
UNIVERSITY OF THE BASQUE COUNTRY UPV/EHU

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# "EXPLORATION OF FRUGAL INNOVATIONS AND THEIR IMPLICATIONS IN INDUSTRIES"

Doctoral thesis presented by:

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To my husband, parents, and brother

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# Chapter 1 Introduction

## 1.1. Motivation of the thesis and scope of the contribution

An ancient Chinese proverb says, "*When the winds of change blow, some people build walls and others build windmills".* The necessity to introduce new solutions to our VUCA (volatility, uncertainty, complexity and ambiguity) world raises. The series of crises, constraints of resources require unconventional solutions, which should be adapted to the context. Frugal innovation is one of the concepts which is called to address the problem of unserved consumers under scarce resources (Hossain 2018). The word roots from 'Latin frugalis virtuous, from frug-, frux fruit, value' in 1542 (Merriam-Webster 2021). India is known as a motherland for frugal innovations, the term tackled the problems only in developing countries previously, however, lately, it was introduced in developed ones (Wohlfart et al. 2021). The term "frugal innovation" is quite new, and as it becomes more widespread around the globe due to increasing request for sustainable and affordable quality solutions. Although, the term is under debates, academic literature states that frugal innovation is the type of innovation that refers to an inexpensive, effective, uncomplex, sustainable solution under constraints (Hossain 2020, 2021; Zeschky, Winterhalter, and Gassmann 2014), including products, processes, and business models, using fewer resources that are harmless for the environment (Gupta and Wang 2009). Frugal innovation facilitates to achieve sustainable development goals (SDGs) and reach social sustainability goals via the application of FI (Khan 2016).

Frugal innovation is a "redesigning products or/and processes to reduce useless costs" (Wooldridge 2010). It can be seen as a mindset or way of life, a process, and an output all at once (Soni and Krishnan 2014). The principles of frugal innovation are robustness, portability, de-featuring, leapfrog technology, mega-scale production, and service ecosystems (Kumar 2008). From another perspective they encompass such principles as engage and iterate; flex assets; create sustainable solutions; shape customer behaviour;

co-create value with prosumers, and make innovative friends (Radjou and Prabhu 2015). The concept created as one of the win-win solutions for the shared benefit of business and communities, society, and the environment. Hence, innovation efforts require frugal approach and aim to help local businesses and communities to overcome the impacts of a global crisis.

Personally, given the struggle businesses and communities have faced energy, food, pandemic, post-pandemic and financial crises, I felt compelled to illustrate the potential ability of frugal innovations, their real necessity for business and society, and identify the potential markets in terms of industries and countries. Particularly, I was attracted by such industry as dairy farming, since the research on frugal innovations is not presented enough, nevertheless it requires sustainable, effective, and solutions for customers with limited resources. Since the thesis implies a various approach, it could be used by practitioners from all fields of industries, and dairy farming in particular. Given the alarming spread of global crisis and challenging issues with sustainability, we believe that the findings presented in our thesis will appeal to "Sustainable Development Goals" policymakers, and facilitate the formation of strategy and legal. For the academic world, it illustrates the presence of frugal innovations into the specific domain and their absence that provides a future research path, it explores the process of contribution of frugal innovation. Due to the relevance of the concept to the current economic, environmental, and social situation the research on frugal innovation has raised during last decade. The first paper in English appeared was in 2005 (Winkler et al. 2020).

Till nowadays, few attempts were made in academic literature to map the FI, generally in India. The research areas were presented by health, electronics, transportation, finance, IT/ICT, and energy sectors. The research was focused firstly on developing economies and developed countries attracted the attention only the last years (Winkler et al. 2020). Few is known about frugal innovation in developed countries. However, authors Tatum & Russo (2020), Dangelo & Magnusson (2021), Santos et al. (2020) presented collection of general data from the main research on frugal innovation using bibliometric analysis, this provides general mapping of the domain. Thus, there is a need to map the knowledge, taking into account

the raise of last research, as well as to conduct research that covers larger datasets with a qualitative assessment of clusters and research trends with respect to the different variables, such as industry, country, investigation methodology, research type, and most cited articles. To establish an empirical connection between modern concepts of frugal innovation and stakeholders (the business community, society, and the environment) to present a tool valuable in promoting innovative development in the medium run and long-term run. Moreover, the relevance of the research is justified by the increasing number of publications year by year.

Hence, at first, we focused on general exploration of frugal innovations via mapping them. Then we found out the lack and almost absence of research in such suitable industries for frugal innovations as agriculture, dairy farming, textile, this became a motivation for deeper analysis of these industries. Also, we found that there is a need of deeper research for such essential industry as food retail in pandemic times. Covid crises has affected the communities and business, thus the last one had to respond quickly, one of the essential specially during pandemic is food retail and digital sectors. Hence there is a need to identify the general trends of digital marketing of food retailers and the way their business model has been transformed (Alnawas and al Khateeb 2022). This constructs the common unity of the thesis in a logical manner, flowing from the general exploring the academic literature to the practical one focusing on lacking industries.

Therefore, there is a need explore the ability of frugal innovation to solve social and economic problems of society with a sustainable approach, since their increase during last time. Frugal innovations are called to provide solutions for underserved customer (Hossain 2020), however their social, economic, and sustainable values through organizational innovations and frugal innovative product were overlooked. Thus, there is a need to study how frugal innovation contributes to the business and community. Moreover, given the context of dairy farming and developed economy, it becomes more valuable since the discourse about the requirement of sustainable production in the dairy farming sector increases, whereas the affordability of resources reduces, FAO (2010) claims that dairy farming is responsible for

the large contribution of CH4 and CO2 emissions, also often compromising the welfare of the animals (Keeling et al. 2019). In the meantime, the uncertainty and low prices for milk along with increasing operational expenses such as fuel, and feed push the business to operate under scarce resources even in developed countries. Despite European governments try to support the dairy farming sector with subsidies, and voluntary coupled support (VCS) (European Comission 2020), the business requires some innovations which will respond to their requests. Frugal innovation considers limitation of resources as opportunity, thus, there is a need to investigate how effective they are, serving the customers in developed countries and to examine the frugal innovation in dairy farming in terms of milk production, economic efficiency for a farmer, and ecological impact. There is a lack of research on frugal innovation in this industry, a low-cost milking machine developed in India considered from the perspective of the sustainable business model presented in studies of Hossain (2021) and empowering female entrepreneurship in the dairy business and its driver for a market boost in Kenya mentioned in works of Sydow & Funké (2021), we need to explore the way for the dairy farming to become more effective and sustainable, and to develop methodological approach to assess the effectiveness of frugal innovation management.

Therefore, the thematic unit object of analysis of the thesis is the relatively new business paradigm known as frugal Innovation. This thesis, which is presented in the form of a compendium of articles, aims to deepen knowledge and make contributions in the field of frugal innovation, conceptually as well as from the point of view of a management tool for organizations.

We have started from theoretical review using research published during the decade logically flowing into practical solutions in suitable conditions and required industries.

We introduce a brief mapping to the scope of this Thesis that comprises conceptual as empirical approaches in several papers.

The first paper, "Frugal Innovation: Meta-Analysis of Bibliographic Relationships and Identification of Research Trends for the Period 2010-2021," provides a broad overview of the research trends related to

frugal innovation. It helps to establish a baseline understanding of the field and identify the key themes that have emerged over the past decade. The second paper, "Ten years of frugal innovation: Bibliometric and theoretical review," builds on the first paper by conducting a more in-depth analysis of the literature on frugal innovation. It provides a theoretical framework for understanding frugal innovation and identifies the key themes and concepts that have emerged in the literature. Thus, the above-mentioned papers allowed us to create a universal definition of FI, identify the main research trends in frugal innovation field, identify the industries, countries where frugal innovations are present, explore the ability of frugal innovation to solve social and economic problems of society with sustainable approach. Once, the research trends were identified, including industries, we found the lack in such suitable industries as livestock, and textile. Also, our findings demonstrate the need of research in covid-19 constraints and food. Hence, the further papers focus on practical aspects, rather than in theoretical as previous research papers. Thus, the third paper, "Frugal innovation in the textile industry, as a tool for solving problems in the field of waste disposal and recycling," focuses specifically on the textile industry and how frugal innovation can be used to address issues related to waste disposal and recycling. It provides a practical example of how frugal innovation can be applied in a specific industry and presents the business model for solving problems in the field of waste disposal and recycling in terms of frugal innovations. The fourth paper, "Frugal innovations and main trends of digital marketing in post-covid-19 retail: Case Study of the leading Russian food chains," explores the intersection of frugal innovation and digital marketing in the retail industry. It provides insights into how frugal innovation can be used to address the challenges facing retailers in the post-COVID-19 era. It defines the general trends of digital marketing in food retail in context of frugal innovations during COVID crisis. The fifth paper, "Digital transformation of business model of Russian food retailers during covid-19 pandemic through lens of frugal innovation," further explores the role of frugal innovation in the retail industry, but with a focus on how it can be used to drive digital transformation in the face of a pandemic. It identifies how food

retailers' business model has been transformed in terms of frugal innovation during pandemic. The next papers focus on practical solutions in livestock.

The sixth and seventh papers, "Frugal innovations and implications, a single case study on dairy farming from developed countries" and "Frugal innovation and economic performance of a dairy livestock farm," respectively, focus on the application of frugal innovation in the dairy farming industry. These papers provide practical examples of how frugal innovation can be used to improve economic performance and sustainability in the agriculture and livestock sector. They explore social, economic, and sustainable values of FI, through organizational innovations and frugal innovative product. Identify how frugal innovation contributes to the provider (business) and receiver of frugal innovations (farmers' communities), serving underserved customers in developed countries in context of dairy farming. They determine the results of frugal innovation introduction in dairy farming, diagnosing the effectiveness of frugal innovation management in a livestock farm. Further, the papers examine the frugal innovation in dairy farming in terms of milk production, economic efficiency for a farmer, and ecological impact. Lastly, the research allows to form a methodological approach to assess the effectiveness of frugal innovation management. Together, these papers provide a comprehensive and integrated view of frugal innovation and its implications in various industries. They help to establish a theoretical framework for understanding frugal innovation, provide practical examples of how it can be applied in specific industries, and identify key trends and themes that are emerging in the field. Thus, this PhD thesis developed with a global, integrated, and coherent vision of frugal innovation and its implications in industries.

## 1.2. Theoretical Framework and Methodology

As we delve into the exploration of frugal innovations and their implications in industries, it is important to contextualize the discussion within the broader framework of sustainable development. Sustainable

development refers to the development that meets the needs of the present without compromising the ability of future generations to meet their own needs (World Commission on Environment and Development, 1987). The concept of sustainable development was first introduced in the Brundtland Report, also known as "Our Common Future," which was published by the World Commission on Environment and Development in 1987. The report highlighted the need for a sustainable development path that would ensure economic growth, social equity, and environmental protection (WCED, 1987). Since then, sustainable development has become a central theme in global policy-making and business practices. Sustainable development is a widely researched concept that has been the subject of numerous studies in the academic literature. As noted by Lélé and Norgaard (2005), sustainable development encompasses various dimensions, including environmental, social, and economic. The environmental dimension of sustainable development emphasizes the need for protecting natural resources and biodiversity, reducing greenhouse gas emissions, and mitigating climate change impacts (WBCSD, 2010). The social dimension of sustainable development focuses on reducing poverty, improving access to education and healthcare, promoting gender equality, and protecting human rights (WCED, 1987). The economic dimension of sustainable development emphasizes the need for economic growth that is inclusive, equitable, and environmentally sustainable (UNEP, 2011).

According to Elkington (1997), sustainable development requires a triple bottom line approach that takes into account economic, social, and environmental considerations. The concept of sustainable development has evolved over time and has become an essential framework for addressing global challenges (WCED, 1987). As noted by Geissdoerfer et al. (2017), the circular economy is an example of a practical approach that can help achieve sustainable development by promoting resource efficiency and reducing waste.

There are several frameworks and theories related to sustainable development, including the Sustainable Development Goals (SDGs) adopted by the United Nations in 2015 (UN, 2015). The SDGs are a set of 17 interconnected goals that aim to end poverty, protect the planet, and ensure prosperity for all. The

SDGs provide a comprehensive framework for sustainable development that covers all dimensions of sustainability (UN, 2015).

Within the realm of sustainable development, there are other various economic paradigms that have emerged over the years, including the sustainable economy, circular economy, green economy, and frugal economy. The sustainable economy seeks to create an economic system that is sustainable in the long term, by minimizing negative environmental and social impacts, while ensuring that economic growth and development continue (Gibson-Graham, 2006).

Interconnections and Synergies

Sustainabile Economy and Circular Economy: Both models champion resource efficiency, including product lifecycle management. However, while the former balances social, economic, and environmental aspects, the latter emphasizes reducing material flow in the economy. Green Economy and Sustainabile Economy: Both focus on environmental preservation, but the Green Economy can be seen as a subset of the broader Sustainabile Economy. Frugal Economy and Circular Economy: Both advocate for resource efficiency in product usage. Frugal Economy goes a step further by ensuring that innovations are affordable and accessible (Wang & Li, 2023). Frugal Economy and Sustainabile Economy: Frugality can be incorporated into sustainable economic models to reach goals with fewer resources, thereby increasing overall efficiency (Fig. 1).

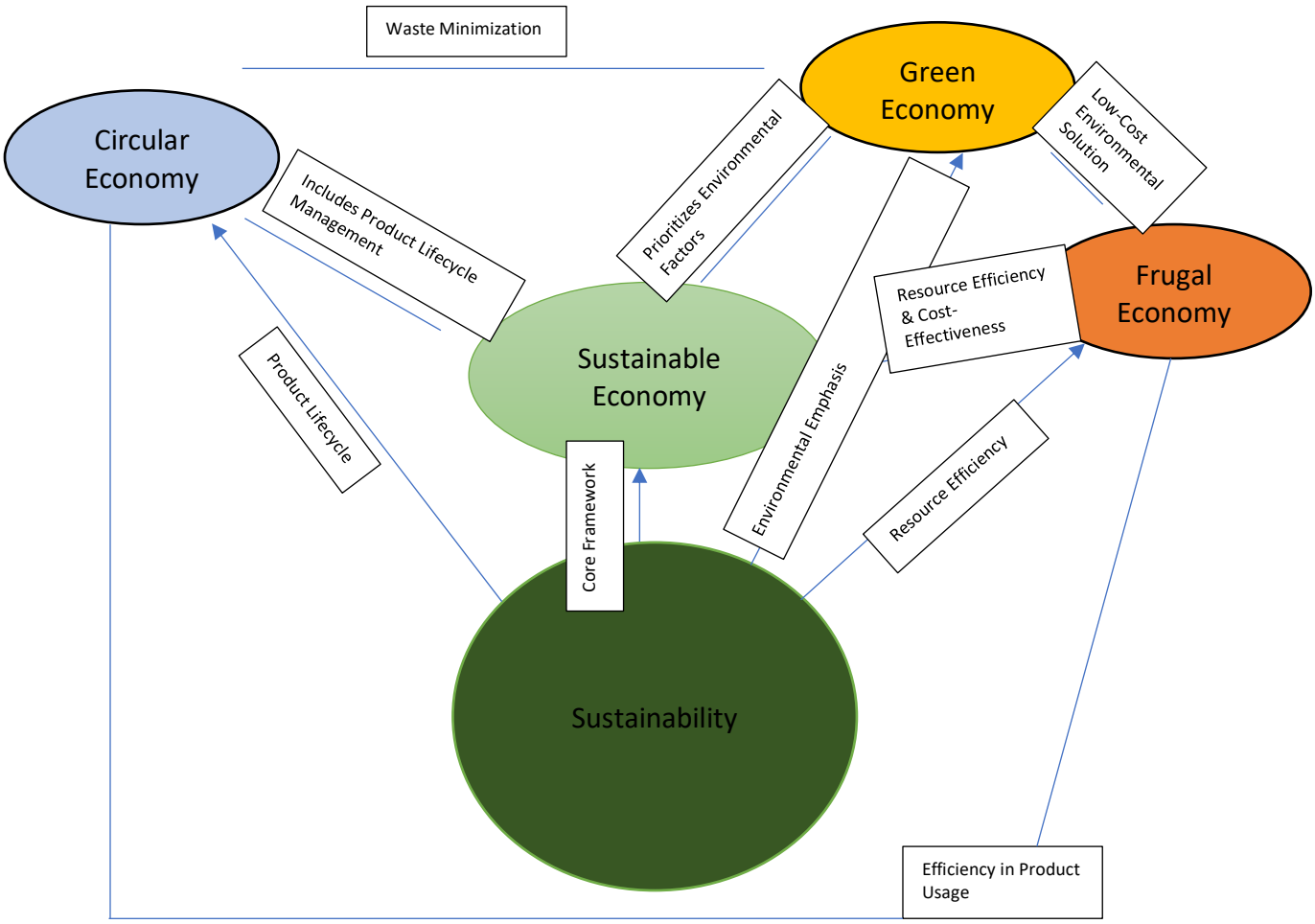



Figure 1. Synergies and interconnections Source: Own contribution.

The sustainable economy is an economic system that aims to maximize social, economic, and environmental well-being while minimizing negative impacts on the environment (Gibbs & Deutz, 2007). It recognizes the interdependence of economic, social, and environmental systems and advocates for their harmonious functioning for long-term prosperity (WCED, 1987). The principles of sustainable development underpin the sustainable economy and emphasize the need to use resources in a manner that ensures their availability for future generations (IISD, 2019). One of the fundamental aspects of the sustainable economy is the use of renewable resources and energy. The promotion of renewable energy sources such as solar, wind, and hydro power is seen as a way to reduce dependence on fossil fuels and decrease greenhouse gas emissions (IPCC, 2018). The sustainable economy also advocates for the use

of clean technologies and sustainable practices, such as green building design, sustainable agriculture, and waste reduction (OECD, 2017). Social equity and inclusivity are also vital components of the sustainable economy. The goal is to ensure that economic growth and development benefit all members of society, including marginalized and vulnerable populations (UN, 2015). This can be achieved through policies that promote fair labor practices, access to education and healthcare, and social safety nets (ILO, 2017). Overall, the sustainable economy is a vision for an economic system that supports long-term prosperity, social equity, and environmental well-being. It requires a paradigm shift in the way we think about economic growth and development and the way we use natural resources. Collaborative efforts among businesses, governments, and individuals are crucial for implementing sustainable economic practices to create a more sustainable future for all (UNEP, 2011).

The circular economy is closely linked to the sustainable economy and is an economic system that aims to minimize waste and maximize the use of resources (Ellen MacArthur Foundation, 2019). It advocates for strategies such as product design for longevity, resource recovery, and recycling to keep materials in use for as long as possible. The circular economy aims to design out waste and pollution, keep products and materials in use, and regenerate natural systems. It is an economic system that seeks to minimize waste and maximize the use of resources by keeping materials in use for as long as possible (Ellen MacArthur Foundation, 2021). In contrast to the traditional linear economy, which is based on a "take-make-dispose" model, the circular economy is focused on creating closed-loop systems where materials are continuously reused and repurposed (European Commission, 2020). There are several key principles of the circular economy. These include designing products and services for longevity and reuse, using renewable energy sources, and minimizing waste through strategies such as recycling and composting (Bocken et al., 2016). The circular economy also emphasizes the importance of collaboration and innovation across different sectors and industries to create more efficient and sustainable resource management systems (Geissdoerfer et al., 2017). The benefits of the circular economy are numerous. By reducing waste and increasing resource efficiency, it can help to mitigate environmental damage and

promote sustainable development (Kirchherr et al., 2017). It can also create economic opportunities and jobs by promoting the growth of new industries and markets focused on the production and reuse of goods and services (Ellen MacArthur Foundation, 2021). However, implementing a circular economy requires a significant shift in the way that businesses and individuals approach resource management. This shift requires changes in product design, supply chain management, and consumer behavior. It also requires collaboration among stakeholders to create the necessary infrastructure and policies to support circular systems (Bocken et al., 2016).

In recent years, there has been growing interest in the circular economy among businesses, governments, and other organizations. Several initiatives and programs have been launched to promote circular practices, including the Ellen MacArthur Foundation's Circular Economy 100 and the European Union's Circular Economy Action Plan (Ellen MacArthur Foundation, 2021; European Commission, 2020). Overall, the circular economy offers a promising vision for a more sustainable and efficient economic system. Its principles align with the goals of sustainable development and provide a framework for creating closed-loop systems that minimize waste and maximize the use of resources. However, realizing the full potential of the circular economy will require continued innovation, collaboration, and commitment from all stakeholders (Kirchherr et al., 2017).

The green economy is centered on sustainable development by incorporating environmental concerns into economic decision-making processes, with the goal of ensuring economic growth while reducing environmental degradation (United Nations Environment Programme, 2011). The green economy has been defined by the United Nations Environment Programme (UNEP) as an economy that outcomes in improved human well-being and social equity, while significantly decreasing environmental risks and ecological scarcities (UNEP, 2011). This definition emphasizes the importance of integrating economic, social, and environmental considerations in the pursuit of sustainable development. One of the key features of the green economy is its focus on renewable energy sources, such as wind, solar, and hydro

power (UNEP, 2011). By promoting the use of renewable energy, the green economy seeks to reduce dependence on fossil fuels and decrease greenhouse gas emissions.

The green economy also promotes the use of sustainable practices in a wide range of sectors, including agriculture, transportation, and construction (UNEP, 2011). For example, green agriculture practices can reduce the use of harmful chemicals and promote soil health, while green transportation options such as public transit and cycling can reduce carbon emissions and improve air quality.

The green economy also emphasizes the importance of creating jobs and economic opportunities in sustainable industries (UNEP, 2011). This can include the development of new technologies and the expansion of existing industries, such as renewable energy and sustainable construction.

Overall, the green economy represents a vision for a more sustainable and equitable economic system that prioritizes environmental protection and human well-being. However, its implementation requires significant changes in the way that businesses and governments approach economic development, as well as strong collaboration among stakeholders to create the necessary infrastructure and policies to support a green economy (UNEP, 2011).

Lastly, the frugal economy is characterized by a focus on creating products and services that are affordable, accessible, and sustainable in limited conditions (Radjou et al., 2015).

The frugal economy is an economic system that is based on the principles of simplicity, affordability, and sustainability (Prahalad & Mashelkar, 2010). It is an approach to economic development that aims to create products and services that are accessible to low-income populations while also promoting sustainable practices (Zeschky, Widenmayer, & Gassmann, 2011). In contrast to traditional approaches to economic development, which often rely on resource-intensive and costly solutions, the frugal economy seeks to identify simple and affordable solutions that can be adapted to local contexts (Govindarajan & Trimble, 2012).

The frugal economy encourages the development of products and services that are designed to be low-cost, resource-efficient, and environmentally sustainable (Zeschky et al., 2011).

Frugal economy recognizes the importance of balancing economic, social, and environmental factors in economic development. It seeks to create economic growth that benefits all members of society, including marginalized and vulnerable populations, while also promoting sustainable resource use and environmental protection (Choudhary et al., 2020). Overall, the frugal economy offers a unique perspective on economic development that prioritizes simplicity, affordability, and sustainability. Its focus on innovation and adaptability makes it a promising approach for creating economic growth that is inclusive and sustainable.

One of the key features of the frugal economy is its emphasis on innovation (Choudhary, Jain, & Shankar, 2020). Innovation has also emerged as a key concept in the field of sustainable development. Innovations refer to new products, processes, services, and business models that are designed to meet a particular need or solve a particular problem (Schumpeter, 1934). Innovations can be classified into various types, including product innovations, process innovations, organizational innovations, and marketing innovations (García-Muiña et al., 2015). Frugal innovation is a phenomenon that emerged in the context of emerging markets, where scarcity of resources and infrastructure limitations created a necessity to develop new products and services that are affordable, functional, and sustainable. Frugal innovation is a term that has gained significant attention in recent years, as it has been seen as an approach that can help address some of the challenges associated with sustainable development and inclusive growth (Bhatti et al., 2020).

Frugal innovations are innovations that designed to meet the needs of consumers in resource-constrained environments (Radjou et al., 2015). The concept of FI originated as one of the win-win solutions for the mutual benefit of business communities, society, and the environment. In this context, innovation efforts require frugal thinking and aim to help local businesses and communities to cope with the short-term impacts of a global pandemic. Innovation efforts can have long-term consequences that increase the resilience of business, society, and the environment (Khan et al. 2017, 2021; Yu and Khan, 2021). In

order that local innovators may use resources within reach frugally and rationally, one has to scan the current literature on the given problem and provide useful insights.

The concept of FI often overlaps with Jugaad innovation, bottom-of-the-pyramid (BoP) innovation, reverse innovation, disruptive innovation, and inclusive innovation. They have the common core elements like affordability, social or sustainable orientation and resource constraints. Jugaad refers to local solution, bottom-of-the-pyramid (BoP) – satisfaction of customers which live under poverty, reverse innovation – inexpensive solutions which were initially successfully introduced in developing countries and then in developed ones, and disruptive innovation – providing new values and overtaking an existing market (Dudakt et al. 2021; Prabhu and Jain, 2015; Radjou and Prabhu, 2014). Furthermore, the concept of inclusive innovation is closely related to frugal innovations. Inclusive innovations are innovations that are designed to ensure that everyone, including marginalized or resource constrained groups, has access to the benefits of innovation (Prabhu et al., 2014). This is achieved by ensuring that the needs of diverse populations are taken into account during the innovation process, and by designing products and services that are accessible and affordable to all (West et al., 2014). Hence, it makes the academic knowledge of FI blurred. FI can be seen also as redesigning products and processes to decline needless expenses (Wooldridge, 2010). Moreover, FI is focused on generating non-complex, sustainable solutions, including products, processes, and business models, using fewer resources that are harmless for the environment (Gupta and Wang, 2009). In recent years, authors have emphasised the role of FI in the achievement of sustainable development goals (SDGs). Khan (2016) claims that it is possible to reach social sustainability goals via the application of FI and that it is customary to equate frugality with sustainability. It is noteworthy that the key challenges of sustainable development lie in the plane of compromises between its distinct but interconnected dimensions (i.e., social, economic, and environmental) (Khan et al. 2020, 2021; Song et al. 2021). For example, it is impossible to achieve a good quality of life without having sufficient economic resources to meet the actual needs of a person. One cannot have good health while living in an ecologically polluted area (Khan et al. 2020a, 2020b;

Nathaniel and Khan, 2020). During a pandemic, social welfare cannot be sustained without basic personal protective equipment (disinfectants) and distribution centre support (safe transport) (Yu and Khan, 2021). Therefore, it can be stated that FI aims at meeting the basic needs of the population (e.g., health, education, and production of goods and services) during the health crisis period to enhance the quality of life of the population through a profit-focused innovative approach. Other authors attempted to distinguish FI from other types of innovation. In doing so, they used two distinct approaches. While some authors focused on classifying FI based on concepts and frameworks, others examined the rules and principles of FI to establish differences between frugal and other types of innovations. The first category of scholars encompasses the following researchers. Cunha et al. (2014) focused on scarcity. Brem and Wolfram (2014) concentrated on sustainability and sophistication in developing countries. Zeschky et al. (2014) focused on the technical and market novelty of the innovations. Ostraszewska and Tylec (2015) considered FI from a similar perspective. According to Soni and Krishnan (2014), FI is a mentality or lifestyle, a process, and an outcome at the same time. Basu et al. (2013) analysed FI from multiple perspectives, such as a driver, process, location, and core capabilities. The second category of scholars is represented by the following authors. Kumar (2008) classified six principles of FI to establish a source of benefits to entrepreneurship, as well as entrepreneurship trends, patterns, and consequences. These principles are robustness, portability, de-featuring, leapfrog technology, mega-scale production, and service ecosystems. Khan et al. (2017, 2019) found that the most significant factor affecting the company's efficiency is the presence of a green information system. Radjou and Prabhu (2014) identified six principles as well, engage and iterate; flex assets; create sustainable solutions; shape customer behaviour; co-create value with prosumers, and make innovative friends.

To put it straight, Zeschky et al. (2014) and Ostraszewska and Tylec (2015) established a novelty criterion. Basu et al. (2013) along with Prahalad and Mashelkar (2010) focused on customer needs. Studies (Brem and Wolfram, 2014), (Basu et al. 2013) highlighted the existence of emerging markets as a feature of FI. Basu et al. (2013) and Kumar and Puranam (2012) described FI as robust, lightweight,

and simple. Studies (Radjou and Parbhu, 2014) and (Brem and Wolfram, 2014) reported sustainability as an inherent characteristic of FI, while Kumar (2008) was focused more on service ecosystems as a related component of sustainability. Studies from Radjou and Prabhu (2014), Prahalad and Mashelkar (2010), and Hossain (2017) were all about creating and sourcing new capabilities, as well as flexing the assets. Winkler et al. (2020) note that research on FI was focused on emerging market economies and developing countries, but recently there has been a shift towards developed countries.

Summarising the above-mentioned FI is a type of innovation that refers to the creation, development, and implementation of a sustainable, efficient, affordable, functional solution without compromising the quality, it may include processes, services or products which meets the needs of scarce-resource customers.

In conclusion, frugal innovations have emerged as an important aspect of sustainable development, particularly in the context of addressing the needs of low-income or resource constrained communities. Thus, frugal innovations can take many forms, from simple technologies such as the Jaipur foot prosthesis (Govindarajan & Trimble, 2012) to complex systems such as microfinance (Zeschky et al., 2011). What these innovations have in common is their focus on simplicity, affordability, and sustainability. They are designed to meet the needs of low-income populations in resource-constrained environments (Prahalad & Mashelkar, 2010).

Hence, frugal innovations are characterized by their ability to create more value with fewer resources and have the potential to transform the way businesses operate and deliver products and services. In this section, we will provide examples of frugal innovations from different industries to illustrate how this approach has been implemented in practice.

One example of frugal innovation comes from the automobile industry. In 2012, Tata Motors, an Indian automobile company, launched the Tata Nano, a low-cost car that was specifically designed for the Indian market. The car was priced at approximately $2,000, making it one of the most affordable cars in the

world (Radjou et al., 2012). The Tata Nano was developed using frugal innovation principles, with the goal of reducing costs while maintaining quality and safety standards. The car's design and manufacturing process were simplified to reduce the number of components and minimize the use of expensive materials. The result was a car that was affordable, fuel-efficient, and met the needs of a large segment of the Indian population.

Another example of frugal innovation comes from the healthcare industry. In 2011, GE Healthcare launched the MAC 400, a portable electrocardiogram (ECG) machine that was designed for use in rural and remote areas of India. The machine was developed using frugal innovation principles, with the goal of reducing costs while maintaining diagnostic accuracy and reliability (Cunningham et al., 2013). The MAC 400 was designed to be portable and easy to use, with simplified features that allowed healthcare workers to quickly diagnose and treat patients. The machine was also priced significantly lower than traditional ECG machines, making it accessible to healthcare providers in resource-constrained environments.

A third example of frugal innovation comes from the consumer goods industry. Procter & Gamble, a multinational consumer goods company, developed a low-cost water purification sachet called P&G Purifier of Water. The sachet contains a powder that can purify 10 liters of water, making it safe for drinking and other uses (Liu et al., 2014). The sachet was developed using frugal innovation principles, with the goal of providing an affordable and accessible solution for water purification in developing countries. The sachet has been distributed in over 100 countries, and it has been estimated that it has provided clean water to over 10 million people.

These examples illustrate how frugal innovation can be applied in different industries and contexts to create value in a way that is socially and environmentally responsible. Frugal innovations can help

address some of the challenges associated with sustainable development and inclusive growth by providing affordable and accessible solutions to underserved populations. These examples highlight the potential of frugal innovation to transform the way businesses operate and deliver products and services, and they provide insights into how this approach can be implemented in practice.

Frugal innovations can be found in a variety of industries, but they are most commonly associated with industries that serve low-income or resource-constrained populations (Bhatti et al., 2018). Examples of such industries include healthcare, IT, transportation, and energy (Kaplinsky & Morris, 2016). In the healthcare industry, frugal innovations may involve the development of low-cost medical devices or the use of mobile technology to deliver healthcare services to remote areas (Hartung et al., 2013). In IT, frugal innovations may involve the development of low-cost, efficient irrigation systems or the use of mobile technology to provide farmers with access to market information (Eisenhardt et al., 2019). In the transportation industry, frugal innovations may involve the development of low-cost, fuel-efficient vehicles or the use of shared transportation systems (Cohen & Vehbi, 2017). In the energy industry, frugal innovations may involve the development of low-cost, renewable energy technologies or the use of energy-efficient appliances (Sauvé & Bernard, 2016). Overall, frugal innovations can be found in any industry where there is a need for affordable and accessible solutions that can improve the lives of low-income or resource-constrained populations (Bhatti et al., 2018). It has been discussed as a core characteristic in sustainable practices (Velananda et al., 2023). Measuring its capabilities has also been explored (Rossetto et al., 2023). These innovations are not just beneficial in urban settings, but also for sustainable development (Hossain et al., 2023). In fact, frugal innovation can be a source of sustainable entrepreneurship to address social and environmental issues (Shahid et al., 2023). It has applications in the service industry as well, particularly in knowledge integration and entrepreneurial firms (Wang & Li, 2023).

Thus, the papers listed above all contribute to the overall exploration of frugal innovations and their implications in industries.

Methodology:

Regarding how the research has been approached, that is, the methodology, various methodologies have been used for achieving the proposed objectives. Our research includes quantitative and qualitative methods in order to gain the objectives. Regarding the first objective, we have conducted a literature review on frugal innovations to address the current state of the academic literature, implementing bibliometric techniques along with a content analysis. Since literature review is relatively subjective, the bibliometric analysis provides more objective and reliable results (Broadus, 1987; Hood and Wilson, 2001). Moreover, we complemented with other research method, such as meta-analysis. Bibliometric analysis as a quantitative method allowed us to explore bibliographic material and patterns of publications. It permitted us to present a comprehensive overview of the research trends in frugal innovation domain. Precisely, we conduct a performance analysis and present the scientific mapping analysis that allows determining the main research trends in the domain. These analyses are accompanied with a comprehensive reading of certain publications reflected in the mapping analysis.

Our study proposes a methodological approach to define the level of penetration of a frugal innovation into the subject areas of scientific research based on the Shannon-Wiener Index. Its value presented in the form of the frugal innovation penetration index in the research domain. We conducted the correlation analysis based on the number of articles implementing the R programming language to identify the connection between the publications made with frugal innovation in the various subject areas. Regression modelling was also carried out in a meta-analysis of the bibliographical coupling in the context of the subject areas. Therefore, the combination of above-mentioned methods allowed us to we attain a complete overview of the academic literature on the frugal innovation. In paper *Frugal innovation in the textile industry, as a tool for solving problems in the field of waste disposal and recycling*, the literature review complemented with cases, was proposed in order to form the conceptual model.

In following papers, for achieving the other objectives proposed, we apply a case study method which allows to explore diverse perspectives and reveal relationship between the complex layers of our

research. The case study permits to analyze various systems, by means of one or several methods Thomas (2011). It explores a real-life, system (case) during a period, through in-depth data collection using diverse data sources, it presents case description and case themes (Creswell 2014). It allows to get the comprehensive results from the deep exploration of the subject and to obtain the conclusion from the retrieved data, and explain the situation better (Lindgreen, di Benedetto, and Beverland 2021; Alam 2021). The last two papers appeared from our collaboration with Greek companies and livestock, which allow us to complement the research. Thus, we have conducted an experiment using as example one of the frugal innovations, implementing regression analysis to identify key factors for improving innovation management efficiency and predictive modeling of the resulting indicators of a dairy farm. We proposed methodological approach for assessing the effectiveness of frugal innovation management on a dairy farm based on key indicators: socio-environmental, economic, and farm efficiency. This contributed to the formation of the scientific hypotheses.

## 1.3. Objectives and Structure of the Study

Regarding the above-mentioned arguments and the need for analysis of the frugal innovation, the main objective of this doctoral thesis is to explore frugal innovations and their implications in industries. Hence, the following objectives are established within this contribution to the literature (from general to more specific):

Observing that frugal innovation has attracted attention as a new field of research:

1. Create a universal definition of FI.
2. Identify the main research trends in frugal innovation field.
3. Identify the industries, countries where frugal innovations are present.

Given that frugal innovation tackles the social issues:

4. Explore the ability of frugal innovation to solve social and economic problems of society with a sustainable approach.
5. Present the business model for solving problems in the field of waste disposal and recycling in terms of frugal innovations.
6. Define the general trends of digital marketing in food retail in context of frugal innovations during COVID crisis.
7. Identify how food retailers' business model has been transformed in terms of frugal innovation during pandemic.
8. Explore social, economic, and sustainable values of FI, through organizational innovations and frugal innovative product.

Given that dairy farming requires sustainable and effective solutions:

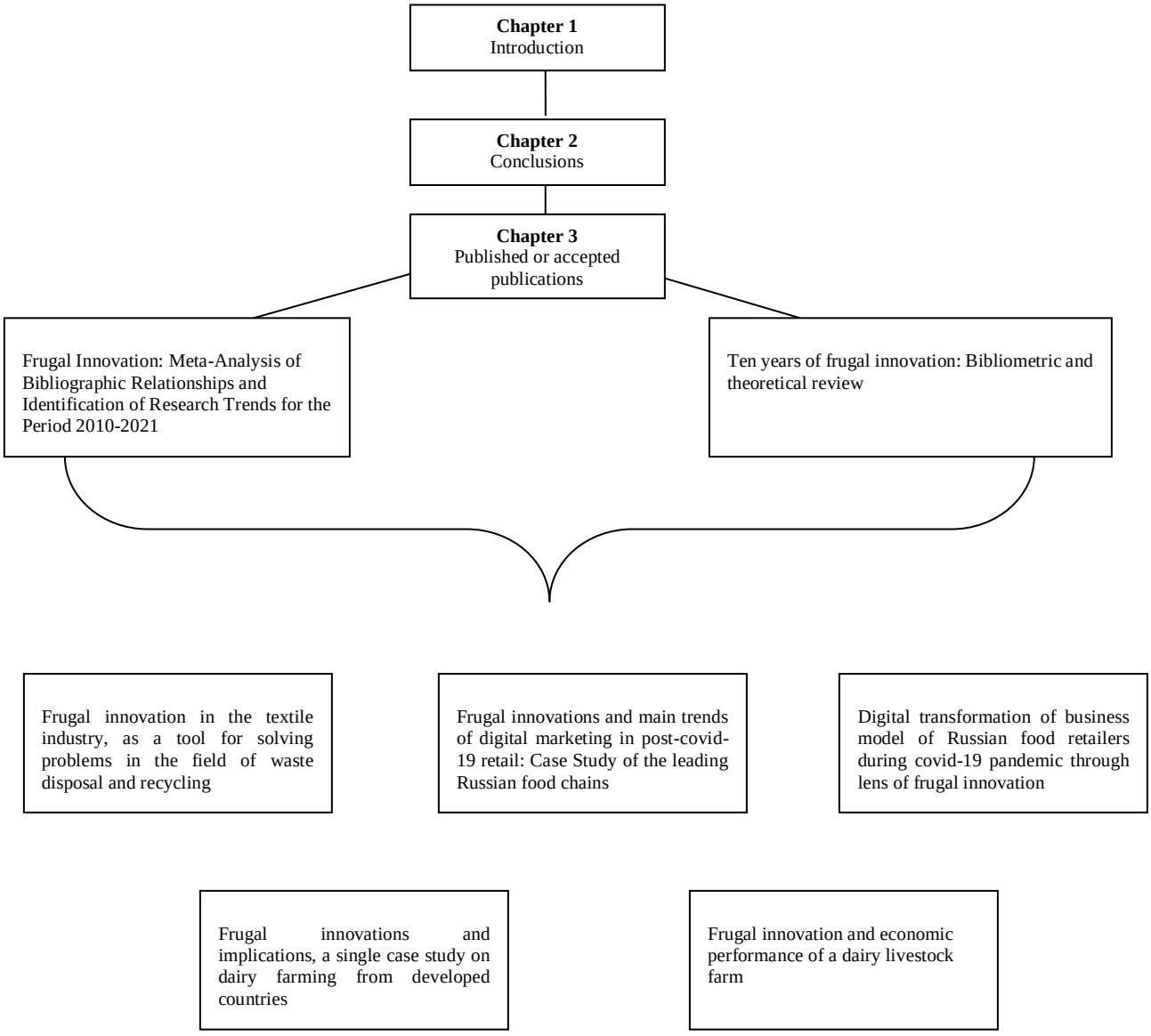
9. Identify how frugal innovation contributes to the provider (business) and receiver of frugal innovations (farmers' communities), serving underserved customers in developed countries in context of dairy farming.
10. Determine the results of frugal innovation introduction in dairy farming.
11. Diagnose the effectiveness of frugal innovation management in a livestock farm.
12. Examine the frugal innovation in dairy farming in terms of milk production, economic efficiency for a farmer, and ecological impact.

13. Form a methodological approach to assess the effectiveness of frugal innovation management.

The published or accepted publications section (Chapter 3) gathers the general and specific objectives (hypothesis, if any) proposed in each particular publication.

The thesis encompasses **three chapters** (see Figure 1.1. Structure of the Doctoral Thesis). The first one, **Chapter 1**. Introduction, includes the motivation of the thesis and the justification of the thematic unit. The theoretical framework that serves as the basis for this research and objectives within this contribution are enunciated as well. This chapter also serves to introduce the identification, summary and discussion of the main results obtained in the papers that make up the compendium of papers of this thesis. At the end the references used in this chapter are listed. After the introductory chapter, follows the chapter with conclusions, **Chapter 2**. In this chapter, the objectives stated in section 1.3. of Chapter 1 (objectives and structure of the study) are combined with the outcomes obtained with the development of the different papers that make up the compendium of articles. The third one, **Chapter 3**, published or accepted publications, consists of publications *"Frugal Innovation: Meta-Analysis of Bibliographic Relationships and Identification of Research Trends for the Period 2010-2021", "Ten years of frugal innovation: Bibliometric and theoretical review", "Frugal innovation in the textile industry, as a tool for solving problems in the field of waste disposal and recycling", "Frugal innovations and main trends of digital marketing in post-covid-19 retail: Case Study of the leading Russian food chains", "Digital transformation of business model of Russian food retailers during covid-19 pandemic through lens of frugal innovation", "Frugal innovations and implications, a single case study on dairy farming from developed countries", "Frugal innovation and economic performance of a dairy livestock farm*" . The bibliographic references used are presented at the end of each publication.

Figure 1.1. Structure of the Doctoral Thesis



## 1.4. Identification of the papers that make up the compendium of papers, followed by their summary and, where appropriate, discussion of their outcomes.

Firstly, we identify the papers we include in full version in the published or accepted publications section (title, journal, main indicators, journal characteristics and our contribution to the journal). Secondly, summary and outcomes from each paper/contribution are mentioned in order to know the different contributions to the literature.

Our thesis gave rise to the following research (see Chapter 3, published or accepted publications, to access the full papers):

1. **Paper *Frugal Innovation: Meta-Analysis of Bibliographic Relationships and Identification of Research Trends for the Period 2010-2021*.** This paper is already published in a high impact journal, *IEEE Transactions on Engineering Management,* 1–15. doi:10.1109/TEM.2022.3169288., Print ISSN: 0018-9391; Electronic ISSN: 1558-0040; Date of Publication: 04 May 2022; Scopus Q1; H-index -97; SJR-0,88; CiteScore 2020 - 4.3; SNIP 2020 - 1.255; CiteScoreTracker 2021-6.2; Impact Score-3.55. *IEEE Transactions on Engineering Management* is an international peer reviewed journal including review and original research works focused on the management of technical functions such as R&D and engineering in industry, government, university, etc. around the globe. It aims to facilitate in decision making in management, policy formation for research, development, and engineering. Our paper is a critical review article based on a bibliographic analysis of research papers carried out on quantitative studies complemented with content analysis that systematizes the knowledge about frugal innovation and trace the research activity in the domain. It provides frugal innovations penetration index for the subject areas of publications and meta-analysis of the level of frugal innovations penetration into the subject areas of scientific research. Correlation analysis and regression

modelling identified the most influential areas for the development of frugal innovation research, among them Engineering and Decision Sciences. Thus, our research contributes to the journal and the academic world, illustrating the presence of frugal innovations into the specific domain and their absence that provides a future research path. Moreover, the research presents a lot of practical solutions and conceptual works, which could be useful for scholars to orientate into research fields. It shows potential ability of frugal innovations, their real necessity for business and society, and identify the potential markets in terms of industries and countries. Since the paper implies a universal approach, it could be used in decision making or policy formation for research, development, and engineering.

**Melnikova, L., & Gilsanz, A. (2022). Frugal Innovation: Meta-Analysis of Bibliographic Relationships and Identification of Research Trends for the Period 2010–2021. *IEEE Transactions on Engineering Management*, pp. 1-15.**

2. **Paper *Ten years of frugal innovation: Bibliometric and theoretical review*** published in *Astra Salvensis*, Scopus Q1, H-INDEX-12; ISSN 23441887, 23934727; SJR-0,22; Impact Score: 0.35; CiteScore 2020-1.6; CiteScoreTracker 2021-1.4; SNIP 2020-0.416; https://astrasalvensis.eu/astra-salvensis-1-2022/. Astra Salvensis it is a double-blind peer-reviewed, open access journal edited by *"Transylvanian Association for Romanian Literature and Culture of Romanian People – ASTRA, Năsăud Department, Salva Circle"* which covers a large range of research topics. It is a multidisciplinary journal which publishes review and original research, focused on socio-humanistic areas, including management and decision making. Since it covers areas of any discussions from socio-humanistic and management areas our paper as a critical literature review based on bibliometric analysis complemented by content analysis contributes to the scope of journal providing additional information on frugal innovation research activity during the decade.

**Melnikova, L., Gilsanz, A., & Leticia Preciado Ortiz, C. (2022). Ten years of frugal innovation: bibliometric and theoretical review. *Astra Salvensis, 10*(1).**

3. **Paper *Frugal innovation in the textile industry, as a tool for solving problems in the field of waste disposal and recycling*** published in *Izvestiya Vysshikh Uchebnykh Zavedenii, Seriya Teknologiya Tekstil'noi Promyshlennosti (Textile Industry Technology);* DOI 10.47367/0021-3497_2021_2_17; Date of Publication: 2021; Scopus Q4 (paper submitted in 2020 when the journal was Scopus Q3); H-INDEX 19; SJR 2020-0.199; CiteScore 2020- 0.4; SNIP 2020-1.058; CiteScoreTracker 2021-0.3. The journal focuses on problems of development of the textile industry. In particular, it publishes articles with applied and theoretical approaches, reviews and original papers of scientific novelty, which are the results of completed research of a problematic or scientific-practical nature and related to the technology and organization of textile production, management in textile industry, decision making, textile engineering and materials science, automation of technological processes, economics, energy, ecology. One of the journal's sections is dedicated to the management science. The journal provides ample opportunities for scientific discussions and the exchange of professional experience in the field of textile management, production and related areas. Thus, our research proposes theoretical model based on frugal innovation in management of textile industry which can be implemented for waste disposal and recycling. The proposed theoretical model based on frugal innovation in management of the textile industry can be of significant value in reducing waste and improving the sustainability of textile production. This model can be tested and validated through empirical research and can provide a framework for textile industry managers to implement more sustainable practices in their operations.

**Melnikova, L. N. (2021). Frugal innovation in the textile industry, as a tool for solving problems in the field of waste disposal and recycling.** ***Textile Industry Technology,*** **2(393), 17–22. https://doi.org/10.47367/0021-3497_2021_2_17**

4. **Paper** ***Frugal innovations and main trends of digital marketing in post-covid-19 retail: case study of the leading Russian food chains*** is a conference paper, Conference *"Global challenges of digital transformation of markets (gdtm-2021)"* accepted for publishing MDPI-NOVA in 2022; Scopus cite score-3.8. The conference was held in 2021, it covers empirical and theoretical research on digital transformation of global markets and the problems of digitalization of business processes, taking into account COVID-19. It tackles the quality of living, new human-centered technologies in Industry 4.0., effective management, including in industry, and knowledge economy. Therefore, one of the conference sections is dedicated to the management science and innovations. Hence, our paper contributes to the conference via presenting the analysis of food retailers' business model transformation, via digital marketing practices through prism of frugal innovation.

5. **Paper** ***Digital transformation of business model of Russian food retailers during covid-19 pandemic through lens of frugal innovation*** is a conference paper, Conference *"Global challenges of digital transformation of markets (gdtm-2021)"* also accepted for publishing MDPI-NOVA in 2022; Scopus cite score-3.8, it includes wide range of publications from practical and theoretical prospections, where digital component is the common core from the perspective of management science. The conference comprises papers from real sector of economy and academic works as well. It covers areas of management such as functional management, human-centered technologies, marketing strategies, industrial management, life quality, methodology and best practices in economics. Our paper contributes to the above-mentioned conference since it analyzes

the digital transformation of food retailers' business model in terms of frugal innovations where exogenous driver considered as pandemic of COVID-19.

6. **Paper** ***Frugal innovations and implications, a single case study on dairy farming from developed countries*** is an original research article currently is under review in *Technology in Society*; Scopus Q1; H-INDEX-58; ISSN 0160791X; SJR 2021-1.138; Impact score-7.82, it is an international journal peer reviewed journal aimed at transformation in technology, society, business, management, and philosophy. It publishes wide range of research works from theoretical approaches to applied one including management, decision making, business innovation and technology management; and development perspective approaches, it includes review and original research articles, where the common thread is the technology in economics, politics, and culture. The journal publishes a lot of works in field of frugal innovation. Presenting a case study of frugal innovation that reveals various aspects of benefits such as sustainability, social, and economic performance through lens of organizational innovations and frugal innovative product our research contributes to the scope of the journal exploring social, economic, and sustainable values of frugal innovation.

7. **Paper** ***Frugal innovation and economic performance of a dairy livestock farm*** is an original research article which is published in Polish journal of environmental studiesissn:1230-1485, Scopus Q2, percentile 55 (General Environmental Science) WOS Science Citation Index Expanded,Q2, IF 1.871. It is an international, transdisciplinary journal publishes original research, technical notes, book reviews, and conference reports aimed at cleaner production, environmental, and sustainability research and practice, the journal devoted to innovations in terms of sustainability and environment, including frugal innovations from theoretical and practical perspectives including applied, empirical and review research. One of the journal's sections is dedicated to the management science, decision making and innovations. The main topics of the

journals are *cleaner production and technical processes, sustainable development and sustainability, sustainable consumption; environmental and sustainability assessment; sustainable products and services; corporate sustainability and corporate social responsibility; education for sustainable development; governance, legislation, and policy for sustainability.* Our study contributes to the journal from the management perspective examining the frugal innovation in dairy farming in terms of milk production, economic efficiency for a farmer, and ecological impact. We propose the methodological approach to estimate the effectiveness of frugal innovation management. The research methodology is based on testing the effectiveness of polysaccharide regulatory complex, a supplementary compound feed, in dairy cattle breeding, the proposed integral indicator of frugal innovation management effectiveness and regression analysis of the factors that create its level. Hence, we aim to explore the complex nature of frugal innovation and the need for its effective implementation, that goes beyond the purely economic benefits and takes into account socio-environmental and direct farming effects of operation for cleaner production and sustainability in the end.

The first publication included in the published or accepted publications, Paper *Frugal Innovation: Meta-Analysis of Bibliographic Relationships and Identification of Research Trends for the Period 2010-2021,* is focused on review of academic research articles on frugal innovation. Firstly, we conducted the initial search of the documents using Elsevier's Scopus database, including all documents on frugal innovation, the final dataset of the review is based on 357 publications published between 2010 and May 08, 2021. We have systematized the knowledge about frugal innovation based on bibliographic analysis, which allowed us to gain a complete picture of the current academic literature in the frugal innovations. Along with the bibliometric techniques, we applied content analysis of clusters, which provide us information about phenomena, and the features of research on frugal innovations according to industry, method and

type of research, and country focus. Also, we provided meta-analysis and systematic literature review of the level of frugal innovations penetration into the subject areas of research domain. Thus, we enabled to recognize the key research trends covered so far and explore the main findings, and possible research trends for future research paths.

The second of the publications included in the published or accepted publications, Paper *Ten years of frugal innovation: Bibliometric and theoretical review,* is the extension of the previous one, and it complements it providing additional information on frugal innovation research activity. Due to the interest of researchers for the frugal innovation domain, and a lack of systemized knowledge, we conducted a study that focuses on analysis of prior research. It aims to provide bibliometric analysis with theoretical review based on data from 238 publications published since 2010 till 2019. Along with bibliographic techniques we provided content analysis of top-cited articles on frugal innovation. Thus, we organized and synthesized 47 papers according to the sector (industry) focus, type/ method of research, country focus, and focus of research. Therefore, we assessed the development of prior research and applied the main findings to trace the future research.

The following one, the third article, *Frugal innovation in the textile industry, as a tool for solving problems in the field of waste disposal and recycling*, serves to make a theoretical model proposal based on frugal innovation in a specific context, the context of the textile industry. During the last decade the implementation of frugal innovations is raising in different industries. Due to its characteristics frugal innovations are essential for textile industry, however the research on this domain is not presented enough in the academic literature. Thus, our research aims to provide a conceptual model that tackles the problem of waste management and recycling in the textile industry. In our research we provide a business model for achieving social, environmental and economic effects, which could be used terms of Sustainable Development Goals.

In addition, the fourth paper included in the published or accepted publications, Conference paper *Frugal innovations and main trends of digital marketing in post-covid-19 retail: Case Study of the leading Russian food chains,* focuses on research in another specific context of food retailers in a certain country, Russia. COVID-19 pandemic caused significant constraints and hence, changes of strategies in different industries. This paper focused on the investigation of the key changes in digital marketing strategies used by Russian food retailers for interconnection with customers during COVID-19 pandemic. Our research focused on digital marketing practices through lens of frugal innovations during the pandemic period of top five retailers adopting an abductive case study analysis approach. Our study reflects the results of the leading Russian food chains (top-5 retailers) based on the secondary data, including quantitative and qualitative surveys conducted by consulting companies (McKinsey, Nielsen, PwC, EIB, RAEC); online resources retail; including expert assessments, trends; review of articles. The common trends of digital marketing in retail in context of COVID crisis are revealed and presented as follows: customer centricity (customization and identification of customer needs, co-creation (involvement of customers into process), omnichannel (better communication with client), customer interaction (customization) and business diversification. Based on provided information we offer recommendations to managers on an effective digital marketing approach to increase customers' purchase intentions through frugal innovation lens.

Next, Conference paper *Digital transformation of business model of Russian food retailers during covid-19 pandemic through lens of frugal innovation* aims to analyze the transformation of Russian food retailers' business model (BM) through perception of digital frugal innovations. Our research considers digital transformation of the BM due to an exogenous driver, i.e., pandemic of COVID-19. The analysis is conducted on the basis of the Osterwalder-Pigneur template. The results show that the aim of customer satisfaction prevails in the most of the key retailers. They try achieve it through collaboration and involvement of the partners; organizational velocity which aims to change the business processes,

products and services; digital transformation that aims at increase of productivity, cost reduction, increase of sales, and market share; business diversification, which includes focus on new products, services, customer involvement, new markets, changing the business model, meanwhile the most important trends are omnichannel and customer interaction.

In paper *Frugal innovations and implications, a single case study on dairy farming from developed countries,* frugal innovation is presented as an affordable, effective, uncomplex, sustainable innovation for unserved customers in limited constraints, it can encompass product, service, or business model. Series of crises including food, energy, and finance caused constraints in dairy farming. Despite of the wide spread of research on frugal innovations, there is a near dearth in dairy farming industry. Dairy farming is one of the industries which requires the presence of the above-mentioned solutions. Therefore, this study analyzes the impact of frugal innovation on the dairy farm's economic performance and how it benefits the seller and the dairy farm in developed countries. It reveals various aspects of benefits such as sustainability, social, and economic performance through lens of organizational innovations and frugal innovative product. This paper examines how frugal innovation contributes to its the provider and receiver. It explores social, economic, and sustainable values of frugal innovation. This study demonstrates that FI benefits to the customer (dairy farmer) improving milk yields and welfare, and reducing costs (vet and feed), finally increasing the profitability. Therefore, it shows how frugal innovation serves underserved customers in developed countries, using a case study from dairy farming.

Regarding to the seventh contribution, *Frugal innovation and economic performance of a dairy livestock farm*, this study is the extension of the prior research, it complements the research on the subject of frugal innovations and their impact. Our study targets to examinate the frugal innovation in dairy farming in terms of milk production, economic efficiency for a farmer, and ecological impact. The study focuses on creating a methodological approach to estimate the effectiveness of frugal innovation management. The

research methodology is based on testing the effectiveness of polysaccharide regulatory complex, a supplementary compound feed, in dairy cattle breeding, the proposed integral indicator of frugal innovation management effectiveness and regression analysis of the factors that create its level. The research aims to explore the complex nature of frugal innovation and the need for its effective implementation, that goes beyond the purely economic benefits and takes into account socio-environmental and direct farming effects of operation. The research examines the way for the dairy farming to become more effective and sustainable.

The collective contribution of these papers to society centers on the evolving importance and application of frugal innovation across various sectors and geographies. These works not only provide a theoretical grounding in the concept but also present empirical studies that reveal its real-world implications. By focusing on diverse areas such as textile waste management, digital marketing trends in food retail, and even dairy farming, these papers illustrate the versatility and broad applicability of frugal innovation. At the core, they all share the imperative of doing more with less, a philosophy increasingly essential in a resource-constrained world. This resonates strongly with sustainability goals and the need for efficient use of resources, aligning with societal shifts towards responsible consumption and production.

In summary, these papers together elevate frugal innovation from a cost-cutting tactic to a strategic approach that intersects with sustainability, digital transformation, and economic resilience. Therefore, their combined societal contribution lies in offering both a conceptual understanding and practical roadmap for businesses, policymakers, and stakeholders committed to sustainable and responsible growth.

For more deep analysis and data about the listed contributions published or accepted publications section can be checked, in Chapter 3.

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# Chapter 2 Conclusions

The present section serves to summarize scope, principal findings, conclusions, and limitations that have emerged from this study.

The aim of this doctoral thesis is to provide a comprehensive review of frugal innovation, a relatively new concept that is still under discussion in the scientific community during the decade, and their implications in particular industries which are suitable for frugal innovations and were not presented enough in research field. The thesis includes two interconnected review papers, *Frugal Innovation: Meta-Analysis of Bibliographic Relationships and Identification of Research Trends for the Period 2010-2021* and *Ten years of frugal innovation: Bibliometric and theoretical review* which cover the research activity during the last decade. The main objectives of the research are to create a universal definition of frugal innovation and to identify the main research trends. The study aims to map frugal innovation in various subject areas and identify the industries, methods, type of paper, and countries where frugal innovation is present, meanwhile identifying the gaps for future research.

The scope of the studies is limited to few numbers of research papers and novelty in this field, subjective attitude towards the choice of publications, bias associated with the selection of words to denote FI, usage of only Scopus database, and articles published only in English, moreover we focused on just four categorisation criteria. This may be an important factor when interpreting the results of this study. Once the gaps of the research field were identified, including industries and countries, the research was conducted based on lacking and suitable for frugal innovations fields. Regarding the paper *Frugal innovation in the textile industry, as a tool for solving problems in the field of waste disposal and recycling*, the scope of research covers only one industry, it is limited to lack of prior research on the subject, limited access to the interviewees and objects of research, lack of available and reliable data for our study, thus we used the secondary data to provide conceptual deliveries. Regarding research *Frugal*

*innovations and main trends of digital marketing in post-covid-19 retail: Case Study of the leading Russian food chains*, and *Digital transformation of business model of Russian food retailers during covid-19 pandemic through lens of frugal innovations*, the main limitations are geographical constraint since the scope covers only Russia and based on secondary data, lack of prior studies, also it reflects the results only of top-5 retailers. The scope of last two papers is limited to only one case, in geographical locations particularly Greece, small sample sizes, short testing periods, focusing only on one industry, and malfunctions with feed equipment. Overall, the findings of the research suggest that frugal innovation has significant potential for contributing to sustainable development goals in various industries.

The first two papers are review papers which are interconnected, and present as one is an extension of another one. Thus, in the papers *"Frugal Innovation: Meta-Analysis of Bibliographic Relationships and Identification of Research Trends for the Period 2010-2021" and "Ten years of frugal innovation: Bibliometric and theoretical review"* we would like to highlight the main findings:

1. The term frugal innovation is relatively new and under discussion in scientific community, thus the first of the objectives was defined as creation of universal definition of FI which is used in our research. This objective was obtained and based on synthesized knowledge frugal innovation refers to the creation, development, and implementation of a new solution to improve effectiveness, affordability, sustainability, robustness, and functionality and meet the needs of resource-constrained consumers.
2. In order to map the frugal innovations into scientific field there is a need to identify the main research trends. Topic of frugal innovation is pretty new for the research, though the dynamic of research significantly raises during last time. Given a struggle of business and communities to overcome series of crisis, we suppose that research on frugal innovation will continue to raise, since their it considers the limitation of resource as an opportunity, not as a threat. Studies were focused on frameworks and phenomena and had mostly general approach. We structured the information on frugal innovation during

the decade, constructed a scientific map, presenting the synthesized information of the previous research. It could be useful for technical, medical, and social scholars. The scientific contribution of this study is the proposed Index of frugal innovation penetration in the subject areas of publications. It has provided an opportunity to diagnose the level of penetration of frugal innovation into the subject areas of research and to confirm a fairly broad and even distribution of frugal innovation in many subject areas of research. An asymmetry of publications in the subject areas of "Business, Management and Accounting", "Environmental Science" and was identified over the study period. A meta-analysis of the bibliographic relationships of publications in the context of subject areas based on correlation analysis and regression modelling has identified the most influential areas for frugal innovation development, among which are "Engineering" and "Decision Sciences". The advantage of the proposed approach is the possibility to diagnose the asymmetry of publication volumes in a particular subject area, which has a significant impact on the level of equal penetration in all subject areas of scientific research. We recommend to focus on such areas as COVID-19 pandemic, food, energy, financial crises, which could be used by policy makers, scholars, and practitioners in order to identify the agenda.

3. The next objective is more precise and aims to identify the industries, countries where frugal innovations are present. This objective was obtained as well. The papers are mostly empirical and mainly presented by case studies in IT/ICT, healthcare, manufacture, and product design. Less of them aimed at finance, multinational corporations, education, construction, engineering, and food. Hence, we would like to highlight the gaps in the academic literature that could be used for future research such industries as agriculture (livestock, dairy, fishing, wood, horticulture); manufacture, textile, chemical, petroleum, mining, metal production; service, hospitality, food retail, tourism fields are almost not presented in research. However, nuclear and space industries are reflected in the domain. Thus, we recommend to focus on the above-mentioned industries/sectors, which demand sustainable and frugal approach. The study into these industries could deliver a lot of practical and theoretical findings. We encouraged

research in IT/ICT crossed with healthcare industry, as a lot of solutions intercross and could bring a lot of practical tools in fight the COVID-19 pandemic, which might be useful for policy makers, scholars, and practitioners when determining further actions with COVID-19. Furthermore, further research according to the time frame could bring a lot of insights in terms of the development, evolution of the domain, and its practical implications. The developing countries and India are the main countries of interest, however there was a rising interest in developed countries during last time. The research in developed countries highlighting practical solutions in various sectors and industries could deliver many insights into the research field. The study estimates research trends and covers the largest dataset, delivering a comprehensive review of the research domain. Among the most cited papers, the most of the researchers were focused on different types or mixed industries, healthcare, energy, water, vehicles, automotive and transportation, IT and ICT, financial services. Most of the papers are also empirical. The vast number of articles focused on India, developing countries, and almost the same number on both developing and developed countries.

4. Taking into account the characteristics of frugal innovation, the further objective targets to explore the ability of frugal innovation to solve social and economic problems of society with a sustainable approach.

Our results demonstrate that frugal innovation could solve social and economic issues of society as well as in developed and developing countries, with a sustainable approach. Limitations of our research - our data are reliant on our subjective attitude towards the choice of publications. Most publications were in English. Only a few papers were published in French or Spanish with abstracts in English. There may be more articles on FI that are written in languages other than English. Furthermore, we recognise a bias associated with the selection of words to denote FI, as some researchers could use related terms. We concentrated on a single phrase, frugal innovation, for greater precision. Due to a varying degree of specificity within the papers, bias may also be found in relation to categorisation criteria (i.e., industry,

country, type of research, and research method). Another limitation is that we focused on just four categorisation criteria, thus it can be extended for future research. We used only Scopus database for our research, including the databases could enrich the future research.

In research *Ten years of frugal innovation: Bibliometric and theoretical review*, publications in English (238) were collected from Elsevier Scopus database during the period of 2010-2019 for using in statistical, bibliometric analysis, and theoretical review. The results reported herein should be considered in the light of some limitations. First, the sample size was limited, our dataset was taken out only from Scopus data base, addition of the other databases would provide more comprehensive information in frugal innovation field. Our research included the examination of the articles that were written in English, while articles which were presented in other languages were unincluded in the examination, extending of other languages would enrich the study. In addition, due to the novelty of the term of frugal innovation, it frequently overlaps with others such as reverse innovation, Gandhian engineering, jugaad, low-cost innovation, etc., there is a probability that some of the researchers substituted the term, thus there is a need of seeking the information on that literature beyond the frugal innovation field. Finally, some articles were enough theoretical and based on the literature review, however, they were illustrated by cases or examples that could lead to the bias in distinguishing them between theoretical and empirical. Groups obtained in the coupling analysis can be taken to analyse and synthesise the information considering different lines of research by the group identified.

5. Taking into account the social aspect of frugal innovation the next objective was to present the business model for solving problems in the field of waste disposal and recycling in terms of frugal innovations.

Paper *Frugal innovation in the textile industry, as a tool for solving problems in the field of waste disposal and recycling* is the conceptual work and suggests frugal innovations could be an option for solving problem of waste management and recycling in the textile industry through changing the business model, thus it affects social, environmental, and economic aspects. This is on of the first papers in terms of frugal innovations in context of textile industry, thus we faced with lack of prior research on the subject. Since this context is a novel for frugal innovations domain it could bring a lot of useful insights. In our research we faced with lack of available and reliable data for our study, thus we used the secondary data to provide conceptual deliveries. The implementation of qualitative methods for future research, such as grounded theory, ethnography, and case studies could lead to development of new theories and concepts. Also, we faced with limited access to the interviewees and objects of research, however our results could be used as the initial steps for further research. Obtaining the access to these kind of sources in future, would influence the outcomes of research, making them more comprehensive and convincing.

6. Since we found there is a need of Covid-19 research in frugal innovation field, the next objective related to one of the essential topics, food was to define the general trends of digital marketing in food retail in context of frugal innovations during COVID crisis.

The paper *Digital transformation of business model of Russian food retailers during covid-19 pandemic through lens of frugal innovation* is interconnected with paper *Frugal innovations and main trends of digital marketing in post-covid-19 retail: Case Study of the leading Russian food chains* both are conference papers and presented by case studies.

The research in paper *Frugal innovations and main trends of digital marketing in post-covid-19 retail: Case Study of the leading Russian food chains,* allowed to obtain this objective where the most common trends in digital marketing of food retail during pandemic in terms of frugal innovation are: customer centricity (customization and identification of customer needs, co-creation (involvement of customers

into process), omnichannel (better communication with client), customer interaction (customization) and business diversification.

7. The next objective is to identify how food retailers' business model has been transformed in terms of frugal innovation during pandemic. As the results of the research paper *Digital transformation of business model of Russian food retailers during covid-19 pandemic through lens of frugal* we found out food retailers' business model has been transformed in terms of frugal innovation during pandemic. Our findings demonstrate the use of extended enterprise concept by the most of the key retailers, via close interaction and involvement of partners; organizational speed which focus on fast change of business processes, products and services; digital transformation that aims at increase of productivity, cost reduction, increase of sales, and market share; business diversification, which includes focus on new products, services, customer involvement, new markets, changing the business model, meanwhile the most important trends are omnichannel and customer interaction. However, all these approaches focus on customer satisfaction.

The research on digital domain through lens of frugal innovations has some limitations and constraints. Firstly, it focuses only on Russia, which can be considered as a geographical constraint, by adding some new geographical locations to further research would enrich the outcomes of the study. Secondly, the sources of the data also have limitations since we have been extracting the secondary data, including quantitative and qualitative surveys conducted by research companies (McKinsey, Nielsen, PwC, EIB, RAEC); online resources retail; including expert assessments. The usage of primary data for future path research would bring new insights to the study. Thirdly, it reflects the results only of top-5 retailers, adding other companies would bring new insights. Forthly, the intersection of digital, retail, and frugal innovation is an immature field of research, thus we faced with a lack of prior studies, thus we recommend to use methodology that implies qualitative methods for exploration of this field.

Paper *Frugal innovations and implications, a single case study on dairy farming from developed countries*

8. Further object was to explore social, economic, and sustainable values of FI, through organizational innovations and frugal innovative product. Paper *Frugal innovations and implications, a single case study on dairy farming from developed countries* as an empirical type of paper reveals these aspects.

Our research demonstrates that frugal innovative products combined with organizational innovations can effectively serve underserved customers and play an essential role in sustainable development. The main organizational innovations split into two categories, customers and organization, which compromises high customization and personal approach, empowerment of customers, customer involvement, education and training for the customer, 'hyper care' for customers, expanding of seller's responsibilities, flexible payments; and organization including empowerment of employees; collaboration with R&Ds (open innovation). The frugal innovative product is represented as affordable, sustainable, efficient, and highly functional.

9. The next objective was to identify how frugal innovation contributes to the provider (business) and receiver of frugal innovations (farmers' communities), serving underserved customers in developed countries in context of dairy farming. We found that frugal innovations benefit to the provider (seller) and receiver (farmer), where the main benefits for the seller are profit from sales and customer loyalty (long last relationship with a customer); and for the farmer from the economics perspective significant increase of profitability, an increase of productivity (boost of average milk yield), a decrease of vet expenses, reduction of feeding costs, production of a high-quality product (improvement of milk quality), flexible payments, additional profit from the dealership; from the perception of sustainability, improvement of animals' health, usage of local feeding materials (support of local production); from the

social perspective, training and consultations; and from service, additional services free of charge. Organizational innovations allow the company to be flexible, to keep close relationships with customers, and to reduce capital investments collaborating with R&D and manufacturing, while frugal innovative products satisfy the main requirements of the customers. Given the context of farmers in the dairy livestock industry in European countries, the main requirements of the dairy farmers refer to an increase of milk boost (productivity) along with health improvement of the herd and profitability. Thus, it comes challenging to satisfy their needs with conventional solutions, however, our study demonstrates that frugal innovation has the ability to tackle these issues.

10. The further objective is to determine the results of frugal innovation introduction in dairy farming. Thus, our research demonstrates that FI (frugal innovation) improves the livestock feeding system and could be implemented globally in the future. Also, FI addresses the environmental footprint of livestock supply chains by elimination of brought from afar such feeding ingredients as palm fat and soybean meal; substitution of soybean meal with local ones, like rapeseed and sunflower meal, meanwhile increasing productivity. Hence, our research demonstrates FI as a contributor to responsible and sustainable livestock production. Animal welfare is one of the significant elements of sustainability and farm profitability. FI presented by the company has a positive impact on the welfare of the animals, particularly the improvement of fertility, digestion, reduction of inflammatory diseases, increase of productive life of cow. Hence, generating a frugal mentality, philosophy, approach in researchers, practitioners, and policymakers is essential for contribution to sustainable development goals (SDG). One of the significant benefits of FI for the farmers is profitability. Our study demonstrates the positive impact on the economic efficiency of the farms, based on such economic indicators as ROI (Return on Investment), IRR (Internal Rate of Return), and payback period. Such approach creates benefits for seller as well, such as profit and

loyal long last relationships with the customer. This research could be useful for dairy farmers, managers of the dairy livestock industry, practitioners from other fields, and policymakers.

Our research has several limitations, hence providing new future research paths. We explored only one case in this industry, exploration of more cases could bring new deeper insights into the dairy livestock industry. Extending the research to other livestock farming and agricultural-related industries could enrich the knowledge of FI in these particular industries. Moreover, exploration of FI using case studies from other industries may add significant value to the research domain of FI. The selected case study was explored in conditions of European countries, by extending the geography of research such as other developed countries or developing countries could bring new insights of FI phenomena according to the geographical location. This study is one of the first that analyses the benefits of FI in dairy farming, in terms of profitability, sustainability, and social aspects, it is presented by case study and the limited number of farms, however, for future study large scale research is recommended for confirmation of validity. The results of frugal innovation in dairy farming show frugal innovation demonstrate an increase in the livestock farm's efficiency, particularly, a milk increase, improvement of welfare of the herd, quality of product, decrease of production costs, specially feeding costs, in a sustainable way.

*Frugal innovation and economic performance of a dairy livestock farm* is the empirical type of paper.

11. The next objective is to diagnose the effectiveness of frugal innovation management in a livestock farm. Based on the assessment of proposed indicators of the effectiveness of frugal innovation management of a dairy farm, integral indicators were determined for the studied groups for three months. During the three-month study period, the vector of frugal dairy farm innovation management increased by 47%. This is confirmed by the FIMPI (the length of the vector Frugal Innovation Management Performance Index indicator). The increase in efficiency is quite noticeable compared to the results for the control groups. The most significant factor in the effectiveness of frugal innovation management on a livestock farm is farm functionality. At the same time, to increase the effectiveness of the frugal

innovation management, a dairy farm should focus not only on economic benefits but also on increasing sustainable development in the context of socio-environmental parameters of a farm as a producer of natural products from healthy animals. The results obtained prove that the proposed frugal innovation (PRC- Polysaccharide Regulatory Complex) has a positive effect on the farm's functioning.

12. Then, our objective was to examine the frugal innovation in dairy farming in terms of milk production, economic efficiency for a farmer, and ecological impact. The study presented the robust results that reflect the positive impact of frugal innovation on three main indicators: milk production, improvement of economic efficiency of the farmers, and sustainability (including health of the herd, support of the local agriculture and contribution to ecological footprint size decrease).

13. The next objective is to form a methodological approach to assess the effectiveness of frugal innovation management. Therefore, the scientific contribution of this study is the proposed methodological approach to assessing the effectiveness of frugal innovation management of a dairy farm. It proves the complex nature of frugal innovations and the need to expand the focus of their implementation, going beyond purely economic benefits and taking into account socio-environmental aspects and farm functioning. The obtained results are confirmed using regression analysis. It confirms the applicability of the formed methodology, and also points to its alternativeness in the process of forming methodological tools for assessing frugal innovation management efficiency on a dairy farm. The study confirms the relationship between the effectiveness of introducing and managing frugal innovation and the economic performance of a dairy farm. However, at the same time, the study proves that the most influential are precisely the specific parameters of farm development.

This study is not free from limitations. Due to the farm’s features, it was not possible to feed permanently selected animals, only groups. Some groups were chosen to demonstrate the effects of the product. The

period of testing was limited to 3 months, and the product might demonstrate all its capabilities in a longer period of time. The product also affects the decrease of enteric methane emissions; however, this farm does not monitor this indicator (Weishaupt et al., 2020). At the moment of testing in June, the farm had malfunctions with feed equipment; despite this, the production of milk was raising in the group fed with PRC, along with decrease of somatic cells (Alhussien and Dang, 2018). The bias (sharp lactation curve, from the "GEA Westfalia" program) was taken into account, and the real data were used. Mastitis cases were measured only in 1st lactation period. In the future, the study can test the proposed methodological approach on a larger number of farms using frugal innovations, forming a universal system of indicators for farms, predicting the effectiveness of frugal innovations management for them. The table below provides a structured roadmap for comprehensive research into the multi-faceted domain of frugal innovation.

| **Research Objectives** | **Results/Conclusions** |
|---|---|
| 1. Create a universal definition of Frugal Innovation (FI). | 1. FI is the creation, development, and implementation of a new solution to improve effectiveness, affordability, sustainability, robustness, and functionality and meet the needs of resource-constrained consumers. |
| 2. Identify the main research trends in the frugal innovation field. | 2. Research on frugal innovation will continue to raise, since their it considers the limitation of resource as an opportunity, not as a threat. Studies were focused on frameworks and phenomena and had mostly general approach. We structured the information on frugal innovation during the decade, constructed a scientific map, presenting the synthesized information of the previous research. It could be useful for technical, medical, and social scholars. The scientific contribution of this study is the proposed Index of frugal innovation penetration in the subject areas of publications. It has provided an opportunity to diagnose the level of penetration of frugal innovation into the subject areas of research and to confirm a fairly broad and even distribution of frugal innovation in many subject areas of research. An asymmetry of publications in the subject areas of "Business, Management and Accounting", "Environmental Science" and was identified over the study period. A meta-analysis of the bibliographic relationships of publications in the context of subject areas based on correlation analysis and regression modelling has identified the most influential areas for frugal innovation |

| Research Objectives | Results/Conclusions |
| --- | --- |
| | development, among which are "Engineering" and "Decision Sciences". The advantage of the proposed approach is the possibility to diagnose the asymmetry of publication volumes in a particular subject area, which has a significant impact on the level of equal penetration in all subject areas of scientific research. We recommend to focus on such areas as COVID-19 pandemic, food, energy, financial crises, which could be used by policy makers, scholars, and practitioners in order to identify the agenda. |
| 3. Identify the industries and countries where frugal innovations are present. | 3. The papers are mostly empirical and mainly presented by case studies in IT/ICT, healthcare, manufacture, and product design. Less of them aimed at finance, multinational corporations, education, construction, engineering, and food. Hence, we would like to highlight the gaps in the academic literature that could be used for future research such industries as agriculture (livestock, dairy, fishing, wood, horticulture); manufacture, textile, chemical, petroleum, mining, metal production; service, hospitality, food retail, tourism fields are almost not presented in research. However, nuclear and space industries are reflected in the domain. Thus, we recommend to focus on the above-mentioned industries/sectors, which demand sustainable and frugal approach. The study into these industries could deliver a lot of practical and theoretical findings. We encouraged research in IT/ICT crossed with healthcare industry, |

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|---|---|
| | as a lot of solutions intercross and could bring a lot of practical tools in fight the COVID-19 pandemic, which might be useful for policy makers, scholars, and practitioners when determining further actions with COVID-19. Furthermore, further research according to the time frame could bring a lot of insights in terms of the development, evolution of the domain, and its practical implications. The developing countries and India are the main countries of interest, however there was a rising interest in developed countries during last time. The research in developed countries highlighting practical solutions in various sectors and industries could deliver many insights into the research field. The study estimates research trends and covers the largest dataset, delivering a comprehensive review of the research domain. Among the most cited papers, the most of the researchers were focused on different types or mixed industries, healthcare, energy, water, vehicles, automotive and transportation, IT and ICT, financial services. Most of the papers are also empirical. The vast number of articles focused on India, developing countries, and almost the same number on both developing and developed countries. |
| 4. Explore the ability of frugal innovation to solve social and economic problems sustainably. | 4. Frugal innovation could solve social and economic issues of society as well as in developed and developing countries, with a sustainable approach. Limitations of our research - our data are reliant on our subjective attitude towards the choice of publications. Most publications were in English. Only a few |

| Research Objectives | Results/Conclusions |
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| | papers were published in French or Spanish with abstracts in English. There may be more articles on FI that are written in languages other than English. Furthermore, we recognise a bias associated with the selection of words to denote FI, as some researchers could use related terms. We concentrated on a single phrase, frugal innovation, for greater precision. Due to a varying degree of specificity within the papers, bias may also be found in relation to categorisation criteria (i.e., industry, country, type of research, and research method). Another limitation is that we focused on just four categorisation criteria, thus it can be extended for future research. We used only Scopus database for our research, including the databases could enrich the future research.<br><br>In research *Ten years of frugal innovation: Bibliometric and theoretical review*, publications in English (238) were collected from Elsevier Scopus database during the period of 2010-2019 for using in statistical, bibliometric analysis, and theoretical review. The results reported herein should be considered in the light of some limitations. First, the sample size was limited, our dataset was taken out only from Scopus data base, addition of the other databases would provide more comprehensive information in frugal innovation field. Our research included the examination of the articles that were written in English, while articles which were presented in other languages were unincluded in the examination, extending of other languages would enrich the study. In addition, due to the novelty of the term of frugal innovation, |

| Research Objectives | Results/Conclusions |
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| | it frequently overlaps with others such as reverse innovation, Gandhian engineering, jugaad, low-cost innovation, etc., there is a probability that some of the researchers substituted the term, thus there is a need of seeking the information on that literature beyond the frugal innovation field. Finally, some articles were enough theoretical and based on the literature review, however, they were illustrated by cases or examples that could lead to the bias in distinguishing them between theoretical and empirical. Groups obtained in the coupling analysis can be taken to analyse and synthesise the information considering different lines of research by the group identified. |
| 5. Present a business model for waste disposal and recycling within the framework of frugal innovations. | 5. Frugal innovations could be an option for solving problem of waste management and recycling in the textile industry through changing the business model, thus it affects social, environmental, and economic aspects. This is one of the first papers in terms of frugal innovations in context of textile industry, thus we faced with lack of prior research on the subject. Since this context is a novel for frugal innovations domain it could bring a lot of useful insights. In our research we faced with lack of available and reliable data for our study, thus we used the secondary data to provide conceptual deliveries. The implementation of qualitative methods for future research, such as grounded theory, ethnography, and case studies could lead to development of new theories and concepts. Also, we faced with limited access to the interviewees |

| Research Objectives | Results/Conclusions |
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| | and objects of research, however our results could be used as the initial steps for further research. Obtaining the access to these kind of sources in future, would influence the outcomes of research, making them more comprehensive and convincing. |
| 6. Define general trends of digital marketing in food retail during the COVID crisis in the context of frugal innovations. | 6. The most common trends in digital marketing of food retail during pandemic in terms of frugal innovation are: customer centricity (customization and identification of customer needs, co-creation (involvement of customers into process), omnichannel (better communication with client), customer interaction (customization) and business diversification. |
| 7. Identify transformations in food retailers' business models due to frugal innovation during the pandemic. | 7. Food retailers' business model has been transformed in terms of frugal innovation during pandemic. Our findings demonstrate the use of extended enterprise concept by the most of the key retailers, via close interaction and involvement of partners; organizational speed which focus on fast change of business processes, products and services; digital transformation that aims at increase of productivity, cost reduction, increase of sales, and market share; business diversification, which includes focus on new products, services, customer involvement, new markets, changing the business model, meanwhile the |

| Research Objectives | Results/Conclusions |
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| | most important trends are omnichannel and customer interaction. However, all these approaches focus on customer satisfaction.<br><br>The research on digital domain through lens of frugal innovations has some limitations and constraints. Firstly, it focuses only on Russia, which can be considered as a geographical constraint, by adding some new geographical locations to further research would enrich the outcomes of the study. Secondly, the sources of the data also have limitations since we have been extracting the secondary data, including quantitative and qualitative surveys conducted by research companies (McKinsey, Nielsen, PwC, EIB, RAEC); online resources retail; including expert assessments. The usage of primary data for future path research would bring new insights to the study. Thirdly, it reflects the results only of top-5 retailers, adding other companies would bring new insights. Forthly, the intersection of digital, retail, and frugal innovation is an immature field of research, thus we faced with a lack of prior studies, thus we recommend to use methodology that implies qualitative methods for exploration of this field. |
| 8. Explore social, economic, and sustainable values of FI through | 8. Our research demonstrates that frugal innovative products combined with organizational innovations can effectively serve underserved customers and play an essential role in sustainable development. The |

| Research Objectives | Results/Conclusions |
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| organizational innovations and frugal innovative products. | main organizational innovations split into two categories, customers and organization, which compromises high customization and personal approach, empowerment of customers, customer involvement, education and training for the customer, 'hyper care' for customers, expanding of seller's responsibilities, flexible payments; and organization including empowerment of employees; collaboration with R&Ds (open innovation). The frugal innovative product is represented as affordable, sustainable, efficient, and highly functional. |
| 9. Identify how frugal innovation contributes to both providers (businesses) and receivers (farmers' communities), especially in developed countries in the context of dairy farming. | 9. Frugal innovations benefit to the provider (seller) and receiver (farmer), where the main benefits for the seller are profit from sales and customer loyalty (long last relationship with a customer); and for the farmer from the economics perspective significant increase of profitability, an increase of productivity (boost of average milk yield), a decrease of vet expenses, reduction of feeding costs, production of a high-quality product (improvement of milk quality), flexible payments, additional profit from the dealership; from the perception of sustainability, improvement of animals' health, usage of local feeding materials (support of local production); from the social perspective, training and consultations; and from service, additional services free of charge. Organizational innovations allow the company to be flexible, to keep close relationships with customers, and to reduce capital investments collaborating with R&D |

| Research Objectives | Results/Conclusions |
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| | and manufacturing, while frugal innovative products satisfy the main requirements of the customers. Given the context of farmers in the dairy livestock industry in European countries, the main requirements of the dairy farmers refer to an increase of milk boost (productivity) along with health improvement of the herd and profitability. Thus, it comes challenging to satisfy their needs with conventional solutions, however, our study demonstrates that frugal innovation has the ability to tackle these issues. |
| 10. Determine the results of introducing frugal innovation in dairy farming. | 10. FI improves the livestock feeding system and could be implemented globally in the future. Also, FI addresses the environmental footprint of livestock supply chains by elimination of brought from afar such feeding ingredients as palm fat and soybean meal; substitution of soybean meal with local ones, like rapeseed and sunflower meal, meanwhile increasing productivity. Hence, our research demonstrates FI as a contributor to responsible and sustainable livestock production. Animal welfare is one of the significant elements of sustainability and farm profitability. FI presented by the company has a positive impact on the welfare of the animals, particularly the improvement of fertility, digestion, reduction of inflammatory diseases, increase of productive life of cow. Hence, generating a frugal mentality, philosophy, approach in researchers, practitioners, and policymakers is essential for contribution to |

| Research Objectives | Results/Conclusions |
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| | sustainable development goals (SDG). One of the significant benefits of FI for the farmers is profitability. Our study demonstrates the positive impact on the economic efficiency of the farms, based on such economic indicators as ROI (Return on Investment), IRR (Internal Rate of Return), and payback period. Such approach creates benefits for seller as well, such as profit and loyal long last relationships with the customer. This research could be useful for dairy farmers, managers of the dairy livestock industry, practitioners from other fields, and policymakers.<br><br>Our research has several limitations, hence providing new future research paths. We explored only one case in this industry, exploration of more cases could bring new deeper insights into the dairy livestock industry. Extending the research to other livestock farming and agricultural-related industries could enrich the knowledge of FI in these particular industries. Moreover, exploration of FI using case studies from other industries may add significant value to the research domain of FI. The selected case study was explored in conditions of European countries, by extending the geography of research such as other developed countries or developing countries could bring new insights of FI phenomena according to the geographical location. This study is one of the first that analyses the benefits of FI in dairy farming, in terms of profitability, sustainability, and social aspects, it is presented by case study and the limited number of farms, however, for future study large scale research is recommended for confirmation of |

| Research Objectives | Results/Conclusions |
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| | validity. The results of frugal innovation in dairy farming show frugal innovation demonstrate an increase in the livestock farm's efficiency, particularly, a milk increase, improvement of welfare of the herd, quality of product, decrease of production costs, specially feeding costs, in a sustainable way. |
| 11. Diagnose the effectiveness of frugal innovation management in livestock farms. | 11. Based on the assessment of proposed indicators of the effectiveness of frugal innovation management of a dairy farm, integral indicators were determined for the studied groups for three months. During the three-month study period, the vector of frugal dairy farm innovation management increased by 47%. This is confirmed by the FIMPI (the length of the vector Frugal Innovation Management Performance Index indicator). The increase in efficiency is quite noticeable compared to the results for the control groups. The most significant factor in the effectiveness of frugal innovation management on a livestock farm is farm functionality. At the same time, to increase the effectiveness of the frugal innovation management, a dairy farm should focus not only on economic benefits but also on increasing sustainable development in the context of socio-environmental parameters of a farm as a producer of natural products from healthy animals. The results obtained prove that the proposed frugal innovation (PRC-Polysaccharide Regulatory Complex) has a positive effect on the farm's functioning. |

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| 12. Examine frugal innovation in dairy farming in terms of milk production, economic efficiency for farmers, and ecological impact. | 12. The study presented the robust results that reflect the positive impact of frugal innovation on three main indicators: milk production, improvement of economic efficiency of the farmers, and sustainability (including health of the herd, support of the local agriculture and contribution to ecological footprint size decrease). |
| 13. Form a methodological approach to assess the effectiveness of frugal innovation management. | 13. The scientific contribution of this study is the proposed methodological approach to assessing the effectiveness of frugal innovation management of a dairy farm. It proves the complex nature of frugal innovations and the need to expand the focus of their implementation, going beyond purely economic benefits and taking into account socio-environmental aspects and farm functioning. The obtained results are confirmed using regression analysis. It confirms the applicability of the formed methodology, and also points to its alternativeness in the process of forming methodological tools for assessing frugal innovation management efficiency on a dairy farm. The study confirms the relationship between the effectiveness of introducing and managing frugal innovation and the economic performance of a dairy |

| Research Objectives | Results/Conclusions |
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| | farm. However, at the same time, the study proves that the most influential are precisely the specific parameters of farm development.<br>This study is not free from limitations. Due to the farm's features, it was not possible to feed permanently selected animals, only groups. Some groups were chosen to demonstrate the effects of the product. The period of testing was limited to 3 months, and the product might demonstrate all its capabilities in a longer period of time. The product also affects the decrease of enteric methane emissions; however, this farm does not monitor this indicator (Weishaupt et al., 2020). At the moment of testing in June, the farm had malfunctions with feed equipment; despite this, the production of milk was raising in the group fed with PRC, along with decrease of somatic cells (Alhussien and Dang, 2018). The bias (sharp lactation curve, from the "GEA Westfalia" program) was taken into account, and the real data were used. Mastitis cases were measured only in 1st lactation period. In the future, the study can test the proposed methodological approach on a larger number of farms using frugal innovations, forming a universal system of indicators for farms, predicting the effectiveness of frugal innovations management for them. |

# Chapter 3 Published or accepted publications

## 3.1. Frugal Innovation: Meta-Analysis of Bibliographic Relationships and Identification of Research Trends for the Period 2010-2021

Published paper in: *IEEE Transactions on Engineering Management, 1–15.* doi:10.1109/TEM.2022.3169288., Print ISSN: 0018-9391; Electronic ISSN: 1558-0040; Date of Publication: 04 May 2022; Scopus Q1; H-index -97; SJR-0,88; CiteScore 2020 - 4.3; SNIP 2020 - 1.255; CiteScoreTracker 2021-6.2; Impact Score-3.55.

Melnikova, L., & Gilsanz, A. (2022). Frugal Innovation: Meta-Analysis of Bibliographic Relationships and Identification of Research Trends for the Period 2010–2021. *IEEE Transactions on Engineering Management*, 1–15. https://doi.org/10.1109/TEM.2022.3169288

The research study "Frugal Innovation: Meta-Analysis of Bibliographic Relationships and Identification of Research Trends for the Period 2010-2021" is a critical review article based on a bibliographic analysis of research articles. Through the use of quantitative studies and content analysis, it systematically arranges the knowledge regarding frugal innovation and tracks the research activities in the field. The report gives a meta-analysis of the degree of frugal innovations penetration into the fields of scientific research as well as a frugal innovations penetration index for several topic areas of publications. The

paper identifies the most important fields for the growth of frugal innovation research, such as engineering and decision sciences, by using correlation analysis and regression modeling.

This article was published in the prestigious IEEE Transactions on Engineering administration, a peer-reviewed international magazine that focuses on the administration of technical operations including R&D and engineering in several global companies and organizations. The goal of the study is to aid in managerial decision-making and policy development for engineering, development, and research. It clarifies the existence and lack of frugal innovations within particular disciplines, presenting a future research direction.

The research also offers important strategies and conceptual works that could aid researchers in navigating their chosen research fields. In addition to highlighting the necessity of frugal innovations for business and society, the report also identifies prospective markets in terms of industries and nations. As the paper implies a universal approach, it could be used in decision-making or policy formation for research, development, and engineering. Overall, the paper provides valuable insights and guidance for researchers, practitioners, and policymakers interested in frugal innovation.

***Abstract*— Global social, economic, and environmental challenges have stimulated the emergence of local innovation initiatives. The current study aims to systematise the knowledge about frugal innovation based on bibliographic analysis. Through content analysis, we collected information about the following features of research on frugal innovations. The scientific contribution of this study is the proposed frugal innovations penetration index for the subject areas of publications. It has provided a meta-analysis of the level of frugal innovations penetration into the subject areas of scientific research. The results show that over the past decade, research on frugal innovations was largely concentrated on IT/ICT, healthcare, product design and manufacture industries, while agriculture, livestock, service, education, and other sectors, requiring frugal and sustainable approaches, received less attention. The findings also suggest that the aetiology of frugal innovation**

**in developing and emerging markets has sparked the interest of developed countries. In this study, frugal innovation is seen as a tool that companies can employ to expand their geographic footprint and move into new industries. A meta-analysis of bibliographic relationships of publications in the context of subject areas based on correlation analysis and regression modelling identified the most influential areas for the development of FI research, among them Engineering and Decision Sciences. The advantage of the proposed approach is that it provides an opportunity to diagnose the asymmetry of the research carried out, which has a significant impact on the level of equal penetration in the subject areas.**

***Index Terms*—bibliometric analysis, clustering, frugal innovation, mapping method, sustainability.**

## Introduction

Conditions of volatility, uncertainty, complexity, and ambiguity of today's world and a series of crises have forced businesses and governments to redirect resources to the domestic market. Thus, innovations have emerged, which enable economies to grow and function amid the pandemic. In the face of emerging medical, social, and economic challenges, the world has discovered a greater potential of innovations targeted at the local innovative endeavours, also known as frugal innovations (FI).

FI makes up a new entrepreneurial landscape, where local firms with limited resources develop innovations for underserved clients in low-income countries [1]-[3]. The concept of FI originated as one of the win-win solutions for the mutual benefit of business communities, society, and the environment. In this context, innovation efforts require frugal thinking and aim to help local businesses and communities to cope with the short-term impacts of a global pandemic. Innovation efforts can have long-term consequences that increase the resilience of business, society, and the environment [4]-[6]. In order that local innovators may use resources within reach frugally and rationally, one has to scan the current

literature on the given problem and provide useful insights. The literature review will enable us to understand the importance of FI and amalgamate the existing materials, knowledge, and skills to form a new innovative solution or repurpose the existing technologies, in a circular economy in particular, so it becomes possible to overcome the COVID-19-induced crisis [7]. During this decade the perception of FI has undergone significant changes. Firstly, nowadays it became related not only to developing economies but also to developed ones [8]. Secondly, the very term "frugal innovation" is relatively new, and as it becomes more popular around the globe due to increasing demand for sustainable and affordable quality solutions, this paper attempts to create a universal definition of FI. The concept of FI often overlaps with Jugaad innovation, bottom-of-the-pyramid (BoP) innovation, reverse innovation, and disruptive innovation. They have the common core elements like affordability, social or sustainable orientation and resource constraints. Jugaad refers to local solution, bottom-of-the-pyramid (BoP) – satisfaction of customers which live under poverty, reverse innovation – inexpensive solutions which were initially successfully introduced in developing countries and then in developed ones, and disruptive innovation – providing new values and overtaking an existing market [9]-[11]. It makes the academic knowledge of FI blurred. Wooldridge [12] sees FI as "reshaping products and processes to decrease needless expenses". Moreover, FI is focused on generating non-complex, sustainable solutions, including products, processes, and business models, using fewer resources that are harmless for the environment [13]. In recent years, authors have emphasised the role of FI in the achievement of sustainable development goals (SDGs). Khan [14] claims that it is possible to reach social sustainability goals via the application of FI and that it is customary to equate frugality with sustainability. It is noteworthy that the key challenges of sustainable development lie in the plane of compromises between its distinct but interconnected dimensions (i.e., social, economic, and environmental) [15]-[17]. For example, it is impossible to achieve a good quality of life without having sufficient economic resources to meet the actual needs of a person. One cannot have good health while living in an ecologically polluted area [18]-[20]. During a pandemic, social welfare cannot be sustained without basic personal protective equipment

(disinfectants) and distribution centre support (safe transport) [21]. Therefore, it can be stated that FI aims at meeting the basic needs of the population (e.g., health, education, and production of goods and services) during the health crisis period to enhance the quality of life of the population through a profit-focused innovative approach. Other authors attempted to distinguish FI from other types of innovation. In doing so, they used two distinct approaches. While some authors focused on classifying FI based on concepts and frameworks, others examined the rules and principles of FI to establish differences between frugal and other types of innovations. The first category of scholars encompasses the following researchers. Cunha *et al*. [22] focused on scarcity. Brem and Wolfram [23] concentrated on sustainability and sophistication in developing countries. Zeschky *et al*. [8] focused on the technical and market novelty of the innovations. Ostraszewska and Tylec [24] considered FI from a similar perspective. According to Soni and Krishnan [25], FI is a mentality or lifestyle, a process, and an outcome at the same time. Basu *et al*. [26] analysed FI from multiple perspectives, such as a driver, process, location, and core capabilities. The second category of scholars is represented by the following authors. Kumar [27] classified six principles of FI to establish a source of benefits to entrepreneurship, as well as entrepreneurship trends, patterns, and consequences. These principles are robustness, portability, de-featuring, leapfrog technology, mega-scale production, and service ecosystems. Khan *et al*. [28], [29] found that the most significant factor affecting the company's efficiency is the presence of a green information system. Radjou and Prabhu [10] identified six principles as well: engage and iterate; flex assets; create sustainable solutions; shape customer behaviour; co-create value with prosumers, and make innovative friends. Prahalad and Hart [30] introduced three frugal forms and rules. Based on [31], we highlighted the common characteristics of FI (Fig. 1).

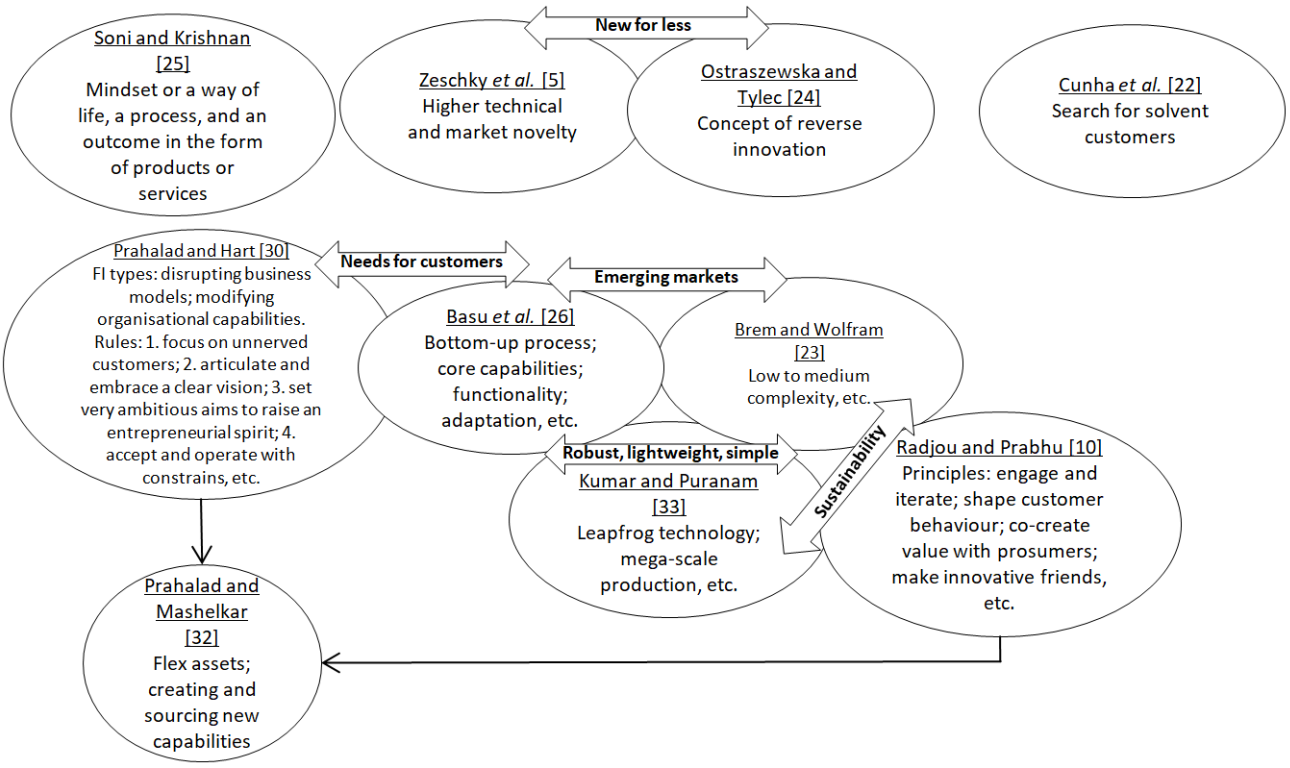


Fig. 1. Common distinguishing characteristics of frugal innovations

To put it straight, Zeschky *et al*. [8] and Ostraszewska and Tylec [24] established a novelty criterion. Basu *et al*. [26] along with Prahalad and Mashelkar [32] focused on customer needs. Studies [23], [26] highlighted the existence of emerging markets as a feature of FI. Basu *et al*. [26] and Kumar and Puranam [33] described FI as robust, lightweight, and simple. Studies [10] and [23] reported sustainability as an inherent characteristic of FI, while [27] was focused more on service ecosystems as a related component of sustainability. Studies [10], [32], and [34] were all about creating and sourcing new capabilities, as well as flexing the assets. Summarising the above, FI refers to the creation, development, and implementation of a new solution to improve effectiveness, affordability, sustainability, robustness, and functionality and meet the needs of resource-constrained consumers.

Until now, there have been few attempts in academia to map the FI-related knowledge, mostly in India [33]. The research areas are largely health, electrical engineering, electronics, transportation, finance, IT/ICT, and energy sectors. Winkler *et al*. [35] note that research on FI was focused on emerging market economies and developing countries, but recently there has been a shift towards developed countries.

The study focused on criteria-based evaluation model investigating reasons of success and failure of FI in developed countries. The results suggest that success of FI implementation in developed countries highly depends on market conditions. Agarwal *et al*. [36] reviewed the current literature on innovation through analysis and synthesis. The researchers found that emerging markets experienced an increase in the use of terminological analysis, while the innovation process was taking place outside these markets, that is, in broader markets. Tatum and Russo [37] turned to bibliometrics and presented a collection of general data from the main works on FI. Dangelo and Magnusson [38] provided a bibliometric map of FI accompanied by a qualitative assessment of clusters based on the Social Sciences Citation Index (SSCI) (Web of Science) database. They focused on content analysis of clusters in general. Santos *et al*. [39] used co-citation analysis based on 42 papers from SSCI database issued between 2011 and 2019. Our study uses the world's largest database, Scopus, and conducts a qualitative assessment of clusters and research trends with respect to the different variables, such as industry, country, investigation methodology, and research type.

The research purpose is to systemise and categorise the current research into FI, as well as bring order to the chaos of scientific knowledge. This study is based on using clustering and mapping techniques in a combined fashion to analyse bibliometric data and establish trends in the FI research over the past decade. The mapping method also served as a mean of foresight research. The paper makes a knowledge map of various works on FI, which businesses and authorities can deploy to assess the prospects for development. The study establishes an empirical link between modern concepts of FI and stakeholders (the business community, society, and the environment) to provide a tool useful in promoting innovative development in the medium run and the long run.

This paper is structured as follows. The first part of the study focuses on reviewing practice problems and existing case studies on the issue under study. The second part, methodology, clarifies the bibliometric approach, data analysis, and limitations. The third part consists of the results of bibliographic coupling analysis and content analysis, as well as discussion, which identifies the focus of each cluster

and common research trends in general, according to industry/sector, country focus, type, and method of research. Finally, the fourth part concludes the study and identifies the directions for further research.

**Methodology**

Bibliometrics is a suitable method to use in different research areas, including management [40], innovation [41], and economics [42]. Unlike a literature review that comes with a certain degree of subjectivity, the bibliometric analysis provides more objective and reliable results [43]. Furthermore, it supplements other research methods, such as meta-analysis and systematic literature review. Bibliometric analysis is a quantitative method to explore bibliographic material and patterns of publication [44], [45]. It is also suitable for presenting a comprehensive overview of the research trends in a particular area of research [46].

To map the publication output of FI research, we performed a bibliometric analysis using Elsevier's Scopus database. The results are summarised as tables and figures. Elsevier Scopus was selected for its reliance on a limited set of selection criteria used by experienced editors. To investigate the topic thoughtfully, we selected articles that provide a more complete understanding of the research domain and can highlight the emerging qualitative and quantitative changes. Documents for the analysis were collected via topic search. For this, we determined whether there was any mention of the topic in the paper's title, abstract, or keywords. A total of 357 publications on FI topic were retrieved, among which there were 213 articles, 73 conference papers, 22 book chapters, 19 reviews, nine notes, five editorials, four indefinite documents, four short surveys, three books, and three conference reviews. The publications under scrutiny are documents published between 2010 and May 08, 2021, the most debatable time period in relation to FI. These years refer to the early stage of research activity in this field. The following information of the documents was used: the name(s) of the author(s), affiliation, year, title, source, keywords, abstract, and counts of citation.

The relatedness of publications was measured via co-citation analysis and using the keywords. To enrich our knowledge on how various authors and publications are connected, we performed quantitative

and content analyses. For the methodical analysis of bibliographic characteristics, a mapping technique was applied [47], [48]. Bibliographic coupling analysis was used to systemise the documents [49]. The idea was to identify the research clusters based on bibliographic coupling and then conduct a deeper analysis. Two research papers are bibliographically coupled if they cite one or more papers in common; the more citations the documents share, the higher the coupling strength and the stronger the relationship between articles. Bibliographic coupling enables scholars to examine the reference lists of documents to find articles that have a similar research focus and identify research subdomains. The bibliometric data were then exported to Microsoft Excel and VOSviewer to generate visualisations.

This study proposes a methodological approach to determine the level of penetration of a particular area (in this case, FI) into the subject areas of scientific research based on the Shannon-Wiener Index. Its value in this study is defined in the form of the FI penetration index in the subject areas of scientific research ($PI_{FI}$):

$$PI_{FI} = \frac{-1}{\log N} \sum_{n=1}^{N} k_n \cdot \log(k_n) \quad (1)$$

N – the total number of subject areas under study; $k_n$ – share of the n-th subject area in terms of the number of publications with the keywords under study.

Maximum value of $PI_{FI}$ can be equal to 1 and is achievable when all particles are equal to 1/N. Minimum value of $PI_{FI}$ can be 0 and is achievable when all publications are made in only one subject area, i.e. one of the particles will be 1 and the others will have zero value. The higher the level of $PI_{FI}$, the more even and broad is the penetration of the area of study (keywords) into scientific research in different subject areas and the dissemination of knowledge on a given area. $PI_{FI}$ does not need to be normalised and reduced to a unit scale of measurement, so it can be used directly as a normalised dimensionless indicator.

A correlation analysis based on the number of publications using the R programming language was carried out to determine the relationship between the publications made with FI in the different subject areas. Regression modelling was also carried out in a meta-analysis of the bibliographical relationships of publications in the context of the subject areas. The study period covers the years 2010-2021. In this case, $PI_{FI}$ is used as the dependent $Y$, and the number of publications in certain subject areas are used as variables: $X_1$ – Economics, Econometrics and Finance; $X_2$ – Business, Management and Accounting; $X_3$ – Social Sciences; $X_4$ – Environmental Science; $X_5$ – Engineering; $X_6$ – Energy; $X_7$ – Decision Sciences; $X_8$ – Psychology; $X_9$ – Agricultural and Biological Sciences.

**Data Analysis**

The first step of data processing was to analyse and assign publications to one of the seven clusters so it was possible to identify and categorise research trends in the data based on the type of research, methods used, the country the article focuses on, and the examined industry. In doing so, we were able to distinguish the knowledge gaps and map the collaborations. The next step was to highlight the top research trends of the entire seven largest clusters from our analysis based on the parameters listed above. For this, we manually reviewed all the articles. In doing so, we also estimated how the FI research has evolved and made predictions regarding the directions of future research.

Limitations of our research - our data are reliant on our subjective attitude towards the choice of publications. Most publications were in English. Only a few papers were published in French or Spanish with abstracts in English. There may be more articles on FI that are written in languages other than English. Furthermore, we recognise a bias associated with the selection of words to denote FI, as some researchers could use related terms. We concentrated on a single phrase, frugal innovation, for greater precision. Due to a varying degree of specificity within the papers, bias may also be found in relation to categorisation criteria (i.e., industry, country, type of research, and research method). Another limitation

is that we focused on just four categorisation criteria. The reader, however, can pay more attention to other contexts, such as time frame.

## Results and discussion

### Scholarly activity in frugal innovation

Fig. 2 demonstrates the scholarly activity by year; the number of publications has significantly increased since 2010, and it is constantly increasing. The first paper in the dataset appears in 2010. Most of the publications (64) were published in 2018 or later. In recent years (from 2019 to May 2021), the scientific activity regarding frugal innovation has tended to decline.

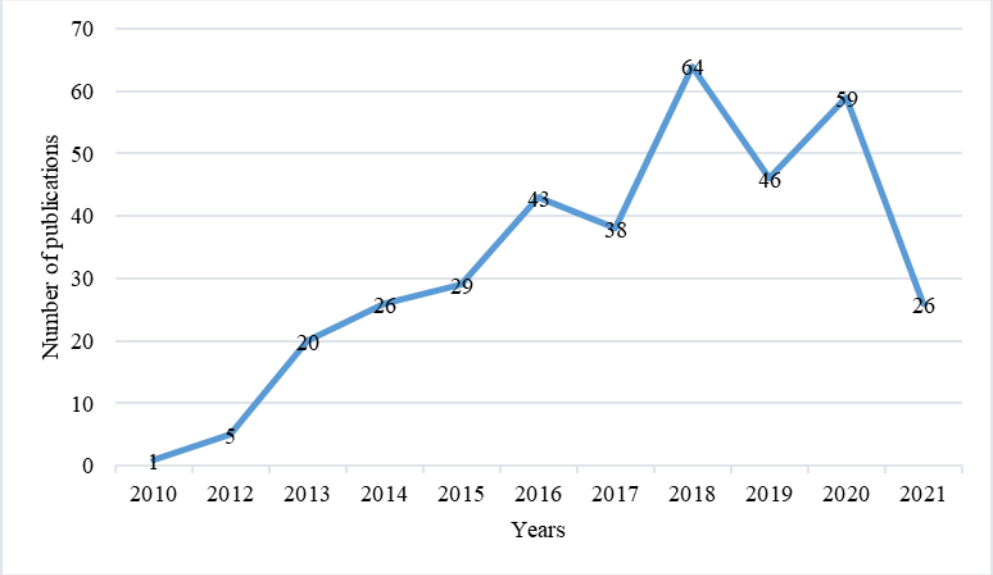


Fig. 2. Number of publications per year

### Bibliometric Analysis: Bibliographic coupling analysis and results

Bibliographic coupling analysis appears once two papers cite a third mutual publication in their bibliographies. It would be supposed that the more mutual references have two papers the stronger thematic connection there will be between them. Out of 357 publications, 290 are bibliographically coupled and assigned to 16 clusters. Of these, we selected seven that are the most illustrative (purple, yellow, blue, green, peach, light blue, and aquamarine). Fig. 3 presents the results of the bibliographic coupling analysis.

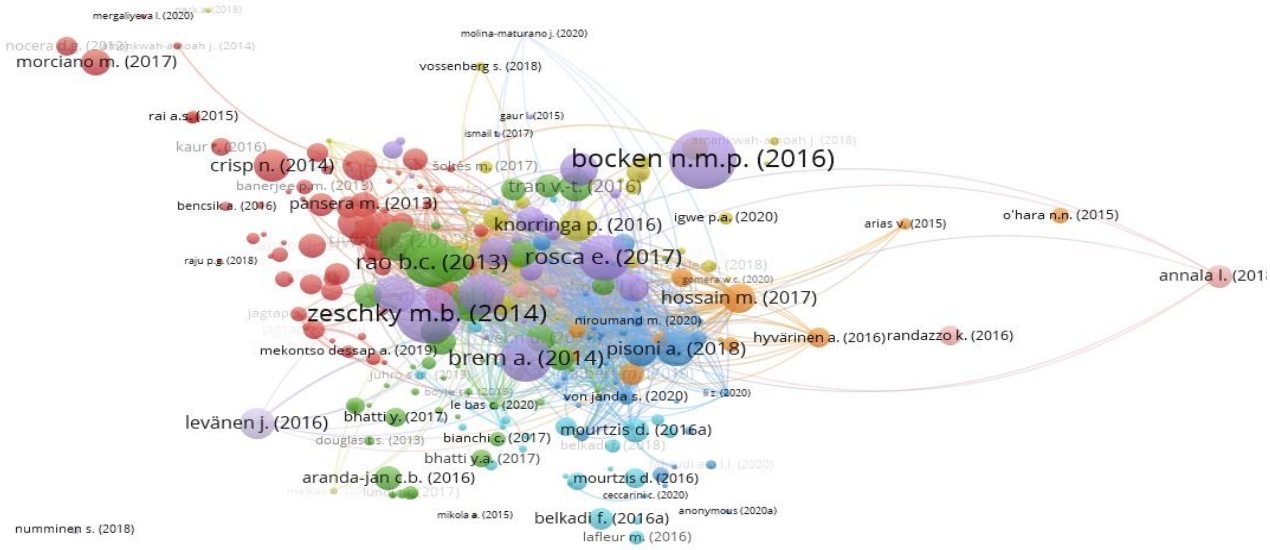


Fig. 3. Bibliographic coupling analysis

Clusters represented by purple, yellow, green, and blue colours are connected more tightly, while those coloured peach, light blue, and aquamarine are more isolated. The size of bubbles indicates the frequency of citations: the larger the bubble, the higher the frequency. The distance between the bubbles indicates the coupling strength and resemblance. The colour of the bubble indicates the research area. Publications in the purple cluster focus on business management, IT/ICT, and healthcare. Publications in the yellow colour focus on healthcare and sustainability. The blue cluster focuses on IT/ICT, manufacture, and product design. The green cluster is about business, IT/ICT, finance, healthcare, and sustainable development. The peach cluster consists of papers on healthcare and IT/ICT. Publications in the light blue cluster focus on manufacturing and business models. The aquamarine cluster focuses on the reviews, biotechnology, healthcare, and IT/ICT.

Fig. 4 shows the distribution of publications by the examined industry (sector).

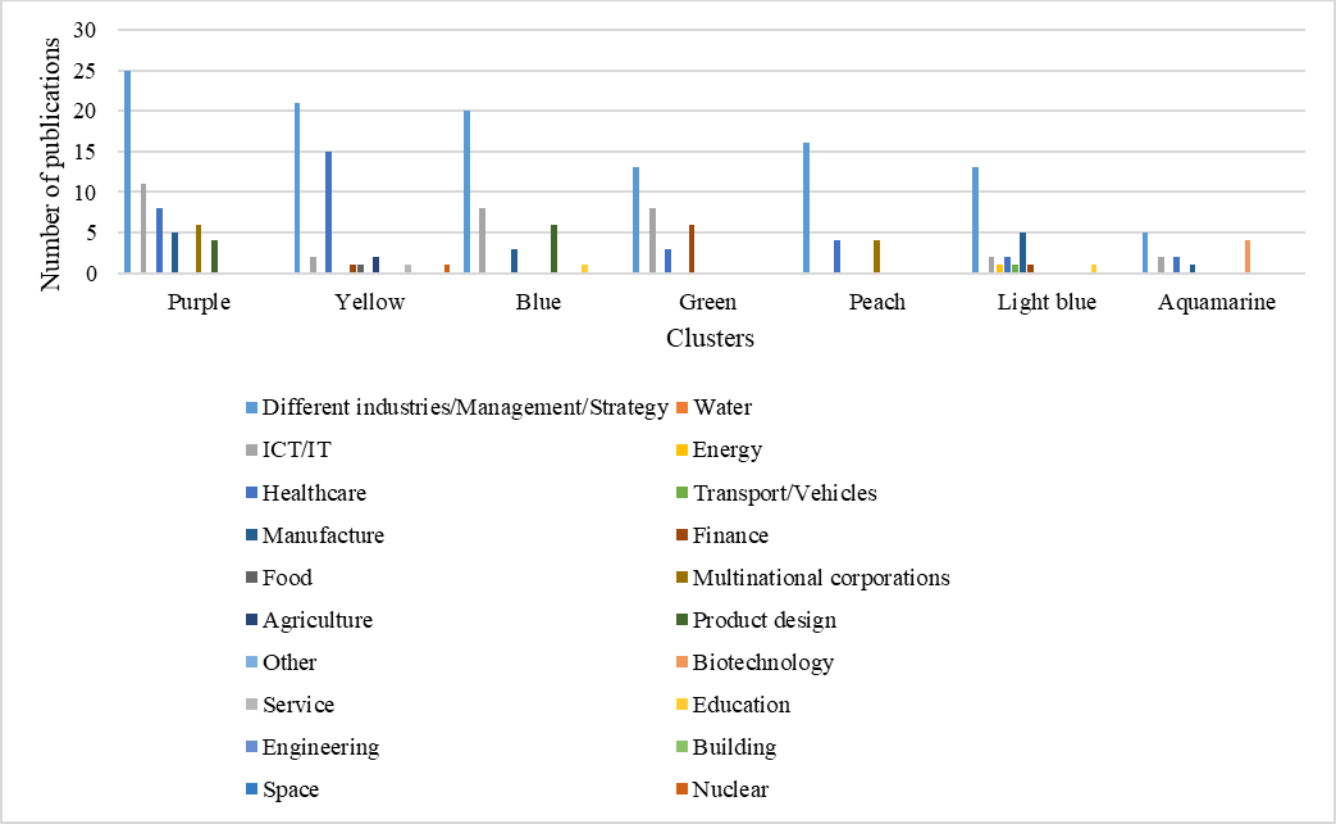


Fig. 4. Distribution of publications within clusters by industry (sector)

Fig. 5 shows the distribution of publications by the examined country.

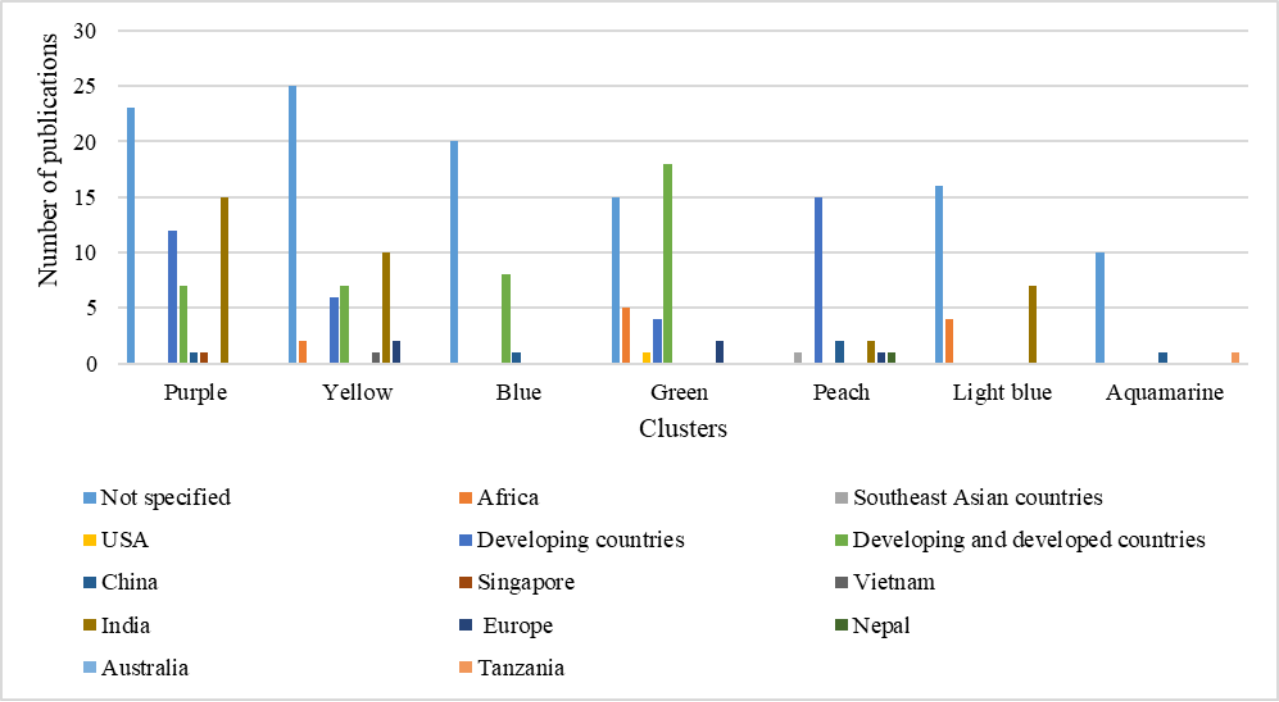


Fig. 5. Distribution of publications within clusters by country

Fig. 6 shows the distribution of publications by research type.

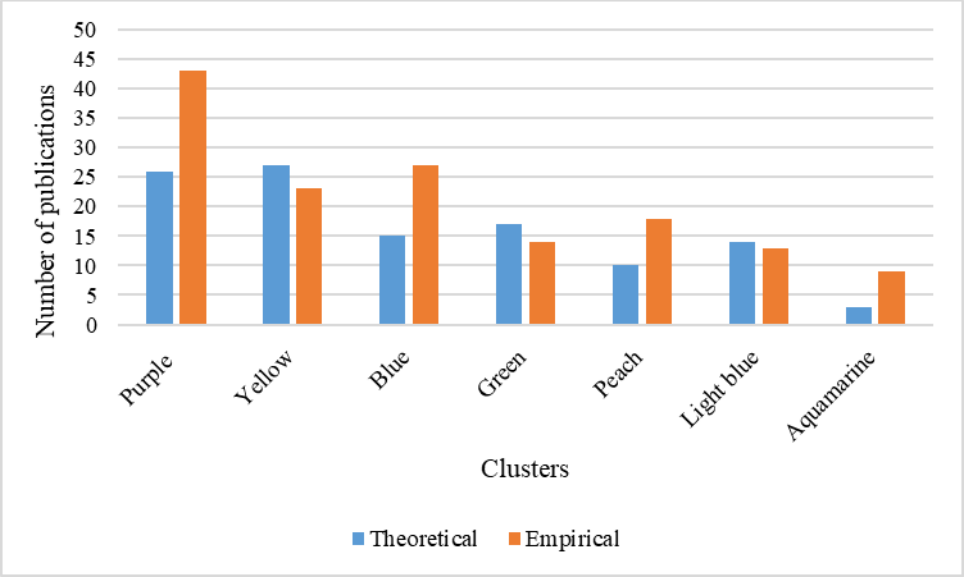


Fig. 6. Distribution of publications within clusters by research type

Finally, Fig. 7 shows the distribution of publications by methodology.

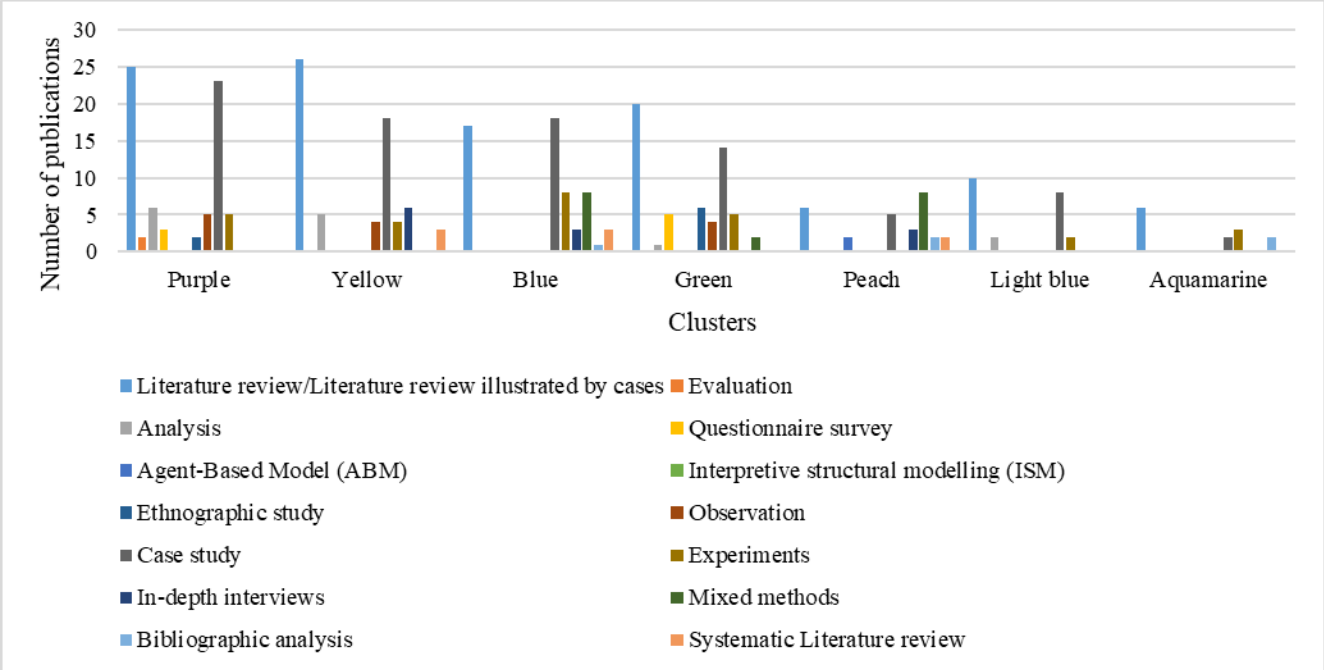


Fig. 7. Distribution of publications within clusters by research methods

## Purple cluster

### Industry (sector) focus

We have analysed common research topics of the purple cluster that consists of 69 publications. The purple cluster consists of papers focused on different industries, IT/ICT, and healthcare (Fig. 4). IT is a large FI segment, where a lot of practical solutions are proposed by authors. FI in IT is almost always

crossed with other industries, in particular finance (online methods of payment for rural areas, etc.), healthcare, and others [50]-[52]. For instance, an online microinsurance via smartphone and M-Farm for small farmers ease the transactions and decrease the costs. Meanwhile, they demonstrate positive effects on private sector productivity and public services. The rationale for this cluster is that it is aimed at FI influence and its outcomes. FI in IT/ICT is a practical instrument for solving problems and developing solutions with scarce resources. The research [53] considers sustainable business models describing the development of FI. The work [54] presented cases of ICT adoption and innovation in developing countries. Studies [55]-[57] were focused on the healthcare industry (ophthalmology, critical healthcare); the authors emphasised the necessity of FI in healthcare and proposed possible solutions. For instance, the frugal approach may be used for the ventilator support for intensive therapy patients, it must be robust and reliable with modes according to their needs without superfluous features. In the category of "different industries", the authors [58] conducted an extensive review of literature, exploring 30 studies and identifying people's low-income drivers and distinctive characteristics of innovation in Indian and foreign enterprises [59], [60]. Badami [61] was concerned with the Jugaad innovations after the financial crisis of 2008. The authors [62] explored how marginalised people were involved and positioned.

**Research type and methods**

Most of the research papers are empirical (Fig. 6), however, since FI is a relatively new phenomenon, some of the empirical papers rely on the description of the real-world data, cases, and do not use a lot of statistics. Theoretical research consists of conceptual and exploratory papers. On account of FI's novelty, little is known, and the term is under debate. Most studies focus on IT/ICT and healthcare industries, also business strategies, management, and sustainability.

**Country focus**

Apart from the category "not specified", as a motherland of FI, India has attracted authors of this cluster (Fig. 5). India has presented practical FI solutions in healthcare (ophthalmology) [55], [56] and digital frugal healthcare solutions [63]. Other researchers focused on energy, transportation, water industries in

India, whereas the most unexpected became the space industry. The authors focused on Indian multinational companies, inputs and outputs of FI in context of organisational characteristics [64]. India is a source for innovation, where disadvantages of infrastructure and public services are its main triggers [65]. Some studies [50], [66] were focused on the idea of benefits for society and community, quality of life, and FI's impact on resource constraints, including new technological solutions [67], [68]. However, some authors [66], [69], and [70] are focused on developed countries, such as Australia, Sweden, and the UK.

**Yellow cluster**

**Industry (sector) focus**

Most authors in the yellow cluster are focused on different industries (Fig. 4), which makes a wide research focus. This group of researchers mostly investigates the general principles of FI; some of them try to distinguish the term from the other resembling terms, categorising them or distinguishing them into types [71]. The link between FI and sustainability is a topic of certain studies [72]-[77]. Sustainability is a very important element of FI. The latter may significantly contribute to SDGs. Furthermore, this cluster considers reverse and disruptive innovations in relation to FI. Researchers try to find links, explore these topics, whereas, some of them use multinational corporations as the main actors. The authors pay a lot of attention to the challenges of FI adoption in the developed markets in times of crisis. The smaller number of papers focus on healthcare, in particular Point-of-Care-Tests, which allow assisting more patients in a shorter time without extra costs in a pandemic context, thus, it becomes crucially important when fighting with COVID-19. Such portable, inexpensive solutions for rapid identification of disease as Diagnostic Chewing Gum, Lateral Flow Immunoassays (nondigital rapid tests), smartphone as a tool for pandemic control, polymerase chain reaction device for Ebola recognition, paper-based 3D microfluidic biochip for the identification of whooping cough, etc. can be used solely. However, in a clinical set-up, they should be used together with laboratory diagnostic tests. These FIs allow diagnosing at the patient's bedside, without wasting any time, and serving a large amount of population in a cost-

effective way. Moreover, by serving broad coverage of patients, contamination can be prevented [78]. Besides, the authors focus on the adaptation of palliative care professionals to FI in the COVID-19 pandemic [79], [80]. They conducted a multinational survey which showed that specialists of palliative care implemented inexpensive solutions, which are flexible and easy to use; they also emphasised the need of collaboration and finance in the context of a pandemic. Authors focused on effect of external and internal knowledge on FI using case of Saud Arabian enterprises [81].

**Research type and methods**

Most of the research papers are theoretical (Fig. 6); they aim to investigate the factors which facilitate the innovations. The conceptual frameworks and linkages between FI and sustainability are common for this cluster. Authors try to explore and investigate the FI phenomena [71]. Apart from the general approach, a lot of scholars used a case study method (Fig. 7).

Cost-effective engineering and design allowed producing the cheapest electric car Tata Nano, which is sustainable and affordable for consumers with low incomes. Sustainability, FI, and the origin of the concept were deeply studied in India [82], [83].

**Country focus**

Most of the papers have a general focus, where the country is not specified (Fig. 5). The authors of the yellow cluster try to distinguish FI types, link them with sustainable human development, and establish a conceptual framework. Besides, the vast number of papers focus on India. India is considered in many papers as a main source of FI; the authors focus on the examination of FI capabilities in India. Firstly, it is explained by the number of remarkable examples and case studies in India, like Tata Nano, lightweight electrocardiogram (ECG), multiple mice with multiple cursors, software addressing system, low-cost solar panel, Tally business software, low-cost healthcare services, and one of the surprising, the implications of design impromptu practices that influence the localisation of reactor technology in India [83]. It demonstrates the possibility of an alternative way of creating complex solutions in scarce

resources. Secondly, the purchasing power of the middle class in North India attracts and stimulates the companies to offer affordable solutions.

**Blue cluster**

**Industry (sector) focus**

Apart from the category "different industries", authors are more focused on the IT/ICT sector (Fig. 4) and less on product design and manufacture. The researchers consider IT/ICT as a tool of FI; they investigate the impact of FI in IT/ICT on business models. IT/ICT FI can decrease transaction expenses, sensor prices, ease customization, supplier selection, and become useful in the COVID-19 pandemic, meanwhile boosting economic and social values. The orientation of IT/ICT FI splits into two subareas: IoT (sensors) and manufacture. For instance, inexpensive wireless monitoring of humidity and temperature is important for museums, apartments, etc. [84]. Moreover, the IoT-based wearable environment is widespread, easily adapted, where inexpensive sensors are reliable [85]. Manufacture is an important element of FI, particularly in COVID-19 circumstances, when it must respond fast. Such FI as digital fabrication of face masks, face shields, and ventilators has spread globally during the pandemic. The case of Isinnova, which provides 3D print life-saving valves for ventilators in Italy, demonstrates how collaboration can influence on the quick response in emergency cases. In times of a pandemic when there was a lack of valves for the ventilators, the start-up printed and distributed valves for critical patients, which provided sustainable work of critical healthcare department. Moreover, a scuba mask was adapted for patients with COVID-19 and distributed in Italy and worldwide [86]. Meanwhile, the collaboration between manufacturers and e-retail platforms using income-sharing agreements can improve the frugality degree of the development-intensive frugal products [87]. For the ease of integration of FI into manufacture customisation and optimum production, IT/ICT is seen as a key element [88].

**Research type and methods**

The type of papers is mainly empirical, where the authors used case studies, experiments, and mixed methods (Fig. 7). The authors explored product design, IT/ICT industries, and resource-constrained environment. Some of the authors used mixed methods, mostly in the IT/ICT sectors, with a focus on methodology and supply chains (Fig. 7).

**Country focus**

Mainly, the blue cluster papers do not focus on a specific country (Fig. 5). We would like to highlight a strong relationship between the industry focus (IT/ICT) and a global approach, which can be a potential direction for future research.

**Green cluster**

**Industry (sector) focus**

In the green cluster, the papers are mostly focused on different industries (Fig. 4). However, some of the authors try to present smartphone application for customers' involvement in the product design phase [89]. The authors emphasise that FI is targeted at the smart use of all resources. Moreover, in the European context, the necessity of FI is high; however, the focus must be on quality and sustainability rather than on the lower cost [90]. Another group of authors proved the sustainability of FI based on the assessment of four cases, emphasising the interrelationship between frugality and sustainability. The authors proved its applicability to a wide area of FI [91]. The combination of frugality with sustainable innovation delivers new insights for sustainable innovation and sustainable development [92]. FI comes from the daily needs, local resources, and communities; it has a trend to be inclusive. Sustainable development requires synergy between global goals and local actions, where FI is an appropriate tool in the local context of scarcity that could facilitate the achievement of these goals and trace the future paths for development [93]. Other authors focused on IT/ICT. All of them have the same components in common; they introduced practical solutions for developing countries. The authors offer to address unemployment problems via digital FI [94]. By evaluating the smartphone training model for small businesses using mixed methods, the authors investigated this model's usability and customers' needs; as a result, the smartphone training pilot application requires better navigation and interface features to

improve usability [95]. The relation between inclusivity and online transactions based on qualitative analysis using a case of Zambia was explored by Peša. Airtel, MTN, and Zoona offer to the rural communities mobile financial services, which are quick, affordable, and efficient for money transfer. However, the case suggests franchising relationships, and it was claimed that, on the one hand, they can facilitate employment and small business, while on the other hand, they can impact the creation of a "grey" area and new socio-economic discrimination [96]. The COVID-19 pandemic has had a global impact on the world economy and society; the case study of digital FI explores cooperation with companies that use flexibility and open innovations to solve problems at the local level. For instance, 3D printing is an example of FI that provides a fast and affordable response in the context of the COVID-19. The results demonstrate that experimentation, initiatives, and diffusion of innovations in a clinical context must be encouraged. Moreover, as FI is in high demand during the pandemic, local digital manufacturers with frugal innovative ideas have a high potential to expand worldwide very fast. The actions of local media in involving the local actors are important for stimulating the R&D activity [97].

**Research type and methods**

Theoretical papers prevail here (Fig. 6). The major method among empirical papers is a case study (Fig. 7). Papers defined problematic issues of poor communities and offered creative, flexible solutions using alternative resources and business models [98].

**Country focus**

The cluster is mainly focused on developed and developing countries (Fig. 5), creating a strong connection between these two "opposite worlds"; the authors focus on the organisation process for reverse innovations. FI requires the presence of a frugal mindset in the R&D community; moreover, it should be located in resource-constrained conditions for a better understanding of the local requirements. Developing countries must be seen as the main market for frugal solutions, where Western companies must construct reverse and frugal capabilities, extending their role from innovations adaptor into value-creator [99]-[102]. The main idea is that a close collaboration process between the developed and

developing worlds through organisational innovations (customers' involvement, empowering the employees, mutual partnership, and product development) could lead to FI with shared benefits.

**Peach cluster**

**Industry (sector) focus**

Apart from general focus, this cluster focuses on the healthcare industry and contains publications that emphasise the necessity of FI in healthcare for providing practical solutions (Fig. 4). Affordable healthcare is one of the basic requirements, which is reflected in SDGs. The common idea of this cluster is to demonstrate findings that make healthcare affordable for every person. However, some of the IT/ICT FI solutions are presented for the global healthcare market [103]-[106], some of them for local [107], including the wide area of implementation such as applications for general and critical healthcare, surgery, eye care, etc. Nowadays smartphone-based software and smartphones are used more often for skin cancer detection, cataract assessment, oral cancer examination, etc.; authors highlight several steps for FI implementation in clinical practice [105]. However, in the context of a pandemic and quarantine, the need for telemedicine and digital healthcare grows; applications and telemedicine could be among solutions for the people without access to healthcare. Authors highlighted the necessity of early collaborations between stakeholders, innovative environments, and private and public partnerships. Authors also identify the differences in distribution and implementation of innovations between developed and developing countries, where FI could bridge both types of countries and provide reasonably priced healthcare for all. Authors demonstrate a "guide" for designers of medical devices in scarce resource environment [108]; it is also shown how to develop affordable healthcare in the USA through the adoption of FI [103]. There is also smartphone diagnostics using images and sensors as a universal solution for developing and developed worlds [106]. Digital solutions and value creation for customers in healthcare became important during the COVID-19 pandemic; telemedicine became vital for terminal patients and for those that have no access to clinics and hospitals [109]. Up-to-date approaches and recommendations for FI are essential in the condition of scarce resources (for developed countries as well) [107], [110].

**Research type and methods**

This cluster is practical and mostly consists of empirical papers (Fig. 6). The most common method in the empirical papers is mixed (Fig. 7). The authors demonstrate practical solutions in terms of FI in healthcare, which covers a wide range of innovations from business models and intangible novelties to devices.

**Country focus**

The main countries are developing and developed (Fig. 5), where researchers demonstrate solutions for both types.

**Light blue cluster**

**Industry (sector) focus**

Most of the studies in this cluster focus on different industries (Fig. 4) and involve a wide range of research directions. Radjou and Euchner [110] defined the main characteristics of FI, such as affordability, simplicity, sustainability, quality, and purpose, which companies can achieve using creativity, empowering employees, and involving suppliers and customers. Development is one of the important subareas of this cluster, in particular, firm's development according to three types (organic, acquisitive, network-based) in emerging economies [111], [112]; entrepreneurship and inclusivity [113]-[115]. FI is often created by local businesses, multinational corporations, social enterprises, and NGOs, while long-term development is underestimated; future research is encouraged to investigate FI from the perspective of long-term development strategy. The worldwide crisis of 2008 followed by the COVID-19 crisis in 2020 increased the need for resourceful and minimalistic frugal solutions, rethinking the previous statement that “frugal means cheap”. Delivering the maximum benefits with minimum exploitation of resources, being sustainable, affordable, and durable, this mindset has to be applied and studied in the post-pandemic world. A paradigm of affordable green excellence of FI, based on affordable access, use of natural resources, and pursuit of technological excellence, is essential in dealing with a post-COVID-19 crisis. FI should move from “cost decrease” to “high affordability”, which could influence new business areas and the development of FI [115]. Investments of developing countries in wind energy continue to rise; among the reasons for this are frugal manufacture and efficiency, which

make “green” energy more affordable. Countries like China, India, and Brazil demonstrate interaction with foreign actors and international expansion, meanwhile, feed-in tariffs and auctioning schemes boost the development of FI [116]. The nucleus of FI is a social aspect; FI offers inexpensive solutions, expands consumer opportunities, and provides affordability to the larger society [117].

**Research type and methods**

Most papers are theoretical (Fig. 6); a lot of them are illustrated by cases (Fig 7), including entrepreneurship cases [111]. The empirical papers are mostly presented by case studies, IT FI such as massive open online courses for refugees [118], accumulation of knowledge by Chinese companies [119], and public healthcare [120].

**Country focus**

Papers here do not consider particular countries; some papers focus on India, others on African countries (Fig. 5). The category “not specified” explores the FI phenomena, complementing the resourceful and sustainable component with higher value propositions [19], where FI is seen as a key to emerging markets [121].

**Aquamarine cluster**

The aquamarine cluster focuses on “different industries”, biotechnology, healthcare, and IT/ICT. Based on co-citation analysis, authors categorise product and service innovations into eight types [122]. The connection between sustainability and FI is explored through literature review and qualitative content analysis; a positive relationship between FI and sustainability was identified by most papers. The findings demonstrate that FI is socially and economically sustainable. However, regarding the ecological part, the authors proposed a new term, “sustainable frugal innovation” [123]. In times of the COVID-19 pandemic, disinfection is a significant element of disease prevention. The robust, inexpensive plasma devices can sterilise instruments, surfaces, and even water [124]. Such devices could be used against the COVID-19 spread, despite the geographical location. Besides, 3D printing, which is used in cardiology for heart disease diagnosis, is necessary for developing countries, but since nowadays the healthcare system is limited in resources, it could be used in developed countries as well [125]. This cluster is mostly

presented by empirical papers, with experimental and case study methods. The researchers are not focused on a specific country, which demonstrates the universal approach, where the findings could be used in various countries.

**The common research trends by subject areas**

Based on the number of publications in different subject areas of scientific research from 2010 to 2021, a meta-analysis was conducted and the FI penetration index was calculated. The results are shown in Fig. 8.

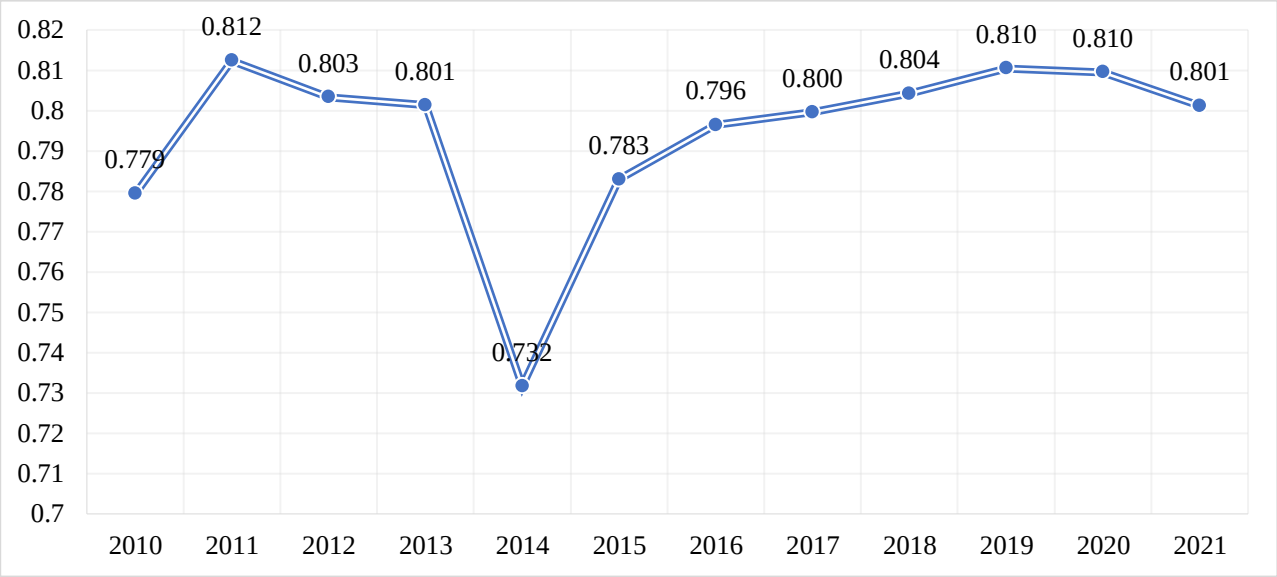


Fig. 8. FI penetration index in subject areas of research

Source: Formed by the author

During the period under study, the FI penetration index for the subject areas of research was mostly at around 0.8. This value is close to 1, which demonstrates a positive result. In 2014, however, a decrease to 0.732 was recorded. This is due to a more than two-fold increase in the number of publications in Business, Management and Accounting, as well as a lack of publications in Environmental Science this year and a three-fold decrease in the number of publications in Agricultural and Biological Sciences. This contributed to the asymmetry in the context of publications with FI in the researched subject areas. The FI penetration index in 2021 was 0.801, which indicates a sufficiently wide and even distribution in many subject areas of scientific research.

A correlation analysis with the number of publications was carried out to determine the relationships between the implemented publications with FI in different subject areas. The results obtained are given in the form of a correlation matrix based on the application of the R programming language in Fig. 9.

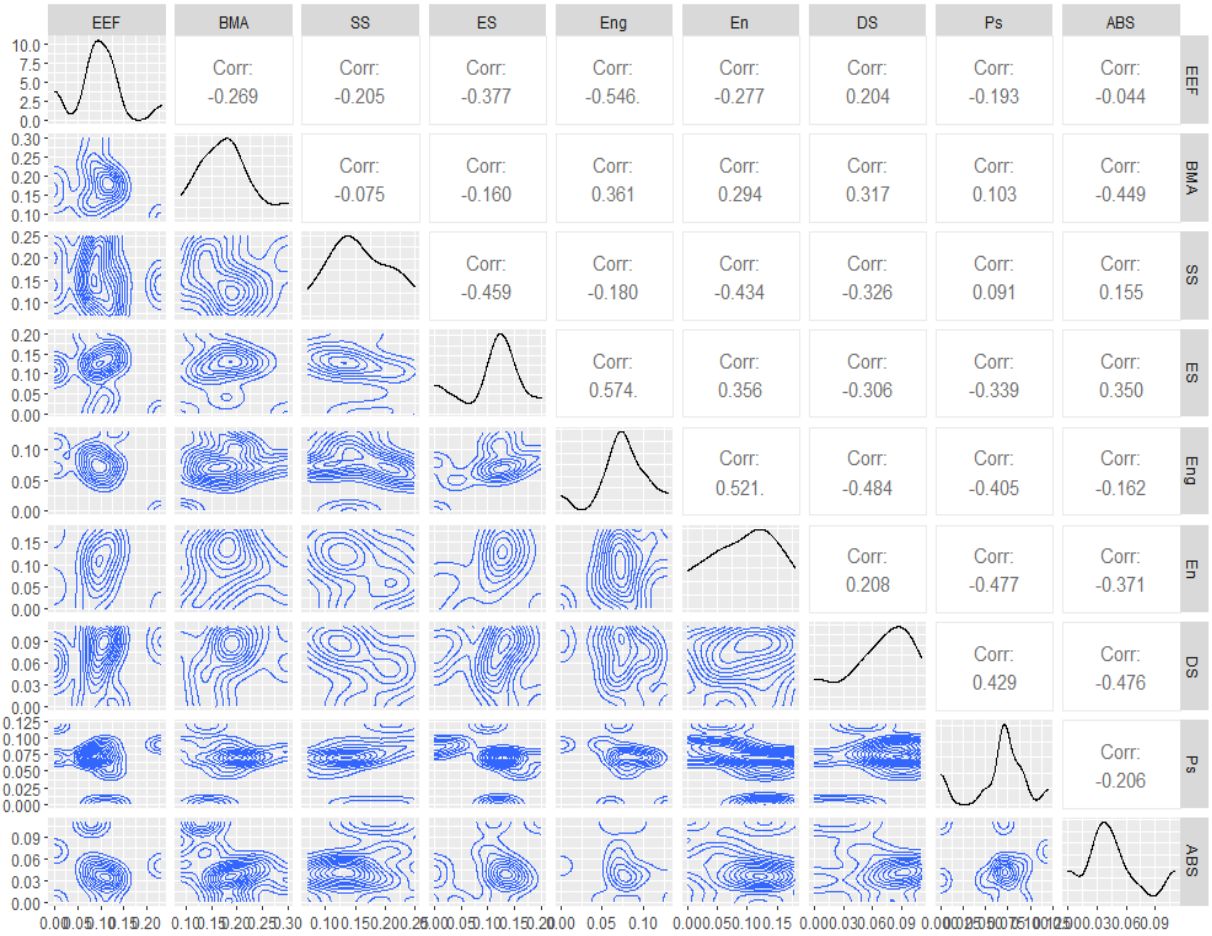


Fig. 9. Correlation matrix of subject areas in the context of publications with FI

Note: EEF – Economics, Econometrics and Finance; BMA – Business, Management and Accounting; SS – Social Sciences; ES – Environmental Science; Eng – Engineering; En – Energy; DS – Decision Sciences; Rs – Psychology; ABS – Agricultural and Biological Sciences.

Source: Formed by the author

A significant relationship in the context of publications with FI is observed for Business, Management and Accounting and Decision Sciences, Environmental Science and Energy - above 0.9. A regression analysis was conducted to determine the impact of the increase in publications in the studied subject

areas on the level of FI penetration in scientific research, the main indicators of which are shown in Table 1.

Table 1. Indicators of regression analysis of the number of publications with FI by subject area for 2010-2021

| Indicators (subject areas) | Coefficients | Standard error | t-statistics | P-value | Bottom 95% | Top 95% |
|---|---|---|---|---|---|---|
| Y-intersection | 0.688 | 0.0277 | 24.8594 | 0.0016 | 0.5685 | 0.80 |
| Economics, Econometrics and Finance | 0.081 | 0.0516 | 1.5724 | 0.2565 | -0.1408 | 0.30 |
| Business, Management and Accounting | -0.416 | 0.0383 | -10.8455 | 0.0084 | -0.5808 | -0.25 |
| Social Sciences | 0.135 | 0.0371 | 3.6390 | 0.0679 | -0.0246 | 0.29 |
| Environmental Science | 0.153 | 0.0432 | 3.5396 | 0.0714 | -0.0329 | 0.33 |
| Engineering | 0.888 | 0.1452 | 6.1147 | 0.0257 | 0.2632 | 1.51 |
| Energy | -0.018 | 0.0484 | -0.3708 | 0.7463 | -0.2260 | 0.19 |
| Decision Sciences | 0.764 | 0.0966 | 7.9126 | 0.0156 | 0.3487 | 1.17 |
| Psychology | 0.085 | 0.0908 | 0.9310 | 0.4501 | -0.3061 | 0.47 |
| Agricultural and Biological Sciences | 0.340 | 0.0788 | 4.3199 | 0.0496 | 0.0014 | 0.67 |

Source: Formed by the author

It is not appropriate to form a regression model based on the data obtained, as the P-value for the factor in the subject area "Energy" exceeds the permissible value of 0.05 and is 0.7463. This indicates that the modelling is inadequate and this factor should be excluded from the model. The regression modelling iterations also excluded "Economics, Econometrics and Finance", "Social Sciences", "Environmental Science", and "Psychology". The results obtained after excluding the factor "Energy" are shown in Table 2.

Table 2. Regression analysis of the number of publications with FI by subject area, 2010-2021, excluding Energy

| Indicators (subject areas) | Coefficients | Standard error | t-statistics | P-value | Bottom 95% | Top 95% |
|---|---|---|---|---|---|---|
| Y-intersection | 0.750 | 0.0155 | 48.4815 | 0.0000 | 0.7134 | 0.7866 |
| Business, Management and Accounting | -0.432 | 0.0511 | -8.4556 | 0.0001 | -0.5533 | -0.3115 |
| Engineering | 0.837 | 0.0993 | 8.4349 | 0.0001 | 0.6026 | 1.0721 |
| Decision Sciences | 0.638 | 0.1012 | 6.3010 | 0.0004 | 0.3985 | 0.8772 |
| Agricultural and Biological Sciences | 0.327 | 0.0851 | 3.8396 | 0.0064 | 0.1255 | 0.5280 |

Source: Formed by the author

Based on the results of the regression analysis performed, a model for the penetration of FI research across different subject areas can be identified in the form of the following equation:

$$PI_{FI} = -0.432 \cdot BMA + 0.837 \cdot Eng + 0.638 \cdot DS + 0.327 \cdot ABS \quad (2)$$

The applicability of the generated regression model is confirmed by a number of control criteria. The P-value for all studied indicators (subject areas) is within the normative value of 0.05. The coefficient of determination is 0.94, which also positively characterises the adequacy of the developed model. Student's t-test indicates the applicability of the model because $t_{obs} = 10.38$ exceeds $t_{crit}$=2.18. The adequacy of the model formed is also confirmed by Fisher's criterion, as $F_{tabl} < F$ (4.12<26.97).

"Engineering" and "Decision Sciences" are the most influential on the FI penetration index in the subject areas of scientific research. At the same time, an inverse correlation is observed for "Business, Management and Accounting". This is primarily due to the fact that in this subject area the largest number of publications with FI is observed during the period under study. This creates a certain asymmetry in the volume of publications towards a given subject area and consequently reduces the level of equal penetration in all subject areas of research.

This research has much in common with the work of other scholars. For example, it takes into account changes in understanding of FI over time to identify knowledge gaps and lay the groundwork for future

research in economic development [34], [36]-[39], [126] and [127]. The authors investigate links between FI and sustainable human development [72], supply chain sustainability [73], sustainable production methods of construction [74], as well as the combination of sustainability, diffusion, and FI [92]. The advantage of the research conducted is its comprehensive approach, which allows one to examine clusters and trends in research with respect to various variables, such as industry, country, research methodology, and type of research. We found that clusters were focused on the general characteristics of FI. In contrast to this study, they are focused on a particular manifestation of FIs. This, on the one hand, points to the diversity of research conducted on the issue at hand: the intellectual structure of the emerging field of FI research [38], [128]; success factors, inputs, deliverables [129], and barriers of FI [130]; the influence of external and internal sources of knowledge [81]; adaptation of the frugal approach to innovation to overcome the extraordinary pressures emanating from the spread of the COVID-19 pandemic [97], [126]. On the other hand, these studies show the fragmentation of the obtained results, which are almost impossible to compare with each other, because they pursue different goals.

**Conclusion**

Our study demonstrates that during ten years, clusters focused on FI frameworks and phenomena and had mostly general approach. Many papers are empirical and mainly presented by case studies in IT/ICT, healthcare, manufacture, and product design. Fewer research papers focused on finance, multinational corporations, education, construction, engineering, and food. Therefore, the study demonstrates a near dearth of FIs in such industries as agriculture (livestock, dairy, fishing, wood, horticulture); manufacture, textile, chemical, petroleum, mining, metal production; service, hospitality, food retail, tourism, and sports industries. For future research, we recommend to pay more attention to the above-mentioned industries/sectors, which require sustainable and frugal approach. The research into these industries could bring a lot of practical and theoretical insights. Results showed surprising research activity in the nuclear and space industries. A special feature of the study is the use of a comprehensive approach that allows the study of clusters and research currents depending on various variables, such as industry, country,

research methodology, and type of research. Based on the methodological framework used, it was found that the clusters formed during the study period showed general characteristics of FI. At the same time, in comparison with the given research, they focus on a certain aspect of innovative activity. This allows one to note, firstly, the diversity of studies devoted to the range of topics under consideration and, secondly, the fragmentation of the achieved results, which can hardly be compared with each other, because they solve different problems. The conducted research provides an opportunity to link different directions into a single spectrum and identify areas in which the problems of innovation have been insufficiently studied. In the long term, it will allow researchers of FIs to master new ways and identify new reference points and starting points in other scientific cross-sections devoted to FIs. Regarding the country focus of research, besides the developing countries and India, there was a growing interest in developed countries. For future research, we suggest drawing more attention to the developed countries highlighting practical implications in various sectors and industries. In addition, our research delivers useful insights in the FI domain; qualitative analysis with bibliometric techniques provides a synergy effect, which permits to present the map of FI in a more accomplished way. The study assesses research trends in FI and covers many publications, providing a comprehensive vision of the research domain. Our theoretical contribution reflects the gaps in academic literature, showing the top research trends during the decade. We structured the information on FI during the decade, constructed a scientific map, presenting the synthesised information of the previous research. It could be useful for technical, medical, and social scholars. We found that FI could solve social and economic problems of society including in developed and developing countries, with a sustainable approach. The scientific contribution of this study is the proposed Index of FI penetration in the subject areas of publications. It has provided an opportunity to diagnose the level of penetration of FI into the subject areas of research and to confirm a fairly broad and even distribution of FI in many subject areas of research. An asymmetry of publications in the subject areas of “Business, Management and Accounting”, “Environmental Science” and “Agricultural and Biological Sciences” was identified over the study period.

A meta-analysis of the bibliographic relationships of publications in the context of subject areas based on correlation analysis and regression modelling has identified the most influential areas for FI development, among which are "Engineering" and "Decision Sciences". The advantage of the proposed approach is the possibility to diagnose the asymmetry of publication volumes in a particular subject area, which has a significant impact on the level of equal penetration in all subject areas of scientific research.

We suggest for further research to focus on FIs use or could be used in the COVID-19 pandemic, which might be useful for policy makers, scholars, and practitioners when determining further actions with COVID-19. Moreover, future research is encouraged in terms of IT/ICT together with healthcare industry, as many FI solutions cross both these industries and might deliver a lot of practical instruments, which could be used to fight the COVID-19 pandemic. Furthermore, further research according to the time frame could bring a lot of insights in terms of the development, evolution of the domain, and its practical implications.

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## 3.2. Ten years of frugal innovation: Bibliometric and theoretical review

Paper published in *Astra Salvensis*, Scopus Q1, H-INDEX-12; ISSN 23441887, 23934727; SJR-0,22; Impact Score: 0.35; CiteScore 2020-1.6; CiteScoreTracker 2021-1.4; SNIP 2020-0.416; https://astrasalvensis.eu/astra-salvensis-1-2022/

Authors: Lidia MELNIKOVA, Ainhize GILSANZ, Claudia Leticia PRECIADO-ORTIZ

Astra Salvensis is a multidisciplinary journal focused on socio-humanistic areas, including management and decision making. Therefore, the paper's contribution to the scope of the journal is particularly relevant for management scholars and practitioners interested in frugal innovation. The paper's critical literature review, based on bibliometric analysis complemented by content analysis, provides valuable insights and guidance for researchers interested in frugal innovation in the management field. The paper's publication in Astra Salvensis further highlights its significance in contributing to the field of frugal innovation research, specifically within the realm of management.

**Abstract**. The last decades topic of frugal innovation attracted the attention of scholars and practitioners. The introduction of something innovative in resource-constrained conditions represents a challenging issue. The developing countries were the prior focus of research; however, there is rising attention regarding the countries with developed economies as well. Thus, due to the interest and lack of systemised information on this topic, this study aims to clarify and to analyse the significant findings from the current literature on frugal innovation. The aim of the research is to present a comprehensive bibliometric analysis complemented with a perspective of theoretical review, based on the data that incorporates the research papers including the term of frugal innovation from 2010 till October 10, 2019, which clarifies the present-day focus of research in this topic and summarises areas of research. In doing

so, we carried out a bibliometric analysis and analysed 238 publications that have been published since 2010 till 2019, along with the theoretical review, based on the insights identified from a group of top-cited articles on frugal innovation. We organised and synthesised 47 papers according to the sector (industry) focus, type/ method of research, country focus, and focus of research. Thus, we estimated the evolution of past research and used the key findings to outline future research pathways.

**Keywords:** frugal innovation, economical improvements, publications, information, literature review, analysis.

## Introduction

A combination of bibliometric analysis with a theoretical approach delivers the synergy effect for research of the scope and conceptualisation into this kind of innovation. In our research paper, we present the bibliometric analysis of the academic discussion on frugal innovation, since bibliometric indicators can reflect necessary and important facts-based insights, decreasing the subjective factor of research activity (Moed et al., 1985), while the theoretical literature review is used to assess the prior research (Tranfield et al., 2003). Few attempts were undertaken to present bibliometric analysis on frugal innovations, among of them authors R. Tiwari and K. Kalogerakis (2016), C.T.S. Tatum and S.L. Russo (2020), while V. DAngelo and M. Magnusson (2020) were focused on intellectual communities, meanwhile the sectors were not considered. Our research presents also, the insights of the top-cited publications considering the sector (industry) focus, type/ method of research, country focus, and focus of research. Hence, the relevance of the period 2010-2019 is justified by the increasing number of publications year by year. Moreover, the term “frugal innovation” was under discussion during these years, and was reconsidered significantly. Initially definition was aimed at developing countries, countries with low incomes, and further at developed countries (Zeschky et al., 2014a), while the perception and criteria of the definition changed significantly.

The origin of the concept has been addressed to the "emerging economies", especially India. The etymology of the word "frugal", (XVI century); from Middle French frugal, also frugi "useful, proper, worthy, honest, temperate, economical". Different authors consider frugal innovation with diverse perspectives. Among them, Radjou et al. (2012) defined it as "fail cheap, fail fast, fail often". Furthermore, frugal innovation is based on affordability, accessibility, availability, and sustainability (Varadarajan, 2011; Radjou et al., 2012). However, it is important to highlight that frugal innovations contribute to sustainability (Hossain, 2020). Due to its sustainable feature, the definition of frugal innovation also overlaps with "responsible innovation" (van Beers et al., 2020). Frugal innovation is the reconsideration of business models, reconfiguration of value chains, and redesign of products in order to save resources and serve the inclusive markets in constrained conditions in a sustainable way (Bhatti, 2012). The phenomenon may be described in different categories, dimensions or avenues of research: first, frugal innovation aims at customers with low incomes as co-creators of solutions, target groups and satisfaction of the primary customers' requirements without complexity (Zeschky et al., 2011); second, the obtaining sufficient level of taxonomy with low R&D investments by adapting product management, production, and development (Bhattacharyay, 2012); and, finally, provided solutions may be used for developed countries.

The aim of the research was to present a comprehensive bibliometric analysis complemented with a perspective of theoretical review, based on the data that incorporates the research papers including the term of frugal innovation from 2010 till October 10, 2019, which clarifies the present-day focus of research in this topic and summarises areas of research.

**Materials and Methods**

However, so far, a lot of scholars have focused on the determination of the term, trying to define its relevance for business in the context of consumers in developing countries (Tiwari and Herstatt, 2012; Radjou and Prabhu, 2015; Ramdorai and Herstatt, 2015), and developed countries. For instance, N. Radjou and J. Euchner (2016) argue that frugal innovation provides solutions that integrate five key

variables: affordability, simplicity, sustainability, quality, and purpose (Table 1). T. Weyrauch and C. Herstatt (2016) claim that it must lead to a significant decrease in expenses, focus on the key features, modify output level. However, the optimised performance criterion, such as geographical location has to be adapted, since it is strongly related to the customer. Also, the characteristics may be distinguished into three major groups: market; product; and business (Sjafrizal, 2015).

**Table 1.** Different criteria of frugal innovation

| **Variable, criteria and perspectives identification** | | **Authors** |
|---|---|---|
| Five key variables of frugal innovation | Affordable price; Incomplex; Ecological friendly; Good enough quality; Clear purpose; | (Radjou and Euchner, 2016) |
| Three criteria of frugal innovation | Significant decrease in expenses, focus on the key features, modify output level; | (Weyrauch and Herstatt, 2016). |
| Combination of characteristics into 3 major perspectives | Unserved market with a constraint on resources;<br>Products with low cost, high reliability and using state-of-the-art technologies;<br>Effective business model with a razor-thin profit margin; | (Sjafrizal, 2015) |

*Source: Author's preparation.*

The base of frugal innovation is good-enough innovation but targeted on resource-constrained environments, providing a new value proposition, however lately it also targets the economically developed world (Zeschky et al., 2014a). The concept has also been recognized due to the fact of the limitation and less exploitation of resources. The data used in this work were extracted from the Elsevier Scopus database. The search was conducted on October 10, 2019, and consisted of filtered publications

that had the phrase "frugal innovation" in its title, summary, or keywords. Two hundred thirty-eight documents were obtained: 136 articles, 50 conference papers, 15 book chapters, 13 reviews, eight notes, five editorials, four short surveys, three books, two conference reviews, one type, and one indefinite document. The period of the publications ranged between 2010 and 2019. The information obtained from each publication includes such data as, publication name, author(s) and their affiliations (institution and country), year, source of the publication, summary, and cited references. The visualization and analysis were performed by Microsoft Excel, then VOS viewer.

**Results and Discussion**

The outcomes presented in Figure 1 reflect the increase of information in terms of frugal innovation. From 2010 (n = 1), the number of publications is increasing in the following period at the sustained rate, in 2012 it appears 5, 2013 rises to 18, and continues with the growing trend in the subsequent years to date (2014 – 24, 2015 – 27, 2016 – 43, 2017 – 35, 2018 – 61). Each direction has its own progress, as was mentioned by Dereck J. Solla Price in 1956 about the exponential growth of scientific information which claims that existing global information doubles rapidly every 10-15 years (Ardanuy, 2012).

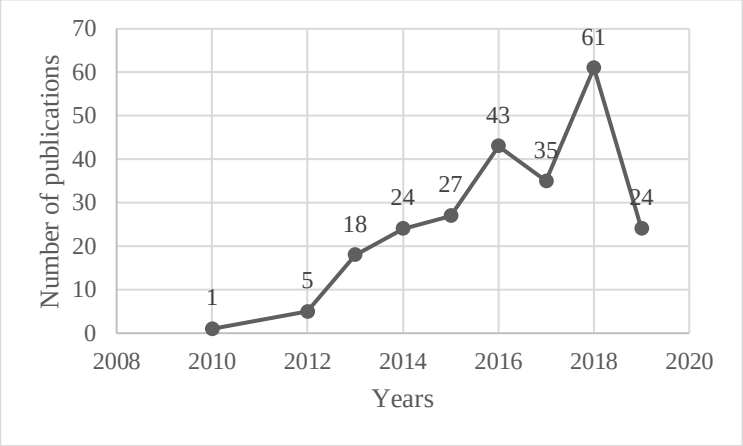


**Figure 1.** Yearly distribution of the number of publications

In total, 159 different authors were identified, 87 of them have only one publication, 45 have two publications and 27 authors have three or more publications up to a maximum number of seven publications, such as D. Mourtzis, Figure 2 presents authors that have the highest number of publications.


**Figure 2.** Top 5 of authors with the highest number of publications

In Figure 3, the 72 authors who published at least two documents are represented below, generating a total of 28 different working groups. The most significant workgroup is represented by red colour and made up of 8 elements, the following two groups are formed by six authors, one is green and the other is blue. It can also be observed that this blue group is the only one that is linked to another purple one with

five authors. The yellow group appears to be more substantial, it contains five elements, but the first two groups are not connected with other workgroups.

Each circle represents an author in this network that has at least two publications. The dimensions of the circle indicate the number of research papers per author, while the linkages, collaboration between authors. The colours indicate the cooperation cluster. The analysis was performed with VOS viewer.

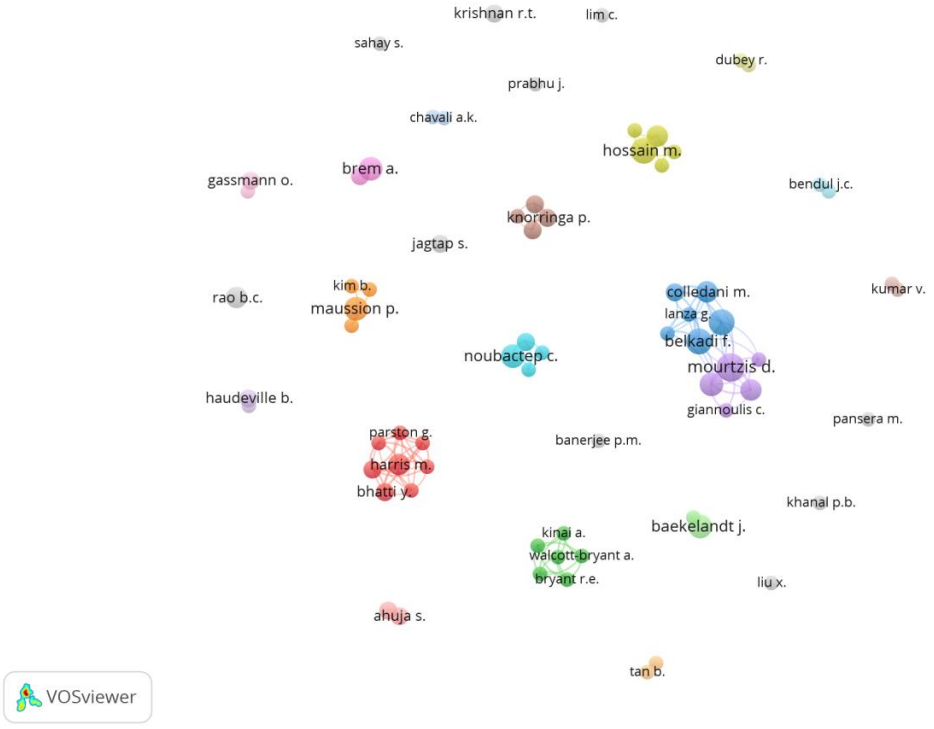


**Figure 3.** Co-author cooperation in frugal innovation research

The 238 documents found on frugal innovation, in 122 diverse sources, among them, journals, conference papers, books, which stands for the diversity of approaches in this field. Figure 4 shows the Top-5 of the sources with the vast number of articles published on the topic, with the European Journal of Development Research on top (n = 9), followed by Journal of Cleaner Production (n = 8), CIRP procedure (n = 5) and Sustainability Switzerland (n = 5). According to the indexes of citations, the highest

ranking has Journal of Cleaner Production, n = 7.32), the "Scimago Journal Rank" (SJR), that estimates the impact factor according to Scopus database, the "Source Normalized Impact per Paper index" (SNIP) including the study area of the journal.

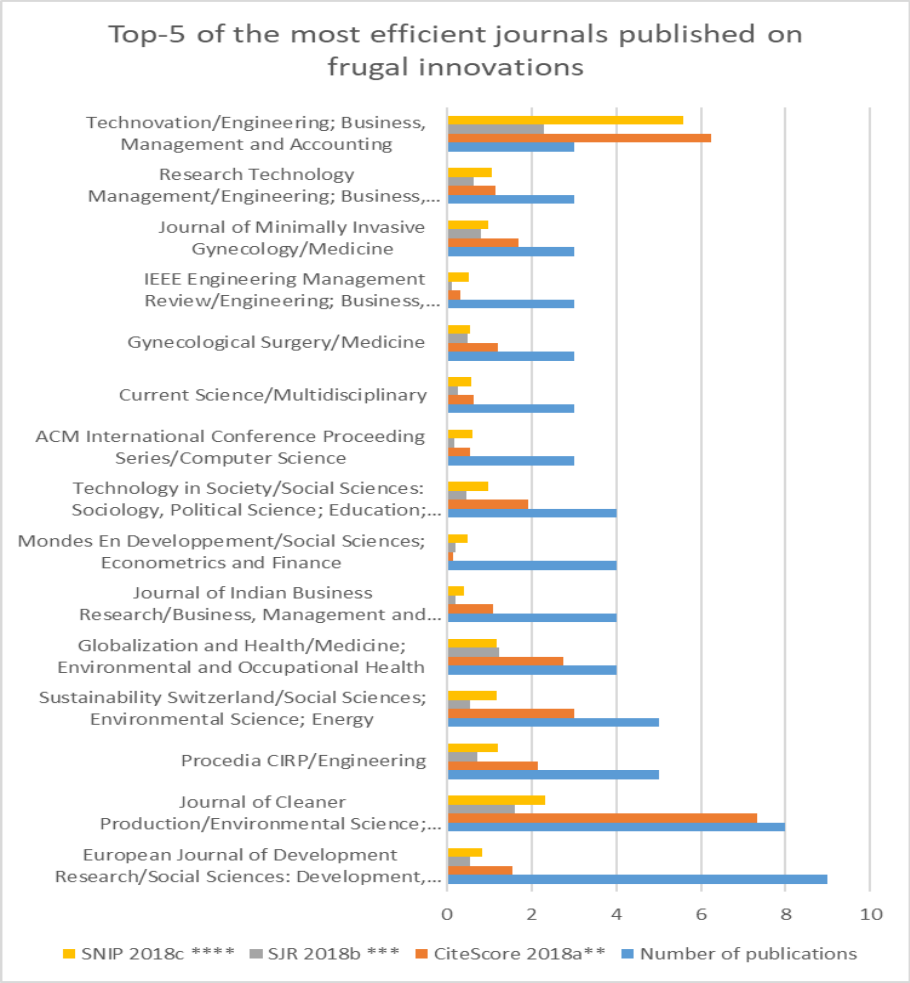


**Figure 4.** Top 5 of the most efficient journals published on frugal innovations

*Note: ** "CiteScore" estimates mean citations obtained per scientific paper in the serial; *** "SCImago Journal Rank" evaluates weighted citations obtained by the serial. It depends on the subject area and prestige (SJR) of the citing serial; **** "Source Normalized Impact per Paper" evaluates actual citations obtained relative to citations anticipated for the serial's subject area.*

The countries and affiliated institutions are indicated according to the Scopus database. 47 countries or territories were identified, and 13 publications appear with an indefinite allocation. Figure 5 shows a worldwide distribution. It is observed that 40.42% (n = 19/47) of the publications appear in the European continent, followed by 23.40% (n = 11/47) of the Asian continent, 17.02% (n = 8/47) in the American continent such as in the African continent, and 2.12% (n = 1/47) in Oceania.


**Figure 5.** Frugal innovation publications distributed by country

Figure 6 shows the most productive countries on frugal innovation. The leading countries are India (46 publications), United States (39 publications), United Kingdom (29 publications), France (28 publications), and Germany (26 publications).

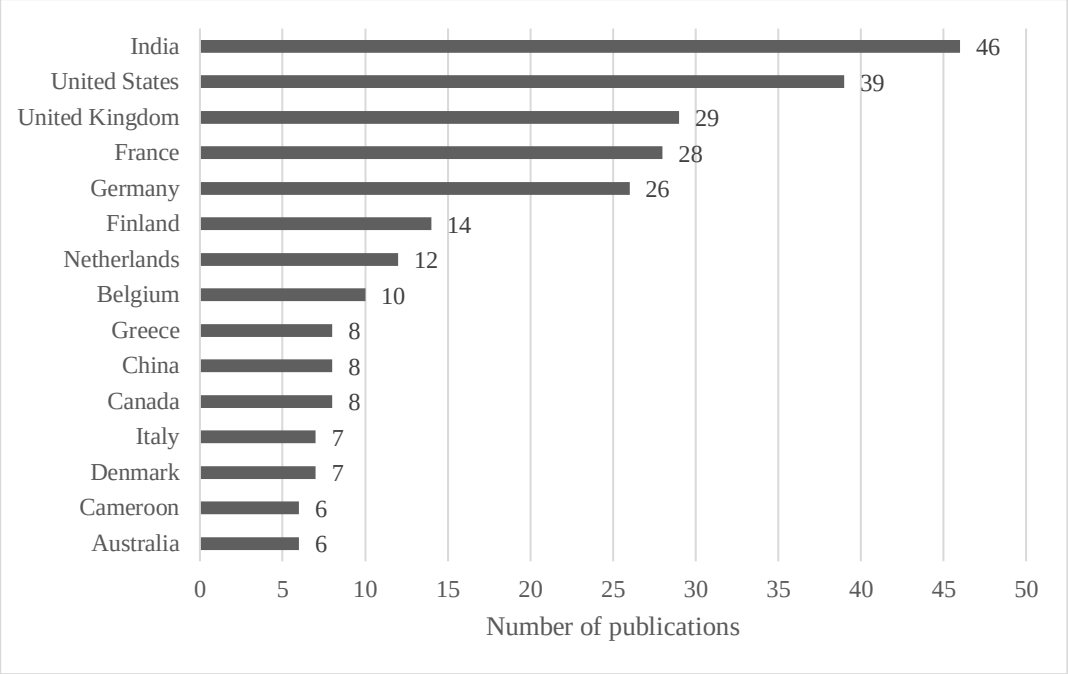


**Figure 6.** Top 5 effective countries in frugal innovation

*Note:* Countries which produce equivalently have the same score number.*

47 countries were identified, ten of them are not related to any working group. The rest is represented in the following figure 7. The remaining 37 countries are all linked to each other, forming nine different working groups. The group with the highest number of members is the red one with eight countries (Canada, Finland, Kenya, Netherlands, Rwanda, South Africa, Sweden, and Vietnam), the next group indicated by the green colour, formed by six items (France, Cambodia, Greece, Italy, Tunisia, and Turkey); the blue group shaped by five countries (United States, Venezuela, Switzerland, Slovakia, and Colombia). The yellow group is represented by four items (Germany, Portugal, Brazil, and Belgium) and the purple by (China, Tanzania, Zimbabwe, and Cameroon). Australia, India and Norway are indicated by aqua colour; United Kingdom, Qatar, and Nigeria are presented by orange colour; Denmark and Spain are indicated by coffee colour, while Japan and South Korea by pink colour.

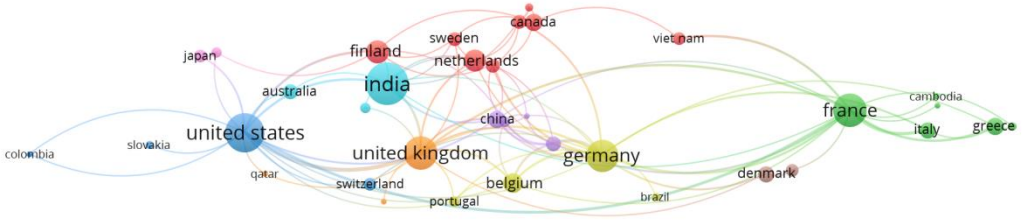


**Figure 7.** Collaboration clusters according to the countries and territories in frugal innovation

The dimension of the circle stands for the number of research papers, and the linkages, for the strong point of the cooperation. The colours identify the cooperation groups. The results showed 160 different institutions of authors' affiliation. It is observed that 55.62% (n = 89/160) of the institutions appear only once, 26.87% (n = 43/160) appear twice and 17.5% (n = 28/160) appear three or more times. Figure 8 shows the Top-5 productive institutions on frugal innovations.

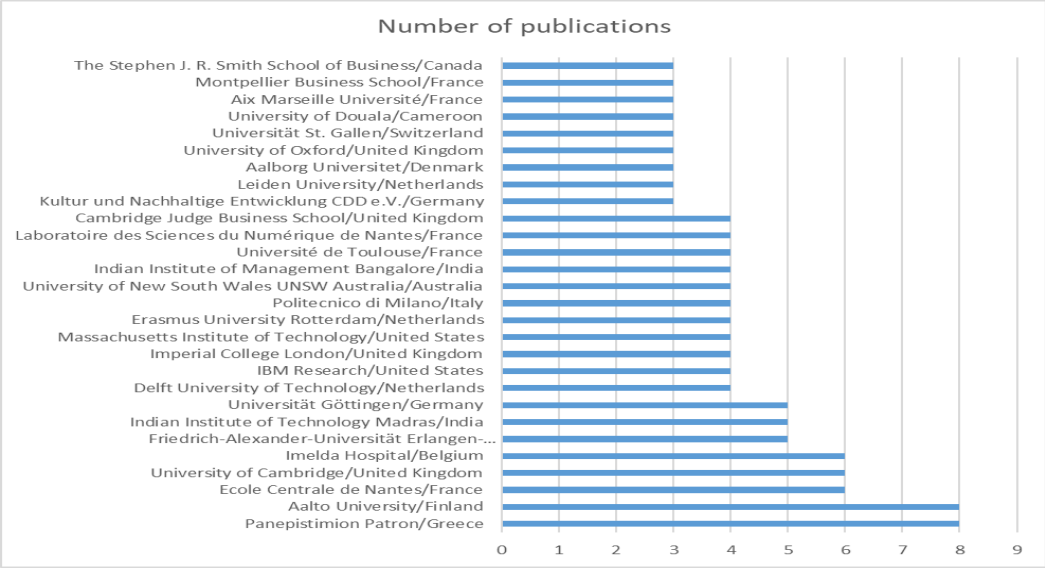


**Figure 8.** Top 5 of the most productive institutions on frugal innovations

Bibliographic coupling analysis occurs when two publications refer to a third common paper in their bibliographies. It would be presumed that the larger number of references in common have two publications, the more significant thematic relationship will be between them.

Of the 238 publications, 15 relevant working groups are generated (with more than two articles up to 36, the largest); that means that among the production of frugal innovation topic, 15 bibliographic aggregations have been generated, and each of them shares common references. Figure 9 is the result of the most interconnected workgroups.

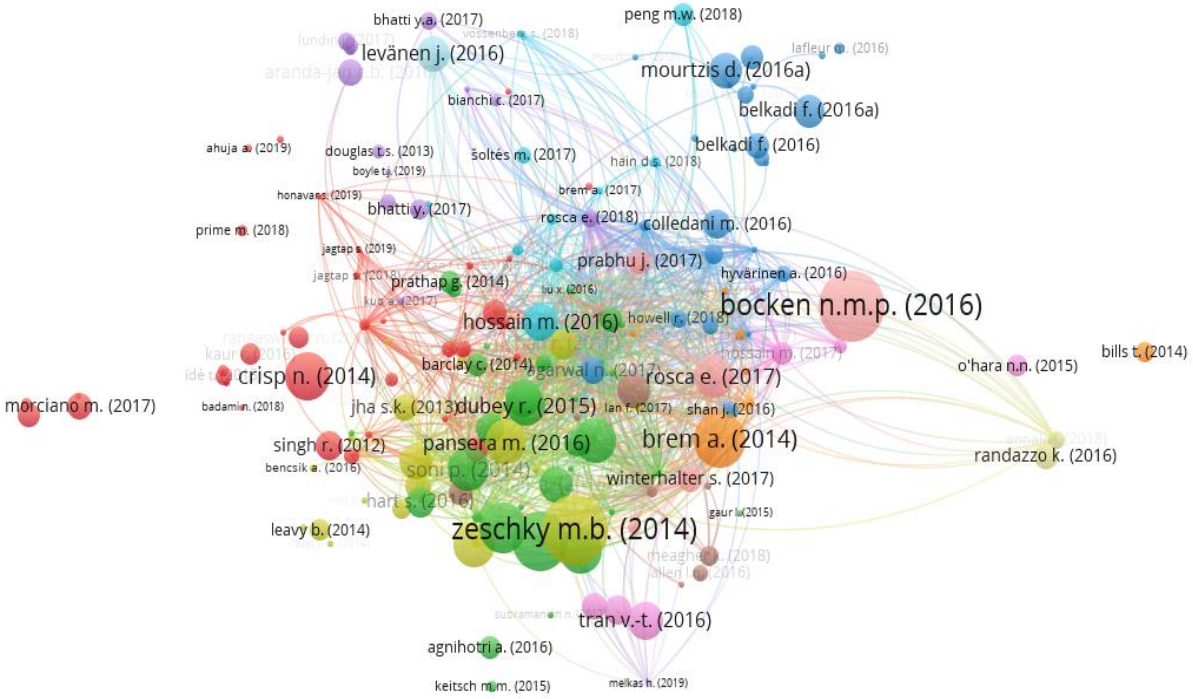


**Figure 9.** Bibliographic coupling analysis

On the grounds of the title and abstract analysis of the research papers in the largest clusters, a relevant mark defined. The yellow is the major one and refers to the field of frugal innovation mainly

related to health, IT, energy, and generally focused publications. The green colour refers to the practical solutions, introducing cases of frugal innovations in different industries, while the orange cluster represents publications on engineering, ICT, advanced frugal innovations, product design. The authors in the blue cluster are concentrated on business strategies, management, and sustainable development in terms of frugal innovations. The purple cluster is more practical and strongly focused on the healthcare industry, whereas the pink cluster is focused on small business, economic development, and investments in terms of frugal innovations.

The citation analysis provides the number of times publications/or authors have been cited by others in Scopus. In total, 1392 citations have received the 238 documents found; nevertheless, by subtracting the self-citation, there are 1102 total citations, which would mean that on average, 4.63 citations per document. This part includes synthesis and analysis of the research conducted by a group of top-cited articles in frugal innovation, which includes 47 articles (Table 2). In addition to the identifying data of the articles and the reference to quotations, topic, industry (sector) focus, type of research paper/method, country focus and the main focus of research are considered.

**Table 2.** Analysis of tip-cited publications on frugal innovations

| No * | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Document Title | From cost to frugal and reverse innovation: Mapping the field and implications for global competitiveness | Towards a sufficiency-driven business model: Experiences and opportunities | How disruptive is frugal? | Research and development from the bottom up - introduction of terminologies for new product development in emerging markets | Assessing India's lead market potential for cost-effective innovations | Mutual learning and reverse innovation-where next? |
| Authors | (Zeschky et. al., 2014a) | (Bocken and Short, 2016) | (Rao, 2013) | (Brem and Wolfram, 2014) | (Tiwari and Herstatt, 2012) | (Crisp, 2014) |
| Topic | Innovation \| Emerging markets \| Frugal innovations | Business model \| Industry \| Business model innovation | Innovation \| Emerging markets \| Frugal innovations | Innovation \| Emerging markets \| Frugal innovations | Innovation \| Emerging markets \| Frugal innovations | Health \| Income \| Health care |
| Journal Title | Research Technology Management | Environmental Innovation and Societal Transitions | Technology in Society | Journal of Innovation and Entrepreneurship | Journal of Indian Business Research | Globalization and Health |
| Total cites | 71 | 57 | 48 | 39 | 35 | 33 |
| Average citation per year | 14.20 | 19.00 | 8.00 | 7.80 | 5.00 | 6.60 |
| Sector (industry) focus | Different industries | Furniture manufacturer, clothing manufacturer, sports gear manufacturer, document management system manufacturer, vehicle, equipment ('unprinter') manufacturer | Different industries | Different industries | Cooling systems/ Energy/ Water/ Vehicles | Healthcare |
| Type/ method of research | Empirical/ literature review and a seriesof case studies | Empirical/ case study | Empirical/case study | Theoretical/ conceptual/ literature review, synthesis, induction, deduction | Empirical/ analysis, literature review, synthesis | Theoretical/exploratory/ literature review, synthesis, |
| Country focus | Not specified | Developed countries | Not specified | Not specified | India | Not specified |
| Focus of research | Analysis and discussion of the various types of innovations related to frugal type/Analysis of approaches/Frame work for practitioners and actors of real business | Sufficiency as a key element of sustainable business framework/Definition of proper strategy in order to get the correct attitude to the sufficiency | Identification of different types of frugal-innovations in terms of disruptiveness/ Examination of the resembling types for formalizing the process of frugal innovations based on examples, that will complement the common one | The presentation of a complete summary of the resembling definitions of frugal innovations and their identification. Introduction of the conceptual framework according to sophistication, sustainability, and focus on developing countries | Assessment of reasons that influence on India and leads to emerging of frugal innovations/India as a country with a leading position on frugal innovations | Focused on creating a practical local solution in healthcare, which could be useful for developing and developed economies |

| 10 | 10 | 9 | 9 | 8 | 8 | 7 |
|---|---|---|---|---|---|---|
| Antecedents of innovation and contextual relationship | Frugal and reverse innovation - Literature overview and case study insights from a German MNC in India and China | Business models for sustainable innovation – an empirical analysis of frugal products and services | Organising for reverse innovation in Western MNCs: The role of frugal product innovation capabilities | Crafting sustainable development solutions: Frugal innovations of grassroots entrepreneurs | Capability building through innovation for unserved lower end mega markets | Frugal innovation: Aligning theory, practice, and public policy |
| (Dubey et al., 2015) | (Agarwal and Brem, 2012) | (Rosca et al., 2017) | (Zeschky et al., 2014b) | (Pansera and Sarkar, 2016) | (Lim et al., 2013) | (Soni and Krishnan, 2014) |
| Strategy implementation \| Execution \| Middle managers | Innovation \| Emerging markets \| Frugal innovations | Innovation \| Emerging markets \| Frugal innovations | Subsidiaries \| Multinational corporations \| Multinational enterprises | Innovation \| Technology \| Inclusive innovation | Catch-up \| Innovation \| Latecomer firms | Innovation \| Emerging markets \| Frugal innovations |
| International Journal of Business Innovation and Research | 2012 18th International Conference on Engineering, Technology and Innovation, ICE 2012 - Conference Proceedings | Journal of Cleaner Production | International Journal of Technology Management | Sustainability (Switzerland) | Technovation | Journal of Indian Business Research |
| 24 | 24 | 25 | 25 | 28 | 28 | 29 |
| 6.00 | 3.43 | 12.50 | 5.00 | 9.33 | 4.67 | 5.80 |
| Different industries | Different industries/ Multinational Corporation (manufacture) | Health/ Different industries | Healthcare / Electronics | Hygiene/ Energy/ Agriculture/ | Vehicles/Automotive | Different industries |
| Empirical/ interpretive structural modelling (ISM) | Empirical/ Case study | Empirical/ Case study | Empirical/ Case study | Empirical/ Case study | Empirical/Case study | Theoretical/conceptual/ literature review, synthesis, induction, deduction |
| India | Germany/ India/ China | Developed and developing countries | Developed and developing countries | India | India | Not specified |
| The history of innovations in India/Determination of prerequisites of innovations in India | Approaches and establishment of multinational corporations in developing countries. Differentiation of frugal and reverse innovation and analysis of the practices of German multinational corporations | The systemisation and description of the business model in terms of frugal and reverse innovation/Facilitation of sustainable development | Process of organisation of the international RandD in multinational corporations of the healthcare and electronics industries in terms of reverse innovations | Four case studies of business in scarce resource conditions in India. Examination of businesses that create ecological, inexpensive products from available materials | Exploratory case (Tata Motors' Nano) of the building innovation capabilities. Creating a process that would provide a solution in producing budget service or product and would have an impact on the building of innovation capability | Fulfilment of the key knowledge about frugal innovation. The author distinguishes the categories and levels of frugal innovations. Focused on academic basics of economics in order to provide key factors of frugal innovations |

| 16 | 16 | 15 | 15 | 15 | 14 | 13 | 12 | 11 |
|---|---|---|---|---|---|---|---|---|
| How frugal innovation promotes social sustainability | Poverty, Business Strategy, and Sustainable Development | Frugal Innovation and Development: Aides or Adversaries? | Can frugal go global? Diffusion patterns of frugal innovations | Total Vaginal NOTES Hysterectomy: A New Approach to Hysterectomy | Emerging economies drive frugal innovation. | Innovation in India: A review of past research and future directions | New development: Eight and a half propositions to stimulate frugal innovation | Frugal innovation in medicine for low resource settings |
| (Khan, 2016) | (Hart et al., 2016) | (Knorringa et al., 2016) | (Hossain et al., 2016) | (Baekela, 2015) | (Emerging Economies Drive Frugal Innovatio, 2013) | (Nair et al., 2015) | (Hartley, 2014) | (Tran and Ravaud, 2016) |
| Innovation \| Emerging markets \| Frugal | Base of the pyramid \| Bottom of the pyramid \| Poverty alleviation | Innovation \| Technology \| Inclusive innovation | Innovation \| Emerging markets \| Frugal innovations | Natural Orifice Endoscopic Surgery \| Laparoscopy \| Orifice specimen | Biomedical equipment \| Hospitals \| Equipment maintenance | Hazards \| Critical infrastructures \| Public listed | Co-production \| Production \| Public services | Gastroenteritis \| Fluid Therapy \| Intravenous rehydration |
| Sustainability (Switzerland) | Organization and Environment | European Journal of Development Research | Technology in Society | Journal of Minimally Invasive Gynecology | Bulletin of the World Health Organization | Asia Pacific Journal of Management | Public Money and Management | BMC Medicine |
| 14 | 14 | 16 | 16 | 16 | 17 | 18 | 20 | 21 |
| 4.67 | 4.67 | 5.33 | 5.33 | 4.00 | 2.83 | 4.50 | 4.00 | 7.00 |
| Energy/ Mobile phone/ Financial service/ | Different industries | Mobile phone/ Financial service/ | Cooling systems/ Automotive/ Energy/ Financial service / Healthcare | Healthcare | Healthcare | Different industries | Different industries | Healthcare |
| Empirical/ Case study Literature review, analysis, synthesis | Theoretical/ Literature review, analysis synthesis, induction, deduction | Theoretical/ Literature review, analysis synthesis, induction, deduction | Empirical/ Case study, comparison, analysis | Empirical/ Experiment, observation, comparison, analysis | Theoretical/ Literature review, analysis synthesis, induction, deduction | Theoretical/ Literature review, analysis synthesis, induction, deduction | Theoretical/ Literature review, analysis synthesis, induction, deduction | Theoretical/ Literature review, analysis, synthesis, induction, deduction |
| Developing countries | Not specified | Developing countries | Developing and developed | Not specified | Developing countries | India | Not specified | Not specified |
| Creation of the linkage between social sustainability and frugal innovations, using the insights of different cases | Analysis of vast literature and approaches about the opportunities and limitations of the companies that could decrease the poverty and deliver sustainable development. | Discussion about the necessity of empirical approach for frugal innovations in order to assess the proper time and location for facilitating the inclusive development | Exploration of various kinds of frugal innovation distribution, identifying four forms: local, closeness, distance, and international distribution | Demonstration of the practicability of frugal innovation in gynaecological surgery/The innovation provides less adverse effects and could be also used in scarce resources conditions | The reflection of the necessity and the vision of frugal innovation, through conducting interviews with doctors, hospital stakeholders | Insights from India's companies and institutions in terms of innovation systems and processes/review and organisation of previous research | Definition of some key ideas and practices that would impact on innovations in the public sector | Discussion about the necessity of different types of frugal innovations in medicine, how essential they are, supported by literature |

| 20 | 20 | 19 | 19 | 18 | 17 | 17 | 17 |
|---|---|---|---|---|---|---|---|
| Implications of frugal innovations on sustainable development: Evaluating water and | Designing metallic iron-based water filters: Light from methylene blue discoloration | Frugal innovation | Local innovation: The key to globalization | Serving poor people in rich countries: The bottom-of-the-pyramid business model solution | Frugality, grassroots and inclusiveness: New challenges for mainstream innovation theories | Open innovation as a new paradigm for global collaborations in health | Jugaad-From 'Making Do' and 'Quick Fix' to an Innovative, Sustainable and Low-Cost Survival Strategy at the Bottom of the Pyramid |
| (Levänen et al., 2016) | (Btatkeu-K. et al., 2016) | (Bhatti et al., 2013) | (Jha and Krishnan, 2013) | (Angot and Plé, 2015) | (Pansera, 2013) | (Dandonoli, 2013) | (Singh et al., 2012) |
| Innovation \| Emerging markets \| Frugal | Iron \| Dechlorination \| Nanoscale zero-valent | Design \| Product development \| Tool frames | Innovation \| Emerging markets \| Frugal innovations | Innovation \| Emerging markets \| Frugal innovations | Innovation \| Technology \| Inclusive innovation | Health \| Income \| Health care | Innovation \| Emerging markets \| Frugal innovations |
| Sustainability (Switzerland) | Journal of Environmental Management | Globalization, Change and Learning in South Asia | IIMB Management Review | Journal of Business Strategy | African Journal of Science, Technology, Innovation and Development | Globalization and Health | International Journal of Rural Management |
| 10 | 10 | 11 | 11 | 12 | 13 | 13 | 13 |
| 3.33 | 3.33 | 1.83 | 1.83 | 3.00 | 2.17 | 2.17 | 1.86 |
| Water/ Energy/ | Water | Different industries/ Multinational Corporations | Different industries/ Multinational Corporations | Different industries | Different industries | Healthcare | Different industries |
| Empirical/ Case study Literature review, analysis, synthesis | Empirical/ Experiment, measuring, analysis, synthesis, induction, deduction | Theoretical/ Literature review, analysis synthesis, induction, deduction | Empirical/in-depth interviews, analysis | Theoretical/ Conceptual article/ Literature review, analysis synthesis, induction, deduction | Theoretical/ Literature review, analysis synthesis, induction, deduction | Empirical/ Observation, analysis, synthesis, induction, deduction | Empirical/ interviews, analysis |
| Developing countries | Not specified | Developing and developed countries | Developing and developed countries | Developing and developed countries | Developing countries | Not specified | India |
| Evaluation of the most common frugal innovations in literature in energy and water sectors according to Sustainable Development Goals (SDG) | Design of water filtration as a frugal innovation | Discussion about globalization that has impacted South Asia, in terms of organisations' respond to opposing issues, where multinational companies could take advantage of the South Asian companies | Reflection of lessons, challenges of multinational corporations from developed and developing countries in terms of innovating | The suggestion of the scarce resource innovations transfer to the firms for developed countries through adapted business models, taking into account the location of strategies application | Different kind of innovation concepts and perception of innovations that appear in countries with scarce resources. Analysis of the main drivers of this kind of innovations | Description of an early-stage pilot project based on open innovation in scarce resources which involves communities, partners, and expertise. Discussion of the solutions that would involve developed economies | Focused on the innovations "Do It Yourself" level/innovations in local business in scarce resource conditions |

| 23 | 22 | 22 | 22 | 21 | 20 | 20 |
|---|---|---|---|---|---|---|
| Mapping the frugal innovation phenomenon | Exploring the dynamics of water innovation: Foundations for water innovation studies | A systematic literature review of constraint-based innovations: State of the art and future perspectives | Efficient steam generation by inexpensive narrow gap evaporation device for solar applications | Theory of open inclusive innovation for reciprocal, responsive and respectful outcomes: Coping creatively with climatic and institutional risks | Frugal innovation: Doing more with less for more | Business Models for Frugal Innovation in Emerging Markets: The Case of the Medical Device and Laboratory Equipment Industry |
| (Hossain, 2017) | (Wehn and Montalvo, 2018) | (Agarwal et al., 2017) | (Morciano et al., 2017) | (Gupta et al., 2016) | (Prabhu, 2017) | (Winterhalter et al., 2017) |
| Innovation \| Emerging markets \| Frugal innovations | Innovation \| Sustainable development \| Socio-technical transitions | Innovation \| Emerging markets \| Frugal innovations | Desalination \| Steam generators \| Solar steam | Open innovation \| Innovation \| Organizational ambidexterity | Economics \| Innovation \| Demand reduction | Business model \| Industry \| Business model innovation |
| Technology in Society | Journal of Cleaner Production | IEEE Transactions on Engineering Management | Scientific Reports | Journal of Open Innovation: Technology, Market, and Complexity | Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences | Technovation |
| 7 | 8 | 8 | 8 | 9 | 10 | 10 |
| 3.50 | 8.00 | 4.00 | 4.00 | 3.00 | 5.00 | 5.00 |
| Healthcare/ ICT/ Transportation/ Vehicles/ Automotive/ Energy/ Water/ Financial service | Water | ICT | Water/Energy | Different industries | Manufacturing/ Food/ Automotive/ Energy | Healthcare |
| Empirical/ Systematic approach in the literature review, analysis synthesis, induction, deduction, comparison | Theoretical/ Conceptual/ Literature review, analysis synthesis, induction, deduction, comparison | Empirical/ Systematic Literature review, analysis, synthesis, induction, deduction, comparison | Empirical/ Experiments, analysis, synthesis, induction, deduction, comparison | Theoretical/ Conceptual/ Literature review, analysis synthesis, induction, deduction, comparison | Theoretical/ Conceptual/ Literature review, analysis synthesis, induction, deduction, comparison | Empirical/ Case study Literature review, analysis, synthesis, induction, deduction |
| Not specified | Not specified | Not specified | Developing countries | Developing countries | Developing and developed countries | India, China |
| Exploration of the trend of published articles that use a case study method on frugal innovations | Introduction of the framework in water innovations topic/ main key findings for future research | Systematically organisation and synthesis of approaches to innovations related to scarce resources conditions. The research distinguishes innovations into different types. | Development of solar steam generator as a water filtration device and implementation for rural places with limited access to resources. | The link between frugal innovations and open innovation concepts/Challenges of perception/Climate challenges/obligations of formal and informal actors | Introduction of the concept of frugal innovation/Incomplex, affordable, budget solutions, in scarce resources conditions/discussion on strategies/practical examples | Focused on disruptive forms of innovations. Establishment of approaches in order to satisfy the customers with limited access to the resources |

| 27 | 26 | 26 | 25 | 25 | 24 | 24 | 24 |
|---|---|---|---|---|---|---|---|
| Innovation at the middle of the pyramid: State policy, market segmentation, and the Chinese | Frugal innovation for supply chain sustainability in SMEs: multi-method research design | Investigating the suitability of Fe<sup>0</sup> packed-beds for water defluoridation | Co-production of frugal innovation: Case of low-cost reverse osmosis water filters in India | Value capture and value creation: The role of information technology in business models for frugal innovations in Africa | The growth of the firm in (and out of) emerging economies | Cannibalizing the Informal Economy: Frugal Innovation and Economic Inclusion in Africa | Frugal approach to innovation: State of the art and future perspectives |
| (Thun, 2018) | (Shibin et al., 2018) | (Heimann et al., 2018) | (Annala et al., 2018) | (Howell et al., 2018) | (Peng et al., 2018) | (Meagher, 2018) | (Pisoni et al., 2018) |
| Global value chains \| Fair trade \| Lead firms | Supply chain management \| Supply chains \| GSCM practices | Iron \| Dechlorination \| Nanoscale zero-valent | Base of the pyramid \| Bottom of the pyramid \| Poverty alleviation | Innovation \| Emerging markets \| Frugal innovations | Internationalization \| Emerging markets \| Outward foreign direct investment | Base of the pyramid \| Bottom of the pyramid \| Poverty alleviation | Innovation \| Emerging markets \| Frugal innovations |
| Technovation | Production Planning and Control | Chemosphere | Journal of Cleaner Production | Technological Forecasting and Social Change | Asia Pacific Journal of Management | European Journal of Development Research | Journal of Cleaner Production |
| 3 | 4 | 4 | 5 | 5 | 5 | 6 | 6 |
| 3.00 | 4.00 | 4.00 | 5.00 | 5.00 | 5.00 | 6.00 | 6.00 |
| Automotive | Different industries | Water | Water | IT | Different industries | Mobile phones/ Financial service | Different industries |
| Empirical/ Case study Literature review, analysis, synthesis | Empirical/ Mixed methods, survey, analysis, synthesis, induction, deduction, comparison | Empirical/ Experiments, analysis, synthesis, induction, deduction, comparison | Empirical/ Mixed methods, interviews, literature review, analysis, synthesis, induction, deduction | Theoretical/ Conceptual/ Literature review, analysis synthesis, induction, deduction, comparison | Theoretical/ Conceptual/ Literature review, analysis synthesis, induction, deduction, comparison | Empirical/ Mixed methods, literature review, analysis, synthesis, induction, deduction | Empirical/ Systematic Literature review, analysis, synthesis, induction, deduction, comparison |
| China | Not specified | Not specified | India | Africa | Developing countries | Africa | Not specified |
| The influence of the absence of market segments in the automotive industry on the company's development in developing countries | The hierarchical conceptual framework based on supply chain sustainability and frugal innovations for a business entity. Frugal innovation is a key element for the supply chain. | Design of inexpensive water filtration based on Fe0 | Affordable water filtration system "reverse osmosis" (RO) which delivers pure water in India | Demonstration of information technology (IT) in frugal innovations, and its impact on business in terms of delivering frugal innovations to the customers with limited access | Exploration of three major key elements for business development/Growth as the main component of research/Company's growth/Introduction of topics and insights of the last twenty years of research | Examination of four mechanisms of unfavorable incorporation in terms of frugal innovation, based on cases of M-Pesa and micro-insurance | Exploration of the development of the concept of frugal innovation; analysis of the results; identification of gaps in the current literature |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 27 | Frugal Innovation and Development Research | (Leliveld and Knorringa, 2018) | Innovation \| Emerging markets \| Frugal innovations | European Journal of Development Research | 3 | 3.00 | Mobile phones/ Financial service | Theoretical/ Literature review, analysis synthesis, induction, deduction, comparison | Africa | Focused on the determination of frugal innovations. Contribution to inclusive innovation and development, illustrated by Mobile Money and Financial Inclusion |
| 27 | Does Frugal Innovation Enable Sustainable Development? A Systematic Literature Review | (Rosca et al., 2018) | Innovation \| Technology \| Inclusive innovation | European Journal of Development Research | 3 | 3.00 | Different industries | Empirical/ Systematic Literature review, analysis, synthesis, induction, deduction, comparison | Not specified | The potential impact of frugal innovation on sustainable development, particularly concerning different types of the private sector |

** Equally total citation number has the same ranking number.*

Our research contributes with a descriptive analysis based on the industry (sector) focus, type of research paper/method, and country focus of the most cited articles in frugal innovation. The most of the researchers were focused on different types or mixed industries (23%), healthcare (15%), energy (11%), water (10%), vehicles, automotive and transportation (9%), IT and ICT (7%), financial services (6%) and the other less than 6%. A lot of researchers were focused on the different type of industries, we have also included in that group conceptual and exploratory papers, which are focused on the general information about the frugal innovations and may be implemented in different industries. M. Zeschky et al. (2014a; 2014b) were focused on various types of innovations in resource-constrained conditions. According to these authors, companies searching for relevant offers for developing countries should return them to the Western world. Due to the novelty of phenomena of frugal innovation, there are plenty of research papers that are aimed at investigating a term, definition of frugal innovations.

B.C. Rao (2013) says that conducting the research on frugal-innovations, it highlights the features of the innovations and also tests the disruptiveness with respect to other innovations. The terms have the same base of the BoP (bottom-of-the-pyramid). Some of the researchers are focused on poverty

reduction, while others try to establish a linkage between formal and informal economies. The social aspect is a key element for future scenarios; nevertheless, the researches should not underestimate the unique path of development of countries with low income and the difference of developed economies that faced with the industrial revolution (Pansera, 2013). Some multinational companies demonstrate both types of innovations, frugal, and reverse. Siemens has developed different frugal products, and at the same time implements reverse innovations through them. Multinational corporations try to offer a disruptive product, while good-enough innovations have more possibilities to be distributed in the market (Agarwal and Brem, 2012). Multinational corporations deliver a vast number of innovations to the developing countries, India in particular, and the global world. They are focused on developing close relationships, co-creating with customers, empowering engineers, and product development (Jha and Krishnan, 2013).

It is important to increase exchanges between developing and developed countries in healthcare for the facilitation of knowledge transformation and exchange. The Laboratories are vital in knowledge exchange and support, they have to be implemented not only in middle-income countries but to be examples of reverse or frugal innovations (Crisp, 2014). The Dutch company Qiagen is another example of frugal innovation that provides an HPV (human papillomavirus) care device, in order to find out the virus for places with limited access to the healthcare system. It is portable and suitable for rural conditions. All these features were not available previously (Zeschky et al., 2014a). However, frugal innovations may have difficulties with adoption, even if they provide a low-cost solution to healthcare issues. Many frugal innovations do not spread to other places with similar problems; they stay local, "below-the-radar". Another example is the auto-transfusion with an absence of blood donor that was developed in South Africa, however, the healthcare system of the neighboring country was not familiar with this (Tran and Ravaud, 2016).

Some of the researchers were focused on the effective water filtration systems based on frugal innovations' principles (Btatkeu et al., 2016; Annala, et al. 2018; Heimann et al., 2018). J. Levänen et al.

(2016) estimated the most remarkable cases of frugal innovations, including the water sector in the literature. One of the notable case studies demonstrates the reverse osmosis (RO) technology which was implemented in India, shows that the involvement of the consumers is a significant part of creating solutions in terms of frugal innovations. This permits the businessmen to customize and adapt their solutions to the requirements of their clients and leads to private cost reduction (Annala et al., 2018).

Craft skills East Africa focuses on the rural environment in Africa, providing green energy, using local materials in a sustainable way to serve the communities with limited access to the energy sources. SELCO supplies solar power to underserved villages, rural places, using an innovative approach that provides credits for the customers through financial organisations (Khan, 2016). Another research was focused on the water distillation, implementing the solar energy for purifying the water, that is crucially important for the rural areas (Morciano et al., 2017). Most of the publications are empirical and presented by 63 %, the rest of them are theoretical and consist of 37 %.

The literature review covers 37% of research studies; most of the papers are conceptual and exploratory. Several authors are focused on theoretical perspective, trying to distinguish the phenomena of frugal innovations from others (Brem and Wolfram, 2014; Soni and Krishnan, 2014; Gupta et al., 2016; Tran and Ravaud, 2016; Agarwal et al., 2017). The case study method (28%) is one of the common methods that the authors use in the research on frugal innovations, due to the lack of information on this topic. Siemens provided successful solutions for developing countries, implementing the case study, the research is focused on the establishment of multinational corporations in developing countries, and their innovation strategies. The study distinguishes relative terms of frugal innovations and analyses various practices of the German multinational corporation (Agarwal and Brem, 2012). Also, the case study approach was used by S. Winterhalter et al. (2017). His research is focused on the healthcare sector investigating the value creation process in terms of achieving a new market in developing countries. M. Zeschky et al. (2014b) focus on the R&D organisation processes of multinational corporations in the healthcare and electronics sectors, using the data and information from four case studies. The systematic

literature review was presented by such authors as M. Hossain (2017), and N. Agarwal et al. (2017), E. Rosca et al. (2018), A. Pisoni et al. (2018). Experiments were used by other authors, Btatkeu et al. (2016), M. Morciano et al. (2017), S. Heimann et al. (2018) in the water sector and J. Baekelandt (2015) in healthcare. However, due to the fact of terms overlapping such as frugal innovations, reverse innovation, sustainable innovations, etc., in fact, much more papers could be extracted.

As we have identified, researchers of the top-cited articles in frugal innovation have mostly focused their research effort on three groups of countries. Thus, the vast number of articles focuses on India, developing countries, and almost the same number on both developing and developed countries. The 39% of articles can be categorised in an additional group named "Not specified countries", including conceptual, exploratory papers that have a theoretical perspective and may be implemented in different countries. A lot of researchers in their studies (19%) were focused on India. Economic reforms starting in India in 1991 followed by the fast-economic development of the country, which became an attractive topic for scholars focused on organisations and management practices (Nair et al. 2007). With a large number of higher education institutions and investigation activity India could become an innovation and knowledge transfer centre, however, during the last years, the level of successful innovations is still low, which stands for some shortcomings. The analysis demonstrates that there is a need to establish infrastructure, including all the sectors, in order to unlock the innovative potential. Hence, there is a need for deeper research on outcomes associated with infrastructure investment and their results in innovation. Therefore, it is necessary to facilitate the development of small and medium enterprises. The research shows that innovation and entrepreneurship are interconnected; facilitating entrepreneurship requires financial and knowledge support (Nair et al., 2015).

The economic growth of developing countries influences significantly on the world of global business. The mean rate of increase of emerging economies is far above developed countries, which provides a strategic opportunity for the market extension (OECD 2009; Drummond 2012;). Developing countries that are represented by the custumers with low income and scarce resources which constitutes

one of the rapidly increasing markets (Kravets and Sandikci, 2014). The companies that can keep balance in the low price and innovation, delivering high value to the client have a competitive advantage in the market (Mudambi, 2011). The notion of frugal innovation and its features for a wide range of people that employ scarce resources is crucially important for developing and developed countries as well (Prabhu 2017). However, the adaption of business models from countries with limited resources to the countries with developed economies, requires the consideration of the location of strategies application (Angot and Plé, 2015). Interaction with local institutions, involvement of the clients, empowerment of employees and focus on product development allow multinational corporations to provide frugal innovations in developing and developed countries as well. This approach allowed companies to succeed in the global market (Jha and Krishnan, 2013). Y.A. Bhatti et al. (2013) claim that globalization has influenced on South Asia, multinational corporations have to take into account the knowledge of South Asian organisations, and to use the opportunity of investment in them, while South Asian organisations could develop a regional and international partnership. However, M. Hossain et al. (2016) have clarified how the frugal innovations distribute, according to four dimensions. The authors found out that the difference in socio-economic conditions is an obstacle for the distribution of frugal innovations.

**Conclusions**

In this study, publications in English (238) were collected from Elsevier Scopus database during the period of 2010-2019 for using in statistical, bibliometric analysis, and theoretical review. The results reported herein should be considered in the light of some limitations. First, the sample size was limited, our dataset was taken out only from Scopus data base, addition of the other databases would provide more comprehensive information in frugal innovation field. Our research included the examination of the articles that were written in English, while articles which were presented in other languages were unincluded in the examination, extending of other languages would enrich the study. In addition, due to the novelty of the term of frugal innovation, it frequently overlaps with others such as reverse innovation,

Gandhian engineering, jugaad, low-cost innovation, etc., there is a probability that some of the researchers substituted the term, thus there is a need of seeking the information on that literature beyond the frugal innovation field. Finally, some articles were enough theoretical and based on the literature review, however, they were illustrated by cases or examples that could lead to the bias in distinguishing them between theoretical and empirical. Groups obtained in the coupling analysis can be taken to analyse and synthesise the information considering different lines of research by the group identified.

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## 3.3. Frugal innovation in the textile industry, as a tool for solving problems in the field of waste disposal and recycling

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Melnikova, L. N. (2021). FRUGAL INNOVATION IN THE TEXTILE INDUSTRY, AS A TOOL FOR SOLVING PROBLEMS IN THE FIELD OF WASTE DISPOSAL AND RECYCLING. Textile Industry Technology, 2(393), 17–22. https://doi.org/10.47367/0021-3497_2021_2_17

Our research paper named "Frugal Innovation in the Textile Industry: A Tool for Solving Problems in the Field of Waste Disposal and Recycling" published in the journal Izvestiya Vysshikh Uchebnykh Zavedenii, Seriya Teknologiya Tekstil'noi Promyshlennosti (Textile Industry Technology). The development of the textile industry is the main focus of this journal, which also covers theoretical and applied approaches. It features articles on management, decision-making, engineering, materials science, automation, economics, energy, and ecology, as well as a section on management science. As part of our contribution to the journal, our research suggests a theoretical framework that can be used to waste disposal and recycling that is based on thrifty innovation in the management of the textile industry.

**Статья посвящена проблеме переработки и утилизации отходов в текстильной промышленности. Предложен один из вариантов решения данной проблемы с помощью бережливых инноваций, по средствам изменения бизнес-модели, где основными участниками являются производитель текстиля и потребитель. При использовании**

**бережливых инноваций достигается социальный, экологический и экономический эффект. Данная модель может быть эффективна в рамках реализации Целей Устойчивого Развития.**

**The article is dedicated to the problem of waste management and recycling in the textile industry. We offer frugal innovations as an option for solving this problem, through changing the business model, where the main participants are the textile manufacturer and the consumer. By implementing frugal innovations social, environmental, and economic effects is achieved. This model can be effective in the terms of implementation of the Sustainable Development Goals.**

**Ключевые слова: бережливые инновации, отрасль текстильной промышленности, отходы текстильной промышленности, переработка отходов, система управления отходами, цели устойчивого развития**

**Keywords: frugal innovations, textile industry, textile waste, recycle waste, waste management, sustainable development goals**

На сегодняшний день проведено много исследований по теме бережливых инноваций, в основном рассмотрены такие промышленности как, здравоохранение, информационные технологии (ИТ), энергетическая промышленность, транспорт и водный сектор, однако бережливым инновациям в текстильной промышленности не уделялось достаточно внимания. За последние 10 лет (с 2010 года) среди самых цитируемых авторов в базе данных Scopus, научные работы имели общий характер направленности, только 15% работ направлены на сектор здравоохранения, 11% на энергетический сектор, в то время как исследовательские работы в текстильной промышленности в рамках бережливых инноваций проводились в малом количестве. Актуальность применения бережливых инноваций в сфере текстильной промышленности обосновывается увеличением потребления текстильного волокна в мире, как представлено на рис. 1 [1]. Также, стоит учитывать прогнозы мировых тенденций потребления текстиля, в соответствии с которыми мировое потребление всех видов текстильных волокон к 2030 году увеличится до 120 млн. метрических тонн [2].

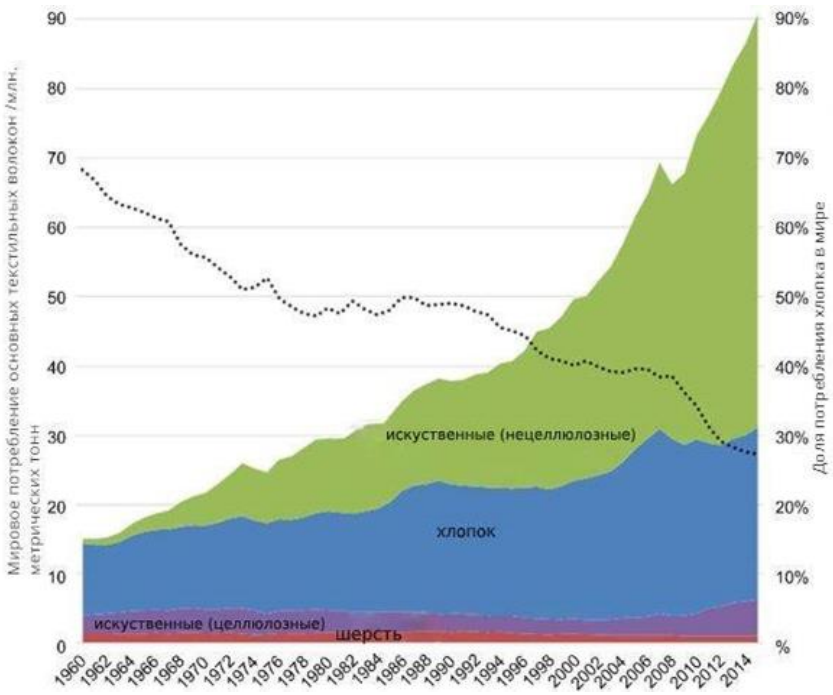


*Рис. 1*

Таким образом, при увеличении потребления в текстильной промышленности становится очевидной проблема утилизации и переработки отходов. Отходы в текстильной промышленности представляют собой бывшую в употреблении одежду, в мире производится около 13 миллионов тонн текстильных отходов ежегодно, 95% из которых могут быть повторно использованы или переработаны. Также, стоит отметить, что индустрия моды занимает 3 место в числе самых загрязняющих отраслей в мире. Использование бережливых инноваций может способствовать решению проблем утилизации и переработки отходов текстиля. Бережливые инновации призваны решать в первую очередь экономические, социальные и экологические проблемы общества. Изначально термин бережливые инновации появился в Индии и был адресован к потребителям с ограниченными ресурсами в странах с развивающейся экономикой [3]. Впоследствии, в связи с ограниченностью тех, или иных ресурсов понятие бережливых инноваций распространилось и на страны с развитой экономикой. Термин бережливые инновации достаточно новый и рассматривается под разными углами, так можно выделить основные определения.

1. Бережливые инновации представляют собой модернизацию продуктов и процессов с целью снижения ненужных затрат [4].

2. Бережливые инновации — это инновации, которые, прежде всего, отличаются доступностью для покупателя с точки зрения цены, возможности приобретения или использования, и устойчивостью [5].
3. Бережливые инновации — это пересмотр бизнес-моделей, изменение цепочек создания стоимости и модернизация продуктов с целью экономии ресурсов для обеспечения инклюзивных рынков в условиях ограниченности ресурсов в рамках устойчивого развития [6].
4. Бережливые инновации — это инновации, несущие большую ценность с меньшими затратами [7].

Также, бережливые инновации имеют определенные принципы:

- Активное взаимодействие с клиентами;
- Формирование поведения потребителей;
- Творческое сотрудничество с потребителями;
- Дружественные связи с другими сторонниками инноваций;
- Гибкое использование производственных мощностей и ресурсов;
- Выработка ресурсосберегающих и экологичных решений;

Бережливые инновации ориентированы на простые и экологичные продукты, процессы, услуги и бизнес-модели, использующие ограниченное количество ресурсов, имея при этом минимальное вмешательство в окружающую среду, именно это определение на наш взгляд является наиболее полным и подходит для решения задач в текстильной промышленности. Также, стоит отметить связь бережливых инноваций с устойчивостью и устойчивым развитием. Бережливые инновации очень часто рассматриваются как характеристики устойчивого развития и образа жизни, вследствие чего бережливость и устойчивость перекликаются [8]. Цели Устойчивого Развития

(ЦУР) имеют прежде всего экологическую, социальную и экономическую направленность, бережливые инновации также могут способствовать их достижению [9].

Одежда занимает основное направление в текстильной промышленности и всегда была одним из способов выражения, индивидуальности и индикатором принадлежности к какому-либо культурному или социальному слою. Это поспособствовало формированию такой отрасли как «быстрая мода» или «фаст фэшн» (fast fashion), быстрого обновления ассортимента брэнда несколько раз в сезон. Ещё 50 лет назад модные вещи не были доступны для среднего класса населения, изготавливались на заказ, либо имели высокую стоимость, однако желание людей выглядеть модно, не тратя при этом большие деньги привело к формированию массового рынка «быстрой моды», по относительно низким ценам. Основоположниками являются такие компании как, Zara (входящая в Inditex group), H&M, Benneton. В основу бизнеса легла концепция «быстрый ответ», производство продукта максимально быстро и экономически эффективно, реагируя на быстро меняющиеся вкусы потребителей в режиме реального времени. Среди особенностей стратегии производителей стоит выделить: понимание желаний целевой аудитории; предложение товаров «высокой моды» по приемлемой цене для среднего класса потребителя; выстраивание отношений между покупателем и производителем, удовлетворяя в первую очередь потребности покупателя; уделяется особое внимание цепочке поставок (для снижения стоимости в процессе передвижения товаров от разработки до розничных магазинов). Так компания Zara снизила время между разработкой и производством, сократив производственные издержки, производит более 30000 единиц продукции ежегодно для почти 1600 магазинов в 58 странах, новинки поставляются 2 раза в неделю в магазины, улучшая потребительский выбор одежды и доступность продукта [10]. Для улучшения понимания рынка целевой аудитории и тенденций используется специальный отдел специалистов по внедрению и наблюдению в кругах «высокой моды» [11].

Однако, несмотря на все преимущества для потребителя, рынок быстрой моды сталкивается с критикой: производится большое количество отходов, вследствие частых покупок и выброса одежды; плохие условия труда для жителей развивающихся стран; производство одежды наносит урон водной, наземной и атмосферной экосистемам; нанесение вреда здоровью работникам (использование токсичных химикатов, повышенный уровень шума, опасность мелкофракционных частиц хлопка; недостаток эргономичности в условиях труда). Все вышеперечисленные пункты противоречат ЦУР и концепции устойчивости в целом.

Таким образом, сталкиваясь с рядом проблем в данной отрасли, очевидной становится возможность использования бережливых инноваций в текстильной промышленности, которое может способствовать решению данных проблем, в частности с проблемой утилизации и переработки отходов. Основываясь на принципах бережливых инноваций, представляем модель в виде рис. 2, применение которой позволяет осуществлять деятельность компаний в текстильной промышленности в рамках Целей Устойчивого Развития, без потери экономической выгоды.


*Рис.2*

Использование бережливых инноваций в текстильной промышленности по средствам изменения бизнес-модели позволяет существенно сокращать отходы в текстильной промышленности, стимулировать «экологичное» поведение и уважительное отношение к окружающей среде

потребителей, сохранять или увеличивать экономическую выгоду для производителя. Потребитель (клиент) приносит вышедшую из использования одежду (текстиль) в магазин производителя, производитель отдаёт часть одежды (текстиля) на благотворительность (в случае сохранения потребительских свойств), часть идёт на повторную переработку. Взамен потребитель получает «баллы», «скидочные купоны», которыми может расплачиваться за последующие покупки, при этом поддерживается лояльность потребителя.

Также, в связи с отсутствием в некоторых странах системы переработки мусора, производители текстиля могли бы являться ключевым звеном в переработки пластика, так как пластиковые бутылки сделаны из полиэтилентерефталата (ПЭТ), этот же материал служит в дальнейшем для производства нитей и волокон полиэстера. Потребитель (клиент) может приносить использованный пластик (пластиковые бутылки) пригодный впоследствии для создания полиэстера производителю, производитель текстиля отправляет их на переработку, взамен потребитель получает скидочный купон или «бонусы» для оплаты покупок в данном магазине.

На основании данной бизнес-модели бережливые инновации включают в себя:

- Вовлечение в процесс создания общей ценности потребителей (клиентов)
- Формирование «экологичного» и «осознанного» поведения потребителя
- Активное взаимодействие с потребителями (клиентами)
- Сотрудничество с исследовательскими организациями в сфере инновационных разработок в текстильной промышленности
- Изменение производственной цепочки и направления использования производственных мощностей
- Создание ресурсосберегающего решения

Таким образом, реализация бережливых инноваций в текстильной промышленности имеет экологический, социальный и экономический эффекты (рис.3).


*Рис. 3*

Экологический эффект достигается с помощью существенного снижения отходов в текстильной промышленности и ПЭТ отходов, формируется «экологичное», «осознанное», уважительное поведение потребителя к окружающей среде. Социальный эффект формируется за счёт благотворительности, по средствам передачи одежды (с сохранением потребительских свойств) малоимущим гражданам. Экономический, за счёт стимулирования спроса, лояльности и вовлечения потребителя.

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## 3.4. Frugal innovations and main trends of digital marketing in post-covid-19 retail: Case Study of the leading Russian food chains

Conference paper, Conference *"Global challenges of digital transformation of markets (gdtm-2021)"*

accepted for publishing MDPI-NOVA; Scopus cite score-3.8; Paper accepted in 2022.

Authors: Burmistrov A., Melikova E., Melnikova L., Kolosova T.

The conference "Global challenges of digital transformation of markets (gdtm-2021)" is primarily focused on the difficulties and possibilities brought about by digital transformation in international markets, with a focus on efficient management approaches in this setting. Our paper, which examines thrifty innovation in digital marketing within the Russian food retail industry, thus fits the conference well and adds to its management-focused portion. For managers and decision-makers trying to negotiate the hurdles of digital transformation in their own companies, our examination of business model transformation in the food retail industry via the lens of frugal innovation offers helpful insights.

**ABSTRACT**

The article investigates the main changes in digital marketing strategies adopted by Russian food retailers for interconnection with customers during COVID-19 pandemic. The COVID-19 pandemic stimulated emergence of innovations which operate in context of scarce resources, also known as frugal innovations. This study focused on digital marketing practices through lens of frugal innovations during the pandemic period of top five retailers using an abductive case study analysis approach. The development of frugal innovation increased during pandemic, namely in food retail sector. We discuss exploratory case studies from main key food retailers on the perception of marketing digitalization and food retail. It reflects the results of the leading Russian food chains (top-5 retailers) based on the secondary data, including quantitative and qualitative surveys conducted by leading Russian and foreign research companies (McKinsey, Nielsen, PwC, EIB, RAEC); online resources retail; including expert assessments, trends; review of articles on impact of COVID-19 on

business transformation from journal databases Elsevier, Springer, Emerald, Wiley Online etc. The general trends of digital marketing in retail in context of COVID crisis are revealed. We found out that the most common trends are: customer centricity (customization and identification of customer needs, co-creation (involvement of customers into process), omnichannel (better communication with client), customer interaction (customization) and business diversification. The results of the present research offer recommendations to managers on how to create an effective digital marketing approach to efficiently raise customers' purchase intentions via frugal innovation lens.

**Keywords**: Digital marketing, omnichannel, customization, food retail, COVID-19, frugal innovation

## Introduction

When it comes to retail, the link between marketing and revenue is undeniable. Today, the retail sector is experiencing global changes driven by rapid advancement of digital technologies. COVID-19 pandemic has accelerated these transformation processes. One of the solutions, which tackles social, economic, and environmental problems promptly is frugal innovations (FI) (Vesci et al. 2021). FI gives a quick response in times of limited resources, for instance digital manufacture of masks, adaption of scuba diving masks for ventilation, face shields (Corsini, Dammicco, and Moultrie 2021). FI is a creation or implementation of new product, service, or process, which is affordable, functional, without technological complexity, sustainable aims at satisfaction of customer needs in limited resources (Hossain 2021; Melnikova 2017). FIs refer to six principles "engage and iterate, flex your assets, create sustainable solutions, shape customer behavior, co-create value with prosumers, and making innovative friends" these foster to create cost-effective, good quality solutions in scarce resources (Radjou and Euchner 2016). However, some of them may be seen as open innovation (Mikheev et al. 2021; Shmatko et al. 2021). The key retailers started to follow these principles once faced with COVID-19.

From the perspective of FI limitations and restrictions are seen as opportunities, for instance isolation and quarantine caused online education, telemedicine, detection of various disease via digital camera of smartphone, online services, and other types of FIs. Digital transformation influenced on “value creation”, “delivery”, and “capture” in each sector. These caused generation of new business models such as FI and circular economy (Vaska et al. 2021).

The customers were spending more and more time on digital channels like Facebook, Instagram, Zoom, and WhatsApp during the COVID-19 lockdown duration (He and Harris 2020). Therefore, the role of digital marketing in reaching out to customers has increased.

Researchers predicted a shift in demand from physical stores to online almost 10 years ago. At that time, the retailer's online store was a real competitive advantage. “It is now widely recognized that the Internet’s power, scope and interactivity provide retailers with the potential to transform their customers’ shopping experience, and in so doing, strengthen their own competitive positions” (Alnawas and al Khateeb 2022).

“There are a number of challenges and opportunities retailers face on their long-term radar such as changes in consumer behavior and consumer digitalization. These drivers affecting retail sector should be a key consideration for retailers of all shapes and sizes” this was reflected in the review of 24 years of research (Penu, Boateng, and Babatope 2022). Then it was a long-term prospect. The companies had enough time to prepare, building digital capacity, test, and launch Internet channels (Rudskoy et al. 2019).

Research has predicted that by 2025, nearly 20% of retail will be done through online channels. At the same time, even in countries with a developed digital economy, online food sales lag far behind the rest of retail. Meanwhile such digital FI as online delivery and digitalization has social contribution to the fight with pandemic, since it reduces the physical contacts, and influence the decrease of contamination. It is important to demonstrate recent trends in digital marketing in retail in post-covid period. The purpose of this article is to investigate the main changes and trends of Russian top 5 food chains.

## Materials and methods

The paper presents the case study of the leading Russian food chains (top-5 retailers) based on the secondary data, including:

- quantitative and qualitative surveys conducted by leading Russian and foreign research companies (McKinsey, Nielsen, PwC, EIB, RAEC),
- news and information sites (rbc.ru, Interfax.ru, finam.ru),
- online resources retail (Retail.ru, sostav.ru, etc.),
- dedicated resources with expert assessments, trends, and case studies of digital marketing (Think with Google, Yandex, vc.ru),
- first-party, second-party, and third-party data about companies,
- scientific articles by Russian and foreign authors on the impact of COVID-19 on business transformation. Following journal databases were screened: Elsevier, Springer, Emerald, Wiley Online & so on.

The following key phrases were used in the search: COVID-19 (coronavirus) and food retail, food industry during the pandemic of COVID-19, food retail digital transformation lead by COVID-19, digital marketing in retail, food online retail, digital marketing for food retail and COVID 19, and a combination of keywords and phrases related to the food industry.

## Results

### Leading players in the Russian food market

The share of TOP-5 chain food-retailers in Russia, according to various estimates, is from 28% to 30% of the market (see Figure 1). At the same time, over the past 5 years, the total share of leaders has grown by almost 40% (in 2015, it was only 20.6%).

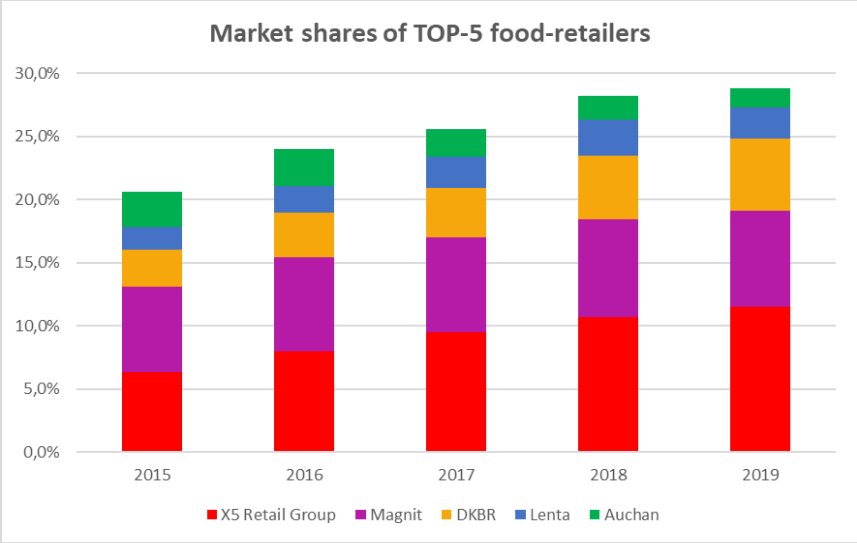


Figure 1. Market shares of TOP-5 food-retailers.

Source: the authors

FMCG market is more consolidated in developed countries, In Europe, the share of the TOP-5 reaches 73% (Germany), in the US – 47% (see figure 2).

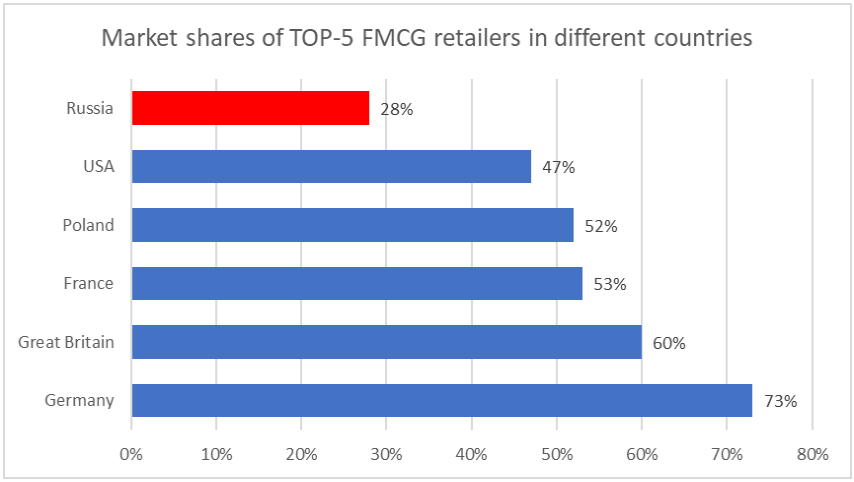


Figure 2. Market shares of TOP-5 FMCG retailers in different countries.

Source: the authors

X5 Retail Group is the largest retailer in Russia by turnover. The multi-format grocery retail company appeared in 2006 as a result of the merger of retail chains Perekrestok (in Moscow since 1995) and Pyaterochka (founded in 1999). In 2008, the Karusel hypermarket chain was added.

As of 30/06/2020, the company managed 17,025 stores: 16,096 Pyaterochka stores, 867 Perekrestok supermarkets, and 62 Karusel hypermarkets. Shops are located in 66 regions of the Russian Federation in 7 Federal districts. X5 plans to increase the number of locations to 20 thousand in 2023 and open stores in the Far East. Moreover, the company owns 42 distribution centers and e-grocery Perekrestok.ru, mail services Fivepost.ru, and Express delivery infrastructure.

Net retail revenue of X5 Retail Group in 2019 increased by 13.3% compared to 2018 and amounted to 1.73 trillion rubles. At the end of 2019, it rose from 47th to 42nd place in the top 250 retailers of the world Global Powers of Retailing 2020 and ranked 11th in the top 50 fastest-growing retailers in the world (according to Deloitte).

In the first half of 2020, X5's revenue increased by 14.2% to RUB 962.625 billion. Net profit increased by 7.2% to 24.45 billion rubles.

Magnit is the leader in the number of stores. It was founded in Krasnodar in 1994. As of 30/06/2020, the chain has 20,894 stores in 65 regions of Russia and 38 logistics complexes in more than 3,700 localities. About two-thirds of retail outlets operate in cities with a population of fewer than 500,000 people, and about half of all outlets are open where fewer than 100,000 people live. Magnit plans to increase its share in the Russian market to 15% by 2023.

The company operates several businesses that grow vegetables, produce groceries and confectionery, as well as greenhouses and mushroom complexes.

Magnit's total revenue for 2019 increased by 10.6% to RUB 1.37 trillion, while net retail revenue increased by 9.5% to RUB 1.33 trillion. Magnit's revenue for the 1st half of 2020 amounted to 763.4 billion rubles. Despite the pandemic, in the 2nd quarter of 2020, Magnit showed revenue growth of 13.7% year-to-year.

DKBR Mega Retail Group limited appeared on the market in 2019 by the merger of Dixy, Bristol, and Red and White chains. The new retail player became the third in Russia in terms of revenue after X5 Retail Group and Magnit. Dixy has been on the market since 1992. In 1999, the first "discounter" retail store was opened.

As of 31/12/2019, the group operates more than 13,000 stores, including 2,659 food stores (2,508 Dixy and 111 Victoria), 40 Megamart hypermarkets, and over 10,000 Minimart hypermarkets. Dixy operates in 739 cities and towns in the Russian Federation.

The combined company's revenue in 2019 is estimated at 800 billion rubles. DKBR does not disclose data for 2020. Lenta went down to 4th place after the merger of the DKBR in the ranking of the largest retail chains in Russia, but it is the first largest hypermarket chain in the country. It was founded in 1993 in Saint Petersburg. It operates 249 hypermarkets in 88 Russian cities and 131 supermarkets in Moscow, St. Petersburg, Siberia, the Ural, and Central regions, as well as 12 major distribution centers.

In 2019, the chain increased revenue by 1% to 417.5 billion rubles. Retail revenue in the first half of 2020 increased by 9.6% year-to-year and amounted to 213.4 billion rubles.

Auchan Retail Russia is a Russian subsidiary of the French Auchan Retail group, which has been operating on the Russian market since 2002. In 2019, the market share of Auchan in Russia decreased to 1.5%, and in 2015 it was almost 2 times more. In the food market, Auchan is in the TOP-5, but in the overall rating of Russian retailers, it is on the 9th line after M.Video-Eldorado, DNS, Wildberries, and Leroy Merlin. To date, the chain has 284 stores: 63 hypermarkets, 44 Auchan City superstores, 11 stores, 166 supermarkets, and 17 distribution centers. The company does not disclose data on the results of 2019, however, according to InfoLine, Auchan's revenue in the Russian market last year fell by 13% and is less than 300 billion rubles.

In 2020, Auchan is the only one of the TOP-5 that, according to experts, continues to lose revenue. Auchan's revenue in April 2020 decreased by 25%, and in May by 17% compared to April and May of last year. The chain has closed 30 stores over the past year.

**Changes and innovations during the pandemic**

The process of launching online stores in Russia stretched over 2 decades. The largest food market players were in no hurry to develop online channels (see Table 1).

Table 1. E-Commerce Development by major FMCG retailers.

| Year of e-commerce launching | Major FMCG retailers in Russia |
|---|---|
| 2000 | Utkonos |
| 2009 | Azbuka Vkusa |
| 2013 | Globus Gourmet |
| 2014 | Metro, Auchan |
| 2015 | O'Key |
| 2016 | Semya |
| 2017 | Spar, Perekrestok |
| 2018 | Red and White, Globus |
| 2019 | VkusVill, Verniy |
| 2020 | Magnit, Pyaterochka, Lenta |

At the beginning of 2020, the situation changed dramatically. Food chains were forced to set up online sales and delivery of groceries to customers within weeks. Depending on the equipment, digital maturity, the level of development of their own logistics, they solved this problem in several ways – by strengthening (like X5 Retail Group) or launching (like Lenta) their own delivery, developing self-pickup of already assembled goods (like Magnit), as well as entering into partnerships with leading delivery companies: Sbermarket, iGoods,etc. (like Dixy, Auchan, Magnit, Lenta).

To expand their virtual presence, companies will need to assess their capabilities and then determine how best to augment them. Even retailers without a strong digital presence, for example, could partner with online marketplaces or delivery services (Music et al. 2022).

The Table 2 below illustrates distribution options for market leaders in Russia.

Table 2. Distribution mechanisms of TOP-5 food-retailers.

| Distribution mechanisms | X5 Retail Group | Magnit | DKBR | Lenta | Auchan |
|---|---|---|---|---|---|
| Own home delivery logistics | + | + | + | + | + |
| Click & collect models | - | + | - | + | + |
| Third party delivery models | + | + | + | + | + |

X5 Retail Group launched its own express delivery at the end of 2019. Now, this service fulfils 12-13 thousand orders daily. In July 2020, X5 announced the launch of the Okolo express delivery service and a unified technological platform for hyperlocal service, which operating model based on partnerships with small companies in different cities of Russia.

One of Magnit's key projects is the delivery via Yandex services. Besides, since August 2020, Magnit has been testing express delivery from Delivery Club. Until the end of 2020, it will be available in Moscow, St. Petersburg, and the 15 largest cities in Russia. Magnit is also testing a new format - pickup without leaving the car. Terminals are installed in a specially designated parking area, where customers register and wait for a store employee who delivers the order directly to the car to minimize contacts with other customers.

On March 11, 2020, Dixy began selling its products on the Ozone marketplace. In April, its organized delivery in partnership with Sbermarket, and in May launched its own express delivery of products in Moscow. By the end of the year, the chain plans that the service will cover all regions of Dixy's presence.

Lenta cooperates with leading delivery operators Sbermarket and iGoods, but amid the pandemic launched its own express delivery, Lentochka, which is still inferior to professionals, but improving gradually.

The pick-up project (click & collect) was developed by Lenta inside the core IT solutions of the company, so all processes are fully integrated with the cash register system and the loyalty program of

the chain. The order is collected by the line staff of the offline store. When a customer arrives, the information desk employee accepts payment from them and adding bonuses.

At the end of 2019, Auchan announced plans to develop online sales, the share of which in revenue is still small, but in April 2020, it urgently launched delivery from iGoods.

*Customer relations and omnichannel*

From production to payment - everything is personalized and customer-centric - 91% of shoppers are more likely to shop from brands that recognize, remember, and provide relevant suggestions and recommendations. Retailers need to rethink all stages of customer experience (synchronized CRM + research based on big data exploring) (Rizky Wijaya and Mudjahidin 2022;

- As part of the Feedback program, X5 launched the Spy Club project - a unique system for checking and evaluating stores directly by guests, aimed at the operational improvement of outlets. Customers of stores act as a mystery shopper and check stores for quality of food, cleanliness, and order, as well as compliance with general standards. Information about the identified deficiencies is sent by e-mail to store directors for prompt elimination. For completing tasks, the club agent receives points on his loyalty card. Checks by Spy Club agents are already underway in all regions where Pyaterochka operates, in 65% of stores/

- Besides Spy Club project (to improve the consumer experience)? X5 has developed a system for unified customer identification that will allow them to use the services and products of all retail chains, seamlessly switching between systems.

- To increase customer satisfaction, Magnit opens a special testing studio in Krasnodar, where it will constantly work with consumers to assess the quality of products under the company's own trademarks. Thus, Magnit plans to study in detail the response of consumers, increase the

advantages of its brands, launch positions that are relevant to customer preferences, and magnify sales. In the near future, test studios are planned to open in two more million-plus cities.

- The current Magnit loyalty program will be replaced by the Superapp application at the end of 2020. It will be supplemented with the ability to order the delivery of products, a payment service through which it will be possible to pay for utilities or communications. A service for scanning and paying for goods without cash registers and cashiers are already being tested.

- Lenta implemented a Big Data client analytics system based on loyalty cards and open data from social networks. Innovative analytical services are based on artificial intelligence and machine learning technologies. The platform used by the Lenta not only remembers and analyzes all purchases made by a specific cardholder but also compares them with data from social networks. The work resulted in personalized offers for groups of buyers, an increase in the average check, and frequency of visits.

**Discussion**

Over the past few months, the Russian market has undergone global changes - the second largest player (Magnit) acquired the Dixy, the largest DKBR member, and Lenta got the chain of stores Billa, which significantly strengthened its position in the market.

In 2015, the 10 largest retailers in Russia accounted for 25% of the turnover, in 2019 this figure increased to 33%, and in 2020 - right up to 37%, and will only continue to increase, mainly due to the expansion of networks into the regions.

According to researchers' forecasts, by the end of 2021, the share of the TOP-10 leading Russian retailers will reach 40% of the total turnover in the market, and the TOP-5 will exceed 30% of the market, which corresponds to the general trend of players' consolidation.

We would especially like to note that the acquisition of Dixy has become unprecedented in terms of both competition and customer care. In addition to the enlargement of player #2 (Magnit) and strengthening

his fight with X5 Retail Group, the antimonopoly service set a condition – zeroing the mark-up on one low-cost product in the categories: “milk”, “bread” and “poultry”. Buyers should win (both Magnit and Dixy buyers have below average income), thus solving the social problem of improving the quality of life in conditions of decreasing incomes of the population.

Some experts believe that at first Magnet will zero the markup and may even provide additional discounts to attract buyers, but in the long term, prices will return to their usual level.

In further research, we will analyze how the market has changed after the unprecedented consolidation of one of the players, what responses X5 has taken and in what direction the quality of life of consumers in this market has changed.

The second important area of our research is FoodTech, a new direction that integrates digital technologies into the food industry and food delivery to the end-user.

The FoodTech market in Russia has existed for more than 20 years, but during the pandemic, online food sales increased by more than 3 times (see Figure 3), and in the first half of 2021 its volume almost reached online sales of the all 2020.

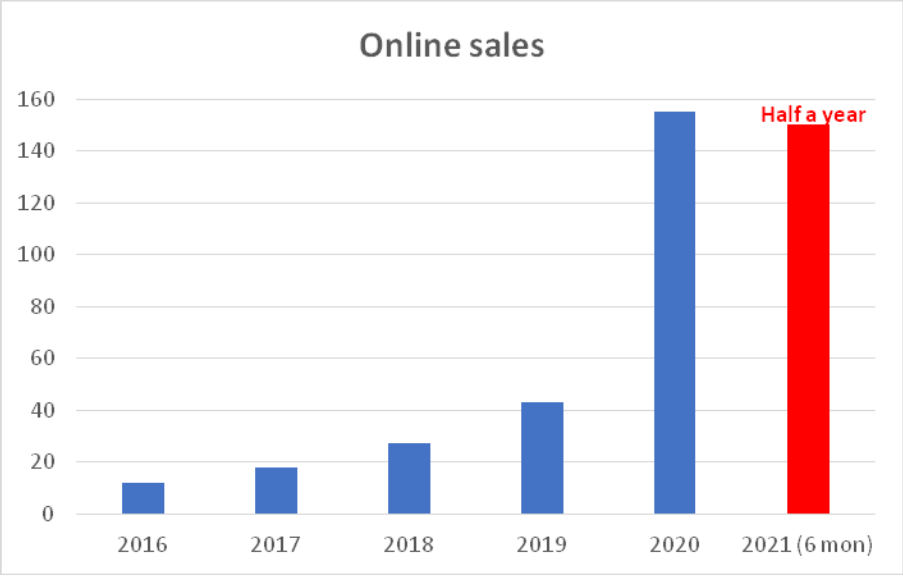


Figure 3. Dynamics and market volume of the FoodTech, billions of rubles, on years.

Source: the authors according to INFOLine Russia TOP online food retail.[1]

When the first coronavirus restrictions were lifted, some experts predicted the stagnation of this market, as visits to offline stores began to recover. However, over time, we see that this was a temporary phenomenon (see Figure 4).

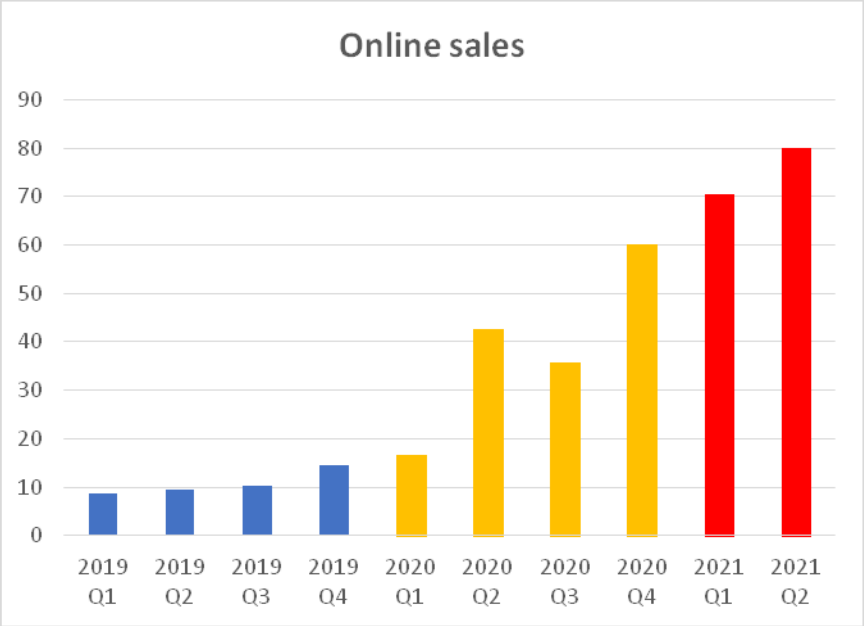


Figure 4. Dynamics and market volume of the FoodTech, billions of rubles, quarterly.

Source: the authors according to INFOLine Russia TOP online food retail[2]

Buyers are accustomed to the convenience of home delivery of groceries; in the current conditions of fierce competition, it becomes free and fast (express delivery beats large-scale delivery ("vprok")).

1 "Giperskachok onlajn-torgovli: novy`e lidery` i ix strategii" [«Hyper-jump of online trading: new leaders and their strategies" (in Russian)] INFOLine Russia TOP online food retail. Video 12.08.2021 URL.: https://www.retail.ru/video/giperskachok-onlayn-torgovli-novye-lidery-i-ikh-strategii/ :
2 "Giperskachok onlajn-torgovli: novy`e lidery` i ix strategii" [«Hyper-jump of online trading: new leaders and their strategies" (in Russian)] INFOLine Russia TOP online food retail. Video 12.08.2021 URL.: https://www.retail.ru/video/giperskachok-onlayn-torgovli-novye-lidery-i-ikh-strategii/ :

We plan to study FoodTech trends in our further research.

**Conclusion**

Having analysed the situation on the market, as well as the results of research of Russian and foreign companies, we highlight the following trends of digital marketing in retail in terms principles of FIs:

***1. Customer Centricity***: functional boundaries within organizations are also being dismantled to align structures to customer needs. The process has been further accelerated through digital as big data is now making it possible to analyze shopper behavior in great detail and customize the delivery format to individual consumer requirements through personalization (Elrhim and Elsayed 2020; Sun and Zhang 2021).

***2. Co-creation*:** consumers help co-create the value proposition basis their willingness to provide feedback which helps refine delivery models on an ongoing real time basis, e.g. "the Spy Club project" launched by X5 Group (Qidi 2021; Bu, Parkinson, and Thaichon 2022)

***3. Omnichannel***. Due to the pandemic, consumers have become more flexible when choosing a buying channel. 73% of shoppers do not differentiate between online and offline purchases (up from 65% before the crisis). Consumers are interested in integrated services and a convenient buying process regardless of the chosen channel (ben Mimoun, Lancelot Miltgen, and Slama 2022). Seamless integration of the website, mobile application, store, call center, instant messengers - all touchpoints with the client is required. Researchers wrote about omnichannel interaction with consumers back in 2012-2014. According to Alexandrova and Kochieva (2020) "retailers must pursue a strategy of an integrated sales experience that blends online and instore experiences seamlessly". "The retail model will evolve from a single/multiple channel model to an integrated hybrid cross-channel model." (İzmirli, Ekren, and Kumar 2020). In future physical stores will closely related to digital experiences and technologies (von Briel 2018). Back in 2019 omnichannel seemed like a prospect, but now it has become a reality. Already today, the development of omnichannel business models is the focus of business leaders and marketers.

***4. Customer interaction.*** "The shifting customer behaviors brought on by COVID-19 reflect the acceleration of anticipated trends, the emergence of new preferences, and a complete reversal of some long-held routines" (Hashem and Hashem 2020). To collect initial information, companies need customer insights, their assessment of the range, service, and synchronized CRM. To process the information received, in addition to the appropriate software, technologies for working with big data are required, as well as specialists who can work with Big Data, combine, and analyze data from different sources (marketing, procurement, sales, etc.) (Liu et al. 2021). "The challenge is to continuously monitor customer demand signals, identify the right insights, and act quickly to turn them into relevant, valuable customer interactions" (Kumar and Ayodeji 2021).

Also, the most important trend in changing retailers' business models is **business diversification** – mastering new directions: products, services, ways of interacting with customers.

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## 3.5. Digital transformation of business model of Russian food retailers during covid-19 pandemic through lens of frugal innovation

Conference paper, Conference *"Global challenges of digital transformation of markets (gdtm-2021)"* accepted for publishing MDPI-NOVA; Scopus cite score-3.8; Paper accepted in 2022.

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The paper "Digital transformation of business model of Russian food retailers during Covid-19 pandemic through the lens of frugal innovation" is a conference paper that was accepted for publishing in MDPI-NOVA in 2022. The conference, "Global challenges of digital transformation of markets (gdtm-2021)", has a Scopus cite score of 3.8 and focuses on a wide range of publications related to practical and theoretical perspectives on the digital transformation of markets, with management science as its common core. It includes papers from both the real sector of the economy and academia, covering various areas of management, including functional management, human-centered technologies, marketing strategies, industrial management, life quality, methodology, and best practices in economics. Our paper contributes to this conference by analyzing the digital transformation of food retailers' business model in terms of frugal innovations, taking into account the exogenous driver of the Covid-19 pandemic.

**ABSTRACT**

The purpose of this paper is to provide an analysis of how Russian food retailers' business model (BM) has been transformed. COVID-19 forced the emergence of numerous frugal innovations, which tackle the social and business issues in times of restrictions. One of them is the digital frugal innovation. This paper considers digital transformation of the BM due to an exogenous driver, i.e., pandemic of COVID-19. The analysis of changes in the elements of the business model based on the Osterwalder-Pigneur

template is carried out. The key directions of business model digital transformation in retail are revealed. Our findings demonstrate the use of extended enterprise concept by the most of the key retailers, via close interaction and involvement of partners; organizational speed which focus on fast change of business processes, products and services; digital transformation that aims at increase of productivity, cost reduction, increase of sales, and market share; business diversification, which includes focus on new products, services, customer involvement, new markets, changing the business model, meanwhile the most important trends are omnichannel and customer interaction. However, all these approaches focus on customer satisfaction.

**Keywords**: Digital transformation, business model, e-grocery, food retail, COVID-19, frugal innovation

## Introduction

The pandemic has caused a rapid increase in e-commerce, due to people's fears of getting infected when shopping in stores. Dynamic changes in customer behavior have created a new demand. Customers began to order online food and goods that they previously bought in online stores. “The spread of COVID-19 is an event at landscape level and the implementation of ‘stay at home’ changes the socio-technical (sub-) regime of food retail. The results specify the windows of opportunity in the current transition” (Dannenberg et al. 2020).

Frugal innovation (FI) has been recognized as one of the solutions which tackle social, economic, and environmental issues in scarce resources. Since the COVID-19 crisis caused numerous restrictions and lack of resources, companies including retailers have drawn their attention to the above-mentioned types of innovations. FI considers the resource-scarce as an opportunity, it implies the development of solutions under restricted resource and other limitations, which are affordable, uncomplex, sustainable, it also focuses on the satisfaction of underserved customer needs, which cannot be fulfilled conventionally (Melnikova 2021; Hossain 2021; Hossain, Simula, and Halme 2016; Zeschky, Widenmayer, and

Gassmann 2011). Other researchers in different countries note that the crisis can become not only a problem but also an opportunity for development. For example, the Italian economist D. Archibugi, back in 2017, noted the impact of the crisis on innovation. “Crisis can create and push innovations and their diffusion because of changing socio-political contexts”(Archibugi 2017). Retailers were forced to urgently rebuild the entire sales system and develop an infrastructure for online sales – through aggregators and marketplaces or by promoting their own channels.

Lee and Malerba (2017) distinguish “three types of windows of opportunity: windows that are opened by new basic technologies like within digitalization; windows based on a new type of demand or a major shake-up of existing demand; institutional windows induced by public intervention.”

“Digitalization during ‘stay at home’ could be such a field of special demands and policy intervention. The innovation of food online trade has already emerged in a niche and could now significantly affect the middle – and mediating – level of the socio-technical regime and possibly the landscape”(Dannenberg et al. 2020).

As a result of the pandemic, companies had to adapt all processes to operate in a constantly high-demand mode. The hype akin to New Year's was observed continuously for two spring months. Grocery chains around the world have had to rebuild and adapt to this rhythm, especially in online sales.

E-grocery (trade in food, beverages, household chemicals, and so on – the product ranges of hypermarkets via the Internet) suddenly become the focus of all retail chains. Before 2020, the online store was an additional option for food chains, but now it has become one of the main sales channels. This has as-yet unclear implications for the long-term digital transition of the food retail sector and the further expansion of e-grocery. It is necessary to find out if changes in online trade, that were incremental before the COVID-19 pandemic, would become disruptive for the traditional retail business model.

Regarding the investigations of pandemic effect on food retail, its implication has been considered in the context of:

- **food industry** (Nakat and Bou-Mitri 2021). Nakat and Bou-Mitri explore the current knowledge about COVID-19 and its impact on the food industry. Their literature review marks an increasing number of published studies related to COVID-19 and the food industry, food safety, supply chain, and demand, which indicates the relevance of this subject and the need for more in-depth research in all countries.
- **food processors** (Hailu 2020). Hailu investigates the impact of COVID-19 on the Canadian food industry. He notes a simultaneous increase in retail demand for processed food and a decrease in demand for foodservice. Moreover, Hailu points to supply and demand shocks: supply problems related to border closures and demand problems due to changing consumer behavior.
- **food security** (Erokhin and Gao 2020). Erokhin and Gao revealed interactions between food security and the dynamics of COVID-19 cases, food trade, and food inflation. They emphasized the need for stability of food supply chains, necessity to design coherent and effective policies to mitigate the impact of COVID-19 on food security across developing countries. Research of 45 developing countries, differing in income level, detected that insecurity effects of COVID-19 were more conspicuous in upper-middle-income economies (food trade restrictions and currency depreciation, what we also see in Russia) than in the least developed countries (predominantly food inflation).
- **food safety** (Shahbaz et al. 2020). Researchers studied the spread of COVID-19 via person-to-person transmission at local, regional, national, and international levels and suggested methods needed to prevent the spread of Covid-19 in the foodservice and retail sector.
- **supply chain and demand** (Singh et al. 2020; Rejeb, Rejeb, and Keogh 2020; Mahajan and Tomar 2021). Whereas the first, point out that lockdown gives rise to a shortage of labor force and logistics disruptions. The result is supply-side shocks and a sudden surge in demand-side to the food supply chain like what Hailu (2020) noted. Rejeb, Rejeb, and Keogh (2020) collected data from a leading scientific database (e.g. Scopus), books, chapters, conference proceedings, reports, websites, journal

articles, and presented a critical literature review to examine the impact of Covid-19 on the food supply chain.

- Mahajan and Tomar (2021) used a novel dataset from one of the largest online grocery Indian retailers to look at the impact on product stockouts and prices. They clarify that supply chain disruption is the main driver behind this fall and illustrate how online data can be used in conjunction with other datasets for real-time planning, logistics, and organization.
    - **on food retail** (Dannenberg et al. 2020; Goddard 2020). The authors investigated the impact of the pandemic on fast growth online grocery retail in Germany and Canada. Researchers from Germany have shown disproportionate growth in online grocery trading, as well as identifying driving and limiting factors. This article, like our research, focuses on food (e-grocery) retailing and its expansion, both economically and spatially. They found no notable change and noted that food retail in Germany has remained largely unchanged in terms of dominant business models and distribution mechanisms, and this is where we see the difference from Russian retailers. Goddard (2020) notes that the impact of the COVID-19 outbreak on the food retail sector in Canada is significant and falls into two lines: the actual impact on human health and dramatic changes in food consumer behavior. In addition, she claims that, in the context of the pandemic in Canada, about 30% of the budget spent on food away from home has shifted to retail which is similar to Russia.

It is important to note that the observed increase in the number of studies on various aspects of the impact of COVID-19 on the food sector indicates the urgency of the problem. At the same time, despite the increased interest in this issue, the influence of COVID-19 on the transformation of business models of food retailers, is not sufficiently covered. The purpose of this article is to fill in the gap, investigate the measures taken by Russian retailers, and assess their dynamics of development and prospects.

**Theoretical background**

FI is known as a type of innovation that tackles social, economic, and environmental issues in scarce resources. The term first appeared in 2006, in the Renault-Nissan case, as a cost-effective, quick solution under limited resources Radjou and Euchner (2016). FIs were born in developing countries, focusing primarily on customers from Bottom of the Pyramid (BoP). Lately, they were used in developed countries as well. The largest category of FIs is focused on the IT sector (Hossain 2021). "Frugal Innovation is a design innovation process in which the needs and context of citizens in the developing world are put first to develop appropriate, adaptable, affordable, and accessible services and products for emerging markets" (Basu, Banerjee, and Sweeny 2013). FI is a "new developed products or services for very specific applications in the context of limited resources" (Pisoni, Michelini, and Martignoni 2018). FI refers to design or implementation of new inexpensive products, business models, and services without unnecessary complexity, functional, affordable for each category of customers (van Beers, Knorringa, and Leliveld 2012). To sum up, according to the issues we explored in our study, we consider FI as a type of innovation which refers to quick response to the issue, affordability, functionality, simplicity, sustainability focusing on the needs of customers in scarce resources. The main principles of FI are: "engage and iterate, flex your assets, create sustainable solutions, shape customer behavior, co-create value with prosumers, making innovative friends" (Radjou and Euchner 2016).

Usually, the examples of FI in the digital sector are crossed with others among them are online banking for rural areas in Africa, digital cameras of smartphone for disease detection, digital manufacture of masks in COVID-19 pandemic, and telemedicine during quarantine for patients, including terminal patients. Some aspects of FI are seen in open innovations (Didenko et al. 2021; Bril et al. 2021).

## Materials and methods

### Data

In this article, we will focus on the Russian grocery market, where the digital transformation of business models helps retailers meet the rapidly changing needs of customers.

We analyzed not only research and survey results, specialized media information, official statistics, company data but also actual food-related articles, newspapers, various sources publications, and online

media articles, and so on from March 2020 to October 2020 to gain factual knowledge about the impact of the pandemic on business.

The research is based on the following sources:

- quantitative and qualitative surveys conducted by leading Russian and foreign research companies (McKinsey, Nielsen, PwC, EIB, RAEC),
- news and information sites (rbc.ru, Interfax.ru, finam.ru),
- online resources retail (Retail.ru, sostav.ru, etc.),
- dedicated resources with expert assessments, trends, and case studies of digital marketing (Think with Google, Yandex, vc.ru),
- first-party, second-party, and third-party data about companies,
- scientific articles by Russian and foreign authors on the impact of COVID-19 on business transformation. The following journal databases were screened: Elsevier, Springer, Emerald, Wiley Online & so on.

**Analysis**

The analysis of the obtained data was carried out based on the Osterwalder-Pigneur business model canvas (Osterwalder et al. 2005), which covers all four main business areas: the company's financial efficiency, sales, infrastructure, and interaction with consumers.

**Results**

The share of the leading 5 chain food retailers in Russia, according to various estimates, grows from 20% in 2015 to most nearly 30% in 2019. In time present, the leaders in Russia are X5 Retail Group (marker share in 2019 is 11.5%), DCBR (7.6%), Magnit (5.7%), Lenta (2.5%), and Auchan (1.5%). The market is fragmented due to the large territory of our country and some remoteness of its regions. Even the leading retailer X5 does not operate in the Far Eastern Federal District and is very poorly represented in the Siberian and North-Caucasian Federal Districts. There is great growth potential, but there are many logistical and organizational challenges.

The COVID-19 pandemic has forced leading Russian food chains to set up online sales and grocery delivery to customers within weeks. Depending on the equipment, digital maturity, the level of development of their logistics, they solved this problem in several ways – by strengthening (like X5 Retail Group) or launching (like Lenta) their delivery, developing self-pickup of already assembled goods (like Magnit), as well as entering into partnerships with leading delivery companies: Sbermarket, iGoods,etc. (like Dixie, Auchan, Magnit, Lenta).

To expand their virtual presence, companies will need to assess their capabilities and then determine how best to augment them. Even retailers without a strong digital presence, for example, could partner with online marketplaces or delivery services (Sheth 2020).

The main distribution options for market leaders in Russia are the following: own home delivery logistics, third party delivery models (both are implemented by all leading retail chains), click & collect models (Magnit, Lenta, Auchan).

So, to reach out to customers in the context of the crisis caused by the COVID-19 pandemic retailers had to transform the building block "Channels" by turning to omnichannel interaction with them (customers). It's worth mentioning that nearly all elements of business models have changed to some degree (see Table 1 below).

Table 1. Main trends in changing retailer's business models.

| Business model's building blocks | Main trends in changing building blocks |
|---|---|
| Customer segments | entering new markets (drug trade) |
| Value propositions | co-creation (consumers help to co-create the value propositions) |
| Customer relationships | personalized and customer-centric |
| Key activities | hyperautomatization (deep automatization, including decision-making processes) and robotization of internal business processes |
| Key resources | big data (making it possible to analyze shopper behaviour) |

| Business model's building blocks | Main trends in changing building blocks |
|---|---|
| Key partners | • digitalization of interaction with suppliers and partners<br>• «extended enterprise» |

In July 2020, McKinsey researchers surveyed 899 CEOs from various companies and found out what changes and solutions allowed them to remain effective and gain competitive advantages in 2020. "The online survey was in the field from July 7 to July 31, 2020, and garnered responses from 899 C-level executives and senior managers representing the full range of regions, industries, company sizes, and functional specialties" (LaBerge et al. 2020, "How COVID-19 has pushed companies over the technology tipping point—and transformed business forever", ed. Seiler, D. Last Modified October 5, 2020. Accessed August 6, 2021: https://www.mckinsey.com/business-functions/strategy-and-corporate-finance/our-insights/how-covid-19-has-pushed-companies-over-the-technology-tipping-point-and-transformed-business-forever?).

Table 2 below shows which of the main trends are reflected in the actions of leading Russian food chains. This is an unprecedented increase in the speed of decision-making and implementation of changes, the digital transformation of business, as well as the development of partner programs. Successful retailers interact with customers all along the user's path, carefully study changing demands, use various communication channels and sales methods, and ways to deliver products to their customers.

Table 2. General trends of changes in the TOP-5 players.

| | extended enterprise | organiza-tional speed | digital transformation | customer interaction | business diversify-cation | Omni-channel |
|---|---|---|---|---|---|---|
| X5 Retail Group | + | + | + | + | + | + |
| Magnit | + | + | + | + | + | + |
| DKBR | + | - | + | - | + | - |
| Lenta | + | + | + | + | - | + |
| Auchan | + | - | + | - | - | - |

Auchan, which is losing revenue, was marked only by partnerships with suppliers and digitalization, without which it is impossible to work in 2020. We do not see any quick and clear organizational changes that would allow this chain to not lose sales in the changed conditions. Auchan does not develop relationships with customers, identify needs, increase loyalty, etc. It also does not provide a "seamless" omnichannel interaction experience, although the Auchan online store was launched back in 2014, one of the first among major food chains.

DKBR also does not communicate well with clients. Their main efforts this year are aimed at maintaining the operation of all networks and franchises, selling through the marketplace, and organizing delivery with partners, as well as developing their express delivery.

Lenta does not diversify its business (but tests new concepts), wherein, it is the best in loyalty programs and the development of customer relationships. The company elaborated on a successful loyalty program to track consumer preferences and customer behavior. 97% of all sales in Lenta stores are carried out using loyalty cards; today the company has about 16 million active cardholders.

X5 and Magnit are fighting for leadership in the Russian market. Each of these networks has created its strategy, which reflects not only all the main trends but also its developments and solutions. This

allows us to reach a qualitatively new level of relations with customers, partners, suppliers, organization of interaction between departments within the company, work with Big Data, and so on.

**Discussion**

During the buying rush, sales growth was demonstrated by all channels, even hypermarkets, in which the sales dynamics have been negative over the past years. However, after overcoming the threshold of peak demand, offline sales slowed down at a high pace. By mid-April, the values returned to their usual level: in discounters and supermarkets, the growth was 13%, while in hypermarkets they decreased to -14%.

At the same time, the dynamics of online sales did not follow the general trend, remaining at a level significantly higher than the average annual rate. Nielsen found that the online FMCG market had shown an increase of + 92% at the end of the year ended in April 2020. For the previous similar period, it was almost 2 times less (+ 50%) (see Figure 1).

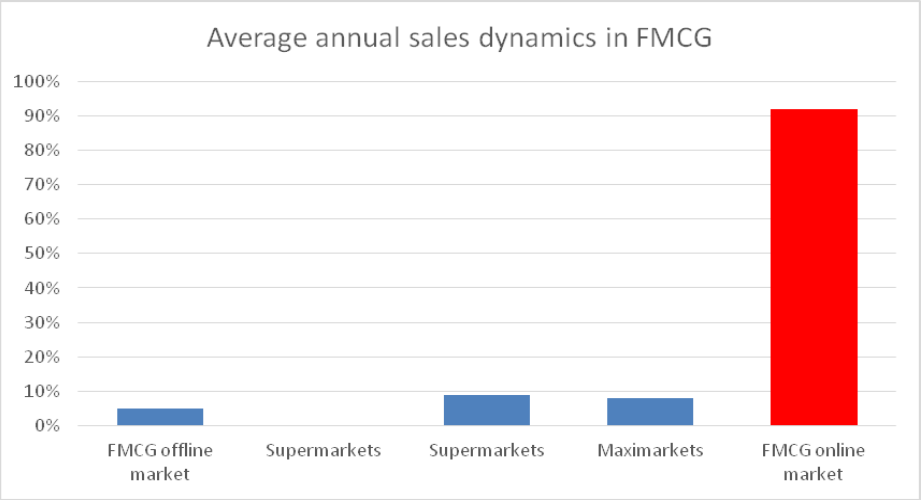


Figure 1. Average annual sales dynamics in FMCG.

According to Yandex research, the trend for the development of e-commerce in the FMCG sector has every chance of gaining a foothold in the long term, since from 56% (food) to 75% (personal hygiene

products) of respondents did not plan to reduce the share of online purchases even after removing all restrictions.

During the pandemic, people have developed a habit that is no longer so easy to abandon. Choosing a product on the Internet (even food) has become a daily routine for most, and networks with an underdeveloped Internet channel are already perceived as irrelevant. Even with the normalization of the epidemic situation, the removal of restrictions, the absence of fear of infection, and the return to "normal" life - the shopping experience will not be the same.

Research showed that “online retailers will have more sales over the next five years, even if their customers choose physical stores. This underlines the importance of integrating online and offline commerce, omnichannel interaction with consumers, and providing them with a choice of a convenient way of communication” (Ramazanov et al. 2021) (see Figure 2).

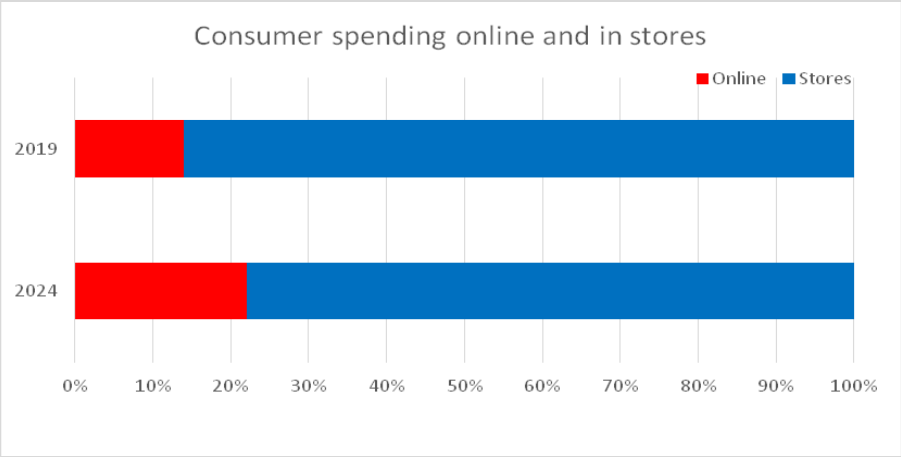


Figure 2. Consumer spending online and in stores.

Researchers argue that by 2024, 53% of retail revenue will be generated by companies with a business model that includes digital sales channels, while in markets with strong digital marketing, such as the UK and the US, omnichannel retailers will account for two-thirds of total income.

It seems that the companies themselves also believe that the achieved level of online sales is far from the limit and are planning additional investments in this area even with a reduction in other costs. Nielsen surveyed directors of the companies involved in the FMCG production and sale, in the matter of what they intend to do to improve business efficiency. 62% of manufacturers and 85% of retailers said they need to increase their investments in online retail in the next 12 months, and 23% and 38% respectively plan to revise the company's strategy with a focus on online (see Figure 3).

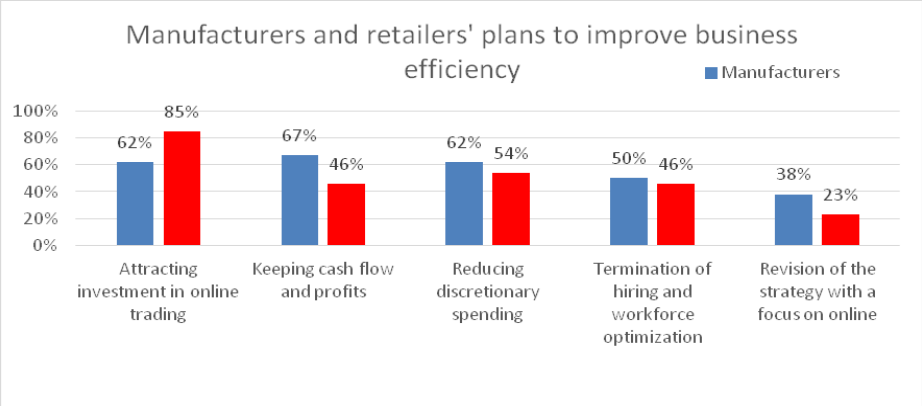


Figure 3. Manufacturers and retailers ' plan to improve business efficiency.

**Conclusion**

Having analyzed the situation on the market, as well as the results of research of Russian and foreign companies, we highlight the following trends in changing business models and methods of business interaction in terms of FI:

**1. Extended enterprise**, increasing the number of joint projects. During the pandemic, digital-oriented businesses needed global infrastructure development, while offline companies needed a streamlined distribution system through online channels. These changes require significant investments, both financial and time. Partnerships are becoming the most effective way to quickly get the missing resources. Companies use the extended enterprise concept, which implies close interaction with suppliers and partners, aimed at meeting the needs of end-users. It can be both contractual relations, cooperation, and strategic partnership, which implies the integration of processes, systems, information, and employees.

**2. Organizational speed**, an increase in the dynamics of the passage of business processes, and a rapid change in products and services following customer requests. During six months of work in a pandemic, companies were forced to not only adjust strategies but also implement new digital platforms, test various formats, and very quickly make effective tactical decisions to meet changing customer needs. “Amid the COVID-19 pandemic, executives and directors say their organizations are making extensive changes with one overriding goal: to increase the speed at which they adjust strategic direction, make, and implement tactical decisions, and deploy resources. Leaders see three primary opportunities to overcome these challenges: building faster decision-making mechanisms, improving internal communication and collaboration, and increasing the use of technology overall development strategy and as a change management mechanism (de Smet et al. 2020, "The need for speed in the post-COVID-19 era—and how to achieve it", ed. Hanselman H. Last Modified September 9, 2020. Accessed August 5, 2021. https://www.mckinsey.com/business-functions/organization/our-insights/the-need-for-speed-in-the-post-covid-19-era-and-how-to-achieve-it.). Digital transformation is understood to be a significant increase in productivity, cost reduction, an increase in sales, market share, etc. Through the introduction of digital technologies, which become not only a source of economic efficiency but also an essential component of the business. “Digital adoption has taken a quantum leap at both the organizational and industry levels. According to a new McKinsey Global Survey of executives in July 2020, their companies have accelerated the digitization of their customer and supply-chain interactions and their internal operations by three to four years. And the share of digital or digitally enabled products in their portfolios has accelerated by a shocking seven years” (LaBerge et al. 2020, "How COVID-19 has pushed companies over the technology tipping point—and transformed business forever", ed. Seiler, D. Last Modified October 5, 2020. Accessed August 6, 2021: https://www.mckinsey.com/business-functions/strategy-and-corporate-finance/our-insights/how-covid-19-has-pushed-companies-over-the-technology-tipping-point-and-transformed-business-forever?).

**4. Business diversification** – mastering new directions (products, services, ways of interacting with customers), new markets, changing the business model. Leading food retailers, using their infrastructure, enter new markets (drug trade), develop new formats (discounter), develop their delivery services (Lentochka, Okolo).

Also, the most important trends are **omnichannel** and **customer interaction** (Burmistrov A and Melikova E 2021)**.**

Companies that were able to reconstruct quickly at the beginning of 2020, adapt their strategy to changing conditions, using FI business models and approaches, they launch new business processes and build actual relationships with consumers have every chance not only to increase revenues in the short term but also to occupy the market share of companies who failed to cope with the organizational, logistical, analytical, and digital transformation of their business. The direction of further research will be the retailers' development trends study in the post-covid period.

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## 3.6. Frugal innovations and implications, a single case study on dairy farming from developed countries

Paper is under review in *Technology in Society* (Melnikova & Gilsanz); Scopus Q1; H-INDEX-58; ISSN 0160791X; SJR 2021-1.138; Impact score-7.82.

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Paper Frugal innovations and implications, a single case study on dairy farming from developed countries is an original research article currently is under review in Technology in Society; Scopus Q1; H-INDEX-58; ISSN 0160791X; SJR 2021-1.138; Impact score-7.82, it is an international journal peer reviewed journal aimed at transformation in technology, management, society, business, and philosophy. It publishes wide range of research works from theoretical approaches to applied one including management, decision making, business innovation and technology management; and development perspective approaches, it includes review and original research articles, where the common thread is the technology in economics, politics, and culture. The journal publishes a lot of works in field of frugal innovation. Presenting a case study of frugal innovation that reveals various aspects of benefits such as sustainability, social, and economic performance through lens of organizational innovations and frugal innovative product our research contributes to the scope of the journal exploring social, economic, and sustainable values of frugal innovation.

**Highlights**

- This study explores how frugal innovation (FI) contributes to the provider and receiver of (FI).

- It explores social, economic, and sustainable values of FI, through organisational innovations and frugal innovative product.

- It demonstrates that FI benefits to the customer (dairy farmer) improving milk yields and welfare, and reducing costs (vet and feed), finally increasing the profitability.

- It shows how frugal innovation serves underserved customers in developed countries, using a case study from dairy farming.

**Abstract**

The dairy sector requires sustainable production along with profitability and social aspects. This research targets to explore how frugal innovation (FI) impacts the dairy farm's economic performance and how it benefits the seller and the dairy farm in developed countries. It explores various aspects of benefits such as sustainability, social, and economic performance which can become a win-win solution. Our results demonstrate the main benefits for farmers are, increase of profitability, and welfare of the herd. This research is one of the first on FI in the dairy farming sector. Exploring the FI case from dairy industry contributes to the academics presenting how and what benefits deliver FI. From the practical perception, it could be useful for dairy farmers, policymakers, and other actors on the market, since it shows how a company using FI can meet the customers' needs, delivering benefits to dairy farming, making it more sustainable and profitable.

**Keywords**: frugal innovation; dairy industry; profitability; sustainability; developed countries

**Introduction**

Frugal innovation (FI) is called to provide solutions for unserved customers in limited constraints (Hossain 2018). The term was born in developing countries tackling only them previously, however, lately, it was referred to developed ones (Wohlfart et al. 2021). FI is the type of innovation that refers to an affordable, effective, uncomplex, sustainable solution for limited constraints circumstances (Hossain 2020, 2021; Zeschky, Winterhalter, and Gassmann 2014). The discourse about the necessity of sustainable production in the dairy farming sector raises, while the affordability of resources decreases, FAO (2010) claims that dairy farming appears as one of the major contributors of CH4 and CO2 emissions, also often compromising the welfare of the animals (Keeling et al. 2019). Meanwhile, the instability and low prices for milk along with raising operational costs like fuel, and feed make the business to operate under scarce resources (FAO 2020). European governments try to support the incomes of the dairy farming sector via providing subsidies, and voluntary coupled support (VCS) (European Commission, 2020). However, it is not enough, the number of farms with dairy cows reduced by 81 percent over the period from 1983 to 2013, which is also associated with low profitability of the dairy farming business (Augère-Granier M.L. 2018), and several crises faced the dairy farming industry had a significant negative impact on competitiveness and economic performance of this sector. Thus, there is a need for a win-win solution that could tackle the above-mentioned problems. FI can be considered as an effective way to serve dairy farmers sustainably. However, there is a near dearth of research on FI in the dairy sector, though, a low-cost milking machine developed in India considered from the perspective of the sustainable business model presented in studies of Hossain (2021) and empowering female entrepreneurship in the dairy business and its driver for a market boost in Kenya mentioned in works of Sydow & Funké (2021).

Using a single case study of FI in developed countries, this research provides several contributions. First, it identifies the process of how FI benefits the dairy farmers and seller in terms of profitability,

sustainability, and social aspects. Secondly, it shows how FI contribute to sustainable development goals. Thirdly, it demonstrates what benefits receive the dairy farmers and providers of FI.

Understanding how FI benefits the business entities in terms of process and results is crucially important, and studying them together could reveal a 'black box' for understanding how sustainably serve the businesses (dairy farms), increasing their economic performance in developed countries. Hence, the objective of our research is to explore the way how FIs provide the benefits to the customer and provider of FI and to identify these benefits in terms of sustainability, profitability, and social aspects in developed countries, taking into account the specific context of the dairy farming industry. We focus on how affordable, effective, sustainable FIs are, how do they benefit the companies' performance.

**Theoretical review**

FIs are called for solving economic, social, and sustainable problems of the community. Nowadays, they serve customers in developed and developing countries as well, however, there is strong pressure from dairy livestock farming to serve them in an economically effective and sustainable way. Companies try to develop solutions that could satisfy the needs of communities in scarce resources. Here we present the discussion of literature for FIs, their presence in developed countries, relevance, necessity, and justification for adoption in dairy farming as follows.

**Frugal innovations**

During the last decade, FI attracted the attention of researchers which is reflected in a boost of publications (Dangelo and Magnusson 2021; Melnikova and Gilsanz 2022).The first research paper on FI in English appeared in 2005 (Pisoni, Michelini, and Martignoni 2018). The ontology of the word refers to 1542 it appeared from 'Latin frugalis virtuous, from frug-, frux fruit, value' (Merriam-Webster 2021). FI presents a new business approach where companies provide solutions for underserved customers in the context of scarce resources while contributing the sustainability (Hossain 2020). The phenomenon is pretty new and indeed the definition of FI is under debate. FI is seen as creating resource-limited but quality and more affordable than existing solutions (Zeschky, Winterhalter, and Gassmann 2014).

According to Agarwal et al. (2017) FI refers to a good enough, inexpensive solution that serves the requirements of scarce-resource customers. Others claim that FI is a 'resource-efficient innovation' (Ploeg et al. 2020). FI was born in India and created for developing countries (Krishnan and Prashantham 2019), it was aimed at filling the needs of Bottom of the Pyramid (BoP) customers by cheap 'good enough' quality products or services (Radjou, Prabhu, and Ahuja 2012; Prahalad C.K. 2005). FI can be seen as a mindset, as a process, or as an outcome, and practised independently. It focuses on doing more with less, providing effective solutions without investing or owning R&D (Radjou and Euchner 2016). They can appear from grassroots, domestic companies or Multinational Corporations. Previous research delivered initial insights into serving scarce-resource customers in developing countries (Gupta and Thomke 2018; Hossain 2020). Some of the authors suggest criteria and principles for defining FI, such as decrease of cost, core functionality, optimisation (Weyrauch and Herstatt 2016); quality, affordable price, incomplexity, and sustainability (von Janda et al. 2020); 'engage and iterate', 'make innovative friends', 'create sustainable solutions', 'flex your assets', 'shape customer behaviour', 'co-create with other prosumers' (Radjou and Prabhu 2015); robust, lightweight, and simple (Basu, Banerjee, and Sweeny 2013); 'low to medium sophistication', 'medium sustainability', and 'medium emerging market orientation' (Brem and Wolfram 2014). There are different examples of FI solutions from domestic companies and Multinational Corporations, from engineering and manufacturing to business models, for instance, 3D printing in cardiology (Ali et al. 2020); digital creating of face masks, face shields and valves in fighting with Covid-19 (Corsini, Dammicco, and Moultrie 2021); or business model for low-income patients in eye care clinics (Arshad, Radi, and Radi 2018)Summarising the above-mentioned FI is a type of innovation that refers to the creation, development, and implementation of a sustainable, efficient, affordable, functional solution without compromising the quality, it may include processes, services or products which meets the needs of scarce-resource customers.

**Developed countries**

Despite the fact that FIs were previously used in developing countries, lately, they became related to developed ones (Zeschky, Winterhalter, and Gassmann 2014). The need for FIs in Europe has increased during the last years (Kroll et al., 2016). Moreover, the series of crises from 2020-2022, including food and energy, decrease in real incomes, concern about the environment, and sustainability led to the higher demand for FIs, since their affordability, sustainability, and prompt response globally, including developed countries (UN 2022; Eurostat 2021). The Paris Agreement and 'European Green Deal' require sustainable production and consumption, with fewer resources and reconsideration of production chain, meanwhile, the use of scarce resources for production and limitation of consumers' resources create a potential market for FIs in developed countries, particularly in Europe (Glanemann, Willner, and Levermann 2020; Fetting C. 2020). Moreover, the trend in developed countries for sustainable consumption refers to a frugal mindset for production and consumption as well, customers concerned about the profile of the producer in terms of sustainability. There is also a need for the adaption of FI to the environment of particular locations and circumstances for developed countries (Brem et al. 2020). For instance, for consumers from developed countries, quality and sustainability are more important than low prices (Costa, Teixeira, and Brochado 2020). Thus, 'sustainable frugal innovation' could be more attractive for them (Albert 2019). The FI in developed countries refers to a 'second-degree frugal innovation' (Winkler et al. 2020), while FI which is firstly introduced in developing countries and then transferred to developed one refers to 'reverse innovation'. The readiness for FI in developed countries improved and underserved customers present a large potential market, companies need to use new practises by involving economic, social, and environmental aspects to boost their competitiveness (Melkas et al. 2019; El-Kassar and Singh 2019).

**Dairy farming industry**

Dairy farming requires sustainable production which includes environmental performance, social issues, public health, and profitability (FAO 2010). FI is one of the concepts that tackles these aspects.

**Emissions and env**ironmental issues

Dairy farming is one of the most intensive contributors to emissions. The dairy sector contributes over four percent to the total global anthropogenic amount of Greenhouse Gas (GHG), while the entire livestock refers to 18 percent of emissions. The emissions of GHG from *cradle to farm gate* include processes for producing and delivering grass, crop residues, by-products, and concentrates, feed crops; ruminant enteric fermentation (CH4); emissions from manure storage (CH4 and N2O). The production of GHG emissions from the dairy herd accounts for 1,969 million tonnes of CO2 of which 1,328 million tonnes (±26 percent) are referred to milk. Methane (CH4) is considered the main contributor from dairy farming and is estimated for 50 percent. It is also correlated with low milk production per head and low digestibility of the feed, moreover, the lowest emissions per kg of milk yield are presented in developed countries with higher milk yield (FAO 2010). The production of palm oils which are used in feeding doubled from the period 2000 and 2019 (USDA 2021). This in turn influenced land converted from the forest and natural grasslands, deforesting, and became a significant preoccupation for the global community (Wilkinson J.M. and Young R.H. 2020; Taheripour, Hertel, and Ramankutty 2019).

Feed digestibility plays a crucial role in GHG emissions, ten percent improvement of digestibility provides a 14.8 percent reduction on GHG emissions for an extensive system, while for intensive systems it is 10.1 percent. In practise, the quality of feed is interlinked with milk yield and growth. Thus, if we suppose the boost of milk ten percent along with digestibility improvement, it stands for a 19.2 percent reduction of GHG emissions for extensive, and 15.4 for intensive systems (FAO 2010). Without measures for efficiency improvement, total GHG emissions from the dairy sector are assumed to increase by 38 percent (Bizzarri and Gapon 2019). However, there are and other aspects of environmental sustainability such as water use and pollution, biodiversity erosion and air pollution that have to be considered. The above environmental issues require win-win solutions that could prevent climate change (Bizzarri and Gapon 2019).

**Welfare of** the animal

Animal welfare is another important issue for sustainability and farms profit, it is inseparably related to ethical, political, economic, environmental, and social issues, where the consumers' concerns play a crucial role (Keeling et al. 2019; Vogeler, Hornung, and Bandelow 2020). For instance, the welfare of the animals correlated with food safety, since its poor conditions raise the contamination and virulence of many zoonotic diseases, as well as non-communicable diseases and the risk of antimicrobial resistance. Moreover, the ethical aspect of the problem refers to the unacceptability of the ways that compromise animal welfare (Cox and Bridgers 2019). Also, the welfare of animals affects positively diversification of the market, quality production, national trade image, development, and sustainability (Alonso, González-Montaña, and Lomillos 2020).

**Profitabili**ty of dairy farms

The profitability of dairy farms is also a topic of concern for the global community. Due to the sustainable increase of input costs the cost of milk production raised, while the Dairy Price Index in 2020 tends to decrease, furthermore the increased feed costs also affected the profitability of dairy farms (FAO 2020). The number of the farms reduces, meantime the size of the herd increases since mainly large dairy farms can be competitive using large scale economy, this in turn influence negatively on the presence of Small Medium Enterprises (SME) in the industry (de Andrade Ferrazza et al., 2020). Another important aspect of farms profitability are direct payments and subsidies which significantly contribute to the farmers' income, and remain a stable component, especially from 2010, in 2017 the share of subsidies in dairy farmer's profit accounted 34 percent, and Voluntary Coupled Support (VSC) from 2015 which positively influenced the revenues from milk (European Comission 2021). However, these measures are not enough to stimulate profitability and development of dairy farming. Dairy farming requires the implementation of new technologies, business models, and innovations such as FI since its orientation, which could contribute to farmers' profitability (Läpple and Thorne 2018). Thus, due to its target FIs could be one

address the above-mentioned issues and contribute to Sustainable Development Goals (SDG), which agenda by 2030 requires progressive actions (UN 2016).

## Data and methods

We applied a case study method which permits explore various perspectives and reveal connections between the complex layers of our research question. The case study allows to analyse different systems, using one or several methods (Thomas 2011). It explores a real-life, case (system) during some period, via in-depth data collection using diverse data sources, it presents case description and case themes (Creswell 2014). A single case study is used for the description of the existence of phenomena and presenting high-quality theory (Siggelkow 2007). It permits to understand deeper the exploring subject and to get the conclusion from the analysed data, and explain the situation better (Lindgreen, di Benedetto, and Beverland 2021; Alam 2021).

### Case selection

FI refers to the emerging category of academic research (Hossain 2018). Moreover, there is a lack of research into FIs in livestock and agriculture industries. Our case study contributes to this young research domain. We chose the case of *Biosmart milk solutions*, as an obvious example of FIs, since their product, service, business model considered as sustainable, affordable, incomplex, and functional, developed for customers with scarce resources, and follows six principles (Radjou and Prabhu 2015). Company provides solutions for agriculture and dairy farming, as this case presents a lot of insights from the perception of provider and receiver of FI, which is suitable for the exploration of phenomena.

### Data collection

Data sources included primary data such as interviews, documents, observations; secondary data including internet, financial reports, and sales reports since multiple sources are essential for triangulation (Santos et al. 2020). We conducted observations with visiting once per week participants during six months, and several in-depth face-to-face interviews of the inventors, manufacturers, sellers

(distributors), as providers of frugal innovations, and receivers - owners of dairy farms, vets, feeding specialists. The data is based on provided documentation including financial, marketing, and technical documents. At the first step, we collected the secondary data of the inventor and producer from the internet, marketing catalogues, reports. This provided general information about the case. At the second step for deeper investigation, we used open structured questions. The participants provided information about their development in the past, their current situation, and future. We have recorded some of the interviews, while the rest were noted. Then we started the field visits and observations, we noted all the information after the visit in digital form. During our visits to the frugal innovation providers, we collected extensive material that allowed us to enrich our research. Our visits to the frugal innovation receivers – farms, included all day long observations, questioning the vets, owners, feeding managers, studying the documentation from the farm's software regarding the past and current statement of the farms. We focused on the state of the farms before and after the implementation of the 'Polysaccharide Regulatory Complex' (PRC). Long observations, discussions, and witnesses permitted us to get a more complete picture of the providers and receivers of FI. Moreover, the data regarding the farm, the output from the FI implementation was extracted from the farm's software.

**Data analysis**

In order to explore phenomena, we combined data and literature. We used Atlas software for qualitative analysis, the data were collected in pdf file and proceeded through the software. In order to generate broad themes, we applied preselected codes and open coding to obtain different elements which are used in our concept. Via open coding, we read the dataset and identify codes. We used main elements such as economic performance of the company, economic performance of the dairy farm, sustainability, frugal business model. We revised the data and literature for the research domain and generated new codes in a repetitive cycle (Alam 2021). We iterate and combine various codes, this allowed us to design broad groups of coding from 41 initial codes.

**Case description**

*Biosmart milk solutions* is one of the examples of frugal innovations in Europe. The company provides solutions in the livestock and agricultural sector. According to (Radjou and Prabhu 2015) the company follows the six principles 'engage and iterate', 'flex your assets', 'create sustainable solutions', 'shape customer behaviour', 'co-create with other prosumers', 'make innovative friends'. The company is staffed with Ph.D. holders in the field of veterinary medicine, livestock, and economics. It operates in Europe, predominantly in Southern Europe, the results from the dairy farms provided from Greece. The company aims to provide innovative solutions for dairy farms that decrease the cost of production while increasing productivity and health of the animal, as a result, the farmer gets a healthier herd, and significant boost of milk, while covering the expenses for the purchase of the product and receiving extra profit from the increase of the milk yield. Also, it has other directions such as decrease of cost production of the broilers, beef meat, keeping the high quality of the meat; monitoring and forecasting of agricultural diseases based on IT/ICT.

*What does the company provide?*

The company offers a PRC – supplementary feeding complex for cattle based on polysaccharides with a prebiotic effect, which supports animal with healthy energy, provides power and capacity to overcome many stresses and health issues, while improving productivity. Under influence of the technology, the animal's body generates the right amount of energy capacity (power source) that provides: higher productivity, higher reproduction rates, strong immunity, as well as resistance to various stresses, such as changes in the diet, seasonal decrease in the diet quality, heat stress (Kosolapova et al. 2020). *Biosmart milk solutions* provides assistance and adaption of the product until the farmer gets convincing results such as milk boost and decrease of expenses. The company employs six principles of FI (Radjou and Prabhu 2015).

*What does the company do according to each principle?*

*Engage and iterate*

For to better understand customer needs *Biosmart milk solutions* applies customisation and individual approach with their clients, before the sale process the company collects all the necessary information from the farm including milk yield, cost of production, health parameters of the herd, ration parameters, quality of milk, etc., this permits to get the complete profile of the farm for to get better results in future; then they conduct manure washing which reflects the digestibility and metabolism of the animals; after that, they conduct biochemical blood tests of the animals, which reflect the health parameters of the animal. This permits to get more clear vision, what and how can be improved on the farm. Further, the company presents an individual plan for the farmer, since most farmers are pretty limited in resources, they need to know how profitable it will be for them the implementation of PRC. Company presents economic efficiency from the use of a PRC based on the individual characteristics of the farm. Once the farmer starts to use the product on the farm, the company visits the farm once or twice per week, conducting weekly manure washing, gathering the feedback and data; blood biochemical analysis in 1,5, and 3 months for monitoring of health parameters. For receiving customer insights and achieving robust results on the farm, the company provides free of charge consultations during product usage.

*Make innovative friends*

The company does not own an R&D department, it collaborates with different R&D companies and research institutes, manufactures of innovative solutions, and R&D departments of universities, which provide innovative solutions for livestock and agriculture. However, the company implements six principles of FI (Radjou, Prabhu, and Ahuja 2012). It performs as an integrator and adaptor of FI products and services according to the needs of local customers in developed countries, without production.

*Create sustainable solutions*

PRC aims at the improving of milk productivity, a decrease of the cost production, meanwhile improving the welfare of the herd. Once the milk starts to boost and becomes stable, the company starts to exclude soybean, and fat from the total mixed ration (TMR), and then substitute with local materials. Since the company operates in Europe, the delivery of palm fat and soybean from the U.S., Asia, and Latin America leaves a large CO2 footprint. Moreover, the production of palm fat or oil influences significantly deforestation and biodiversity (Afriyanti, Kroeze, and Saad 2016; Vijay et al. 2016). The elimination of palm fat from the TMR of the cattle could have a positive effect on this issue.

*Flex your assets*

Satisfied customers which got convincing results, become the dealers of the company, and distribute the product to their colleagues, gaining extra profit. This permits to establish a trustworthy and reliable relationship between the seller and customer. Meanwhile, such distributorship structure allows to integrate into the market faster and smother, presenting successful cases to the customers. Moreover, the company works mostly through dealership networks, such organisational system allows to decline costs on the sales department.

*Shape customer behaviour*

The company provides reports once or twice a month of the farm's development according to the economics and health parameters of the herd, providing advice on what else can be improved on the farm. The technology aims to improve the health of the herd, the owners of the farm consider the health of the animals as the priority issue, since it influences the productivity, lifespan, and cost decrease of the vet expenses. The product allows to eliminate some of the expensive and harmful ingredients from the TMR of the animal and later when the milk is increased, substitute them with locally produced ingredients, this encourages the farmer to purchase from the local producers; the awareness about the decrease of the CO2 footprint from logistics also benefits to the credibility of the product.

*Co-create with other prosumers*

The company offers personalised solutions to the farmers, according to their specific needs and issues. Gathering the data and information from the farm allows the company to develop an individual solution. Providing them not just product, but consultations regarding feeding and other issues; teaching; free of charge. Such integration into the farm provides tailored solutions, meanwhile, customers are involved in their creation, since the company educates farmers about the feeding technologies, effective farm management, thus farmers get extra knowledge which they use into practise. Since the company focuses on the farm's results such as the economic efficiency of the farm, and the health of the herd, thus company and farmer have the same common goal, they become both co-creators. Also, the company focuses more on feeding, however, it participates in dealing with many issues that occur at the farm for free, such as analysis of TMR for quality and ingredients, problems with management issues, employees, etc., which are out of their responsibility. Moreover, satisfied customers can integrate into distribution, participating in business development.

**Analysis and results**

FI delivers values to their customers and company's shareholders, where the first can be considered as various values, and the last monetarised (Hossain 2017; Jha et al. 2016). FI aimed at creating, designing new products, services, or business models, which are high functional, cost decreased, effective, incomplex, affordable, valuable for scarce resources (Bhatti 2012; Rao 2013; Lim and Fujimoto 2019; Hossain 2020). Based on the data analysis, we developed a framework for FI, as presented in Figure 1 to answer the question of how does the FI benefit the receiver and provider in the dairy livestock context, we focused on the processes and results.

**Organisational innovations**

Organisational innovations refer to new methods of doing business, organising workplaces, external communications. In business they may include a wide range of activities: development or implementation of new business strategy, new management methods, development and implementation of new

organisational structures; novelty in the labour time; implementations of quality control systems, certifications, modernisation and implementation of the new logistic system; interaction with R&D departments, implementation of knowledge management; creation of new partnership; involvement of stakeholders (Donbesuur et al. 2020). These changes aim to improve firm performance directly in terms of quality, flexibility, productivity, or speed and can therefore be considered a distinct form of innovation.

Before the customer purchases the product, *Biosmart milk solutions* customise the service according to the issue, before any sale process starts the company investigates the current issues. The initial stage includes: data collection from the farm (milk parameters, ration, and health of the herd) to understand the future steps shall be taken, the current health of the herd, the situation on the farm, and possible opportunities for improvement; manure washing allows to identify digestion problems and rumination; conducting biochemical blood tests of the animals which reflect the current health issues of the herd; observation of the farm; general interviews with the owner, and vet. These data permit the company to find out the problems and to present to the farmer detailed current performance of the farm; to identify actions required to address the problems; to plan future actions. Then, the company develops individual plan with a detailed description of all the steps of work; since the farmers operate under scarcity, they do not spend money in vain, and each expense have to be justified and reasonable, thus the company presents an offer that justifies the purchase, with economic efficiency indicators and detailed ration. These allow the farmer to understand the profitability. Involvement and close collaboration with customers create teamwork between the seller (provider of FI) and the customer (farm/receiver of FI). The solution that offers the company based on the data provided by the farmer, deep integration into the farm's environment and farmer's feedback lead to successful results. The mutual collaboration and willingness of the farmers to be open to resolving the issues together facilitate the working process and faster achievement of the results. The implementation of the PRC requires participation and involvement of the farmer, changing of feeding ration. The farmers also provide regular feedback, sometimes asking for

additional consultation about feeding, staff, and equipment. *Biosmart milk solutions* also provides educational seminars which include: regular seminars about feeding; visiting progressive farms; webinars with producers and R&D. Also, the company provides educational seminars about sustainability. This influences the goodwill of the company, meanwhile increasing the consciousness of the farmers. The company delivers additional services free of charge upon the request of the customer, for instance, it may be headhunting, harvesting, etc. Customer support, maintenance, and regular farm monitoring (biochemical blood test of the herd, manure washing, evaluation of health parameters, body score, cost of feeding, farm's economic profit, etc.), a monthly presentation of farm improvement indicators (economic, feeding ration, milk yield, health) facilitates the building of a trustworthy relationship between provider and receiver of FI. In fact, purchasing the product the customer gets a lot of side above-mentioned benefits from the company. Considering the scarce resources of the farmers, the company offers various flexible methods of payments, such as deferred payment, or discount if farmer pays on time. Employees provide regular feedback and ideas on how to improve, and actions are needed to be taken for improvement. They are engaged in the process of delivering the solution to the customer. The company encourages their activity monetary, through trips, or personal benefits. Most of the employees have the ability to make some decisions on their own. These deliver better flexibility, connection with employees, innovative activity, and creativity. Employees care more about the quality of the delivered products and services since they carry their responsibility. The inbound open innovation type allows to use external sources to utilise the inventions, new solutions, and patents through close collaboration. The organisation works and collaborates with R&D and the manufacture which produces the product, this allows to be flexible in terms of production and investments. The regular collaboration and communication processes with the manufacture of frugal innovative product (PRC) provide cost

reduction on R&D activity and a win-win solution for participants, manufacturer, R&D, and company (seller); using customers' feedback for development and adaption of the product.

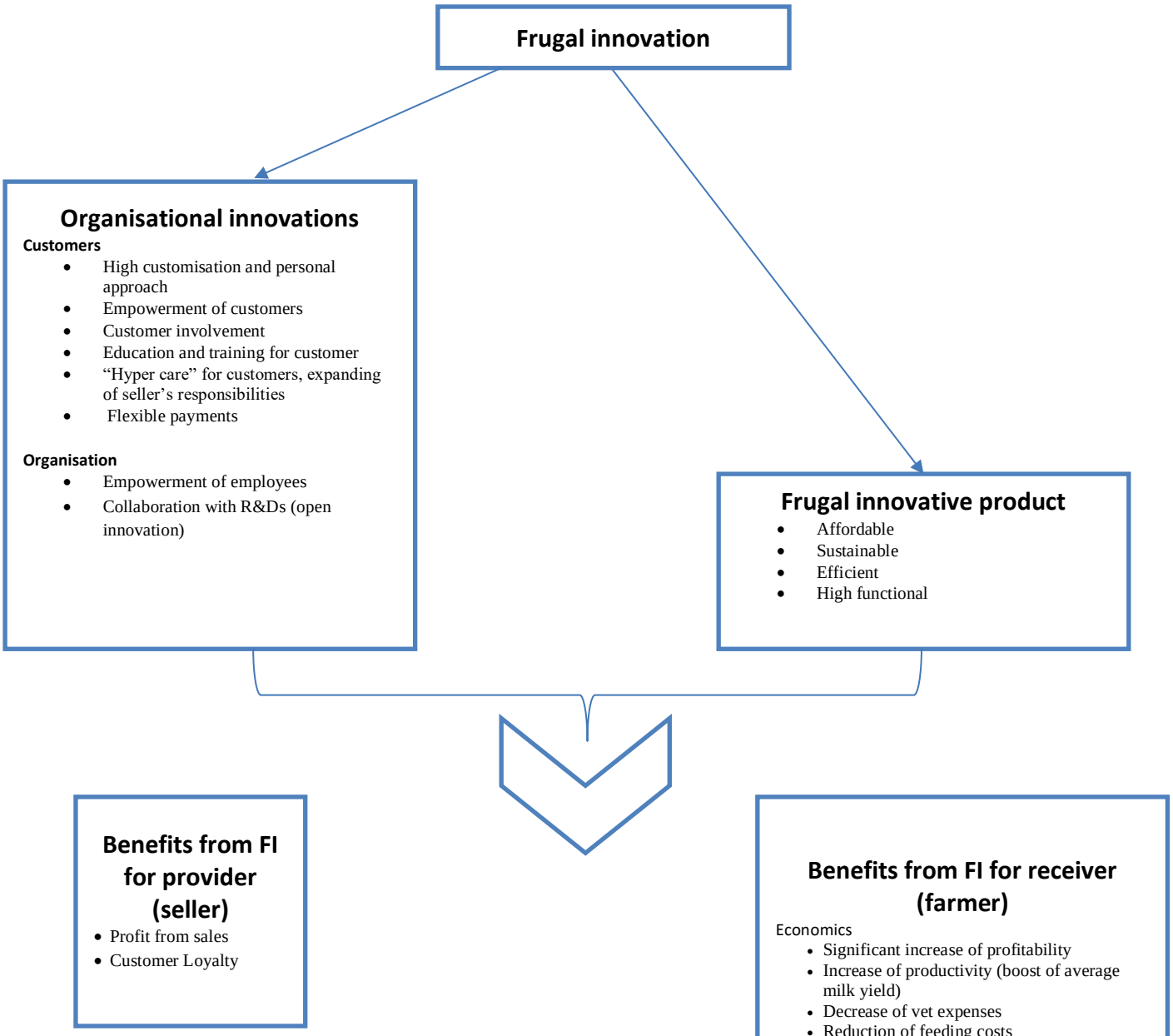

**Figure 1.** A framework for frugal innovation.

**Frugal innovative product**

Scarce resources in dairy farming, which also caused by raised prices on feeding materials, fuel, etc. impacted on product prime cost, thus this motivated for creating a product that delivers economic profit to the farmers. PRC supports cattle with healthy energy and provides resources to overcome many stresses and challenges, meanwhile increasing productivity, improving health, and decreasing costs. It allows the animal's body to generate the right amount of energy capacity (power source) that provides: higher productivity, higher reproduction rates, stronger immunity, as well as resistance to various stresses, such as changes in the diet, seasonal decrease in the diet quality, heat stress, etc. The product is considered affordable since it generates extra profit for the farmers in a near future, via boosting milk production; eliminating expensive ingredients from the ration; reducing the concentrate part of the ration; vet and feeding costs. The company presents individual commercial plan with expected revenues and detailed steps of product implementation. In one month of product implementation, the farmers see the first results: the milk starts to boost; the animals' digestion and rumination improve; somatic cell count (SCC) which is an indicator of udder health in dairy farms decreases; cases of mastitis as one of the common economic and health issues in dairy farms reduce (Bobbo et al. 2021); health parameters improve. Farmers start to gain additional profit from extra milk yield and decrease in vet expenses. While the average milk yield boosts and achieves constancy, the company starts to eliminate the expensive feeding ingredients (molasses, propylene glycol, glycerol, propionate, protected fat; sources of amino acids such as protected protein; hepatoprotectors, such as choline chloride), then it substitutes expensive ingredients like soybean meal, which is usually brought from distant countries with local feeding materials. This facilitates the reshaping of farmers' consumer behaviour in a sustainable way. Permanent monitoring, digestion analysis combined with biochemical blood tests provides control of the health parameters. After 3 months vets noticed visible improved reproductive parameters, open days, pregnancy rate, heat stress resistance during summer, increase of milk production.

**Benefits from FI for provider**

The frugal approach in the organisation system and open innovations as collaboration with R&D and manufacturer allow to reduce the expenses. Customer loyalty and long last relationship generate business stability and sustainable income.

**Benefits from FI for receiver**

We assessed the data from 10 farms before and after the product usage. In order to understand how FI benefits the farms, we based on provided data from the farms' software. The results presented in Figure 2 demonstrate a significant boost of milk yield in all 10 farms, 4,95 kg. per head per day in average in six months, where average milk production increased 11 percent in two months, and 14,3 percent in six months. Figure 3 shows that the cost of TMR in all 10 farms decreased, in average 8.3 percent, considering the fact of increase of feed consumption, in average six percent. However, despite the increase of average milk production, the milk quality also improved or remained the same based on fat, protein, and SCC it can be seen in Table 1, where the average SSC decreased 36 percent. As presented in Table 2, in all 10 farms, vets notice significantly less new cases of mastitis; improvement of rumination and digestibility based on digestion analysers. After six months of product implementation vets confirmed improvement of fertility, the pregnancy rate has improved by 30-40 percent. Before the use of a product, the farms had to inseminate 2.8 times in average until the confirmed pregnancy, while after six months of product usage it reduced to 2.5 times. During the heat stress, the feed consumption remained on a high level. Such health parameters of the animals like biochemical blood tests, body score improved, while the diseases of the reproductive system, digestion system, and legs which were the most common for the farms have decreased. Thus, vet expenses decreased since the animals' health significantly improved. Based on provided data from 10 farms the vet expenses on average reduced 20 percent.

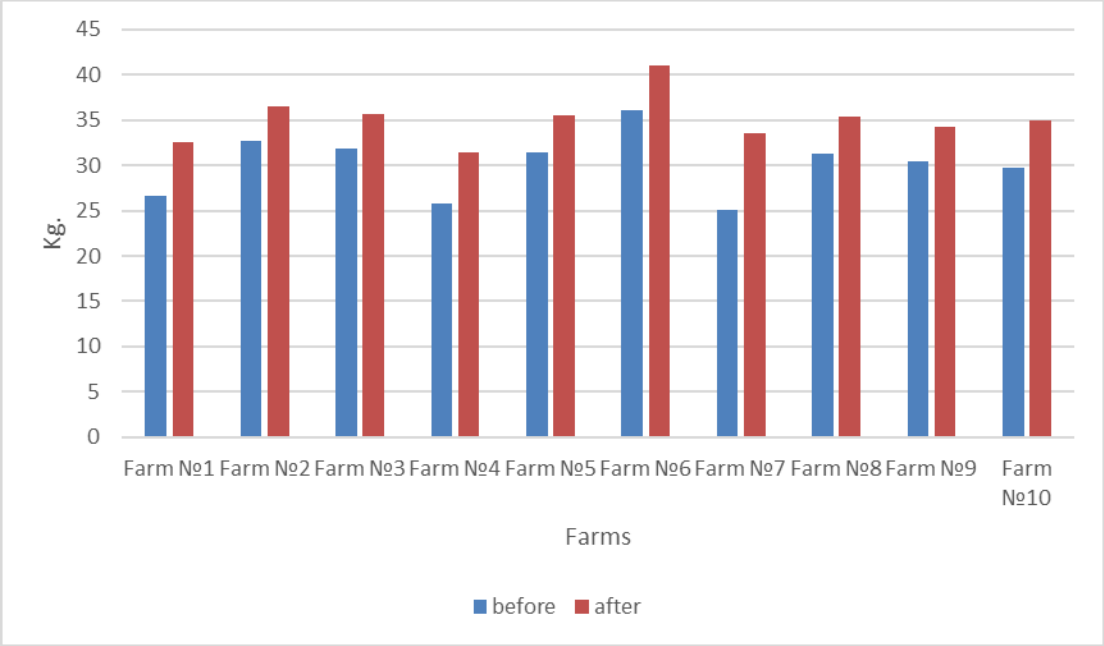


**Figure 2.** Average milk yield at the dairy farms after six months of FI (PRC) use.

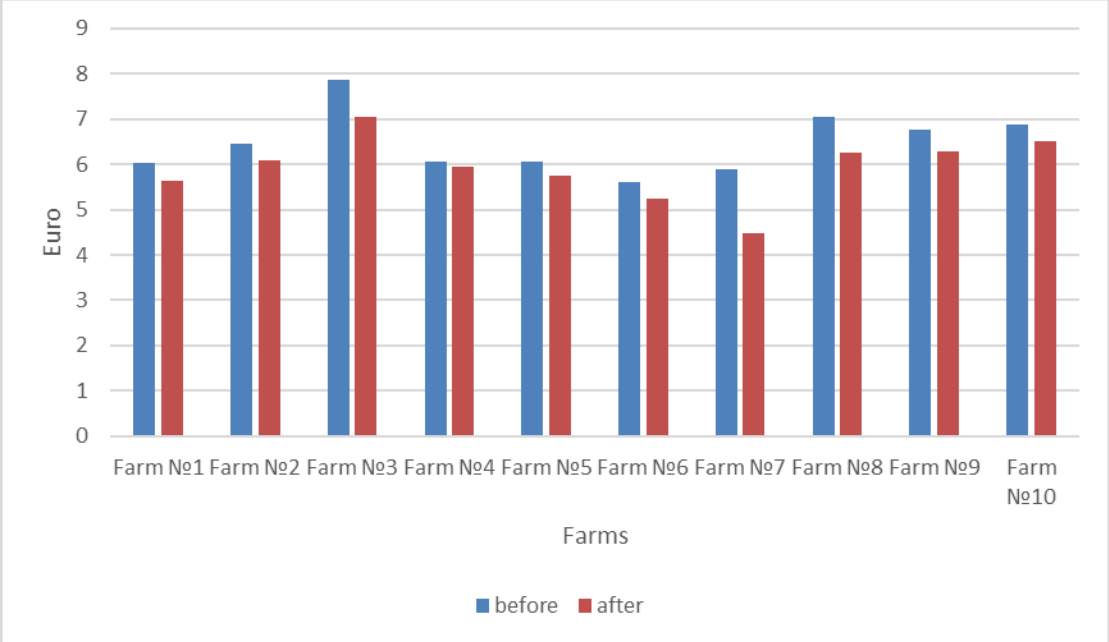


**Figure 3**. Cost of TMR at the dairy farms before and after the implementation of FI (PRC).

**TABLE 1.** Milk quality parameters indicators after six months of FI ("PRC") use

| | Fat before the usage of "PRC", % | Fat after the usage of "PRC", % | Total protein before the usage of "PRC", % | Total protein after the usage of "PRC", % | SCC before the usage of "PRC", cells/ml | SCC after the usage of "PRC", cells/ml |
|---|---|---|---|---|---|---|
| **Farm №1** | 3.65 | 3.85 | 3.05 | 3.20 | 550 000 | 163 000 |
| **Farm №2** | 3.78 | 3.82 | 3.34 | 3.35 | 221 000 | 183 000 |
| **Farm №3** | 3.80 | 3.85 | 3.35 | 3.40 | 455 000 | 301 000 |
| **Farm №4** | 4.00 | 4.0 | 3.40 | 3.42 | 352 000 | 287 000 |
| **Farm №5** | 3.85 | 3.85 | 3.25 | 3.30 | 347 000 | 208 000 |
| **Farm №6** | 3.85 | 3.75 | 3.35 | 3.29 | 332 000 | 179 000 |
| **Farm №7** | 4.20 | 3.95 | 3.43 | 3.45 | 405 000 | 228 000 |
| **Farm №8** | 4.05 | 3.90 | 3.38 | 3.41 | 478 000 | 309 000 |
| **Farm №9** | 4.25 | 3.95 | 3.50 | 3.45 | 117 000 | 92 000 |
| **Farm №10** | 4.40 | 3.90 | 3.60 | 3.38 | 241 000 | 146 000 |

**TABLE 2.** Health parameters of the dairy cattle after six months of FI ("PRC") use

| | Farm №1 | Farm №2 | Farm №3 | Farm №4 | Farm №5 | Farm №6 | Farm №7 | Farm №8 | Farm №9 | Farm №10 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Cases of mastitis before the usage of "PRC" clinical mastitis incidence per 100 cows per year based on routinely collected herd data** | 42 | 33 | 35 | 36 | 32 | 41 | 32 | 35 | 29 | 32 |
| **Cases of mastitis after the usage of "PRC"** | 31 | 32 | 27 | 33 | 28 | 34 | 30 | 30 | 27 | 29 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **clinical mastitis incidence per 100 cows per year based on routinely collected herd data** | | | | | | | | | | |
| **Open days before the usage of "PRC"** | 128 | 155 | 142 | 185 | 144 | 125 | 150 | 147 | 155 | 136 |
| **Open days after the usage of "PRC"** | 122 | 146 | 135 | 172 | 138 | 114 | 142 | 139 | 148 | 127 |
| **Rumination before the usage of "PRC", %** | 35 | 37 | 34 | 32 | 36 | 35 | 31 | 32 | 34 | 31 |
| **Rumination after the usage of "PRC", %** | 39 | 42 | 42 | 38 | 43 | 42 | 40 | 41 | 39 | 41 |

Considering the FI (PRC) as an investment for the farmers, we performed its economic evaluation using ROI (Return on Investment), IRR (Internal Rate of Return), and payback period indicators. Table 3 and 4 present the calculation of economic performance of the 10 dairy farms, where the average payback period is 1.5 months, while the average profit per day per cattle is 1.45 euros. The calculation of farms' economic performance, includes only profit from extra milk yield and decrease of TMR cost.

**TABLE 3.** Economic performance of the dairy farms

| **Farm** | **ROI (%)** | **IRR (%)** |
|---|---|---|
| **1** | 1420 | 345 |
| **2** | 890 | 187 |
| **3** | 1108 | 281 |
| **4** | 1081 | 233 |
| **5** | 977 | 212 |
| **6** | 1284 | 284 |

| | | |
|---|---|---|
| **7** | 1525 | 362 |
| **8** | 1127 | 299 |
| **9** | 883 | 176 |
| **10** | 920 | 248 |

**TABLE 4.** The mean parameters of the dairy farms' economic performance

| | |
|---|---|
| **Mean ROI (%)** | 1122 |
| **Mean IRR (%)** | 263 |
| **Mean payback period, months** | 1.5 |
| **Mean profit per cow per day, euro** | 1.45 |

Due to the scarcity, most of the farmers have problems with payments. Thus, the company offers deferred payments and discount once the farmer pays on time, he gets a lower price. Moreover, the farmers may become dealers and have an additional income.

Company conducts several types of training and seminars about feeding, animal health, and sustainability, webinars with R&D. Knowledge transfer is one of the most important elements of the company. Regular seminars and training permit farmers to get extra knowledge on the latest innovative technologies and approaches in feeding and to feel participants in the process. Visiting progressive farms increase the farmers' inspiration and involvement. Farmers get training and additional education in the required field according to their issues and demands. Moreover, upon request company provides additional services such as headhunting, harvesting, etc. for the farms depending on their needs free of charge.

Company substitutes expensive, brought from afar feeding materials like soybean meal with local produced rapeseed and sunflower meal which supports local production. Moreover, the CO2 footprint of brought from afar feeding materials like palm oil-based products, and soybean meal remains high enough (FAO 2010), the switch to locally produced feeding materials allows to contribute to its reduction. Moreover, the total elimination of palm fat, and part or total of soybean meal contributes to sustainability, since the production of palm fat causes deforestation (Vijay et al. 2016). The elimination of the above-mentioned ingredients could allow farms in the European continent to operate in a sustainable way. In fact, with purchase of frugal innovative product (PRC) farmers get numerous additional benefits.

**Conclusion**

Our research demonstrates how frugal innovative products combined with organisational innovations can effectively serve underserved customers farmers in the dairy livestock industry in European countries and play an essential role in sustainable development. It has examined how FI benefit the provider of FI (seller) and receiver of FI (farmer) in terms of process. We analysed a single case study of frugal innovations through the lens of organisational innovations and frugal innovative products in conditions of livestock dairy farming. We found the main organisational innovations are split into two categories, customers and organisation, which compromises high customisation and personal approach, empowerment of customers, customer involvement, education and training for the customer, 'hyper care' for customers, expanding of seller's responsibilities, flexible payments; and organisation including empowerment of employees; collaboration with R&Ds (open innovation). The frugal innovative product represents as affordable, sustainable, efficient, and highly functional. These lead to the benefits for the provider (seller) and receiver (farmer), where the main benefits for the seller are profit from sales and customer loyalty (long last relationship with a customer); and for the farmer from the economics perspective significant increase of profitability, an increase of productivity (boost of average milk yield), a decrease of vet expenses, reduction of feeding costs, production of a high-quality product (improvement of milk quality), flexible payments, additional profit from the dealership; from the perception of

sustainability, improvement of animals' health, usage of local feeding materials (support of local production); from the social perspective, training and consultations; and from service, additional services free of charge. Our research demonstrates how important may appear FIs in dairy livestock industry, the way how they benefit farmers' communities and businesses. The company serves the FI in European countries, where usage of organisational innovations and frugal innovative products provide a synergy effect with numerous benefits. Organisational innovations allow the company to be flexible, to keep close relationships with customers, and to reduce capital investments collaborating with R&D and manufacturing, while frugal innovative products satisfy the main requirements of the customers. The main requirements of the dairy farmers refer to an increase of milk boost (productivity) along with health improvement and profitability. Thus, it comes challenging to satisfy their needs with conventional solutions, however, our study demonstrates that frugal innovation has the ability to tackle these issues.

This research has a number of implications for practitioners. First of all, from the perception of sustainability we introduced the novel feed sources, since livestock provides approximately forty percent of total agricultural production in developed it states the necessity of the livestock enhancing feeding system along with animal welfare. Our research demonstrates that FI improves the livestock feeding system and could be implemented globally in the future. Also, FI addresses the environmental footprint of livestock supply chains by elimination of brought from afar such feeding ingredients as palm fat and soybean meal; substitution of soybean meal with local ones, like rapeseed and sunflower meal, meanwhile increasing productivity. Hence, our research demonstrates FI as a contributor to responsible and sustainable livestock production. Animal welfare is one of the significant elements of sustainability and farm profitability (Broom 2021). Our research demonstrates that FI presented by the company has a positive impact on the welfare of the animals, particularly the improvement of fertility, digestion, reduction of inflammatory diseases, increase of productive life of cow. Hence, generating a frugal mentality, philosophy, approach in researchers, practitioners, and policymakers is essential for

contribution to sustainable development goals (SDG). One of the significant benefits of FI for the farmers is profitability. Our study demonstrates the positive impact on the economic efficiency of the farms, based on such economic indicators as ROI, IRR, and payback period. Such approach creates benefits for seller as well, such as profit and loyal long last relationships with the customer. This research could be useful for dairy farmers, managers of the dairy livestock industry, practitioners from other fields, and policymakers. Our research has several limitations, hence providing new future research paths. We explored only one case in this industry, exploration of more cases could bring new deeper insights into the dairy livestock industry. Extending the research to other livestock farming and agricultural-related industries could enrich the knowledge of FI in these particular industries. Moreover, exploration of FI using case studies from other industries may add significant value to the research domain of FI. The selected case study was explored in conditions of European countries, by extending the geography of research such as other developed countries or developing countries could bring new insights of FI phenomena according to the geographical location. We have analysed data retrieved only from ten farms, enlarging the number of farms in future research could deliver other insights and provide information for statistical analysis. This study is one of the first that analyses the benefits of FI in dairy farming, in terms of profitability, sustainability, and social aspects, it is presented by case study and the limited number of farms, however, for future study large scale research is recommended for confirmation of validity. As FI in the livestock industry and process of its benefits are emerging fields of research we used case study as qualitative method, adding quantitative methods to verify the construct, combining with qualitative or implementing mixed methods could provide new directions of research and explore the research from another perspective. PRC allows to eliminate expensive and brought from afar feeding ingredients, while increasing the productivity of the farms and improving health parameters of the animals, for future research we recommend to investigate how disruptive the product (PRC) is in the dairy livestock industry. Sustainability is one of the important elements of the FIs and livestock industry. Also, for future research, we recommend to implement quantitative methods to assess the contribution according to

sustainable development goals, such as a decrease of CH4 in dairy livestock; deeper research on the use of local feeding materials, and CO2 footprint. Hence, integrated approaches in policy-making could bring essential insights from practical and academic perspectives. Also, cross-country comparison could bring useful insights according to different conditions. For future research also could be useful to conduct the research according to the groups of ruminants which are used for yielding such as goats, dairy cattle, sheep, buffalos. In brief, considering the emerging stage of the research domain, FIs offer plentiful avenues for future research.

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## 3.7. Frugal innovation and economic performance of a dairy livestock farm

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Paper “Frugal innovation and economic performance of a dairy livestock farm” is an original research article which is published in Polish journal of environmental studiesissn:1230-1485 Scopus Q2, percentile 55 (General Environmental Science) WOS Science Citation Index Expanded,Q2, IF 1.871It is an international, transdisciplinary journal publishes original research, technical notes, book reviews, and conference reports aimed at environmental, and sustainability research and practice, the journal devoted to management, innovations in terms of sustainability and environment, including frugal innovations from theoretical and practical perspectives including applied, empirical and review research. One of the journal’s section is dedicated to the management science, decision making and innovations. The main topics of the journals are cleaner production and technical processes, sustainable development and sustainability, sustainable consumption; environmental and sustainability assessment; sustainable products and services; corporate sustainability and corporate social responsibility; education for sustainable development; governance, legislation, and policy for sustainability. Our study contributes to the journal from the management perspective examining the frugal innovation in dairy farming in terms of milk production, economic efficiency for a farmer, and ecological impact. We propose the methodological approach to estimate the effectiveness of frugal innovation management. The research methodology is based on testing the effectiveness of polysaccharide regulatory complex, a supplementary compound feed, in dairy cattle breeding, the proposed integral indicator of frugal innovation management

effectiveness and regression analysis of the factors that create its level. Hence, we aim to explore the complex nature of frugal innovation and the need for its effective implementation, that goes beyond the purely economic benefits and takes into account socio-environmental and direct farming effects of operation for cleaner production and sustainability in the end.

**Abstract**

In times of resources scarcity, frugal innovation attracts more and more attention of scholars and practitioners. Dairy farming is one of the vulnerable industries in developed and developing countries, requiring higher milk productivity, financial support of farmers, meanwhile reducing methane. It is a challenging issue to increase the milk production and decrease the costs in a sustainable way. This study attempts to examine the frugal innovation in dairy farming in terms of milk production, economic efficiency for a farmer, and ecological impact. The study aims to form a methodological approach to assessing the effectiveness of frugal innovation management. The research methodology is based on testing the effectiveness of polysaccharide regulatory complex, a supplementary compound feed, in dairy cattle breeding, the proposed integral indicator of frugal innovation management effectiveness and regression analysis of the factors that form its level. The scientific contribution of this study is the proposed methodological approach to assessing the effectiveness of managing dairy cattle farm innovation. It proves the complex nature of frugal innovation and the need for its effective implementation, going beyond the purely economic benefits and taking into account socio-environmental and direct farming effects of operation. This study's results present the potential ability of frugal innovation to become disruptive due to significant changes in the common feeding rations of the dairy cows; however, this could be a future path for research. The research presents the way for the dairy farming to become more effective and sustainable. The findings of this research will be insightful for scholars and practitioners who are interested in frugal innovation in dairy farming and effective dairy farm production.

**Keywords:** frugal innovation, dairy farming, livestock, feeding ration, economic effect, socio-environmental effect, field experiment, dairy farms, economic performance, feed, polysaccharides regulatory complex

## Introduction

The topic of innovation has been widely studied, most often from the technological perspective. However, according to Pfotenhauer and Juhl (2017), it is only part of the matter: the focus of innovation on the technology-market dyad means that innovation is both welcomed for its ability to "disrupt" societies and "change the world," and this disruption has nothing to do with the political and social aspects of a state. This idea allows drawing two conclusions about how the discourse on innovation has evolved. First, innovation is seen as an engine of economic development, led by companies and governments in developed countries. In recent years, however, new ideas have come from poorer emerging economies instead of rich developed ones. Initially, it seemed to be a type of innovation that served only a population without funds. However, today it is observed that companies in advanced economies face competition from less expensive and more effective innovation from emerging economies. This has prompted companies in advanced economies to look for ways to innovate to serve markets in their own countries (Liu and Atuahene-Gima, 2018; Pisoni et al., 2018). Second, in addition to the traditional emphasis on technological and profitable innovation, other types of innovation are now gaining relevance. This refers to innovation in livestock production, namely, the development of goods and services that meet the needs of farms while creating new relationships or collaborations. Frugal innovation benefits society as a whole and improves its ability to act (Hossain, 2020), but it does not arise from the search for absolute profitability. Microfinance, which initially meets the goals of reducing disease among animals, improving their nutrition and health, is a textbook example of this kind of innovation. New concepts also include frugal innovation, which meets the needs of the population in a simpler way, without the need for large investments in research and technological development (R&D). On the contrary, because of an unfavorable target audience, this type of innovation tends to offer a new,

less costly, and sustainable solution. Cost-effective innovation does not avoid profitability, but its impact goes beyond that, as it often generates local benefits. In this sense, frugal innovation belongs to social innovation, although a priori it is not aimed at the welfare of society. Frugal innovations today are a reaction to the technological-economic paradigm, which prevails, but their application in animal husbandry is ambiguous and remains rather fragmented (Lee et al., 2019). Moreover, the understanding of frugal innovation is still imprecise due to the lack of criteria for defining it (Santos et al., 2020).

In this context, the research aims to form a methodological approach to assessing the effectiveness of managing frugal innovations. The study was carried out on the basis of polysaccharide regulatory complex (PRC) introduction in dairy farming and the study of its economic and environmental effects. Polysaccharide regulatory complex is a supplementary compound feed based on polysaccharides that regulates rumen microbiota population (and activity) in a targeted way, including the boost of lactic acid utilization into propionate; enhancing propionic SCFA (short-chain fatty acids) production, keeping in balance acetate/propionate/butyrate ratios keeping concentrate part of the feeding ratio low; keeping blood glucose high enough to reach and sustain higher yields. Thus, the animal's body generates the right amount of energy capacity (power source) that provides: higher productivity, higher reproduction rates, stronger immunity, as well as resistance to various stresses, such as changes in the diet, seasonal decrease in the diet quality, heat stress (Buryakov & Kosolapov, 2013; Kosolapova et al., 2020). This will fill the existing scientific gap and allow one to better understand the changes taking place in entrepreneurial and innovative livestock ecosystems and determine the extent to which these forms of innovation contribute to progress in solving global problems, such as social inclusion and negative environmental impacts on farm development. In this sense, there is a clear knowledge gap on measuring the impact of frugal innovations that are not classified as technological. Therefore, this study is aimed at finding answers to such scientific questions:

first, to determine the results of PRC introduction in dairy farming;

second, to diagnose the effectiveness of frugal innovation management in a livestock farm;

third, to assess the relationship between key indicators of frugal innovations' effectiveness and their impact on the integral indicator;

fourth, to form a model of effective frugal innovation management in a livestock farm.

**Literature review**

Transformations in the understanding of innovation have led to changes in the innovation process (Meissner & Kotsemir, 2016); however, frugal innovation, as a way of thinking, process, and result (Pansera, 2018), is rather the result of responding to the daily population needs and, in this sense, refers to social innovation. The concept of frugal innovation is relatively new, so its characterization is still unclear (Tiwari et al., 2017). Its first records appear at the end of the first decade of the 21st century in the business community, and, since 2010, in the academic literature, when the successes of innovative and creative solutions originating in India began to be discussed (Bhatti et al., 2018; Hossain, 2020). Various disciplines, such as development economics, product and process design, sustainability, business strategy, and psychology in aspects such as frugal attitudes and mindset, are now being brought in to study it (Albert, 2019). Frugal innovation relates to the creative ability to do more with less. In a global scenario of resource scarcity and competition based on optimization and cost reduction, the ability to develop this type of innovation can be a solution to the many needs of diverse poor communities. The term "frugal" is used to refer to innovations that create products and services at low cost, as well as the systems and processes used to do so (Khan and Melkas H., 2020). These are innovations born and developed for the poor in response to local problems, using ingenious solutions. According to Lange et al. (2021), these are affordable products, and according to Meagher (2018), frugal innovation includes a frugal mindset, process, and outcome, but these elements can be implemented separately. The authors initially define frugal innovation as innovation created in developing countries, from which a new product emerges, aimed at reducing costs and meeting the needs of the population at the base of the pyramid (BoP) (David-West et al., 2019). However, in literature, a frugal innovation can be called differently depending on different researchers, a country in which it occurred, technological content or

market perception (Bhatti et al., 2018). At first glance, one might say that developing new products and services can be cultural because frugal innovations meet the local needs of a population with fewer resources. The Indian term jugaad innovation (Ananthram and Chan, 2019) or the Brazilian jeitinho (Orra, 2020) are local names for frugal innovation, a new way of finding efficient, affordable, and sustainable solutions developed in complex environments, with limited resources and with social value.

The definition of frugal as such brings one to the notion of low-cost. However, Prabhu (2017) argues that low-cost innovation is a different type of innovation. First, its target market is consumers not only in developing countries, but also in developed countries. Second, the innovator tries to reduce costs without changing the fundamental characteristics of a product too much; often the cost reduction is based not only on innovative business models, but also on lower wages. Another name associated with frugal innovation is reverse innovation. Again, some authors believe that this type of innovation is not synonymous with frugality, because it is essentially a transfer of ideas from the South - developing countries - to the North - developed countries (Agarwal et al., 2020). Cortonesi et al. (2019) deepen the characterization of international innovation flows involving developing countries and broaden the definition of reverse innovation. In addition to the fact that this concept is associated only with the introduction to developed markets of products developed for developing countries, they distinguish two other types of investment in global innovation flows associated with the concept and product development stages.

Another interesting contribution, although there is still little evidence in the literature, belongs to Montoya et al. (2018), who presented a case of reverse innovation, where the flow is not international but occurs in the Mexican health sector. Moreover, da Silva et al. (2019) argue that frugal innovations provide lower total cost of ownership, are reliable and easy to use, and because cost reduction is one of the main points of frugality, firms need to achieve economies of scale to compensate for the low margins they will receive from these sales. As a result, they must have access to the large-scale market. This aspect separates frugal, low-cost, and reverse innovation. The turning point comes when considering the

market itself. That is, products designed specifically for the BoP segment must meet certain basic standards: they must be affordable, functional and durable. Moreover, because of their nature and target audience, their development and production require the conscious inclusion of criteria that take into account that the end product must be economically accessible and have a positive impact on the quality of life of the population - for example, social innovation. This often results in production processes that require less equipment and more creativity. As a result, this new innovative model seeks to penetrate the price-sensitive consumer market, profiting from low margins and high sales volumes (Tiwari and Bergmann, 2019).

Frugal innovation is the result of a bottom-up innovation process aimed at needy populations in emerging markets. Consequently, for an innovation to be considered frugal, it must optimize a product's characteristics, starting with a noticeable reduction in cost and focusing on the main features of its functionality - it must be reliable, portable, adaptable, and simple (Weyrauch and Herstatt, 2016). These features distinguish it from conventional economic and technological innovations, which are created from the top down on the basis of what would be nice to have and the need to generate desirability through attractive design. In a more detailed description, the Frugal Innovation Lab at Santa Clara University (Basu et al., 2013) identifies ten key features that a frugal innovation must have:

(1) robustness or increased resilience to use;

(2) lightweight to be portable because of the difficulty and inconstancy of transportation;

(3) mobile solutions that can be connected anytime and anywhere;

(4) user-oriented or human-centered design;

(5) simplification, minimization of features and functional requirements;

(6) new forms of distribution through non-traditional channels;

(7) adaptation to the local environment;

(8) use of local materials in manufacturing;

(9) renewable technologies;

(10) affordability, representing low operating and production costs.

Frugal innovations meet the social inclusion needs of people at the bottom of the pyramid, but they have also forced developed countries to develop projects with fewer resources and serve very price-sensitive market segments (Tiwari and Bergmann, 2019). In frugal innovation, both the needs of the population and the conditions of developing countries - extremely limited resources and institutional gaps (Batthi et al., 2018) - are determining factors in the development of product concepts and business models. In addition, local entrepreneurs work to improve the social and economic conditions of the most disadvantaged. Consequently, although social purpose is not their essence, frugal innovations can be seen as innovations with social characteristics, that is, creative and innovative ways to solve social problems through local entrepreneurs (Haudeville and Le Bas, 2016), which contribute to social and economic mobility (David-West et al., 2019). Despite this, and recognizing that there is a prevailing positive view of frugal innovation and its beneficial effects on development, there is also criticism of its effects, as it is believed that it may exacerbate capitalism and, to some extent, increase inequality (Akbar and Subramaniam, 2019). Frugal innovation is often associated with sustainability (environmental and social), as it is characterized by a reduction of resource consumption (raw materials, production and financial means, energy, fuel, water, waste). It is more affordable and accessible than traditional innovations (Albert, 2019). Minimizing resource consumption makes products affordable, which in turn leads to environmentally sustainable consumption, an inclusive approach to the concepts of innovation and frugality (Vanegas et al., 2017). Frugal innovations arise at the grassroots level in developing countries and use new business models to promote sustainable development. Frugal innovation transforms underserved grassroots customers into new consumer groups (Hossain, 2021). In addition, there are synergies in the concepts of frugal innovation and sustainability in supply chains (Shibin et al., 2018). Frugal innovation emerges as a paradigm that challenges traditional areas of innovation, which may have the potential to bring together diverse stakeholders to achieve sustainable development goals (Rosca et al., 2018).

However, summarizing the above information, frugal innovation in the context of the present research is the implementation of innovative solutions for local problems in sustainable, affordable, and effective way.

The global growing demand for milk and milk products pushes the production of dairy products including the developed and developing countries. World per capita consumption of dairy products has a tendency to raise by 1.0% p.a. during the decade (OECD, 2020).

An important factor in increasing the efficiency of dairy cattle breeding development is the development and implementation of innovations. The need for their application is due to the negative phenomena that take place in this industry. Innovations in dairy cattle breeding should be aimed primarily at:

- increase in productivity and expansion of dairy cattle;

- use of the best world and domestic genetic resources;

- radical modernization of fodder production, animal housing technology, milking technology using the leading technical developments;

- prevention or introduction of effective and relatively inexpensive disease treatment schemes. Thus, the dairy cattle breeding industry can reach a higher level only with:

- intensification of dairy cattle breeding;

- rational use of the resource potential of the industry;

- improvement of the cattle's genetic potential;

- application of intensive milk production technologies, aimed at increasing the production of competitive products, including by improving the quality and quantity of milk.

At the same time, many problems still remain understudied and require more in-depth study. This is, in particular, the issues of dairy cattle breeding development on an innovative basis. Therefore, this study is aimed at assessing PRC in dairy cattle breeding with the study of its economic and environmental effect. This contributed to the formation of the following scientific hypotheses:

H1: the proposed PRC has a positive effect on farm performance;

H2: the effectiveness of managing frugal innovation on a livestock farm depends more on the economic factors of its implementation;

H3: the effectiveness of frugal innovation management on a livestock farm depends to a large extent on the socio-environmental factors of its implementation;

H4: the effectiveness of frugal innovation management on a livestock farm depends to a large extent on the factors of farm functionality.

**Materials and methods**

The testing was conducted on Campus (Evrofarma). Evrofarma is a dairy factory that has a subsidiary farm "Campus", it also owns biogas production "Biomesti". The company carries out a full milk production cycle, including methane utilization. Campus (Evrofarma) is the biggest in Greece and has 2700 cows, including 1380 high-yielding dairy cows. The farm is modern, uses quality standards and innovation. The farm has comfortable conditions, bedding per cow is 20 m2, 5 times more than EU average. The study used the data collection software "GEA Westfalia", which is integrated in the farm's IT system. It was applied to collect statistical information about milk production volume.

For the monitoring and control of health parameters, blood tests were conducted, provided by the independent laboratory, and control of somatic cells count. Animal health and disease data were provided by farm veterinarians and company records.

Furthermore, the data (health parameters of the dairy cows; volume of milk production) were collected before the start of PRC implementation (see Appendix I). The input data of the farm were investigated; interviews with farm owners and vets about the product effects were conducted. The farm owners and vets defined the priorities for the farm: first – boost milk production, second – improve animal health (mastitis, laminitis decrease), and third – reduction of feeding costs. Check sheet was used as a basic quality tool to collect data, and check list – as protocol for the accurate processing of testing. All the data were analyzed, and the results are reflected.

Testing lasted for 3 months from 4 May 2020 to 4 Aug 2020.

There were around 200 high-yielding cows: 50-70 cows in dry (20 days to calving, “close-up”) period and 140-160 cows (GP6 group) in fresh period; the cows have been fed with PRC for 2 months and 28 days. The dry group was fed 20 days before the calving (Fig. 1).

PRC is a regulatory complex based on polysaccharides, with a prebiotic effect, which supports dairy cows, provides power and capacity to overcome a number of stresses and health issues, while improving productivity (milk yield). It hits the rumen of the cow, meanwhile stimulates the growth of useful biota (microflora) in a targeted way, including the increase of lactic acid utilization into propionate, thus intensifying propionic SCFA production, balancing acetate/propionate/butyrate ratios while keeping concentrate part of the feeding ratio low and blood glucose balanced to reach and sustain higher yields. The use of PRC provides the establishment of effective energy metabolism of the animal, it impacts mainly in three ways: maximizing the activity of cicatricial microflora (selectively cellulolytics and lacto-enzymes); protection and activation of liver cells (increased gluconeogenesis); activation of intestinal microflora and increased intracellular metabolic processes. Special activated microflora of the rumen and intestines with maximum efficiency vanishes roughage and metabolic products of the concentrated part of the feed ration, which protects against acidosis and ketosis and retention of productivity in case of forced temporary using of lower quality feed (low metabolic energy) (Buryakov & Kosolapov, 2013).

It has a powerful stimulating effect on the rumen of a cow, eliminates acidosis due to the activation of specific groups of microorganisms, increases propionate production, and fights insulin resistance, changes dietary eatability (increases forage/roughage, and decreases concentrate part).

The shift in the equilibrium between lactate-synthesizers and lactate-utilizers in favor of the latter, as has been experimentally shown, stimulates increased production of propionate, the main energy molecule of the cow, and also prevents the occurrence of lactic acidosis. An increase in the concentration of microbial propionate in the blood and liver allows the cow to safely reduce accumulated fat levels,

and to utilize surplus acetyl coenzyme A accumulating as a result of fat assimilation. This phenomenon stays behind of the anti-ketosis action. A combination of the above effects allows for soft removal of insulin-resistance in the cow. It also has an immunizing effect - the stimulation of energy production in sufficient quantities due to the harmonious functioning of rumen and liver leads to the removal of the immuno-depressant effect of energy deficit (decreasing mastitis, endometritis, etc.). It has a hepatoprotective effect, so that liver functions properly and the propionate formed in the rumen is effectively transformed into blood glucose. By utilizing hydrogen (generated by fermentation of feed ingredients) into the propionate path, pH in the rumen is kept high enough to allow bacteria to stay active and grow enough for optimal fermentation of feed ingredients. Normally hydrogen is utilized by methane generating archaea, resulting in enteric methane production. PRC redirects the process of hydrogen utilization to propionic SCFA production. Thus, the enteric methane production per unit of milk decreases in reverse proportion to the increased production of propionate. Propionate is a precursor of blood glucose in gluconeogenesis taking place in the liver. Animal health and productive longevity are logical consequences of dealing with metabolic disorders, regulating energy balance by supporting healthy functioning of the digestive system (rumen, intestine, liver), getting animals rid of insulin resistance (Kosolapova et al., 2020). Thus, it aims at improvement of health of a dairy animal and an increase of the milk productivity in a sustainable way. Term sustainability is defined by Callicott and Mumford (1997) as meeting human needs without compromising ecosystems.

Dosage of feeding was 300 grams per head per day.

Cows were fed with PRC with total mixed ration (TMR), from the day of calving till 21st or 28th day. Every Thursday the animals from the fresh group were transferred to the other groups: to the group 1 - cows of 2nd lactation period; to the group 3 - cows of 3rd and 4th lactation periods; to the group 5 - 5th and later lactation periods; to the group 8 - jersey cows only, from all lactation periods; and to group 13 - cows of 1st lactation period (first calving). The group 10 (late in lactation, cows from 200 to 305

days (average 250 days) after calving) was identified as control group and was not fed. The group 2 was identified as control group and was not fed. Then, the curves of lactations were compared.

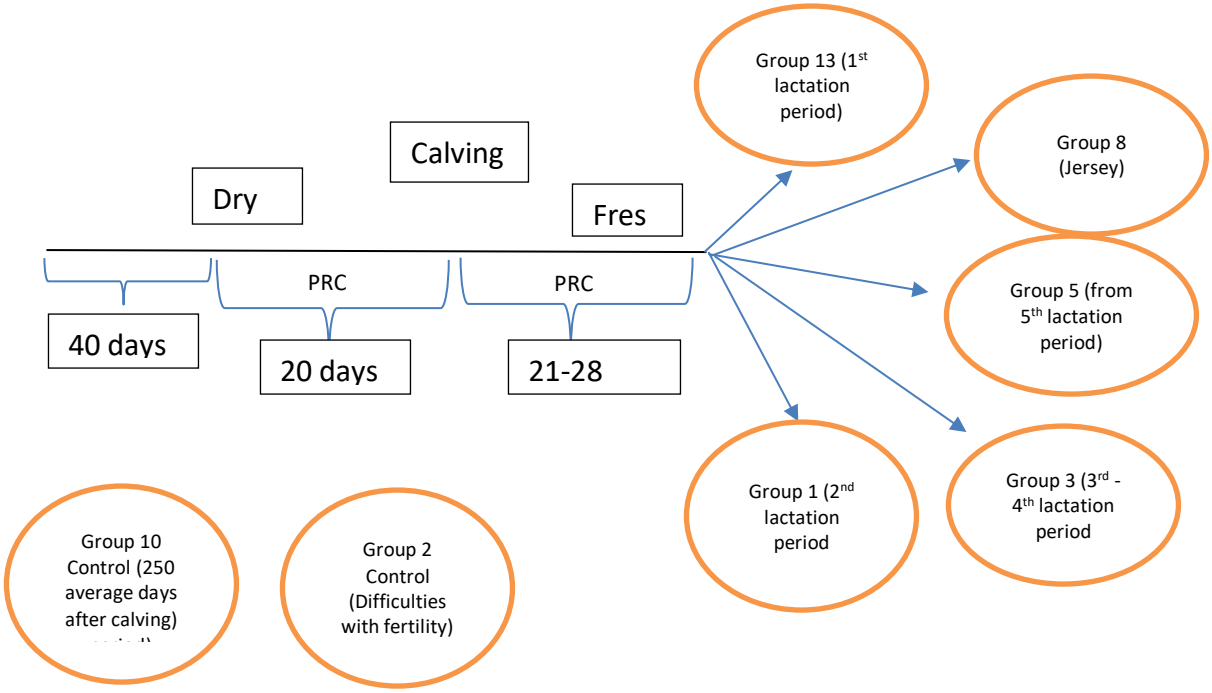


Figure 1. Testing process

Source: generated by the author

From the time of introducing PRC, the milk production in the groups 1, 3, 5, 8, and 13 was monitored. The control groups (GP10 and GP2) were not fed with PRC.

This study focuses on the fact that the introduction of frugal innovations on a livestock farm implies an increase in its efficiency in three areas: socio-environmental, economic, and farm efficiency as a whole. These areas impact the proposed comprehensive indicator of frugal innovation management of a dairy farm in the context of three indicators - socio-environmental efficiency of innovation (SEI), economic efficiency of innovation (EEI), and farm efficiency due to innovation (FEI). Therefore, to confirm this assumption, induction in the opposite direction is used. Wherein, $x_1, x_2, x_3$ denote the

presented parameters of the effectiveness of frugal innovation management on a livestock farm, that is, SEI, EEI, and FEI. Since the efficiency of farm operation has a special role, in accordance with this, the optimizing model in relation to the control action will be expressed as follows:

$$\max_{e_3} aE_2x_3 - \beta E_2(t_3 - t_0) - e_1 - e_2 - e_3$$

the following condition must be fulfilled:

$P_2(x_3 = 1) = \chi_3(1 - exp^{-\lambda_3 e_3})x_2$ ,

$t_3 = t_2 + a_3$ ,

$e_3 \geq 0$ .

It should be noted that $t_3 = t_2 + a_3$ is fixed in the proposed formulation and does not depend on the controlling influence $e_3$. At the same time:

$$E_2x_3 = 1 \cdot P_2(x_3 = 1) = \chi_3(1 - exp^{-\lambda_3 e_3})x_2.$$

This contributes to the following:

$$\max_{e_3 \geq 0} a\chi_3(1 - exp^{-\lambda_3 e_3})x_2 - e_3,$$

Based on this, the solution is easily found from first-order conditions:

$e_3 = \frac{1}{\lambda_3} ln a\chi_3\lambda_3$ , if $a\chi_3\lambda_3 > 1$ and $x_2 = 1$,

$e_3 = 0$, if $a\chi_3\lambda_3x_2 \leq 1$.

Thus, the optimal model $F_3(\cdot,\cdot,\cdot)$of controlling influences $e_3$in the third direction of the proposed model is given as:

$e_3 = F_3(e_2, x_2, t_2) = \frac{1}{\lambda_3} ln a\chi_3\lambda_3$, if $a\chi_3\lambda_3 > 1$ and $x_2 = 1$,

$e_3 = F_3(e_2, x_2, t_2) = 0$, if $a\chi_3\lambda_3x_2 \leq 1$.

The optimal model of frugal innovation management actually has no dependence on the amount of controlling influence on the other direction $e_2$, nor on the timing of achieving the goals $t_2$, but depends

on the actual efficiency in other areas. Thus, this points to the need for effort (controlling influence on farm efficiency – $e_3$) to ensure further farm performance ($x_2 = 1$), than in the case of a decrease in its level ($c$).

Similarly, to the direction of improving farm efficiency, the optimal controlling impact of innovations on a livestock farm's economic efficiency is formulated:

$$\max_{e_3} aE_1x_3 - \beta E_1(t_2 + a_3 - t_0) - e_1 - e_2 - E_1e_3$$

In this case, it is necessary to satisfy the corresponding conditions, therefore it should be noted that:

$$E_1x_3 = E_1(E_2(x_3)) = E_1(\chi_3(1 - exp^{-\lambda_3 e_3})x_2)$$

Considering the level of optimal impact of frugal innovations on a livestock farm $e_3$, defined earlier, one can state:

$E_1x_3 = \chi_3(1 - \frac{1}{a\chi_3\lambda_3})P_1(x_2 = 1)$, if $a\chi_3\lambda_3 > 1$ and $E_1x_3 = 0$, if $a\chi_3\lambda_3 \leq 1$.

$$E_1e_3 = \frac{1}{\lambda_3} ln(a\chi_3\lambda_3)\ P_1(x_2 = 1) = \frac{1}{\lambda_3} ln(a\chi_3\lambda_3)\chi_2(1 - exp^{-\lambda_2 e_2})x_1,$$

if $a\chi_3\lambda_3 > 1$, and $E_1e_3 = 0$, if $a\chi_3\lambda_3 \leq 1$.

Thus, if $a\chi_3\lambda_3$>1 the search for the optimal impact in the context of increasing economic efficiency $e_2$ can be reduced to:

$$\max_{e_2}(a\chi_3 - \frac{1}{\lambda_3} - \frac{1}{\lambda_3} ln(a\chi_3\lambda_3)\chi_2(1 - exp^{-\lambda_2 e_2})x_1 - \beta E_1(t_2 - t_1) - e_2$$

Considering a variable $t_2$ , one can state:

$$\max_{e_2 \geq 0}(a\chi_3 - \frac{1}{\lambda_3} - \frac{1}{\lambda_3} ln(a\chi_3\lambda_3)\chi_2(1 - exp^{-\lambda_2 e_2})x_1 - \frac{\beta}{\mu_3}(\gamma_2 e_2 - \delta_2 e_1 + a_2) - e_2,$$

which is equivalent to

$$\max_{e_2 \geq 0} -(a\chi_3 - \frac{1}{\lambda_3} - \frac{1}{\lambda_3} ln(a\chi_3\lambda_3)\chi_2 exp^{-\lambda_2 e_2} x_1 - (\frac{\beta}{\mu_3}\gamma_2 + 1)e_2.$$

Similarly, in the case $a\chi_3\lambda_3 \leq 1$the optimal control action in the context of increasing economic efficiency $e_2$ can be determined from the following:

$$\max_{e_2 \geq 0} -\frac{\beta}{\mu_3}(\gamma_2 e_2 - \delta_2 e_1 + a_2) - e_2,$$

which provides an opportunity to assert that $x_2 = 0$. Thus, if $a\chi_3\lambda_3$>1 one can argue about the optimal model of the impact of frugal innovations on a livestock farm in the context of increasing economic efficiency:

$$e_2 = F_2(e_1, x_1, t_1) = \frac{1}{\lambda_3} ln \frac{\mu_3\lambda_2\chi_2(a\chi_3 - (1+ln(a\chi_3\lambda_3))/\lambda_3)}{\beta\gamma_2 + \mu_3},$$

if $\frac{\mu_3\lambda_2\chi_2(a\chi_3 - (1+ln(a\chi_3\lambda_3))/\lambda_3)}{\beta\gamma_2 + \mu_3} > 1$ and $x_1 = 1$;

$$e_2 = F_2(e_1, x_1, t_1) = 0, \text{ if } \frac{\mu_3\lambda_2\chi_2(a\chi_3 - (1+ln(a\chi_3\lambda_3))/\lambda_3)}{\beta\gamma_2 + \mu_3} x_1 \leq 1.$$

At the same time, $e_2 = F_2(e_1, x_1, t_1) = 0$ , if $a\chi_3\lambda_3 \leq 1$.

An important component of frugal innovation management on a livestock farm is the inclusion of socio-environmental efficiency in its model, taking into account the control actions defined above in the other two directions. In this case, the target function for search $e_1$ may look like this:

$$\max_{e_1} aE_0x_3 - \beta E_0(t_3 - t_0) - e_1 - E_0e_2 - E_0e_3$$

Therefore:

$$E_0x_3 = E_0(E_1(E_2(x_3))) = E_0(E_1(\chi_3(1 - exp^{-\lambda_3 e_3})x_2))$$

Thus,

$$E_0x_3 = \chi_3(1 - \frac{1}{a\chi_3\lambda_3})E_0(P_1(x_2 = 1)) = \chi_3(1 - \frac{1}{a\chi_3\lambda_3})E_0((1 - exp^{-\lambda_2 e_2})x_1)),$$

if $a\chi_3\lambda_3 > 1$ and $E_0 e_3 = 0$, if $a\chi_3\lambda_3 \leq 1$.

Consequently,

$$E_0 x_3 = \chi_3\left(1 - \frac{1}{a\chi_3\lambda_3}\right)\left(1 - \frac{\beta\gamma_2 + \mu_3}{\mu_3\lambda_2\chi_2\left(a\chi_3 - (1 + ln(a\chi_3\lambda_3))/\lambda_3\right)}\right)P_0(x_1 = 1)$$
$$= \chi_1\chi_3\left(1 - \frac{1}{a\chi_3\lambda_3}\right)\left(1 - \frac{\beta\gamma_2 + \mu_3}{\mu_3\lambda_2\chi_2\left(a\chi_3 - (1 + ln(a\chi_3\lambda_3))/\lambda_3\right)}\right)exp^{-\lambda_1 e_1}x_0,$$

If $\frac{\mu_3\lambda_2\chi_2\left(a\chi_3 - (1+ln(a\chi_3\lambda_3))/\lambda_3\right)}{\beta\gamma_2+\mu_3} > 1$, and

$E_0 x_3 = 0$, if $\frac{\mu_3\lambda_2\chi_2\left(a\chi_3 - (1+ln(a\chi_3\lambda_3))/\lambda_3\right)}{\beta\gamma_2+\mu_3}x_1 \leq 1$ or $a\chi_3\lambda_3 \leq 1$.

As a result:

$$E_0(t_3 - t_0) = E_0(t_2 + a_3 - t_0) = E_0(t_2 - t_1) + E_0(t_1 - t_0) + a_3,$$

$E_0(t_1 - t_0) = E_0\left((\gamma_1 e_1 + a_2)\varepsilon_1\right) = \frac{\gamma_1 e_1 + a_2}{\mu_1}$ and

$$E_0(t_2 - t_1) = E_0(\gamma_2 e_2 - \delta_2 e_1 + a_2)\varepsilon_2 = E_0\left(E_1\left((\gamma_2 e_2 - \delta_2 e_1 + a_2)\varepsilon_2\right)\right) = \frac{1}{\mu_2}E_0(\gamma_2 e_2 - \delta_2 e_1 + a_2)$$

.

It can be expressed otherwise if

$\frac{\mu_3\lambda_2\chi_2\left(a\chi_3 - (1+ln(a\chi_3\lambda_3))/\lambda_3\right)}{\beta\gamma_2+\mu_3}x_1 > 1$,

$$E_0(t_2 - t_1) = \frac{a_2 - \delta_2 e_1}{\mu_2} + \frac{\gamma_2}{\mu_2\lambda_2}\ln\frac{\mu_3\lambda_2\chi_2\left(a\chi_3 - (1 + ln(a\chi_3\lambda_3))/\lambda_3\right)}{\beta\gamma_2 + \mu_3}P_0(x_1 = 1)$$
$$= \frac{a_2 - \delta_2 e_1}{\mu_2} + \frac{\gamma_2\chi_1}{\mu_2\lambda_2}\ln\frac{\mu_3\lambda_2\chi_2\left(a\chi_3 - (1 + ln(a\chi_3\lambda_3))/\lambda_3\right)}{\beta\gamma_2 + \mu_3}exp^{-\lambda_1 e_1}x_0.$$

At the same time, if $\frac{\mu_3\lambda_2\chi_2\left(a\chi_3 - (1+ln(a\chi_3\lambda_3))/\lambda_3\right)}{\beta\gamma_2+\mu_3}x_1 \leq 1$ or $a\chi_3\lambda_3 \leq 1$,

$E_0(t_2 - t_1) = \frac{a_2 - \delta_2 e_1}{\mu_2}$.

Moreover, in the case $\frac{\mu_3\lambda_2\chi_2(a\chi_3-(1+ln(a\chi_3\lambda_3))/\lambda_3)}{\beta\gamma_2+\mu_3}x_1>1$,

$$E_0e_2=\frac{1}{\lambda_2}\ln\frac{\mu_3\lambda_2\chi_2(a\chi_3-(1+ln(a\chi_3\lambda_3))/\lambda_3)}{\beta\gamma_2+\mu_3}P_0(x_1=1)=\frac{\chi_1}{\lambda_2}\ln\frac{\mu_3\lambda_2\chi_2(a\chi_3-(1+ln(a\chi_3\lambda_3))/\lambda_3)}{\beta\gamma_2+\mu_3}exp^{-\lambda_1e_1}x_0$$

.

On the contrary, in the case $\frac{\mu_3\lambda_2\chi_2(a\chi_3-(1+ln(a\chi_3\lambda_3))/\lambda_3)}{\beta\gamma_2+\mu_3}x_1\leq 1$, or $a\chi_3\lambda_3\leq 1$, $E_0e_2=0$.

Thus,

$$E_0e_3=\frac{1}{\lambda_3}\ln(a\chi_3\lambda_3)\,P_0(x_2=1)=\frac{\chi_2}{\lambda_3}\ln(a\chi_3\lambda_3)\,E_0\left((1-exp^{-\lambda_2e_2})x_1\right)$$
$$=\frac{\chi_2}{\lambda_3}\ln(a\chi_3\lambda_3)\,1-\,1-\frac{\beta\gamma_2+\mu_3}{\underline{\mu_3\lambda_2\chi_2(a\chi_3-(1+ln(a\chi_3\lambda_3))}}P_0(x_2=1)$$
$$=\frac{\chi_1\chi_2}{\lambda_2}\ln(a\chi_3\lambda_3)\,(1-\frac{\beta\gamma_2+\mu_3}{\underline{\mu_3\lambda_2\chi_2(a\chi_3-(1+ln(a\chi_3\lambda_3))}}exp^{-\lambda_1e_1}x_0).$$

If $\frac{\mu_3\lambda_2\chi_2(a\chi_3-(1+ln(a\chi_3\lambda_3))/\lambda_3)}{\beta\gamma_2+\mu_3}x_1>1$.

If $\frac{\mu_3\lambda_2\chi_2(a\chi_3-(1+ln(a\chi_3\lambda_3))/\lambda_3)}{\beta\gamma_2+\mu_3}x_1\leq 1$ or $a\chi_3\lambda_3\leq 1$, $E_0e_3=0$.

Integrating the obtained expressions into a single complex in the form of an objective function to determine the optimal model of the control action $e_1$, one obtains the following to determine $e_1$:

$$\max_{e_1\geq 0}-Aexp^{-\lambda_1e_1}-Be_1,$$

where $B=1-\beta(\frac{\delta_2}{\mu_2}-\frac{\gamma_1}{\mu_1})$,

while in the case $\frac{\mu_3\lambda_2\chi_2(a\chi_3-(1+ln(a\chi_3\lambda_3))/\lambda_3)}{\beta\gamma_2+\mu_3}>1$

$$A=-a\chi_1\chi_3(1-\frac{1}{a\chi_3\lambda_3})(1-\frac{\beta\gamma_2+\mu_3}{\underline{\mu_3\lambda_2\chi_2(a\chi_3-(1+ln(a\chi_3\lambda_3))}})x_0-\beta(\frac{\gamma_2\chi_1}{\lambda_2\mu_2}\ln\frac{\mu_3\lambda_2\chi_2(a\chi_3-(1+ln(a\chi_3\lambda_3))/\lambda_3)}{\beta\gamma_2+\mu_3}x_0+$$
$$\frac{\chi_1}{\lambda_2}\ln\frac{\mu_3\lambda_2\chi_2(a\chi_3-(1+ln(a\chi_3\lambda_3))/\lambda_3)}{\beta\gamma_2+\mu_3}x_0+\frac{\chi_1\chi_2}{\lambda_2}\ln(a\chi_3\lambda_3)(1-\frac{\beta\gamma_2+\mu_3}{\underline{\mu_3\lambda_2\chi_2(a\chi_3-(1+ln(a\chi_3\lambda_3))}})x_0)$$

,

and in case $\frac{\mu_3\lambda_2\chi_2\left(a\chi_3-(1+ln(a\chi_3\lambda_3))/\lambda_3\right)}{\beta\gamma_2+\mu_3}x_1 \leq 1$ or $a\chi_3\lambda_3 \leq 1$

$A = 0$.

Thus, it can be argued that the optimal level of control frugal impact in the direction of socio-environmental efficiency, in the case of $A\lambda_1 / B > 1$ and $B > 0$, is equal to

$e_1 = \frac{1}{\lambda_3}\ln\frac{A\lambda_1}{B}$ ; in case $A\lambda_1 \leq B$ and $B \geq 0$ , is equal to $e_1 = 0$. Therefore, it can be argued that there is no comprehensive model of frugal innovation management on a livestock farm if $B < 0$ or at the same time $B = 0$ and $A > 0$. One can assume that in practice, such a situation is not possible.

The author suggests interpreting the level of frugal innovation management of a dairy farm (based on calculating integral indicators: SEI, EEI, FEI) as a vector length (Bakaeva and Chernyaeva, 2017). The author also suggests implementing regression analysis to identify key factors for improving innovation management efficiency and predictive modeling of the resulting indicators of a dairy farm. Fig. 2 shows the scheme for constructing the vector of efficiency of frugal innovation management of a dairy farm based on the calculated integral indicators. As a result of the coordinate axes' mutual perpendicularity, one gets the vector length $\overrightarrow{IMV} = (\mathrm{SEI}; \mathrm{EEI}; \mathrm{FEI})$, which can be defined as the length of the diagonal of a rectangular parallelepiped formed from vectors $\overrightarrow{\mathrm{SEI}_i}; \overrightarrow{\mathrm{EEI}_j}; \overrightarrow{\mathrm{FEI}_k}$ and expressed as follows:

$$\overrightarrow{|\mathrm{FIMPI}|} = \sqrt{\mathrm{SEI}^2 + \mathrm{EEI}^2 + \mathrm{FEI}^2}$$

where $\overrightarrow{\mathrm{FIMPI}}$ – the length of the vector Frugal Innovation Management Performance Index;

SEI – Socio-Environmental Index;

EEI – Economic Efficiency Index;

FEI– Farm Efficiency Index.

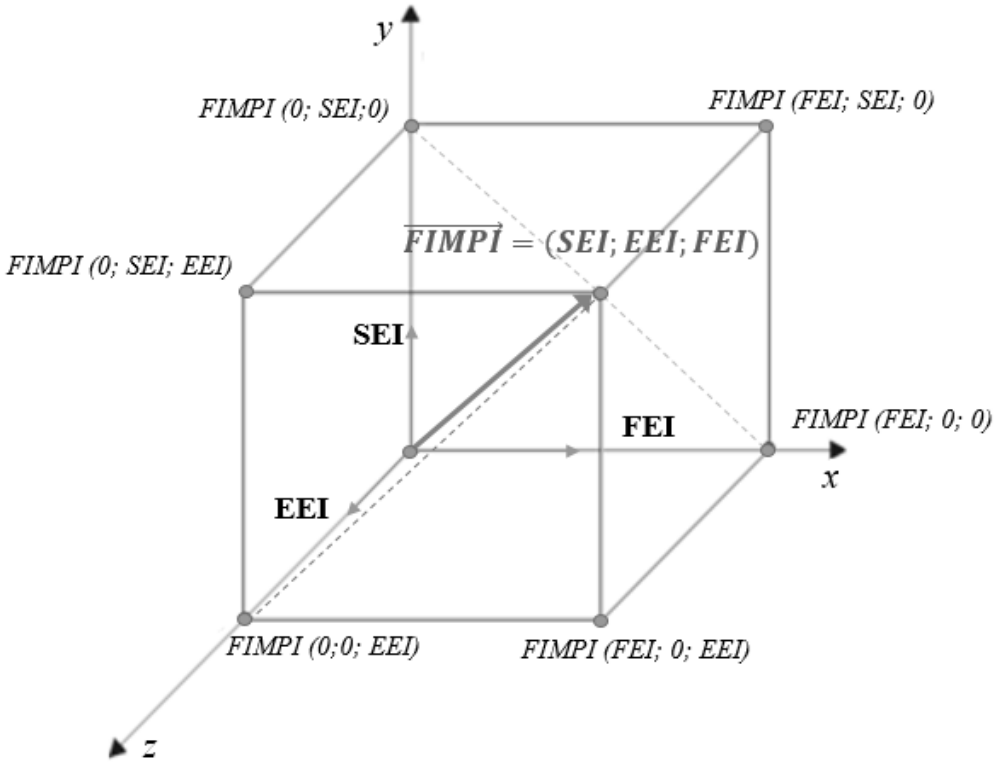


Figure 2. Scheme for constructing the vector of efficiency of frugal innovation management of a dairy farm

Source: developed by the author

Values of SEI, EEI, FEI on the specified model are determined by calculating the arithmetic mean of the indicators that are part of SEI, EEI, FEI. For example, the value of SEI is found by summing the normalized data of such indicators as the indicator of CH4 emissions, the indicator of the presence of harmful substances in the production, the level of energy production from alternative sources (in this case, biogas).

The livestock industry produces 14.5% of the global greenhouse gas (GHG) emissions (Gerber et al., 2013), meanwhile enteric methane (CH4) produced by ruminants is the largest part (17%) of world anthropogenic CH4 emissions (Knapp et al., 2014). Moreover, GHG emissions are most likely to raise by 35% until 2050 due to boost of demand and forecast increase of production (Patra, 2014).

EEI level is found by summing normalized data of such indicators as unit production costs indicator, veterinary costs indicator, production volume indicator. FEI includes such indicators as lactation level indicator, somatic cell level indicator, animal health indicator.

**Results**

After using PRC, the number of days till lactation peak significantly decreased: for 1st lactation, from 144 to 98 days; for 2nd lactation, from 81 to 56 days; and for 3rd+ lactations, from 81 to 54 days. All the lactation periods reached the minimum that had never been on the farm before (Fig. 3).

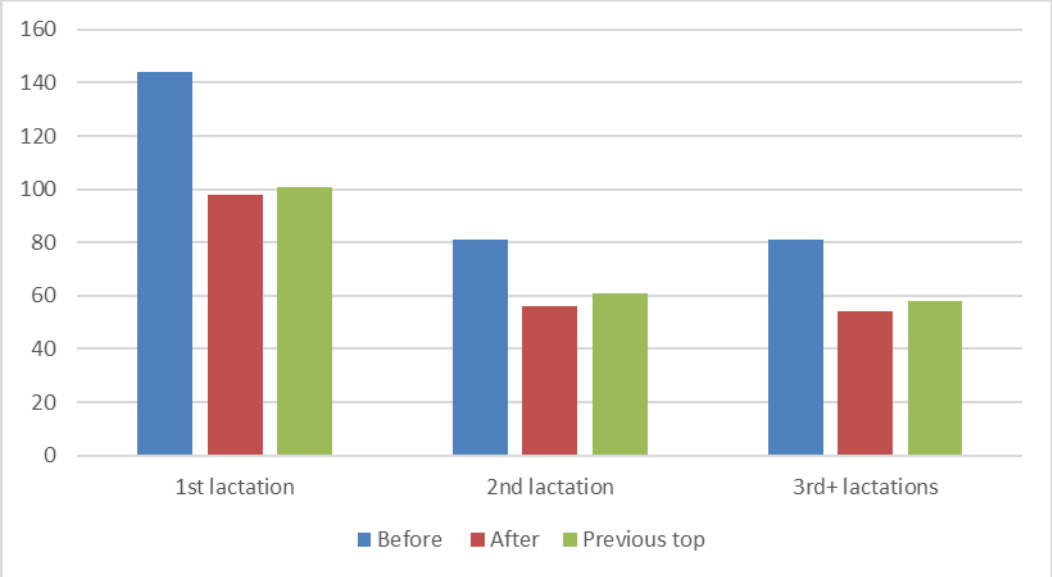


Figure 3. Lactation peak

Source: Formed by the author

Total milk production on the farm (13% of the farm cattle were fed with PRC from 4 May 2020 to 4 Aug 2020) increased from 33.86 to 34.94 kg. The up-left curve of Fig. 4 reflects the milk production.

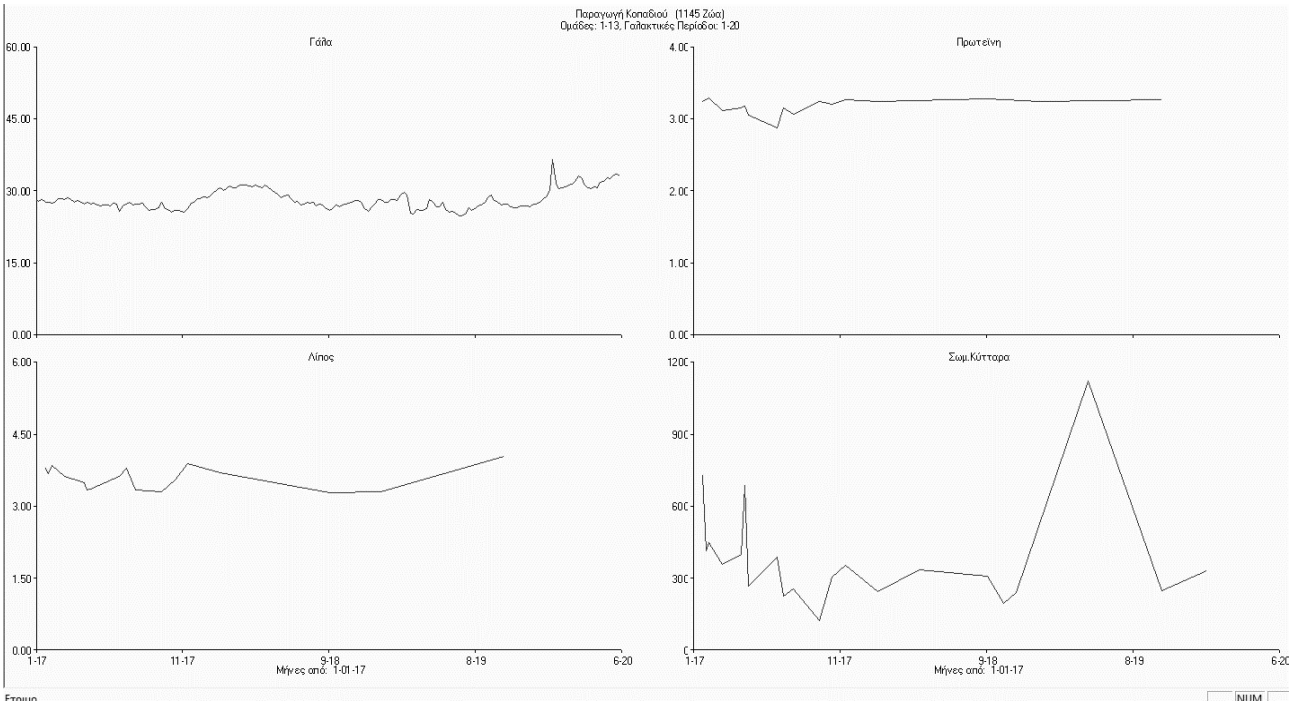


Figure 4. Total milk production on the farm

Source: Formed by the author

Further, the results are presented by a group. Fresh group (GP6) was fed with PRC from 4 May 2020 to 4 Aug 2020. All the animals were fed. The top production of this group was achieved; it is increased up to 5.8 kg (from 26.7 kg to 32.5 kg); the results are reflected in Fig. 5. Protein remains high with high milk productivity: 3.35, while the farm average is 3.10.

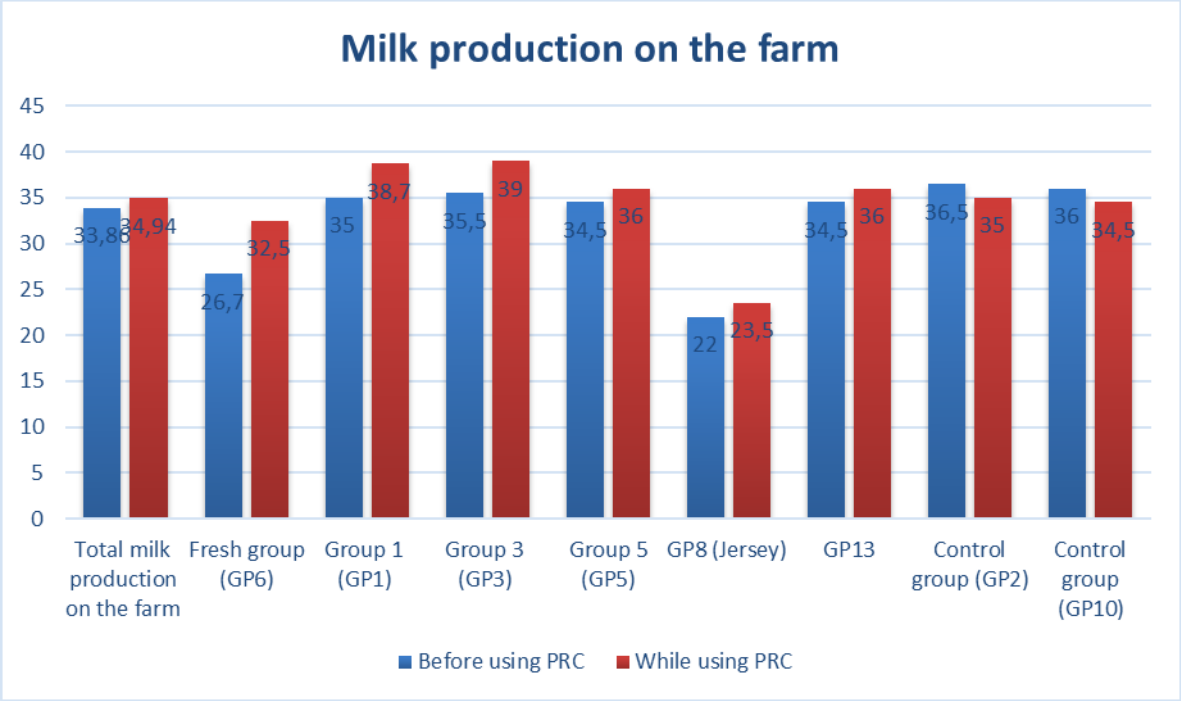


Figure 5. The results of milk production on the farm

Source: Formed by the author

Feeding costs were decreased, including the cost for PRC purchase: from 5.49 to 5.47 euro -0.36% feeding per day per cow; TMR was regulated and the fat (380 gr), wheat (1 kg), and soybean meal (1.72 kg) were excluded. Straw (300 gr), ryegrass (700 gr), clover hey (1300 gr), and corn silage (2500 gr) were included. The expenses for PRC purchase were covered; moreover, the farm had benefit +2 cents per cow per day from feeding savings alone. Healthy ration: NDF (neutral detergent fiber) increased from 35% to 39%; starch in the ration decreased from 24% to 23%; forage/concentrate ratio improved from 42/58 to 53/47.

Peak of lactation. The days for peak of lactation significantly improved: for 1st lactation, from 144 to 98 days; for 2nd lactation, from 81 to 56 days; and for 3rd+ lactations, from 81 to 54 days.

Milk production was improved (based on “GEA Westfalia”) by 3.1% (1.08 kg). By groups: GP6 group had +5.8 kg (17.8%); group 1 +3.7 kg (9.6%); group 3 +3.5 kg (9%); group 5 +1.5 kg (4.2%);

group 8 (jersey) +1.5 kg (6.4%); group 13 +1.5 kg (4.2%). Control groups: group 2 decreased milk production by 4.1% (1.5 kg); group 10 had -1.5 kg (4.2%).

Health parameters. Somatic cell count (SCC) indicates milk quality and food safety, where less than 100,000 cells/mL stands for uninfected cows, and higher than 250,000 - infected cows with significant pathogen levels (Schukken et al., 2003; Schwarz et al., 2010). SCC results for GP6 group were: 570,000 - before testing; 248,000 - on 28th day of testing; and 159,000 - after testing. This result indicates an improvement in animals' immune system functioning, which in the long term could reduce the use of veterinary drugs for the treatment of mastitis. Cows of 1st lactation period (GP6) did not have new cases of mastitis.

Heat stress. Despite of the heat stress (increase of temperature), which influences negatively milk productivity, the animals which received PRC improved their milk yield results [10].

Based on the assessment of nine proposed indicators of the effectiveness of frugal innovation management of a dairy farm, integral indicators were determined for the studied groups for three months, which were normalized and shown in Table 1. Thus, SEI, EEI, and FEI each have three integral indicators. This allowed the author to consider many determinants of PRC's effectiveness, including lactation peak and animal health parameters.

Table 1. Key integral indicators of frugal innovation management of a dairy farm

| Group (month) | SEI | EEI | FEI | FIMPI |
|---|---|---|---|---|
| gp1(1m) | 0.118 | 0.262 | 0.273 | 0.396 |
| gp3(1m) | 0.397 | 0.319 | 0.373 | 0.631 |
| gp5(1m) | 0.255 | 0.416 | 0.490 | 0.692 |
| gp8(1m) | 0.052 | 0.256 | 0.241 | 0.356 |
| gp13(1m) | 0.331 | 0.380 | 0.481 | 0.697 |
| gp1(2m) | 0.517 | 0.207 | 0.354 | 0.660 |
| gp3(2m) | 0.432 | 0.127 | 0.237 | 0.509 |
| gp5(2m) | 0.343 | 0.206 | 0.747 | 0.848 |
| gp8(2m) | 0.384 | 0.065 | 0.749 | 0.844 |

| | | | | |
|---|---|---|---|---|
| gp13(2m) | 0.408 | 0.419 | 0.977 | 1.138 |
| gp1(3m) | 0.204 | 0.275 | 0.567 | 0.662 |
| gp3(3m) | 0.126 | 0.045 | 0.446 | 0.466 |
| gp5(3m) | 0.132 | 0.376 | 0.463 | 0.611 |
| gp8(3m) | 0.127 | 0.203 | 0.950 | 0.980 |
| gp13(3m) | 0.599 | 1.000 | 0.696 | 1.358 |

Source: Formed by the author

Using the obtained key indicators, a complex FIMPI was determined, which can be expressed as the length of the frugal innovation management vector of a dairy farm for a certain period of time (Fig. 6); the results were further compared.

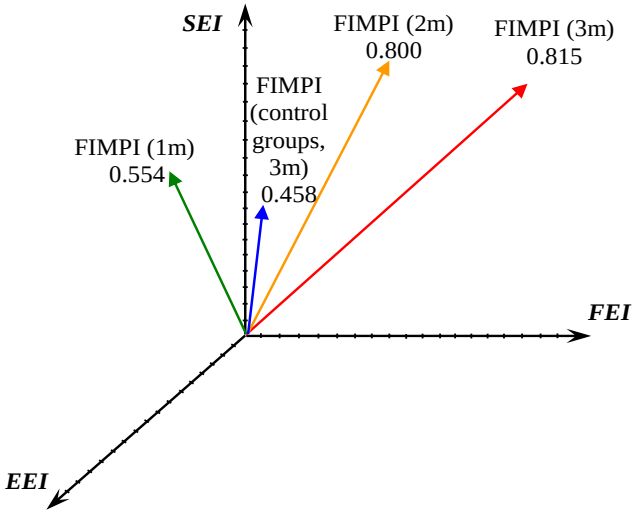


Figure 6. Vector of frugal dairy farm innovation management

Source: Formed by the author

During the three-month study period, the vector of frugal dairy farm innovation management increased by 47%. This is confirmed by the FIMPI indicator. At the same time, its focus was on FEI. The increase in efficiency is quite noticeable compared to the results for the control groups. This is the basis for accepting hypothesis H1, since the results obtained prove that the proposed PRC has a positive effect on the farm's functioning.

To build a frugal innovation management model for a dairy farm, it is necessary to determine the level of interconnection between the investigated components, presented as indicators. Based on the collected data and calculated indicators for three dimensions of frugal innovation management efficiency, a correlation matrix of the factors under study was formed, which is shown in Fig. 7.

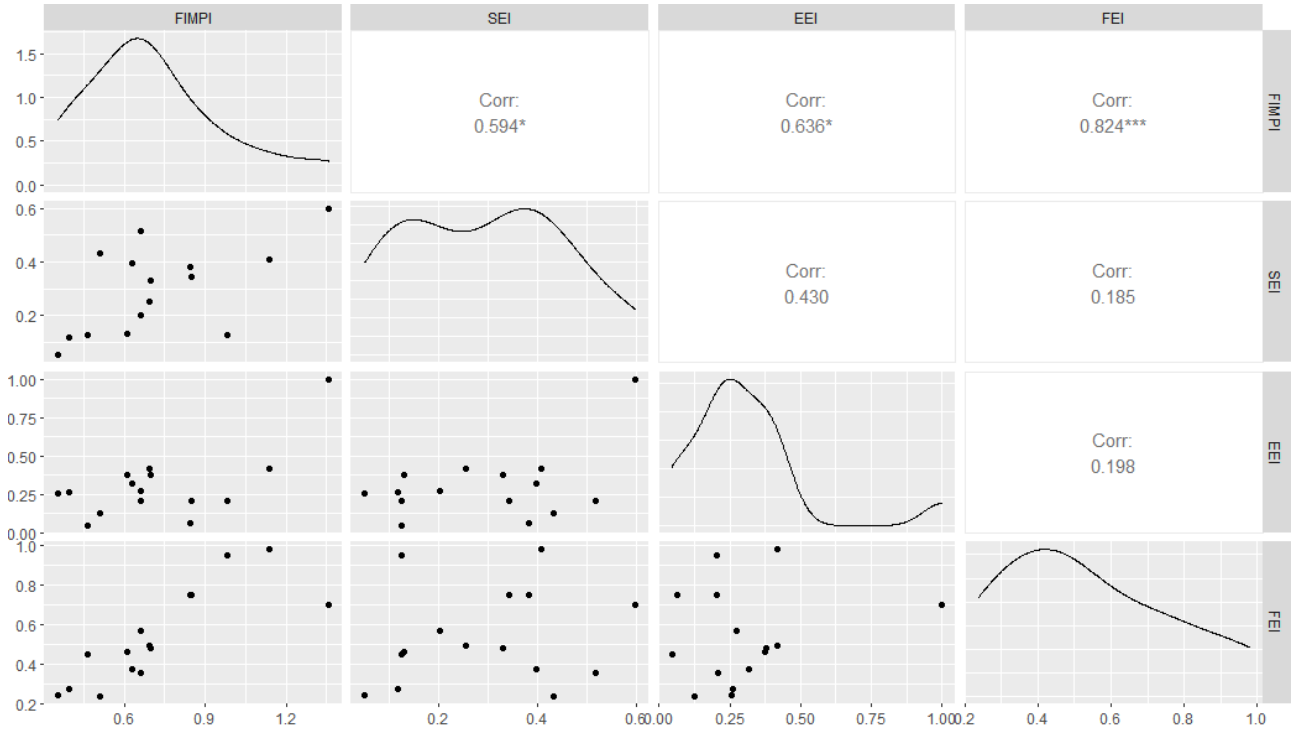


Figure 7. Correlation matrix of FIMPI constituent indicators for the studied groups according to observations for three months

Source: Formed by the author

Based on the obtained matrix, it can be argued that there is no strong correlation between the studied variables. This allows them to be used as components of a frugal innovation management model for a dairy farm, since they are not interdependent and contribute to the development of an adequate equation model. At the same time, it should be noted that there is a fairly strong relationship between the factors under study and the main indicator - Frugal Innovation Management Performance Index. The most pronounced correlation is between FIMPI and farm efficiency (FEI), which is 0.824. A sufficient level of interconnection is characteristic of the other two indicators as well. At the same time, they are

very close in value: economic efficiency - 0.636, and socio-environmental - 0.594. For a deeper study of the relationship between the investigated factors and FIMPI, an analysis of variance was carried out for each of its components. The results are shown in Fig. 8.

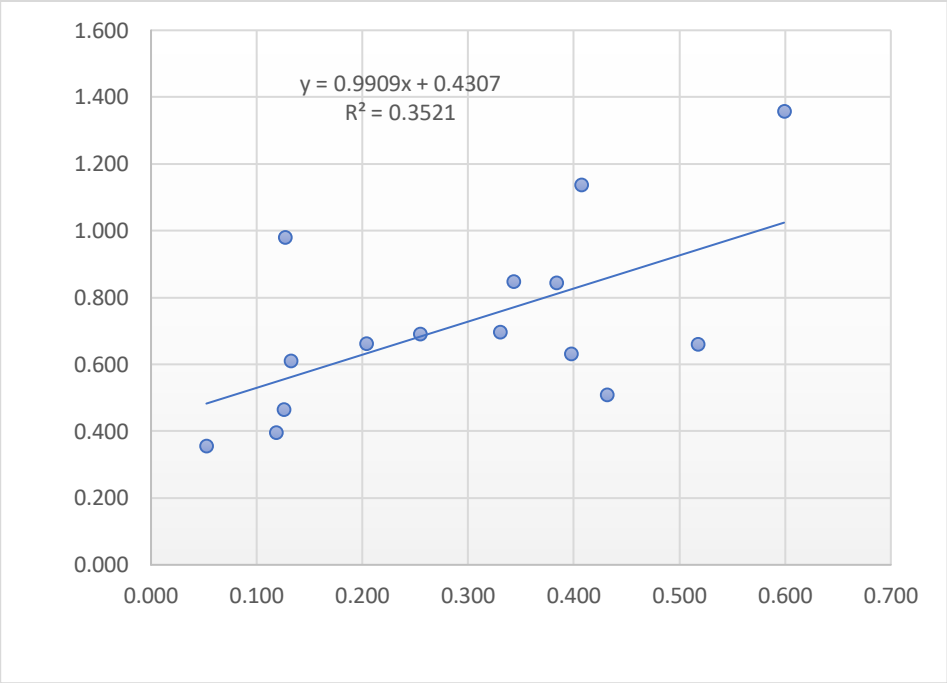


Figure 8. The relationship between socio-environmental parameters and the Frugal Innovation Management Performance Index

Source: Formed by the author

Despite the sufficient level of correlation between socio-environmental efficiency and the Frugal Innovation Management Performance Index, determined when constructing the matrix, there is still no significant interdependence between SEI and FIMPI in an autonomous examination. This is primarily indicated by the coefficient of determination R2=0.35.

To determine the level of influence of economic efficiency on the FIMPI value, an analysis of variance was carried out, the results of which are shown in Fig. 9.

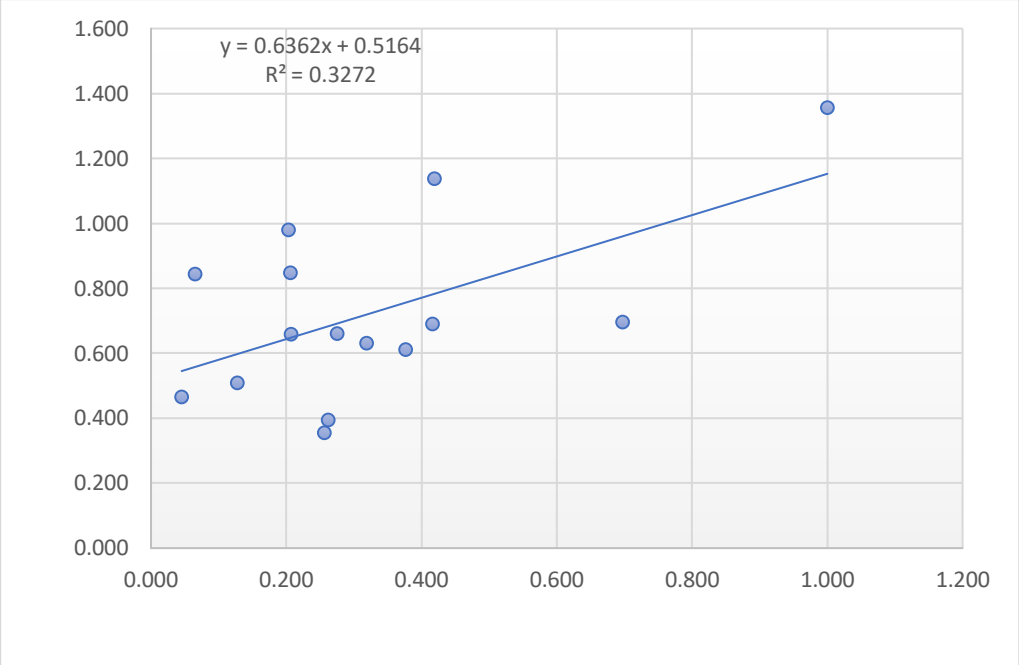


Figure 9. Relationship between economic parameters and the Frugal Innovation Management Performance Index

Source: Formed by the author

Similar to the previous analysis, there is insufficient correlation between EEI and FIMPI to be able to assert a significant impact of cost-effectiveness on frugal innovation management. This also confirms the coefficient of determination R2=0.33.

The relationship between farm efficiency and FIMPI management level is demonstrated on the basis of analysis of variance, the results of which are shown in Fig. 10.

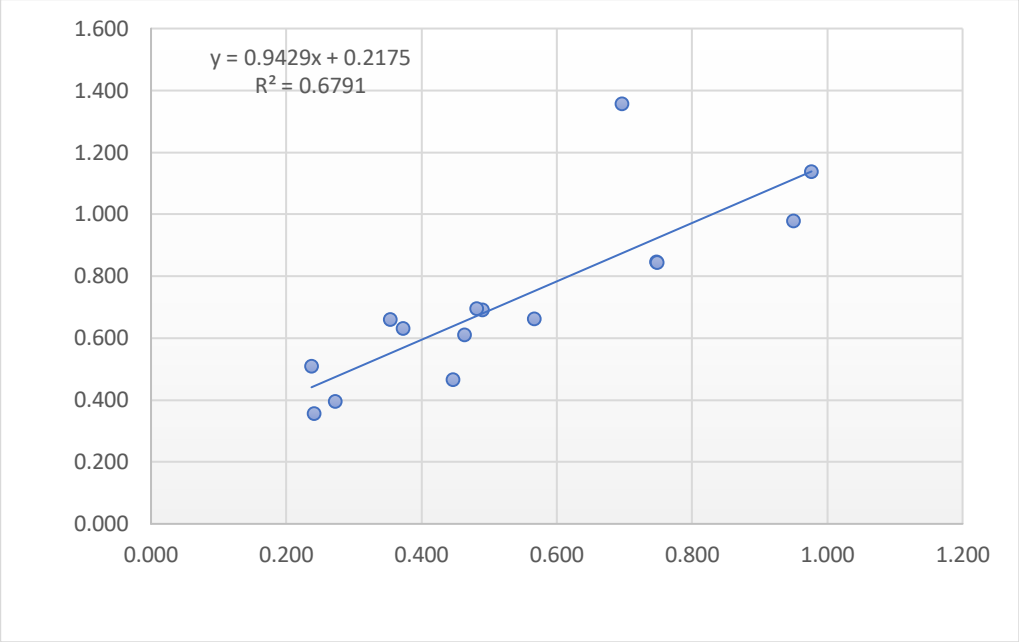


Figure 10. Relationship between farm performance parameters and the Frugal Innovation Management Performance Index

Source: Formed by the author

The resulting pairwise regression equation is applicable and confirms that there is a sufficient relationship between farm efficiency and FIMPI management level. This is indicated by the coefficient of determination R2=0.68. The analysis of variance between the studied indicators and FIMPI separately confirms the presence of the strongest relationship between the management efficiency of Frugal Innovation and the efficiency parameters of the dairy farm itself, but at the same time, a weak influence of the socio-environmental and economic components was recorded.

This study focused on a comprehensive assessment of the effectiveness of frugal dairy farm innovation management. Taking this into account, it is necessary to conduct a variance analysis of the influence of all three constituent elements on FIMPI based on multiple regression (Table 2). Due to the lack of correlation between the studied variables, the formation of a reliable model is assumed.

Table 2. Indicators of modeling the level of frugal innovation management efficiency on a dairy farm in the context of three constituent elements

| | df | SS | MS | F | F Sign | |
|---|---|---|---|---|---|---|
| Regression | 3 | 1.0429 | 0.3476 | 307.7875 | 0.0000 | |
| Residue | 11 | 0.0124 | 0.0011 | | | |
| Total | 14 | 1.0553 | | | | |
| **Factor** | **Coefficients** | **Standard Error** | **t-Stat** | **P-Value** | **Lower 95%** | **Higher 95%** |
| Y-intersection | 0.0096 | 0.0255 | 0.3769 | 0.7134 | -0.0465 | 0.0657 |
| SEI | 0.5135 | 0.0609 | 8.4301 | 0.0000 | 0.3794 | 0.6476 |
| EEI | 0.4464 | 0.0446 | 10.0200 | 0.0000 | 0.3483 | 0.5445 |
| FEI | 0.7952 | 0.0384 | 20.6920 | 0.0000 | 0.7106 | 0.8798 |

Source: Formed by the author

Thus, the model of effective frugal innovation management of a dairy farm can be expressed by the following equation:

$$FIMPI=0.51 \cdot SEI+0.45 \cdot EEI+0.79 \cdot FEI$$

The presented results prove a stable relationship for all three studied indicators. At the same time, the parameters of farm efficiency are characterized by the relationship with the FIMPI both in a stand-alone and in an integrated version. This confirms the P-value, which for the variables is less than 0.05. The applicability of the considered regression model is due to such reference points: R2=0.98, Ftabl<F (3.59<307.79), and, according to Student's criterion, tobs=30.39 exceeds tcrit=2.13. It should be noted that hypotheses H2 and H3 have no grounds for acceptance. On the contrary, hypothesis H4 is accepted, since the most significant factor in the effectiveness of frugal innovation management on a livestock farm is farm functionality. At the same time, to increase the effectiveness of the frugal innovation management, a dairy farm should focus not only on economic benefits but also on increasing sustainable development in the context of socio-environmental parameters of a farm as a producer of natural products from healthy animals.

**Discussion**

The study presented the robust results that reflect the positive impact on three main indicators: milk production, feeding cost, and health of the herd. The most common problems faced by the farmers in high yielding dairy cows are high feeding costs, insufficient milk production, and numerous animal health issues (Devakumar, 2016). During the testing, high yielding dairy cows were fed with PRC; TMR was regulated; unnecessary and expensive ingredients were excluded from TMR; the health parameters, digestion of the animals, milk production, and quality of milk were continuously monitored (Garambois et al., 2020).

The advantage of this study is the proposed methodological approach to assessing the effectiveness of frugal innovation management on a dairy farm based on key indicators: socio-environmental, economic, and farm efficiency (Dressler and Bucher, 2018). The proposed system of indicators can be supplemented with other indicators that reflect the specifics of a farm's activities, for example, marketing or sustainable development (Arnold, 2018; Boichenko et al., 2020). Thus, the obtained estimate in the form of an integral indicator FIMPI is complex. This allows for a wider range of indicators and factors to be taken into account compared to an approach focused on obtaining economic benefits (Tiwari and de Waal, 2019). The proposed approach does not negate the need for economic efficiency. However, at the same time, it is supplemented with social and environmental parameters that are important today and are aimed at satisfying farmer ambitions (Molina-Maturano et al., 2020). Of particular scientific interest is the interpretation of the proposed indicator in the form of a vector length (Ma et al., 2018), which also helps to identify the strengths and weaknesses of frugal innovation management on a dairy farm.

This study is not free from limitations. Due to the farm’s features, it was not possible to feed permanently selected animals, only groups. Some groups were chosen to demonstrate the effects of the product. The period of testing was limited to 3 months, and the product might demonstrate all its capabilities in a longer period of time. The product also affects the decrease of enteric methane emissions, however, this farm does not monitor this indicator (Weishaupt et al., 2020). At the moment of testing in June, the farm had malfunctions with feed equipment; despite this, the production of milk was raising in

the group fed with PRC, along with decrease of somatic cells (Alhussien and Dang, 2018). The bias (sharp lactation curve, from the “GEA Westfalia” program) was taken into account, and the real data were used. Mastitis cases were measured only in 1st lactation period.

In the future, the study can test the proposed methodological approach on a larger number of farms using frugal innovations, forming a universal system of indicators for farms, predicting the effectiveness of frugal innovations management for them.

**Conclusion**

The results of using the proposed product as a frugal innovation demonstrate an increase in the livestock farm's efficiency. The lactation curves of groups 1, 3, 5, 8, 13, 10, and 2 were compared. The results show that lactation curves of groups that were fed with PRC increased, and in groups 10 and 2, lactation curves decreased. In general, the application of frugal innovations in the dairy farm based on the use of PRC led to decreased feeding costs, including the cost of PRC: from 5.49 to 5.47 euro (-0.36%), feeding cost per day per cow. Thus, the expenses for PRC purchase are covered, moreover, the farm has benefit +2 cents per cow per day, from feeding savings alone.

Due to PRC use, the milk yield increased by group: GP6 group had +5.8 kg (17.8%); group 1 +3.7 kg (9.6%); group 3 +3.5 kg (9%); group 5 +1.5 kg (4.2%); group 8 (jersey) +1.5 (6.4%); group 13 +1.5 kg (4.2%). This caused an increase of total milk yield on the farm (during the testing it increased by 1.08 kg per head per day). Despite the decreased milk yield in control groups and heat stress, this led to an increased economic profit for the farm, which was 481 euro per day (43,290 euro per 3 months of testing).

The ration became healthier: NDF of the ration decreased from 35% to 39%; starch in the ration declined from 24% to 23%; forage/concentrate ratio improved from 42/58 up to 53/47.

Regarding the milk quality, protein remained high with high milk productivity: 3.35 protein (GP6) with the farm average of 3.10.

Health parameters. There was a decrease in SCC, which refers to milk quality and food safety. SCC results for GP6 group were: 570,000 - before testing; 248,000 - on 28th day of testing; and 159,000 - after testing. This result indicates an improvement in the functioning of animals' immune system, which in the long term will reduce the use of veterinary drugs for the treatment of mastitis. Cows of 1st lactation period (GP6, GP13) did not have new cases of mastitis.

Heat stress. Despite the heat stress (increase of temperature), which negatively influences milk productivity, cows that received PRC improved their milk yield results.

This study raises the question of transferring farm production in general, and especially animal husbandry, to an innovative type of development. The situation is dictated by one thing - market requirements. Neglect of the latter can provoke a catastrophic decline in livestock production in the public sector and, accordingly, a decrease in the level of consumption by the population of basic food products of animal origin. A three-month study demonstrated the benefits that a dairy farm can receive in the context of increasing milk productivity, improving product quality, and reducing its cost. This will provide the population with high-quality dairy products from farms. Further development of the farm requires effective implementation and management of frugal innovations, which imply qualitative transformations that can ensure the farm's competitiveness in domestic and foreign markets and food security of a state.

Thus, innovative activity in the context of a competitive environment and the unstable position of livestock farming, especially dairy farming, is the foundation for ensuring the profitability of milk production on farms. Effective management of frugal innovations requires an appropriate state policy in the field of animal husbandry and should be aimed at supporting research in the field of innovative technologies and their large-scale development. The conducted research shows the advantages of innovative technologies over traditional ones, which affect milk production, and, consequently, profitability.

The scientific contribution of this study is the proposed methodological approach to assessing the effectiveness of frugal innovation management of a dairy farm. It proves the complex nature of frugal innovations and the need to expand the focus of their implementation, going beyond purely economic benefits and taking into account socio-environmental aspects and farm functioning. The obtained results are confirmed using regression analysis. It confirms the applicability of the formed methodology, and also points to its alternativeness in the process of forming methodological tools for assessing frugal innovation management efficiency on a dairy farm. The study confirms the relationship between the effectiveness of introducing and managing frugal innovation and the economic performance of a dairy farm. However, at the same time, the study proves that the most influential are precisely the specific parameters of farm development.

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