwin van Tuijl, Juan Carlo Intriago Zambrano, and Peter Knorringa

1 Introduction

The convergence of digitalization[1] and sustainability is a key debate (del Río Castro et al., 2021) that yields new opportunities and challenges to sustainable development in the Global South (Bonina et al., 2021; Sturgeon, 2021). This debate can be studied from two perspectives. First, the technological leapfrogging (Soete, 1985; Steinmueller, 2001) perspective suggests that digital technologies enable Global South countries to catch up and even surpass countries in the Global North because of the possibility of omitting stages in technological development trajectories and, accordingly avoiding

[1] We broadly define digitalization as the development and use of digital technologies within society, which increasingly rely on these technologies (Tilson et al., 2010).

E. van Tuijl (✉) · P. Knorringa
International Centre for Frugal Innovation (ICFI) and International Institute of Social Studies (ISS), Erasmus University Rotterdam, Rotterdam, The Netherlands
e-mail: vantuijl@iss.nl

P. Knorringa
e-mail: knorringa@iss.nl

J. C. Intriago Zambrano
International Centre for Frugal Innovation (ICFI) and Department of Water Management, Civil Engineering and Geosciences, TU Delft, Delft, The Netherlands
e-mail: J.C.IntriagoZambrano@tudelft.nl

M. Ertz et al. (eds.), *The Palgrave Handbook of Sustainable Digitalization for Business, Industry, and Society*,
https://doi.org/10.1007/978-3-031-58795-5_4

high costs to adapt the legacy infrastructures of previous stages. As an example, a payment platform named M-Pesa enabled Kenya, and consequently other African countries, to shift to a digital banking system relatively quickly, as a strong banking infrastructure in Kenya was lacking (Suri & Jack, 2016). M-Pesa and agricultural platforms, such as Esoko, have been widely adopted by farmers across Africa for mobile payment services (Jellason et al., 2021). Second, the other perspective stems from neo-colonialism and suggests that digital technologies lead to new dependencies and exploitation of actors in the Global South by the Global North, as phrased by terms such as "data colonialism" (Couldry & Mejias, 2019) and "crypto-colonialism" (Howson, 2020). This perspective also encompasses other challenges brought about by digitalization, such as the dominance of large platform operators (e.g., Alphabet and Alibaba) (Muldoon, 2022; Srnicek, 2017; Van Dijck et al., 2018), the monitoring of citizens (Zuboff, 2019), replacement of low qualified workers (Brynjolfsson & McAfee, 2014), and challenges on existing labor rights (Wood et al., 2019). Similarly, digital devices (e.g., smartphones) are difficult to repair, and their producers focus on short life cycles to increase sales of newer versions, leading to a negative environmental impact (Coad et al., 2021). Despite these debates and initial insights into sustainability challenges and opportunities in the Global South, limited evidence on how digitalization contributes to sustainable development (del Río Castro et al., 2021, p. 1).

One key concept to elucidate sustainable development in the Global South is that of frugal innovation (FI), which we preliminarily define as "an approach to creatively solve local problems through complexity reduction" (Busch, 2021, p.14). The rationale for FI is the development of affordable and accessible (Bhatti et al., 2018) resource-scarce solutions to overcome resource constraints (e.g., financial, material, and other resources) to meet the (basic) needs of underserved customers in the Global South (Hossain et al., 2016, p. 133). For instance, Tata and Hindustan Unilever offer low-cost water purifiers that operate in environments with uncertain electricity connections, and General Electric's portable electrocardiogram machines can be used in remote communities without hospitals (Levänen et al., 2015; Radjou et al., 2012). Similarly, M-Pesa offers a digital payment platform for the unbanked (Rosca et al., 2017), and WhatsApp supports female entrepreneurship in refugee camps (Ritchie, 2022). Owing to the focus on saving resources and making affordable products that are easily accessible by many people, it is argued that FI is important in realizing sustainable development outcomes (e.g., Herstatt & Tiwari, 2020; Pisoni et al., 2018; Prabhu, 2017).

A recent stream in FI literature associates FI to digitalization and sustainability, which encompasses two perspectives (Van Tuijl et al., 2024). One perspective explores the use of digital technologies *within* FI processes. For instance, artificial intelligence supports frugal innovators in developing affordable educational tools for disadvantaged people (De Waal et al., 2019). Funding (e.g., Kickstarter) and social media platforms are affordable channels for frugal innovators to reach global investors and buyers, respectively

(Van Tuijl & Knorringa, 2023). Likewise, digital technologies in various stages of the wind energy value chain can contribute to the realization of "affordable green excellence" (Tiwari, 2021). The other perspective elucidates digital technologies *as* FIs based on the idea that social media platforms (e.g., WhatsApp) or open-source digital technologies can be accessed by a large number of people against low or no costs (Prabhu, 2017) on the condition of having digital access and devices. This perspective also explores the development of frugal (i.e., simple, affordable, and accessible) versions of digital technologies, such as self-made drones or low-cost 3D printers (Maric et al., 2016). Both perspectives assume that digital technologies are important for FI to realize sustainability outcomes (Van Tuijl et al., 2024, p. 1). However, it is unclear how frugal digital technologies contribute to sustainable development (Tiwari, 2021) and what possible negative effects are beyond the socio-economic inequality caused by digital exclusion (Leliveld & Knorringa, 2018).

This chapter addresses this challenge by elucidating how a frugal version of digital technology contributes to sustainable development in the Global South. Specifically, we aim to identify nuances in the opportunities and challenges of a frugal digital technology to achieve different SDGs in the Global South. Empirically, we analyze the case study of Futurepump, a frugal "smart connected solar-powered water pump" (Porter & Heppelmann, 2014) ("frugal smart water pump" in brief). This innovation was developed to offer clean and affordable irrigation to improve the quality of life of small-scale farmers (*smallholders*). The case study is based on a comparative study of the effects of digital innovation on sustainable development in the Global South (Van Tuijl et al., 2022a). The case study on Futurepump is selected for three reasons. First, it illustrates how a frugal water pump connected to an IoT platform can deliver affordable solar-powered irrigation to a large group of underserved smallholders. Second, our study is one of the first to establish a digital network for monitoring the performance of affordable solar-driven smallholder irrigation (Wiberg, 2020). Third, it targets clean energy, access to food, and poverty reduction, making it suitable for exploring opportunities and challenges regarding different SDGs.

The remainder of this paper is organized as follows. Section 2 introduces the theory of FI. Section 3 details the case study, and Sect. 4 provides a brief discussion, the main conclusion, and suggestions for further research.

2 Frugal Innovation

Frugal innovation (FI) is a resource-constrained innovation concept based on the principle of "doing more with less" (Radjou et al., 2012), later extended to "to do more with less for many" (Bhatti et al., 2018, p. 6). This latter differentiates FI from efficiency. The concept has been defined in various ways and intensively discussed in theoretical reviews (Agarwal et al., 2017; Hossain, 2018; Pisoni et al., 2018; Sarkar & Mateus, 2022). We surpass this *definition war* (Leliveld et al., 2023) and follow and slightly adapt Leliveld and

Knorringa's (2018, pp. 1–2) definition that FI is a process of "(re)designing products, services, systems, and business models in order to reduce complexity and total lifecycle costs, and enhance functionality, while providing high user value and affordable solutions" in resource-constrained environments (Agarwal et al., 2017). From this definition, it becomes clear that FIs (encompassing products, services, processes, or business models; Hossain et al., 2016) have the following characteristics (Bhatti et al., 2018; Radjou et al., 2012; Weyrauch & Herstatt, 2017): affordability (e.g., low user costs), simplicity (low complexity and concentration on core functionalities), accessibility (can be used by a large number of underserved users) and are appropriate for fulfilling users' needs in a given resource-constrained context. Constrained resources include materials, funding, technology, and skills (Hossain et al., 2016).

FI has been discussed in various scientific disciplines, covering various research topics. For instance, FI researchers have developed solutions in the field of medical science (e.g., three-dimensional printed prosthetics) to provide critical care for patients in remote areas distant from hospitals or to overcome urgent medical constraints (e.g., nurses, face masks, and hospital beds) during the COVID-19 pandemic (Harris et al., 2020; Mekontso Dessap, 2019; Tran & Ravaud, 2016). Moreover, these solutions have been used in frugal design and engineering with the aim of material and complexity reduction in design processes (Liefner et al., 2020). In management and economics, scholars have studied a wide diversity of themes, including sustainable business models (Hossain, 2021; Howell et al., 2018; Rosca et al., 2017); the development of products for bottom-of-the-pyramid markets (Prahalad, 2012); consumers with a frugal lifestyle (Herstatt & Tiwari, 2020); and resource-saving by managers (Ploeg et al., 2021). Different disciplines share the core principles of saving resources and developing solutions that can be used by many people. Moreover, the topics studied across disciplines have revealed the concept's relevance to wider sustainability discourses, as discussed in recent literature reviews (e.g., Albert, 2019; De Marchi et al., 2022).

Scholars have also related digitalization with FI and have assumed that digital technologies are important for realizing sustainable development (Van Tuijl et al., 2024). Various studies have discussed how digital technologies support frugal innovators in the domain of agriculture (this chapter's focus) and provide initial evidence on how such technologies can be used to develop affordable services for smallholders (e.g., poor farmers in remote areas) that could not be reached before. For instance, studies have discussed platforms that support smallholders in accessing services such as advice on soil conditions (Musona, 2021), land mapping services, and water monitoring systems (Agarwal et al., 2020). Other examples include agricultural trading platforms that support smallholders to obtain fairer prices in global markets (Bonina et al., 2021). In contrast, financial platforms, often in combination with satellite data and mobile phones, enable smallholders to access funding and crop insurance (Altamirano & Van Beers, 2018; Van Dijk, 2022; Van Tuijl et al., 2022b). Additionally, scholars have discussed how simple and inexpensive digital technologies can be used to reach smallholders. For instance, Apollo Agriculture provides voicemail-based (rather than video-based) training on how to use agricultural inputs (e.g., quality seed and fertilizer) to illiterate smallholders or those who do not have access to smartphones (Van Tuijl et al., 2022b).

The reviewed literature presents initial evidence on the potential of digital FIs to support smallholders and their assumed positive contributions to sustainable development. However, there is limited attention on how digital FIs contribute to sustainability and cause negative effects beyond the awareness of digital exclusion (Leliveld & Knorringa, 2018). Thus, we address this by identifying the opportunities and challenges faced by frugal smart water pumps.

3 Case Study: Futurepump

This case study is based on a larger study on the effects of digital innovation on sustainability outcomes in the Global South. It deploys a qualitative research approach with semi-structured interviews[2] as the primary data source. The case study on Futurepump relies on eight in-depth interviews with representatives, distributors, funders, and research partners of Futurepump (the firm that developed the smart pump). We interviewed managers, engineers, and data specialists. This diversity in disciplines and actors helped us to get insights into the role of digital technologies across the entire innovation process, ranging from concept development till usage by end-users. We had interviews with actors in the Global South as well as in the Global North. We could not interview end-users due to COVID-19 travel restrictions but tried to limit this bias by asking other interview partners how they interact with end-users and effects of the innovations on end-users. Moreover, we conducted an intensive desktop research strategy to gain insights into the perspective of end-users and to triangulate the interview data.

The interviews were semi-structured and lasted between 45 and 70 minutes. Interviewees were asked about their daily work activities; interactions with other actors; rationales, barriers, and drivers of the development of the Futurepump; and usage and effects of the Futurepump on sustainability outcomes. All interviews were recorded and transcribed. The transcripts were analyzed along the dimensions of the framework used in the large study: rationales and vision; technologies; governance; geography; timing; effects of COVID-19; and barriers, drivers, and effects of digital innovations. Please, see Van Tuijl et al. (2022a) for details.

[2] Interviewees are anonymized by codes comprising a combination of the following letters and numbers: C#G#AT#P#I#. These letters and numbers (#) refer to C# = case number (with C2 = Futurepump, the focus of this chapter); G# = Geographical location where the interviewee is based (G1 = Global South; G2 = Global North; G3 = Brazil; Russia; India; China; South Africa); A# = Actor type number (AT1 = Profit-oriented).

In the rest of this case study, we first introduce the aim and technology of Futurepump to explain how this FI can generate opportunities and challenges for sustainable development in the Global South. Second, we discuss the governance and geography of innovation to identify opportunities and challenges.

3.1 Aim and Technology

Futurepump aims to offer clean and affordable pressurized agricultural irrigation to improve smallholders' quality of life worldwide. This aim aligns with SDGs 2 (zero hunger) and 1 (no poverty). Moreover, the use of solar technology allows us to achieve SDG 7 (affordable and clean energy). The firm attempts to realize these opportunities for sustainable development by developing and implementing a frugal version of a "smart connected solar-powered water pump." The water pump is connected to a platform that operates on the Global System for Mobile Communication (GSM) digital mobile network, which can be considered a frugal version of an IoT platform because it is more affordable and accessible than Internet-based platforms. The technology and rationale of the firm and its innovation partners (see the next subsection) enable cost savings and increased access to agricultural irrigation for a large number of underserved smallholders in various ways.

First, the firm uses small-scale solar pumping systems deemed suitable for sustaining affordable smallholder pressurized irrigation. Using such pumps, smallholders have enhanced the control and management of water resources, thereby securing irrigation, farming cycles, and production (Giordano et al., 2019). Furthermore, solar-powered pumps bear virtually zero-cost operation because they do not require external inputs of electricity or fuel. Therefore, they are cost-effective solutions for resource-constrained smallholders. Moreover, given that photovoltaic panels (which have strongly declined in price in the last two decades; Kavlak et al., 2018) power these pumps, weak or nonexistent fuel supply chains virtually do not affect the operation of these technologies. This makes solar pumps suitable for remote off-grid areas.

Second, connecting the water pump to GSM provides new opportunities for smallholders and other local actors in the Global South. Through this platform, a new pay-as-you-go model is possible, in which smallholders pay to use the pumps (based on the amount of water pumped) instead of buying them at once. This makes the pump more affordable than conventional pumps. The platform also gathers data used in sustainability studies by local researchers. An example is the Real-time East Africa Live Groundwater Use Database (2019–2020) implemented by the University of Nairobi and the International Water Management Institute (IWMI). This project explored water management employing (big) data based on real-time information (collected through the platform) on water withdrawal, irrigated areas, and energy use collected through a platform. The project's primary objective was to inform policymakers and authorities about the sustainable use and management of water resources (C2_G2_AT1_M2). Finally, local distributors, who supply pumps and operate the platform, use the technology to offer predictive maintenance as a new way of providing services to smallholders. This new service approach can increase the service quality and save costs, as indicated by a distributor, "A large amount of it is Technical Support. So, if you can see what is happening on a remote pump then you (…) are able to remotely diagnose problems rather than have people travel for hours, maybe without the spare part that they needed because they did not know what the problem was" (C2_G2_AT1_M2). Thus, the various elements of the frugal smart water pump provide opportunities for various actors in the Global South and for different SDGs.

Despite this potential, our analysis unveils challenges in realizing these opportunities and shows contrasting results and negative effects on sustainable development. First, unfamiliarity with new service models slows the rapid deployment of smart water pumps and results in possible positive development effects. For instance, technological implementation and deployment related to remote monitoring systems may impose additional burdens on local distributors tasked with the last-mile distribution of these pumps. These systems would require additional staff training on how to transmit messages to prospective customers, access the data, and make meaningful use of that data. Owing to these burdens, some distributors choose traditional service contracts rather than being predictive-oriented (C2_G1_AT1_F8). Furthermore, some distributors remain more focused on selling pumps and less on after-sales services (C2_G2_AT1_M2). New digitally enabled service models do not generate value for the distributors. Likewise, the typical low technological literacy and limited understanding of new PAYG models by smallholders may prevent them from engaging in solar irrigation and interacting with the remote monitoring system. For instance, the electronics of the data logger used for the monitoring platform increase the reluctance of the end-user to utilize the smart pump (C2_G2_AT2_E1; C2_G1_AT1_F8). Even when smallholders deploy the new technology, unfamiliarity with the IoT system and/or solar pumping may lead to incorrect usage of the smart water pump, resulting in negative effects. For instance, the "pump for free" approach may lead to water overabstraction. Thus, given that smallholders can now pump without paying any fuel or electricity before using the pump, they may consider it more feasible to pump as much as possible without any environmental consequences.

To solve this challenge, Futurepump undertakes a process of education and familiarization with the concept to demonstrate the advantages of using smart solar pumps (C2_G2_AT1_M2). This educational process occurs in different forms, such as agricultural fairs (through workshops and demonstrations), explanations and testing at distributors' facilities, on-field testing, and digital materials distributed through social media. However, the latter is regarded as a major hurdle because rural customers do not always have access to social media. Moreover, explaining how smallholders save money over time by using new service models is considered challenging (C2_G2_AT1).

In addition to the challenges related to technology deployment and training, our interviewees provided additional challenges related to smart pumps and the potential to realize sustainable development in the Global South. One interviewee argued that the monitoring system does not benefit smallholders directly (C2_G1_AT1_F8). Smallholders may prefer not to rely on that system because it makes the pump less robust (more parts may be prone to failure) and somewhat more expensive (C2_G2_AT2_E1; C2_G1_AT1_F8). For instance, the predictive maintenance component creates (cost) advantages for distributors; however, it also reduces options for smallholders for low-cost self-repair.

Another challenge is that the smart water pump leads to (digital) exclusion caused by additional costs (beyond possible extra maintenance costs), and technological and regulatory constraints. For instance, the pay-as-you-go models may have financial downsides, particularly for the most marginalized, as proposed by the following two distributors:

> We are working with some of the poorer farmers. If we went for all that <remote monitoring system> and had a pay-as-you-go system, it would inevitably be born expensive for the farmer because you pass these costs on. But also, the whole point of pay-as-you-go is, if you don't pay it doesn't work. To me, all becomes self-defeating because if the farmer runs out of money halfway through the season and can't afford the pump payment, then he stops getting irrigation. Then the crop fails, then he's got no money. You know that's not good for anybody. (C2_G2_AT2_F7)

> If, for example, a farmer takes the pump and doesn't pay, switching them off is not the way to make them pay. There is another reason that are not paying. And if you do good asset financing, you don't switch people (…). You actually ask them what is going on and they try to solve the issue. (C2_G1_AT1_F8)

These quotes suggest the possibility of direct exclusion enabled by the new pay-as-you-go service model. In contrast, in the case of conventional pumps, exclusion is only possible when distributors return the pump or close the water connection on-site. Remotely located farmers may also be excluded from effectively adopting the proposed technologies. First, smallholders may encounter difficulties reaching them, particularly under poor road conditions and long travel times. Second, this remoteness also implies that the remote monitoring system is virtually inapplicable in certain locations where the GSM network lacks coverage. In addition, a lack of harmonized GSM regulations between countries may impede adoption of this technology (e.g., SIM cards are not easily attainable, and border areas are in a GSM limbo).

Finally, the costs of SIM cards and connections to GSM networks, which are ultimately paid for by the farmer, may become another financial hurdle to realizing the desired effects of the smart pump for sustainable development (C2_G2_AT1_M2; C2_G1_AT1_F8). This is particularly challenging in countries where legislation does not facilitate the mass acquisition of SIM cards.

Uganda is an example of this case, in which the SIM card is delivered only after thorough user registration (C2_G1_AT1_F8).

3.2 Governance and Geography

Developing the smart pump relies on several actors with different backgrounds (Table 1). Figure 1 illustrates the geography and relationships among these actors. Regarding relationships, these help us provide insights into challenges and opportunities for development in relation to the wider debate on leapfrogging versus the digital divide between actors in the Global South and Global North.

The initial idea for developing an affordable water pump (the platform was added later) for resource-constrained smallholders in the Global South started in 2006 in the Global North. This occurred when Practica—a non-profit technical advisory organization from The Netherlands—conducted research on five potentially feasible and appropriate water pumps to support smallholder irrigation. The organization shortlisted a technology worth exploring that operated on a solar thermal-powered steam engine. Starting in 2008, this

Table 1 Actors involved

Actor	*Location*	*Role*
Practica	The Netherlands	Research and development
International Development Enterprises (iDE)	USA	Market research and field testing
Renewable Energy and Energy Efficiency Partnership (REEEP)	Austria	Financial support for pumps' field testing in Ethiopia
Private entrepreneur	UK	Co-founder of Futurepump
Futurepump	UK	Management, distribution, and sales
Futurepump	India	Manufacturing
Kijani Testing	Kenya	Field-testing service
USAID—Powering agriculture	USA	Financial support to explore financial schemes in Kenya
Distributors (e.g., Malawi Fruits, SolarNow)	Different countries in the Global South	Last-mile distribution
Research institutes (e.g., International Water Management Institute (IWMI) and University of Nairobi)	Sri Lanka Kenya	Research with data generated by the smart pump
National SIM card providers	Different countries in the Global South	Enablers of GSM network
Smallholders	Different countries in the Global South	End-users of the pumps

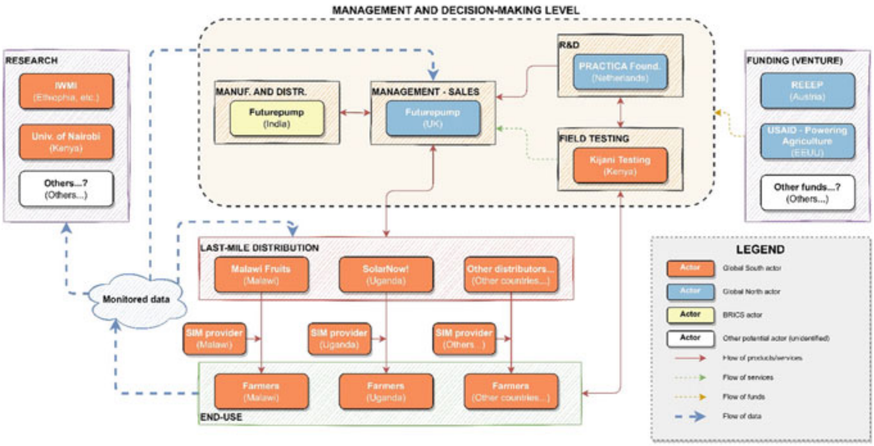

Fig. 1 Geography and interactions (*Source* Own elaboration)

pump underwent field testing in collaboration with the International Development Enterprises (iDE), a USA-based international non-profit organization that aims to empower entrepreneurs to end poverty. In 2011, owing to the financial support of the Renewable Energy and Energy Efficiency Partnership, Practica and iDE conducted market research to explore scaling options for the recently tested technologies. The research and test outputs became the primary success milestone that led to the formal establishment of Futurepump as a social enterprise in 2012. Later, Futurepump shifted to solar technology in 2014 and introduced a smart water pump by connecting it to a remote monitoring platform in 2018.

Accordingly, the actors in the Global North conduct several key activities. Futurepump and Practica are responsible for research on the core technologies of the smart pump. The headquarters of Futurepump (in Bugay, Suffolk County, eastern UK) oversee the overall management of the firm and its products. In addition, data collected through the remote monitoring system is stored, processed, and analyzed in the UK. Furthermore, REEEP and subsequent investors (not all listed in Table 1) are based in the Global North. Thus, regarding the key assets of funding, basic research, and management, a dependency on the Global North seems to exist.

Actors in the Global South conduct practical on-field activities. Kijani Testing in Kenya and, more recently, a new branch of Futurepump in Nepal (C2_G2_AT2_E1) are responsible for field testing the solar pumps during different development stages (C2_G2_AT1_M2, C2_G1_AT1_D3, and C2_G3_AT1_D4). Futurepump in India manages the production and distribution of products worldwide. Distributors in sub-Saharan countries and, to a lesser extent, in Southeast Asian countries deliver pumps to farmers. Finally, smallholders are the end-users of the technologies.

In addition to activities within the Global North or Global South, other activities occur in a noticeable Global North–Global South interaction, providing nuances for development in the Global South. First, the development and production of smart pumps are evident in close collaboration between Practica, Futurepump India, and Kijani Testing (C2_G2_AT2_E1; C2_G3_AT1_D4). These close relationships are evidenced by the representatives of Practica and Kijani Testing.

> Practica is an organization that has a lot of knowledge. We can develop things, but we are not in a position to actually roll them out and get them out into the world. So, we need companies like Futurepump. (C2_G2_AT2_E1)

> So, what we do for Futurepump is we work with the various products that they have, and we install them in various states depending on what information Futurepump is looking to get and we test them and give them feedback on how their products are doing. And then we also follow up with their distribution partners and find out how they are doing as well as do training to their various partners so that they are able to drive more sales and skill in the region. (C2_G1_AT1_D3)

Kijani, a testing and training partner in the field, provides permanent feedback. This feedback helps reduce bias (e.g., missing insights into the local context), which is essential for accelerating the development of the smart pump. Thus, technological dependency on actors in the Global North may exist as well as dependency on actors in the Global South who know and understand the local context. This is further evidenced by the fact that Futurepump does not directly interact with end-users but relies on national distributors (C2_G2_AT1_M2; C2_G2_AT2_F7; C2_G1_AT1_F8) as an interviewee claimed:

> Futurepump is very dependent on the performance of the distributors. Every country has a distributor, but not all of them are as serious or as good as they should be. Maybe most of them, not all of them, but most of them are just after money. You buy the pump cheap, and you sell it for as much as possible and you give it little service as you can (…) The quality of the distributors is very essential, I think, for this particular product because they have to provide the after-sales service. They have to set a proper price (…) It needs pretty strong support. (C2_G2_AT2_E1)

Second, data management occurs in the interaction between the Global South and Global North actors. The water pumping data collected through the pumps' remote monitoring systems is sent through the GSM network and stored in a cloud service hosted by Futurepump in the UK (C2_G2_AT1_M2). Besides Futurepump, distributors and researchers in the Global South (e.g., from IWMI and the University of Nairobi) also have access to these data and use them for new activities in the Global South, such as predictive maintenance and studies on sustainable water management (see the previous subsection).

Despite actors in the Global North and Global South having access to data obtained from the smart pump, the data collection process and subsequent data management present their own challenges. Given that the data are sent through GSM networks, a lack of coverage is a major hurdle for data collection. This will occur not only in areas without network coverage but also close to the national border areas where GSM networks overlap (C2_G1_AT1_F8). In these geographical locations, the remote monitoring system will simply be ineffective, or operate at very high rates:

> Regarding the sending of the data, there is the cost and the SIM cards, and the different costs in different countries. So, I know if someone moves a pump over a border and it changes into a different (provider), it is like roaming charges. (C2_G2_AT1_M2)

Thus, this clearly shows the challenges for the smart water pump regarding scaling of the concept to other regions and the risk for digital exclusion.

4 Discussion, Conclusion, and Further Research

This chapter contributes to the wider debate on digitalization and sustainable development in the Global South. In doing so, we use the theoretical concept of FI and conduct an empirical case study of a frugal smart water pump to identify the challenges and opportunities for sustainable development in the Global South. This section discusses the results and provides the overall conclusion and avenues for further research.

The study findings are summarized in Table 2. Based on these results, we discuss several nuances regarding the opportunities and challenges of the frugal smart pump for development in the Global South. First, we show the nuances of the potential of frugal smart pumps for smallholders. The smart pump reduces operational costs for smallholders owing to the use of solar power and becomes more affordable than conventional pumps through the pay-as-you-go model (Rastogi, 2018). This may help in obtaining the desired goal of improving smallholders' quality of life and aligns with other FI studies referring to the potential of digital technologies to support smallholders (e.g., Agarwal et al., 2020; Musona, 2021; Van Tuijl et al., 2022b). However, in contrast to existing literature, our data also reveals the challenge of increasing rather than decreasing user costs owing to the costs of GSM connections and fewer options for affordable self-repair. Moreover, as a dark side of digital innovation (Coad et al., 2021; McMurray et al., 2019), the platform allows remote distributors to directly exclude smallholders from irrigation services in the case of non-payment, whereas this is only possible on-site[3] with conventional pumps. Further, we show nuances regarding the challenge of digital exclusion (Bonina et al., 2021; Leliveld & Knorringa, 2018), which is caused by costs, technical and legal reasons, and users' lack of understanding of generating value using new digital models. Consequently, this would lead to a digital divide within the Global South, whereby the most marginalized smallholders fall even further behind.

Second, regarding the effect on the environment, frugal smart pumps offer opportunities for energy transition as solar technology has become more affordable and accessible for smallholders. Similarly, data collected through frugal smart water pumps have been used for research and policies to enable sustainable water management. Simultaneously, smallholders' unfamiliarity with the pay-as-you-go service model and/or solar technology may lead to an increase in water abstraction. This confirms the findings of earlier research on FI in the water sector, resulting in contrasting opportunities and challenges for different actors (Hyvärinen et al., 2016).

Third, we show the mutual dependency between actors in the Global South and Global North, bringing further nuances to opportunities for development. Dependency on actors in the Global North exists for a number of key assets (funding, core technology, and management) that would support the neo-colonialism perspective (e.g., Couldry & Mejias, 2019) and limit the

Table 2 Results

Opportunity	*Challenge*
– Energy transition due to solar technology – Data used for sustainable water management	– Risk increase water over-abstraction due to unfamiliarity with solar pumping systems
– Lower operational costs for smallholders due to solar power use – Increasing affordability for smallholders through pay-as-you-go model (as compared to paying a solar pump upfront)	– Higher costs due to GSM connections and reduced options for low-cost self-repair – Low understanding of new digital technologies and payment models hinder fast deployment – Digital exclusion caused by costs, infrastructure, and regulatory challenges
– Distributors' opportunities for cost saving and increased quality of repair services due to predictive maintenance – Dependency actors in the Global South for testing, distribution, and deployment	– Unawareness or unwillingness of distributors to adopt predictive maintenance service models – Dependency actors in Global North for funding, management, and core technologies

[3] We do not have evidence that this direct exclusion occurs. On the contrary, the distributors we interviewed were skeptical about this option. Nevertheless, from a technological perspective, the new digital service model enables this form of direct exclusion.

development potential in the Global South. However, actors in the Global South play an essential role in developing and deploying smart pumps because of their dependency on local research centers (which conduct fieldwork) and distributors (who have access to the end-users). For distributors, the predictive maintenance platform seems to offer opportunities owing to an increase in the efficiency of maintenance and repair activities (cf. Tiwari, 2021). Simultaneously, distributors may slow down the scaling of the smart pump and possible positive development effects, as they are unaware of how to generate value from predictive maintenance models. This aligns with both the IoT platform literature in the Global North (Bilgeri, 2019), where firms struggle with the transition to *dual business models* that combine value creation from physical products and digital services (Visnjic et al., 2022), and with studies on the slow deployment of non-digital technologies in the Global South in the past.

Overall, we present empirical evidence and nuances of how a frugal version of digital innovation offers opportunities and challenges for development in the Global South. This complements conceptual studies on digitalization in the Global South (e.g., Bonina et al., 2021; Sturgeon, 2021) as well as empirical FI studies on digital innovations in agriculture (e.g., van Dijk, 2022), largely focusing on opportunities for actors in the Global South. Thus, our presented challenges provide more insights into the dark sides of FI that are relatively underexplored (Franz, 2022). Moreover, we show small nuances regarding the environmental dimension of sustainability, which has received limited attention in FI studies compared to the economic and social dimensions (Albert, 2019).

As we have explored only one specific case, we suggest further case studies on similar products (i.e., frugal smart connected products) in other countries, as well as on other digital technology types (e.g., Artificial Intelligence) and industries. Furthermore, we identify the opportunities and challenges of a frugal version of digital technology for sustainable development in the Global South but did not elucidate the actual effects. Therefore, we suggest an impact study on effects, such as employment, income generated by actors in the Global South, and environmental resources (e.g., water, energy, and land) used. Finally, we show that actors in the Global South and Global North both have access to data generated by the frugal smart pump. However, further insight into how data access and algorithmic sorting practices occur is necessary to understand whether digital technologies lead to a new form of colonialism or opportunities for leapfrogging.

Acknowledgements This case study is part of the larger project "The Role of New Technologies in Addressing the SDGs: What Is in It for the Global South?" funded by the Dutch Science Organisation (NWO) within the Dutch Research Agenda (NWA) Small projects for NWA (file number NWA.1418.20.005).

References

Agarwal, N., Chung, K., & Brem, A. (2020). New technologies for frugal innovation. In A. J. McMurray & G. De Waal (Eds.), *Frugal innovation: A cross global research companion* (pp. 137–149). Routledge.

Agarwal, N., Grottke, M., Mishra, S., & Brem, A. (2017). A systematic literature review of constraint-based innovations: State of the art and future perspectives. *IEEE Transactions on Engineering Management, 64*(1), 3–15. https://doi.org/10.1109/TEM.2016.2620562

Albert, M. (2019). Sustainable frugal innovation: The connection between frugal innovation and sustainability. *Journal of Cleaner Production, 237*. https://doi.org/10.1016/j.jclepro.2019.117747

Altamirano, M. A., & Van Beers, C. P. (2018). Frugal innovations in technological and institutional infrastructure: Impact of mobile phone technology on productivity, public service provision and inclusiveness. *European Journal of Development Research, 30*(1), 84–107. https://doi.org/10.1057/s41287-017-0115-2

Bhatti, Y. A., Ramaswami Basu, R., Barron, D., & Ventresca, M. J. (2018.). *Frugal innovation: Models, means, methods*. Cambridge University Press.

Bilgeri, A. (2019). *The impact of IoT on specific business model elements-Insights from multibusiness manufacturing companies* (Doctoral dissertation). ETH Zürich. https://doi.org/10.3929/ethz-b-000387657

Bonina, C., Koskinen, K., Eaton, B., & Gawer, A. (2021). Digital platforms for development: Foundations and research agenda. *Information Systems Journal, 31*(6), 869–902. https://doi.org/10.1111/isj.12326

Brynjolfsson, E., & McAfee, A. (2014). *The second machine age: Work, progress, and prosperity in a time of brilliant technologies*. W. W. Norton.

Busch, H. C. (2021). Frugal innovation in energy transitions: Insights from solar energy cases in Brazil. *Cambridge Journal of Regions, Economy and Society, 14*(2), 321–340. https://doi.org/10.1093/cjres/rsab007

Coad, A., Nightingale, P., Stilgoe, J., & Vezzani, A. (2021). Editorial: The dark side of innovation. *Industry and Innovation, 28*(1), 102–112. https://doi.org/10.1080/13662716.2020.1818555

Couldry, N., & Mejias, U. A. (2019). Data colonialism: Rethinking big data's relation to the contemporary subject. *Television and New Media, 20*(4), 336–349. https://doi.org/10.1177/1527476418796632

del Río Castro, G., González Fernández, M. C., & Uruburu Colsa, Á. (2021). Unleashing the convergence amid digitalization and sustainability towards pursuing the Sustainable Development Goals (SDGs): A holistic review. *Journal of Cleaner Production, 280*. https://doi.org/10.1016/j.jclepro.2020.122204

De Marchi, V., Pineda-Escobar, M. A., Howell, R., Verheij, M., & Knorringa, P. (2022). Frugal innovation and sustainability outcomes: Findings from a systematic literature review. *European Journal of Innovation Management, 25*(6), 984–1007. https://doi.org/10.1108/EJIM-02-2022-0083

De Waal, G., Thangarajah, J., & McMurray, A. (2019). Artificial intelligence and frugal innovation: A formidable alliance in future education. In A. Stachowicz-Stanusch & W. Amann (Eds.), *Management and business education in the time of artificial intelligence (AI)—The need to rethink, retrain, and redesign* (pp. 55–74). Information Age Publishing.

Franz, S. (2022). *The changing geography of innovation: Affordable innovation by western MNCs in and for emerging economies in Asia* (Doctoral dissertation). University of Gothenburg.

Giordano, M., Barron, J., & Ünver, O. (2019). Water scarcity and challenges for smallholder agriculture. In *Sustainable food and agriculture* (pp. 75–94). FAO and Elsevier. https://doi.org/10.1016/B978-0-12-812134-4.00005-4

Harris, M., Bhatti, Y., Buckley, J., & Sharma, D. (2020). Fast and frugal innovations in response to the COVID-19 pandemic. *Nature Medicine, 26*(6), 814–817. https://doi.org/10.1038/s41591-020-0889-1

Herstatt, C., & Tiwari, R. (2020). Opportunities of frugality in the post-corona era. *International Journal of Technology Management, 83*(1–3), 15–33.

Hossain, M. (2018). Frugal innovation: A review and research agenda. *Journal of Cleaner Production, 182*, 926–936. https://doi.org/10.1016/j.jclepro.2018.02.091

Hossain, M. (2021). Frugal innovation and sustainable business models. *Technology in Society, 64*. https://doi.org/10.1016/j.techsoc.2020.101508

Hossain, M., Simula, H., & Halme, M. (2016). Can frugal go global? Diffusion patterns of frugal innovations. *Technology in Society, 46*, 132–139. https://doi.org/10.1016/j.techsoc.2016.04.005

Howell, R., Van Beers, C., & Doorn, N. (2018). Value capture and value creation: The role of information technology in business models for frugal innovations in Africa. *Technological Forecasting and Social Change, 131*, 227–239. https://doi.org/10.1016/j.techfore.2017.09.030

Howson, P. (2020). Climate crises and crypto-colonialism: Conjuring value on the blockchain frontiers of the Global South. *Frontiers in Blockchain, 3*. https://doi.org/10.3389/fbloc.2020.00022

Hyvärinen, A., Keskinen, M., & Varis, O. (2016). Potential and pitfalls of frugal innovation in the water sector: Insights from Tanzania to global value chains. *Sustainability, 8*(9), 888. https://doi.org/10.3390/su8090888

Jellason, N. P., Robinson, E. J. Z., & Ogbaga, C. C. (2021). Agriculture 4.0: Is Sub-Saharan Africa ready? *Applied Sciences, 11*(12), 5750. https://doi.org/10.3390/app11125750

Kavlak, G., McNerney, J., & Trancik, J. E. (2018). Evaluating the causes of cost reduction in photovoltaic modules. *Energy Policy, 123*, 700–710. https://doi.org/10.1016/j.enpol.2018.08.015

Leliveld, A., Bhaduri, S., Knorriga, P., & Van Beers, C. (2023). *Handbook on frugal innovation*. Edward Elgar.

Leliveld, A., & Knorringa, P. (2018). Frugal innovation and development research. *European Journal of Development Research, 30*(1), 1–16. https://doi.org/10.1057/s41287-017-0121-4

Levänen, J., Hossain, M., Lyytinen, T., Hyvärinen, A., Numminen, S., & Halme, M. (2015). Implications of frugal innovations on sustainable development: Evaluating water and energy innovations. *Sustainability, 8*(1), 4. https://doi.org/10.3390/su8010004

Liefner, I., Losacker, S., & Rao, B. C. (2020). Scale up advanced frugal design principles. *Nature Sustainability, 3*(10), 771. https://doi.org/10.1038/s41893-020-0585-7

Maric, J., Rodhain, F., & Barlette, Y. (2016). Frugal innovations and 3D printing: Insights from the field. *Journal of Innovation Economics & Management, 21*(3), 57–76. https://doi.org/10.3917/jie.021.0057

McMurray, A., Weerkanoon, C., & Etse, D. (2019). Exploring the dark side of frugal innovation. In A. McMurray & G. de Waal (Eds.), *Frugal innovation: A global research companion* (pp. 311–336). Routledge.

Mekontso Dessap, A. (2019). Frugal innovation for critical care. *Intensive Care Medicine, 45*(2), 252–254. https://doi.org/10.1007/s00134-018-5391-6

Muldoon, J. (2022). *Platform socialism how to reclaim our digital future from big tech.* Pluto Press.

Musona, J. (2021). New business models for frugal innovation: Experience from an enterprise supporting sustainable smallholder agriculture in Kenya. In *Frugal innovation and its implementation: Leveraging constraints to drive innovations on a global scale* (pp. 165–190). Springer. https://doi.org/10.1007/978-3-030-67119-8_8

Pisoni, A., Michelini, L., & Martignoni, G. (2018). Frugal approach to innovation: State of the art and future perspectives. *Journal of Cleaner Production, 171*, 107–126. https://doi.org/10.1016/j.jclepro.2017.09.248

Ploeg, M., Knoben, J., Vermeulen, P., & Van Beers, C. (2021). Rare gems or mundane practice? Resource constraints as drivers of frugal innovation. *Innovation: Organization and Management, 23*(1), 93–126. https://doi.org/10.1080/14479338.2020.1825089

Porter, M., & Heppelmann, J. (2014). How smart, connected products are transforming competition. *Harvard Business Review*, 66–88.

Prabhu, J. (2017). Frugal innovation: Doing more with less for more. *Philosophical transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 375*(2095). https://doi.org/10.1098/rsta.2016.0372

Prahalad, C. K. (2012). Bottom of the pyramid as a source of breakthrough innovations. *Journal of Product Innovation Management, 29*(1), 6–12. https://doi.org/10.1111/j.1540-5885.2011.00874.x

Radjou, N., Prabhu, J., & Ahuja, S. (2012). *Jugaad innovation: Think frugal, be flexible, generate breakthrough growth.* Wiley and Sons.

Rastogi, C. (2018). M-Kopa solar: Lighting up the dark continent. *South Asian Journal of Business and Management Cases, 7*(2), 93–103. https://doi.org/10.1177/2277977918774648

Ritchie, H. A. (2022). An institutional perspective to bridging the divide: The case of Somali women refugees fostering digital inclusion in the volatile context of urban Kenya. *New Media and Society, 24*(2), 345–364. https://doi.org/10.1177/14614448211063186

Rosca, E., Arnold, M., & Bendul, J. C. (2017). Business models for sustainable innovation—An empirical analysis of frugal products and services. *Journal of Cleaner Production, 162*, S133–S145. https://doi.org/10.1016/j.jclepro.2016.02.050

Sarkar, S., & Mateus, S. (2022). Value creation using minimal resources—A meta-synthesis of frugal innovation. *Technological Forecasting and Social Change, 179.* https://doi.org/10.1016/j.techfore.2022.121612

Soete, L. (1985). International diffusion of technology, industrial development and technological leapfrogging. *World Development, 13*(3), 409–422. https://doi.org/10.1016/0305-750X(85)90138-X

Srnicek, N. (2017). *Platform capitalism.* Wiley.

Steinmueller, W. E. (2001). ICTs and the possibilities for leapfrogging by developing countries. *International Labour Review, 140*(2), 193–210. https://doi.org/10.1111/j.1564-913X.2001.tb00220.x

Sturgeon, T. J. (2021). Upgrading strategies for the digital economy. *Global Strategy Journal, 11*(1), 34–57. https://doi.org/10.1002/gsj.1364

Suri, T., & Jack, W. (2016). The long-run poverty and gender impacts of mobile money. *Science, 354*(6317), 1288–1292. https://doi.org/10.1126/science.aah5309

Tilson, D., Lyytinen, K., & Sørensen, C. (2010). Digital infrastructures: The missing IS research agenda. *Information Systems Research, 21*(4), 748–759. https://doi.org/10.1287/isre.1100.0318

Tiwari, R. (2021). Digital transformation as enabler of affordable green excellence: An investigation of frugal innovations in the wind energy sector. . In *Frugal innovation and its implementation: Leveraging constraints to drive innovations on a global scale* (pp. 247–277). Springer. https://doi.org/10.1007/978-3-030-67119-8

Tran, V.-T., & Ravaud, P. (2016). Frugal innovation in medicine for low resource settings. *BMC Medicine, 14*(1), 102. https://doi.org/10.1186/s12916-016-0651-1

Van Dijck, J., Poell, T., & De Waal, M. (2018). *The platform society: Public values in a connected world*. Oxford University Press.

Van Dijk, M. P. (2022). Crop insurance, a frugal innovation in Tanzania, helps small maize farmers and contributes to an emerging land market. *Land, 11*(7), 954. https://doi.org/10.3390/land11070954

Van Tuijl, E., Basajja, M., Intriago Zambrano, J. C., & Knorringa, P. (2022a, July). *The Global South as test-bed for innovations: Digital economy, technologies, effects on development and frame of analysis* (ICFI Working paper number 8).

Van Tuijl, E., Basajja, M., Intriago-Zambrano, J. C., & Knorringa, P. (2022b). Drivers and barriers of a platform-based business model in agriculture: The case of Apollo Agriculture. *DevISSues, 24*(1), 8–10.

Van Tuijl, E., Intriago Zambrano, J. C., and Knorringa, P. (2024). Increasing or decreasing frugality: The connection between digitalization and frugal innovation, *International Journal of Innovation Management*. https://doi.org/S1363919624500130

Van Tuijl, E., & Knorringa, P. (2023). Frugal innovation and digital platforms. In A. Leliveld, S. Bhaduri, P. Knorringa, & C. Van Beers (Eds.), *Handbook on frugal innovation* (pp. 278–294). Edward Elgar.

Visnjic, I., Jovanovic, M., & Raisch, S. (2022). Managing the transition to a dual business model: Tradeoff, paradox, and routinized practices. *Organization Science, 33*(5), 1964–1989. https://doi.org/10.1287/orsc.2021.1519

Weyrauch, T., & Herstatt, C. (2017). What is frugal innovation? Three defining criteria. *Journal of Frugal Innovation, 2*(1), 1. https://doi.org/10.1186/s40669-016-0005-y

Wiberg, D. (2020). *Challenge winner moves forward with IoT to develop world first database*. IWMI. https://www.iwmi.cgiar.org/2020/04/challenge-winner-moves-forward-with-iot-to-develop-world-first-database/

Wood, A. J., Graham, M., Lehdonvirta, V., & Hjorth, I. (2019). Good gig, bad gig: Autonomy and algorithmic control in the global gig economy. *Work, Employment and Society, 33*(1), 56–75. https://doi.org/10.1177/0950017018785616
Zuboff, S. (2019). *The age of surveillance capitalism: The fight for a human future at the new frontier of power*. Profile Books.