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The outstanding relevance of frugal innovation in the manufacturing sector of emerging economies

Relevancia de la innovación frugal en la transformación del sector manufacturero de las economías emergentes

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Abstract:

In this paper, a systematic literature review was conducted to identify the contributions of frugal innovation in the manufacturing sector of emerging economies. This study aims to understand the contribution of frugal innovation, highlighting the relevance and its contribution to this sector within global emerging markets. To approach this research, three indexed databases of high quality and scientific visibility were considered: Scopus, Ebscohost and Science Direct, with a search equation defined by the keywords: "frugal innovation", "frugal", "emerging economies" and "frugal manufacturing" and the exclusion and inclusion criteria, which allowed to select in a first search 15079 articles. As a final result of the filtering process of those documents identified as repetitive, not relevant to the research topic, 52 documents were obtained, which facilitated the identification of the most outstanding frugal innovations, their classification, description, frugal, social and economic contribution in emerging

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communities. The selected documents show that the subsector with the greatest contribution of goods and services derived from the application of frugal innovation corresponds to the energy sector, with 37,5%, followed by the industrial sector, with 20%. The research provides a theoretical reference in which the importance of frugality is highlighted, offering a positive perspective for emerging regions facing shortages in access to fundamental services such as electricity, drinking water and essential goods necessary for a dignified life.

Keywords: frugal innovation, frugal, emerging economies and frugal manufacturing.

Resumen:

En este trabajo se realizó una revisión sistemática de la literatura con el fin de identificar las contribuciones de la innovación frugal en el sector manufacturero de las economías emergentes. Este estudio tiene como objetivo de conocer la aportación de la innovación frugal, destacando la relevancia y su contribución a dicho sector dentro de los mercados emergentes globales. Para abordar esta investigación esta investigación, se consideraron tres bases de datos indexadas de alta calidad y visibilidad científica: Scopus, Ebscohost y Science Direct, con una ecuación de búsqueda definida por las palabras clave: "innovación frugal ", "frugal", "economías emergentes" y "manufactura frugal" y los criterios de exclusión e inclusión, que permitieron seleccionar en una primera búsqueda 15079 artículos. Como resultado final de proceso filtración de aquellos documentos identificados como repetidos, no pertinentes al tema de investigación, se obtuvieron 52 documentos, el cual facilitó la identificación de las innovaciones frugales más destacadas, su clasificación, descripción, contribución frugal, social y económica en las comunidades emergentes. Los documentos seleccionados muestran que el subsector con mayor contribución de bienes y servicios derivados de la aplicación de la innovación frugal corresponde al sector energético, con un 37,5%, seguido del sector industrial, con un 20%. La investigación aporta un referente teórico en la cual se destaca la importancia de la filosofía frugal, ofreciendo una perspectiva positiva para las regiones emergentes que se enfrentan a la escasez en el acceso a servicios fundamentales como la electricidad, el agua potable y los bienes esenciales necesarios para una vida digna.

Palabras clave: innovación frugal, frugal, economías emergentes, sector manufacturero.

1. INTRODUCTION

The concept of frugal innovation, which aims to achieve greater value with fewer resources, has garnered significant interest from both scholars and practitioners in the past decade (Hossain, 2020; Radjou & Prabhu, 2015). Although its origins can be traced back to resource-constrained environments (Prabhu & Jain, 2015; Soni & Krishnan, 2014), frugal innovation is now being embraced and implemented by multinational corporations like Sony, Renault, and GE Healthcare, even in developed markets (Agarwal *et al.*, 2020; Asakawa *et al.*, 2019). The appeal of frugal innovation lies in its ability to simplify processes, reduce production costs, and address pressing global challenges such as climate change, poverty and healthcare (Radjou, 2015; Nylund *et al.*, 2021; Sahasranamam, 2020; Steinfeld and Holt, 2019). Given its broad appeal and relevance, it is essential to take stock of existing research on frugal innovation and establish an agenda for further advancement in this economic field.

In advanced economies, large organizations invest significant resources in research and development to create products/services in line with their target markets, but given the large investment, these are offered at higher prices to cover the costs of the process, which suddenly generates a gap between those who can acquire the goods and those who cannot do so due to limited economic income (Morelos *et al.*, 2021). This last situation is a characteristic of emerging markets (Silva & Moreira, 2022). It is worth mentioning that customers in these countries tend to be demanding and, at the same time, cautious about prices. They demand the high quality offered by industrialized countries even though they are not willing to pay for it. Therefore, companies that want to successfully enter emerging markets must have the ability to adapt and customize their products to market conditions that usually turn out to be completely innovative (Fuchs, 2015).

Thus, when questioning the idea of satisfying the needs of a market without the solution being based on an abundance of resources and an abundance of instruments to move the idea forward, it is convenient to bring up the phenomenon of frugal innovation, which was first presented as a business proposal for companies to develop products,

services or systems with which they could reach unsaturated markets (Lelivelda & Knorringa, 2017). Frugal innovation becomes a new way of looking at business, which forces companies to be more creative, agile and flexible when exploring opportunities and designing different business models, focused on underserved markets (Espinosa, 2014). Similarly, it brings with it profound changes in the innovation value chain, which could have the capacity to generate inclusive development results, if low-income producers and consumers are incorporated into innovation processes on a more equal footing (Knorringaa *et al.*, 2016).

Having said the above, the following question arises that gives rise to the development of this research: What have been the benefits of frugal innovations in the manufacturing sector in emerging countries?

In order to answer the problem question, it is necessary to conduct a systematic review of the literature to learn about these innovations, their relevance and contribution to the manufacturing sector in emerging markets. To do so, it is necessary to explore scientific articles related to the phenomenon of frugal innovation, published in various databases such as Scopus, Ebscohost and Science Direct between 2010 and 2020. During the process, the methodology proposed by Lazaretti *et al.*, (2018) & Jiju *et al.*, (2018) was used, which was structured in three stages as follows: in the first stage, the planning and definition of criteria for the review was carried out; in the second stage, the characterization, selection and analysis of the theoretical foundations of the documents obtained were carried out; and, in stage three, the findings, results and conclusions of the study were recorded.

This article is organized as follows: in the first part, the definition of the problem, its justification, objectives, theoretical basis and methodology are presented. In the second part, the research results that respond to the research objectives are presented, starting with the systematic review of the literature and ending with the classification of frugal innovations and their contribution to the manufacturing sector. Finally, the discussion and conclusions resulting from the research are presented.

2. THEORETICAL FRAMEWORK

The following theoretical framework presents the phenomenon of frugal innovation from its conception, development, characteristics and its relationship with aspects

related to its nature such as competitiveness, sustainability and the manufacturing sector.

2.1. Frugal innovation

The term Frugal Innovation comes from the Hindu word "Jugaad" which means: improvised arrangement or forced alternative solution due to lack of resources (Roiland, 2016). In the Indian context this word takes great force because it represents the new entrepreneurial spirit emerging in that country with a flexible and inclusive approach to innovation (Prabhu & Jain, 2015), which mixes improvisation and pragmatism with the ingenious use of existing resources and technologies to create solutions to traditionally underserved markets (Ahlstrom, 2010).

The challenges and opportunities found in emerging market contexts offer new possibilities to leverage and recombine different resources so that frugal innovation can be developed and implemented in the best way and with the greatest impact. Therefore, many frugal innovators focus on working on skills, lack of resources and the ability to meet demand, in order to achieve affordable and high quality solutions (Bhatti, 2012). As a result, products are obtained whose characteristics are focused on having affordable prices, being durable, easy to use and that their basic functions manage to adapt to the needs of consumers located at the bottom of the pyramid (Cadeddu *et al.*, 2019).

There are currently multiple studies and literature reviews that, show the progress of this type of innovations and the different ways in which they can be defined, but it is possible to state that they all converge on two points: low-cost development - good products/services and business models for low-income customers in developing countries (Hossain *et al.*, 2017).

In this sense, Hossain (2017), defines frugal innovation "as a product, service or solution that emerges despite financial, human, technological and other resource constraints, and whose end result is less costly than competitive offerings (if available) and that satisfies customer needs that would otherwise go unmet". Thus, the recognition of the market potential of resource-constrained consumers and their

increasing competition for these markets has provided the impetus for the phenomenon of frugal innovations (Hyvärinen *et al.*, 2016).

On the other hand, Bound and Thornton (2012) define frugal innovation as innovation that responds to resource constraints, whether financial, material or institutional. Turning these limitations into an advantage by minimizing the use of resources during development, production and delivery, resulting in dramatically lower cost products and services. Thus, successful frugal innovations are not only lower cost, but have the ability to exceed expectations, be available on a large scale and regularly have an explicit social mission (Fuentes *et al.*, 2020).

Similarly, Bhatti (2012) proposes that frugal innovation, beyond costs, is in the quest to create value for underserved markets. So frugal innovation can redefine business models, reconfigure value chains and redesign products, with the goal of making use of resources in different ways and creating more inclusive markets that serve users with affordability constraints, often in a scalable and sustainable manner.

Considering the above, frugal innovation "is the ability to do more with less by creating more business and social value and minimizing the use of resources such as energy, capital and time" (Radjou & Prabhu, 2014 cited in Khan, 2016). In this sense, frugal innovations have the ability to combine low-cost solutions, manufacturing and materials, with a design focused on obtaining basic functionality and a set of minimal features (Simula *et al.*, 2015).

It is worth noting that frugal innovations are not redesigned solutions; on the contrary, they are products and services that are originally developed to solve specific issues within resource-constrained environments. In this way, it is based on new product architectures that often generate a very important or determinant change; for example, by making a stationary product portable, a frugal innovation can reach a completely new group of customers (Zeschky *et al.*, 2014).

Thus, frugal innovation is viewed as "new solutions that respond to the essential needs of consumers in emerging markets by offering good value at an affordable price" (Cai *et al.*, 2019). They are also characterized by generating better business and more social value than traditional businesses (Hossain, 2017). With this, it is highlighted that

frugality is able to demonstrate how the scarcity of resources, rather than their abundance, can generate competitive advantages for some companies (Asakawa et al.,2019).

2.2. Frugal innovation in the manufacturer sector

The existing literature shows that various frugal innovations have materialized through manufacturing, with the manufacturing sector being responsible for realizing a large part of the options available to underserved markets to meet their needs. According to Wintherhalter *et al.* (2017), the health field has had the largest share of frugal innovations in the manufacturing sector, this because of the electrical and electronic devices that have been developed. In second place are transportation solutions and lastly energy.

In the health sector, the company General Electric created a new electrocardiogram called MAci, whose function is to meet India's need for quality medical care. Thus, while in a developed market such as the United States, an ECG costs 2,000 dollars, in India, a MAci costs 400 dollars. It should be noted that both products use the same type of technology, except that the MAci was manufactured locally with indigenous raw materials, which reduced the cost of each test per patient by 50%. Additionally, it is portable, battery operated and weighs less than 1 kg, which makes it easy to transport, allowing it to reach rural areas where electricity is limited. It also has the capacity to record from one to three simultaneous channels, facilitating the performance of between 250 and 500 tests without the need to charge it. This new ECG was designed to be used in adverse conditions, it is very effective, simple to use and can be handled by anyone (Espinosa, 2014).

On the other hand, in the automotive sector, a successful example of frugal innovation is India's Tata Nano vehicle, which was designed as a safe and affordable means of transportation for middle-sector families who could not afford a car. This model became the cheapest car in the world, its price reached up to 50% below a similar product just introduced to the market (Mourtzis *et al.*, 2019).

In the energy sector, the Canadian company Nuru Energy, managed to create USB devices that are charged directly from a recycled charge generator using solar panels

in Africa and India (Morelos, 2019). In many areas of these countries, grid power does not reach the villages, so off-grid solutions must be sought by making use of wind and solar energy, thus making it possible for people with few resources to access electric power, improving their quality of life in a sustainable way. On the other hand, in Gujarat India, a school invented a clay refrigerator that does not need electricity and can store fresh food for a few days in a natural way.

Another example of the contribution of frugal innovation to the manufacturing sector occurred in 2003, when the multinational company Nokia launched the Nokia 1100, a product that reached sales of more than 250 million devices. This made it the best-selling cell phone of the moment, thanks to the fact that its target customers were users in developing countries who only had minimal requirements, such as making calls and sending text messages. The product was available at a very low price and provided communication to millions of low-income people (Winterhalter *et al.*, 2017).

The above examples mention some of the frugal innovations that were developed in different areas, which had to go through a manufacturing process regardless of the sector to which they belong (health, transportation, energy, telecommunications). Thus, it is shown that manufacturing is moving towards a new era of frugal innovation in which companies to stay in the global market base their business on adapting to regional and local markets, which results in new business models that provide low-cost solutions with high value for the customer (Mourtzis *et al.*, 2016). This leads to think that production processes must be increasingly aligned to what frugality represents and makes them protagonists of customer integration and product design.

2.3. Frugal innovation and the competitiveness

Throughout history, innovation has been closely associated with significant financial requirements. In today's economic landscape, a country's and its companies' ability to innovate has become a key factor in determining their competitiveness (Barrichello *et al.*, 2020). Extensive research in the literature also highlights that innovation has traditionally been linked to economic considerations, while the integration of productivity areas with the innovation process is increasingly capturing the attention of researchers (Stott & Tracey, 2018). Consequently, there is a growing focus among

researchers on a new realm of innovation management that simultaneously addresses economic efficiency and competitiveness (Abbas & Liu, 2022).

The frugal innovation approach focuses on the role of firms in executing systemic change, specifically in the competitive process that occurs between traditional and emerging firms as they strive to satisfy consumer needs and preferences (Ballardo *et al.*, 2022). Thus, the approach emphasizes, on the one hand, the power of market pressures to drive companies to respond to the needs of an increasing number of people by delivering higher value products and services. While, on the other hand, resource constraints and competitive forces compel them to find ways to generate this value with the least possible use of resources (Prabhu, 2017).

Frugal innovations aim to create value propositions that become attractive to the targeted customer groups through basic functionalities and minimization of the use of material and financial resources throughout the value chain (Ortiz *et al.*, 2019). In this way, they manage to reduce usage and/or ownership costs, while meeting or exceeding established quality standards (Tiwari *et al.*, 2017). Therefore, these types of innovations are based on the fact that limited resources imply growth potential (Bencsik *et al.*, 2016).

Considering the above, "frugal innovation has the potential to uplift humanity as a whole by giving all individuals the opportunity to be entrepreneurs and discerning consumers at the same time" (Basu *et al.*, 2013). Consequent to this, "the advancement and entrepreneurial improvement of emerging economies, through the application of frugal innovation, has further contributed to the overall growth and development of the global economy in recent years" (Lin *et al.*, 2020).

In view of the above, Gupta (2010, cited in Pansera *et al.*, 2016), proposes that instead of investing in costly R&D programs, innovation policies should focus on the specific and concrete needs of local populations in order to generate the empowerment of technology and their own productive processes through tools that adapt harmoniously to their lifestyles. By taking cultural heritage experiences as a reference and connecting local innovation ecosystems with unique creative skills, it is possible to form competitive advantages of low or medium technological complexity based on solutions

that react to resource scarcity and institutional gaps (Giovindargan and Trimblrn, cited in Bernardes *et al.*, 2019).

In relation to the contributions of frugal innovation in the area of services, the economic growth and competitiveness contributed to the air transportation sector stands out, which recorded a 100% increase in the last decade. Driven by the charm of cities with high tourist value such as: Medellin, Bogota and Cartagena, which managed to demand more than a thousand international flights per week (Chavarro and Sellamén, 2017). Likewise, other goods and services with high ecological and environmental content, nautical and adventure sports, gastronomy, health and cruise tourism stand out with an important contribution to the tourism sector in Colombia (Guzmán, 2017).

2.4. Frugal innovation and sustainability

Sustainability is a term whose meaning has been perceived in many ways and there are diverse opinions about it. The call for global sustainability is reflected in the social, economic and environmental needs of the entire world and the response to this call requires innovative processes in its design to manufacture appropriate, adaptable, affordable and accessible solutions, products and services that adequately consider the needs and context of citizens in developing countries (Gil & Latorre, 2022). This is how frugal innovation has quickly become a standard against which they evaluate sustainable solutions (Basu, Banerjee and Sweeny, 2013). In this sense, adopting frugality involves design principles whose purpose is to intercede for the minimal use of resources to achieve efficient product performance. It also involves the reuse of simpler components and designs that generate products without additional accessories. As a result, frugal products adopt a simple nature that makes them "slim" compared to their "ordinary" counterparts, which become bulky structures due to the consumption of relatively large amounts of resources. Consequently, targeting frugal products helps to keep costs lower and generate a positive impact on sustainability due to lower resource consumption (Rao, 2013).

Considering the above, a common aspect in all frugal innovations is their link to sustainability. These types of innovations are characterized by a lack of resources, either in the development process or in the solution itself. Despite this, they are able to contribute to all three pillars of sustainability capability, managing to be very cost-

effective from an economic point of view, supporting environmental goals by saving material and energy, and generating social benefits by creating affordable products for more people or generating new jobs. Thus, frugal innovation can become a strong driver for sustainability that has not yet been fully exploited (Bünger *et al*, 2016). Also, this type of innovation offers priority to the needs of all stakeholders of the company, including end consumers, environment and future generations. So if the focus is shifted to the way it is produced and consumed, environmental and economic social sustainability can become a global reality (Basu *et al*, 2013). The frugal innovation is often associated with sustainability (ecological and social) due to its characteristic of minimizing the use of resources such as raw materials, production resources, energy, fuel, water, waste and financial resources. In addition to being more affordable and accessible than conventional innovations (Albert, 2019).

3. METHODOLOGY

For the development of this article, a rational and purposeful analysis, descriptive-explanatory in nature, was carried out by means of the systematic literature review method. For the application of the review method, three (3) general stages were established as follows: i) planning and definition of criteria for the review, ii) characterization, selection and analysis of theoretical foundations and iii) report of results and recommendations; for each of the stages, the steps required for the collection of information related to the benefits of frugal innovation in the manufacturing sector in emerging countries were defined (see Table 1). The steps for each of the stages are described below:

3.1. Document classification and selection

In stage 1, planning and definition of criteria for the systematic review, the purpose and relevance of the research were defined, then the search criteria to be taken into account for the systematic review were established. The following exclusion criteria were established: the non-repetition criterion, the temporal criterion between 2010-2020, articles and systematic literature reviews, excluding books and conference papers. Likewise, the inclusion criteria were defined as articles that had open access and were available in pdf format, in Spanish and English, with the following keywords

as the search equation: "frugal innovation", "frugal", "emerging economies" and "frugal manufacturing" (see Table 2). The free bibliometric analysis software VOS viewer was also used to identify the concurrence of the keywords and the authors with the greatest contribution to the research topic, related to each database. The following Figures 1, 2, 3, 4, 5 and 6 present the relationship maps between the keywords and authors reviewed in the different research studies.

In the second stage, it was possible to develop the characterization, selection and analysis of theoretical foundations, from the classification, study and extraction of articles, taking into account the databases: Ebscohost, Science Direct and Scopus. This was done considering the inclusion and exclusion criteria previously defined in the previous stage.

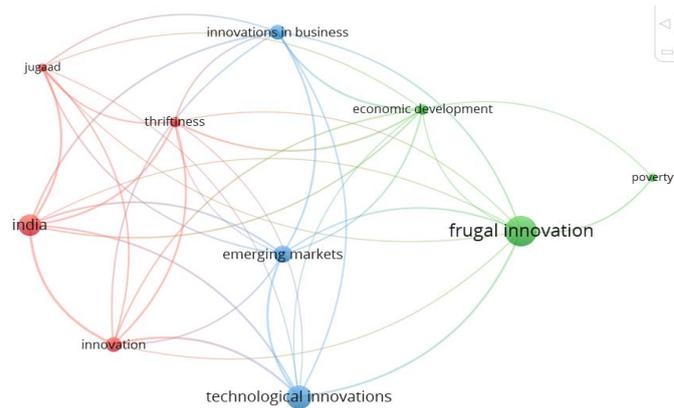
In the third stage, reporting results and recommendations, the information was extracted, selecting case studies that have developed frugal innovations in the manufacturing sector and, finally, a synthesis and analysis of the information was presented, as well as the findings related to the contributions and benefits of frugal innovations in the manufacturing sector in emerging countries.

Table 1. Used Methodology using revision process.

Phase 1.	Phase 2.	Phase 3.
Planification and definition of criterias for the revision	Characterization, selection and theoretical analysis of fundamentals.	Report of results and recommendations
Step 1. Definición del propósito de la revisión sistemática de la literatura	Step 3. Classification of scientific articles. Step 4. Study of the articles	Step 6. Synthesis and analysis of the information
Step 2. Development of the criterias of inclusion and exclusion of having in thought the systematic revision	Step 5. Extraction of the information	Step 7. Presentation of the report from the discoveries and the existing relations

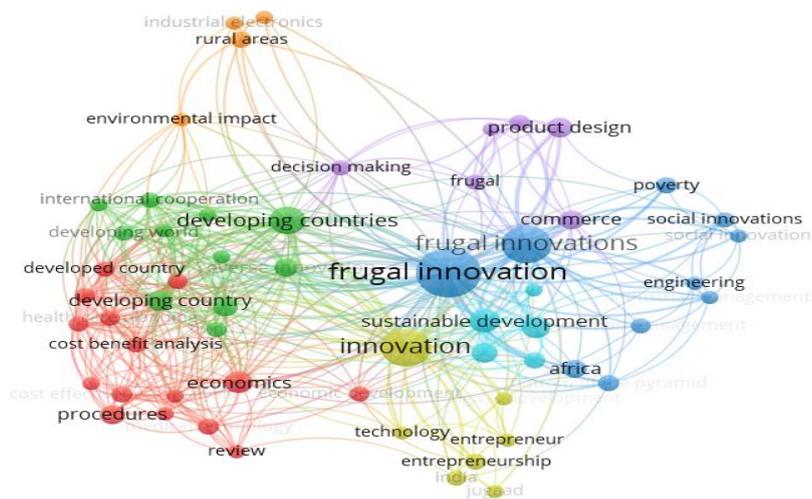
Source: Adapted from Lazaretti *et al.*, (2018).

Figure 1. Currency map of keywords from the database Ebscohost



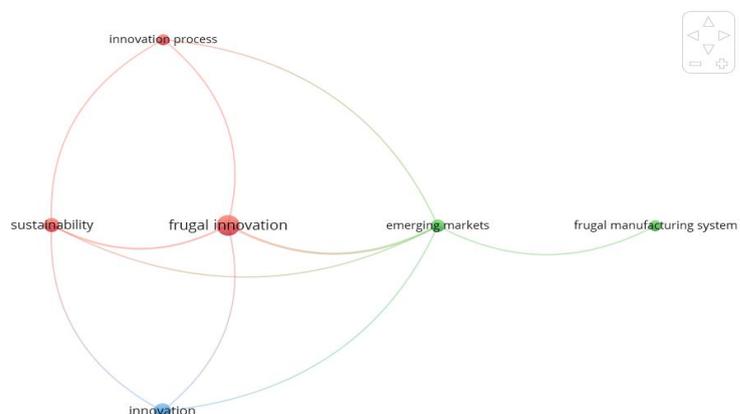
Source: Obtained from VOS viewer software

Figure 2. Currency Map of keywords from the database of Scopus



Source: Obtained from VOS viewer software

Figure 3. Currency Map of keywords from the database of Science Direct



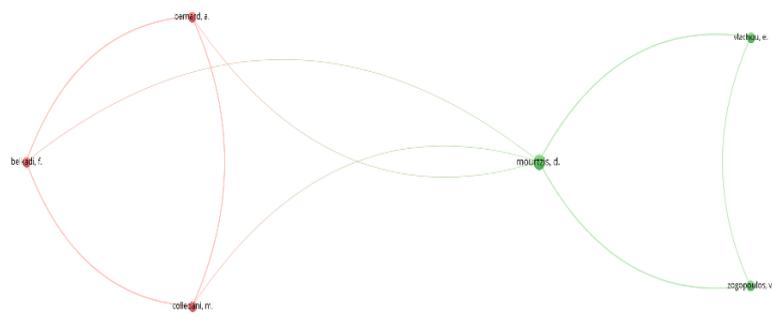
Source: Obtained from VOS viewer software

Figure 4. Currency Map of authors from the database of Ebscohost



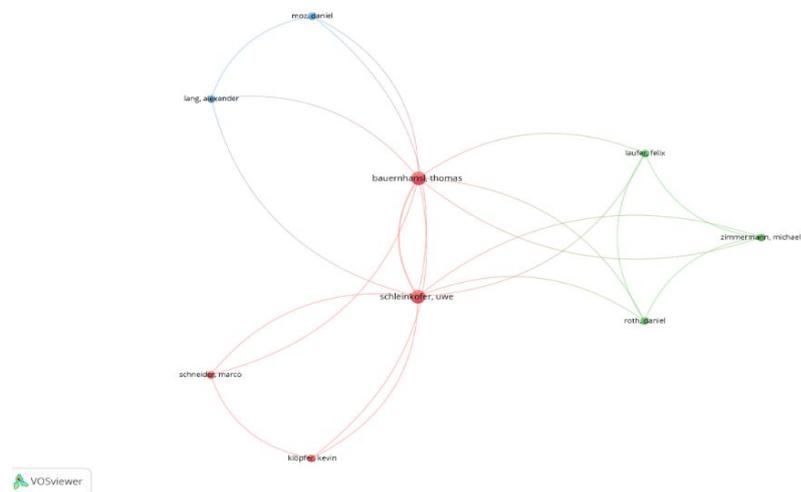
Source: Obtained from VOS viewer software

Figure 5. Currency Map of authors from the database of Scopus



Source: Obtained from VOS viewer software

Figure 6. Currency Map of authors from the database of Science Direct



Source: Obtained from VOS viewer software

Table 2. Criterias of research.

Criteria of Inclusion	Criterios de Exclusión
Articles from scientific academic journals databases: Ebscohost, Science Direct and Scopus, with open access.	gray literature: conference papers, duplicates and books
Articles containing the following keywords: frugal innovation, frugal, emerging economies, and frugal manufacturing	Documents that did not provide relevant and applied information related to the research topic.
Published articles in English and Spanish	Published articles in different languages from the English and Spanish
Published articles between 2010-2020	Published articles before 2010

Source: adaptado de Jju *et al.* (2018).

4. RESULTS

4.1. Systematic revision of the literature

For the systematic review of the literature, the databases Science Direct, Ebscohost and Scopus were used, using the following keywords as the search equation: "Frugal", "Frugal Innovation", "Frugal Innovation and Emerging economies" and "Frugal Innovation and Manufacturing". As a result, 15,079 documents were obtained, whose distribution by database and keyword used is shown in Table 3 below:

Table 3. Distribution of articles from database.

General Results						
Ebscohost		Science Direct		Scopus		Total
Frugal Innovation	389	Frugal Innovation	1205	Frugal Innovation	423	2017
Frugal	5328	Frugal	4487	Frugal	1964	11779
Emerging economies and Frugal innovation	34	Emerging economies and Frugal innovation	600	Emerging economies and Frugal innovation	35	669
Frugal innovation and manufacturing	36	Frugal innovation and manufacturing	556	Frugal innovation and manufacturing	22	614
Total	5787		6848		2444	15.079

Source: Own elaboration

Once the results were obtained by key words, the inclusion and exclusion criteria were applied: temporality, type of article and language (except for non-repetitiveness), which made it possible to filter the results, reducing the number of articles to 1,032. The

following Table 4 shows the distribution of articles after applying the aforementioned criteria:

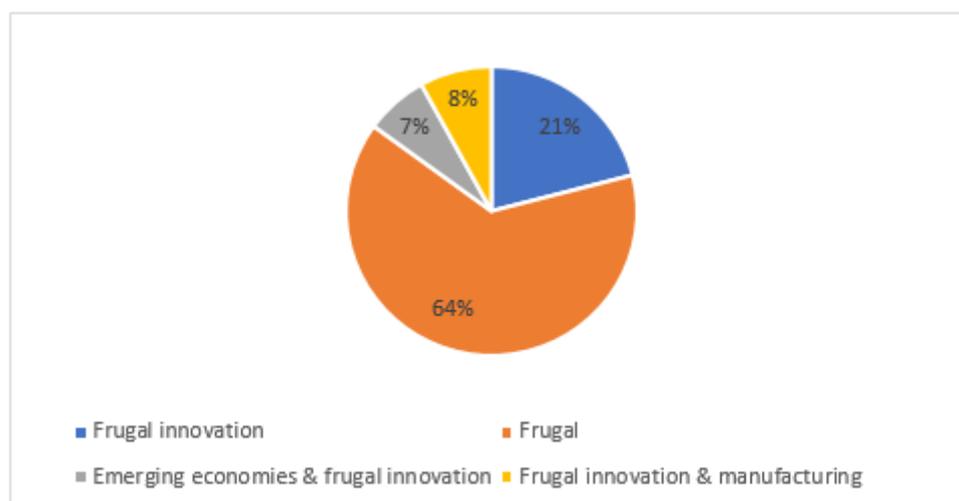
Table 4. Distribution of articles filtered by database.

Results						
Ebscohost		Science Direct		Scopus		Total
Frugal innovation	24	Frugal innovation	132	Frugal innovation	60	216
Frugal	313	Frugal	296	Frugal	49	658
Emerging economies and frugal innovation	10	Emerging economies and frugal innovation	59	Emerging economies and frugal innovation	7	76
Frugal innovation and manufacturing	7	Frugal innovation and manufacturing	67	Frugal innovation and manufacturing	8	82
Total	354		554		124	1.032

Source: Own elaboration

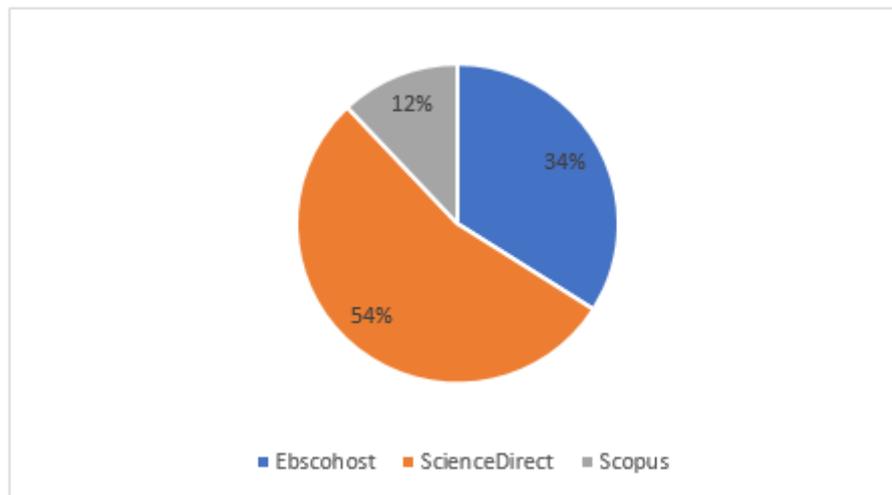
Table 4 shows that Science Direct was the database with the largest number of documents to be consulted. Likewise, "frugal" was the keyword that yielded the largest number of articles, contributing slightly more than half of the documents to be considered for the research. On the other hand, Scopus was the database that contributed the least number of documents during the review. Similarly, keywords such as "Frugal Innovation and manufacturing" and "Emerging economies & Frugal Innovation" accounted for only 15% of the articles. In this sense, the following Figures 7 and 8 show the contributions in percentage terms obtained by choosing the different databases and filtering content through keywords.

Figure 7. Articles by keywords



Source: Own elaboration

Figure 8. Articles by database

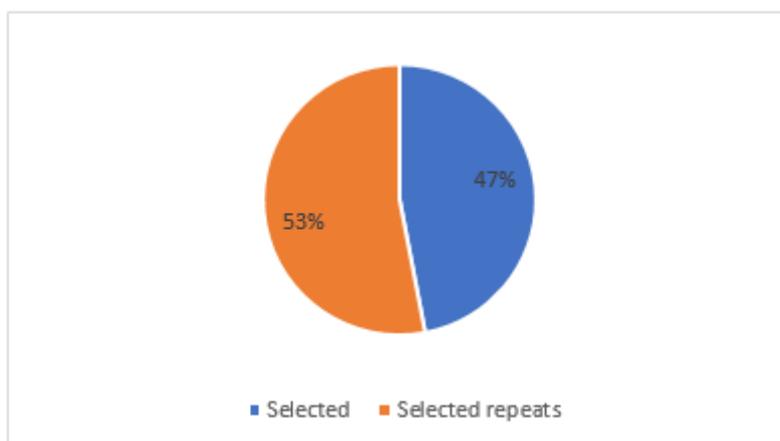


Source: Own elaboration

Once the information necessary for the research had been filtered, we proceeded to review each of the articles obtained, where the key words and summaries of each document were fundamental for the selection of the final articles. During the review it became evident that some articles were not significant for the research since, although they met the criteria defined in the first two phases of the methodology, upon reviewing their content it was identified that they did not meet the third phase, i.e., they did not include specific cases of frugal innovations or the sector mentioned did not belong to manufacturing. For this reason, the list of research articles went from 1,032 to 52 documents.

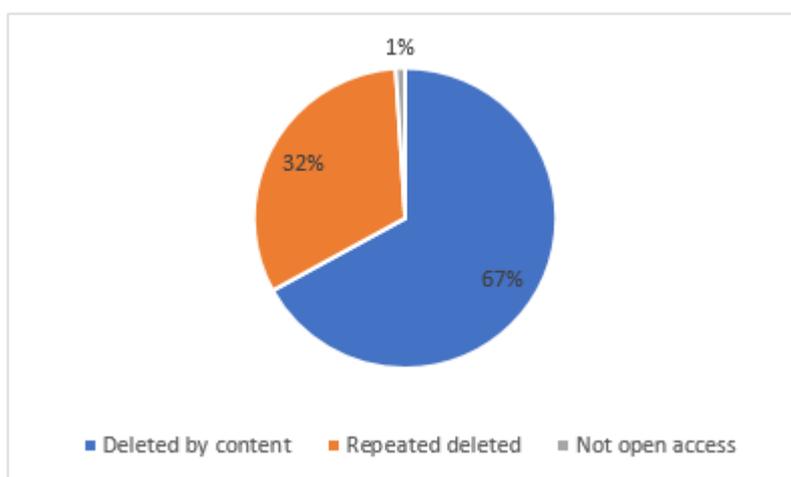
To reach the final selection, it was necessary to eliminate 921 documents, 68% of which did not contribute significant content for the objectives of this research, 32% were repeated documents and the remaining 1% were documents without open access to information. On the other hand, the selected group was made up of 111 articles of which 53% were repeated, so the final list was consolidated with the number of documents defined above (52). The following Figures 9 and 10 represent what is described in this section:

Figure 9. Deleted documents



Source: Own elaboration

Figure 10. Selected documents



Source: Own elaboration

4.2. Frugal innovation classification

Once the articles were selected for analysis, the frugal innovations were identified and classified according to the subsector in which they are useful, on the understanding that they are all part of the manufacturing sector. Table 5 below presents the results obtained:

Table 5. Frugal Innovation per country and year in the manufacturing sector

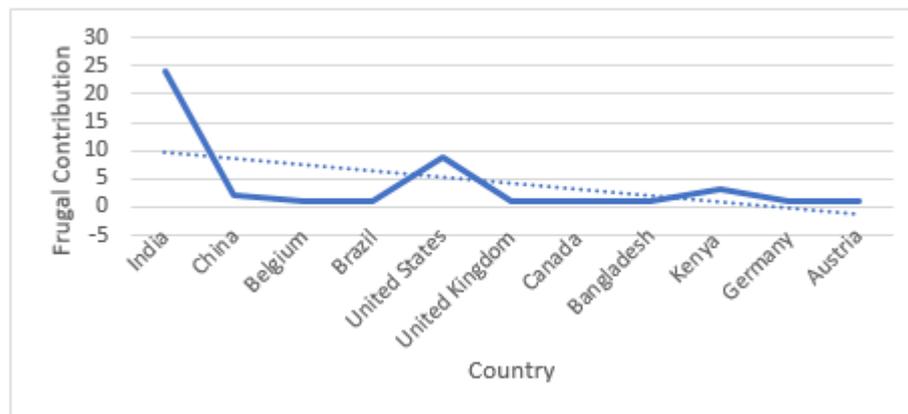
Year	Country	Product/ Business	Subsector
2009	India	Tata Nano	Automotor
2005	India	Tata Ace	
1982	China	SAIC-GM Wuling	
2013	Bélgica	Single port device	
1988	India	Jaipur foot	
2015	Brasil	Solar Earth	

Year	Country	Product/ Business	Subsector
2013	United States	Rice bCPAP	Health
2020	United States	ElectroPen	
2012	United States	Fetal heart monitor	
2013	United States	Mac400	Industrial
2009	India	Tata Swach	
2009	India	ChotuKool	
2001	India	Vortex Gramateller	
2004	India	AM Sanitary Towel Machine	
2000	India	Chetak	
2016	India	Agricultural Biomass Gasifier	
2005	India	Miticool (clay cooler)	
2011	India	Milking machine	
2007	India	Bamboo Splinting Machine	
2013	India	Cotton roving machine	
2014	Reino Unido	Mom	
2008	United States	Embrase	
2008	India	Pureit Classic	
2012	United States	SwipeSense	
1962	-	POCT	
2014	United States	Foldscope	
2008	Canada	Energía Nuru	
1995	India	Selco	
1998	Bangladesh	Grameen Shakti	
2010	India	Boond	
2016	Kenia	Craftskills East Africa limited	
2007	India	Husk Power System	
2012	Kenia	M-KOPA,	
2018	India	Cell site routers	Technology
2019	Germany	(Cyber-Physical Systems) CPS	
2013	China	Weqia	
2016	India	Smart Nano Grid Technology	
2015	Austria	Emporia Mobile Phone	
2007	Kenia	M-Pesa	
2007	United States	Airbnb	

Source: Own elaboration

Figure 11 describes the frugal innovations developed by emerging economies, highlighting India with the highest share (53%) of creative and innovative products, followed by Brazil and Kenya with 20% and 7%, respectively. The country with the lowest frugal contribution is Bangladesh.

Figure 11. Frugal innovation by country



Source: Own elaboration

4.3. Frugal Innovation benefits in the manufacture sector

After classifying the frugal innovations, the benefits of each of them and their contribution to the manufacturing sector as an instrument for improving the quality of life of people in the markets in which they are distributed were compared. Table 6 below summarizes the contributions of the frugal innovations found.

Table 6. Contribution of the frugal innovations in the manufacturing sector.

Year/Author	Product/Business	Benefits /Contribution
2009 / Loveleen Gaur, Supriya Lamba	Tata Nano	Affordable car that functions as a safe means of transportation for middle-sector families with limited resources. In fact, it became the cheapest car in the world, priced up to 50% below a similar product just introduced to the market product recently introduced to the market.
2005 / Rajnish Tiwari, Cornelius Herstatt	Tata Ace	Small commercial vehicle with a payload capacity of 0.75 tons and costing 50% less than any other vehicle. It is also ideal for traveling on India's narrow and busy roads, as well as for long journeys and crowded roads in India, as well as for long journeys.
1982 / Eric Thun	SAIC-GM Wuling	The leading producer of commercial vehicles in mini-trucks, with simple designs inferior to pick-up trucks in power and load capacity. However, its basic approach met the needs of Chinese farmers and allowed a selling price below RMB 50,000.
2013 / Anneleen Reynders & Jan Baekelandt	Single Port Device	The device consists of conventional, reusable laparoscopic instruments and a unique incision port that any surgeon can quickly and easily fabricate. Designed to perform different types of surgeries such as hysterectomy and different types of surgeries such as hysterectomy and unexectomy.

1968/ Rakhshanda Khan	Jaipur foot	Rubber prosthesis adapted to the foot and designed specifically for people of limited resources who have suffered amputations below the knee. This makes it a widely accepted and used widely accepted and used by its target market.
2015/ Nagasushma Devarapalli, Silvia Figueira	Solar Earth	Company dedicated to the development of high quality and affordable solar-powered hearing aids designed for deaf and hard of hearing people located in disadvantaged areas in disadvantaged areas.
2013 / Bull World Health Organ	Rice bCPAP	Device used to treat infants with breathing difficulties. It provides the same therapeutic pressure as devices used in hospitals in the developed world. Thus, it helps the survival of newborns at a significantly lower cost.
2020 / Gaurav Byagathvalli, Soham Sinhal, Yan Zhang, Mark P. Styczynski, Janet Standeven, M. Saad Bhamla	ElectroPen	Portable device weighing 13 grs. requires no electricity and can be easily fabricated by 3D printing. It is used to deliver small molecules (RNA, DNA, drugs) through cell membranes by applying an electric field, making modern synthetic biology accessible in high school, community and low-income laboratories.
2012 / Navi Radjou, Jaideep Prabhu y Simone Ahuja	Fetal Cardiac Monitor	A device that monitors the heartbeat of fetuses in utero, using simple but ingenious microphone technology instead of expensive ultrasound technology. In this way, it is possible to verify the baby's condition without resorting to more expensive diagnostic imaging.
2013 / Nirmalya Kumar y Phanish Puranam	Mac400	Portable electrocardiogram to diagnose cardiac diseases. Its design allows for easy portability so it can be taken to remote villages. It was developed to save energy and has a simple backup source since power is not always available. Its value is 10% of its design price, without sacrificing quality and reliability.
2009 / Rajnish Tiwari, Cornelius Herstatt	Tata Swach	It is the world's cheapest water purifier and offers the following benefits: it does not use chlorine, uses the combination of locally sourced materials with silver nanoparticles for the filters, helps improve performance, removes 90% of contaminants and almost all of the most serious pathogens that can cause serious diseases such as diarrhea, cholera or typhoid fever. Moreover, it has top and bottom storage vessels that hold up to 9,000 liters.
2009 / Rajnish Tiwari, Cornelius Herstatt	ChotuKool	Compact, top-loading portable cooler designed to cope with poor power supply in many parts of India. The product utilizes high quality insulation to keep cool for 2-3 hours without power and is equipped for battery operation.
2001 / Rajnish Tiwari, Cornelius Herstatt	Vortex Gramateller	Highly reliable, rugged, user-friendly and environmentally friendly ATMs. Designed to adapt to complex conditions such as unreliable power supply and higher levels of end-user illiteracy in rural and semi-urban areas of India.
2004/Mario Pansera, Soumodip Sarkar	Machine for sanitary towels	A machine for making good quality sanitary napkins, which requires minimal skills and very little electricity. It is also a source of income for women in local communities.

2000/Mario Pansera, Soumodip Sarkar	Chetak	Fully mechanized and mobile machine for bagging the extracted cotton. Its main contribution was to reduce the cost of cotton cultivation significantly. It also helped to make cotton hulling by-products available for use as a valuable biofuel.
2016/Mario Pansera, Soumodip Sarkar	Agricultural biomass gasifier	Biomass-fueled power generator, with simple design and used to run water pumps, flour mills and almost any type of machine, in addition to domestic lighting.
2005 / Mokter Hossain	Miticool (clay cooler)	Refrigerator made of clay, it does not consume electricity because its cooling system is based on a natural process. In this way, it contributes to sustainability and creates a new market for refrigerators where electricity is not available.
2011 / Mokter Hossain	Milking machine	Milking machine mounted on a stainless steel trolley with easy-to-drag polymer wheels that serves small farmers who would otherwise milk their cows by hand because they cannot afford expensive conventional milking machines. In addition, it consumes very little energy and can be operated manually through a handheld device during a power outage.
2007 / Mokter Hossain	Bamboo Splinting Machine	High capacity machine operated by electricity and suitable for industries that manufacture bamboo slats for the production of incense sticks. An average person can make about 5000 splints per hour when using it.
2013 / Mokter Hossain	Cotton roving machine	Cotton peeling machine that mechanically removes dry cotton from cotton hulls. It is a cost-effective and innovative design that allows the cotton to be efficiently removed from the hull and prepared for ginning. It improves the quality of the extracted cottonseed and ensures higher profits for farmers.
2014 / Mokter Hossain	Mom	Production of baby incubators used to save the lives of disadvantaged premature babies in remote locations.
2008 / Mokter Hossain	Embrase	Production of low-cost incubators used to prevent neonatal deaths in rural areas located in emerging markets.
2008 / Jarkko Levänen, Mokter Hossain, Tatu Lyytinen, Anne Hyvärinen, Sini Numminen and Minna Halme	Pureit Classic	Gravity-driven tabletop water filtration system that requires no electricity or running water. It handles the removal of large particles, certain protozoan parasites, disinfection and removal of excess chlorine and chlorination by-products and chlorination.
2016 / Jaideep Prabhu, Sanjay Jain	SwipeSense	Mobile dispenser used by doctors and nurses to wash their hands during their working day. It is intuitive to use, easy to transport, cost-effective and saves doctors from traveling to remote hand sanitizing stations.
1962 / Tobias Miesler, Christine Wimschneider, Alexander Brem, and Lorenz Meinel	POCT	Medical diagnostic tests that are performed directly at the point of care and do not require laboratories. They generate results in a timely manner, as fewer steps are used and costs are automatically reduced.

2014 / Spring	Foldscope	Microscope made with 97 cents that allows observing microscopic objects with the naked eye through a small spherical lens.
2008 / Mokter Hossain	Energy Nuru	Provides lights and mobile devices with USB port that are charged directly from a recycled charge generator via solar panels at Africa and India
1995 / Mokter Hossain	Selco	A social enterprise in India that provides energy to people who otherwise would not have access to it. In this way, it makes solar energy a viable option for the rural population and underserved households.
1996 / Mokter Hossain	Grameen Shakti	Company responsible for providing various products/services such as: solar energy through its solar home system (SHS); biogas for use as cooking fuel, electricity production and organic fertilizer; and improved cookstoves (ICS) for rural Bangladeshi communities rural communities in Bangladesh.
2010 / Mokter Hossain	Boond	The company provides solar energy at an affordable cost in the northern, eastern and northwestern states of India where the inhabitants lack economic resources.
2016 / Rakhshanda Khan	Craftskills East Africa limited	It builds wind power generation devices from local materials for the purpose of supplying power to small and dispersed off-grid villages in Africa. In addition, its turbines are characterized.
2007 / Jarkko Levänen, Mokter Hossain, Tatu Lyytinen, Anne Hyvärinen, Sini Numminen and Minna Halme	Husk Power System	Biomass gasifier that creates fuel from abundant rice husk residues to provide energy in rural areas of India.
2012 / Navi Radjou	M-KOPA	Solar home system consisting of a kit containing a small solar panel, two LED lamps, an LED flashlight and a cell phone charger. Thanks to these frugal off-grid energy solutions, African households are moving from candlelight to solar power.
2018 / Rishikesh T. Krishnan, Shameen Prashantham	Cell site routers	These products operate in the so-called last mile of the telecommunications network and are the entry point for consumer voice and data. This meets the needs of India's mobile service providers to combine old (2G) and new (4G, 4G) technology to combine old (2G) and new (4G) technology, (MPLS) simultaneously in their mobile service networks.
2019/Uwe Schleinkofer, Kevin Klopfer, Marco Schneider, Thomas Bauernhansl	(Cyber-Physical Systems) CPS	It facilitates the identification of essential customer requirements and the corresponding basic functionality of manufacturing systems. Additionally, it improves the price-performance ratio offered by reducing the cost of the value proposition.
2013 / Yuan Suna, Haiyang Cao,	Weqia	It is a communication system at an organizational level that allows the connection between members of the same company, transcending time, space and departmental boundaries. Likewise, it allows to know the location of all users and to mark people who

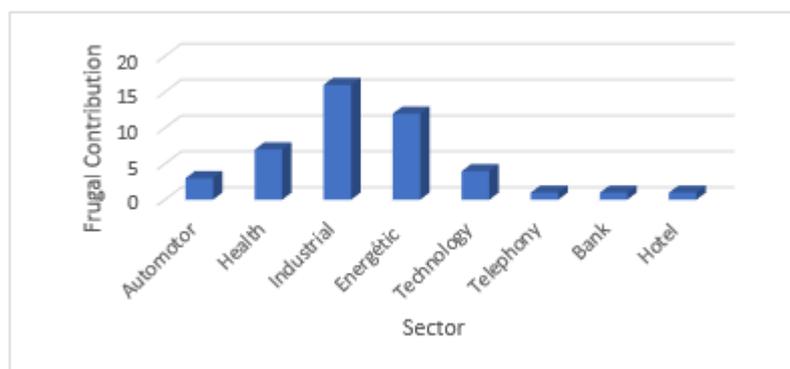
Barney Tan, Rong-An Shang		have knowledge and skills in a specific field to start conversations, build relationships and take advantage of social ties to promote the exchange of information.
2016 / Jaideep Prabhu	Technology Smart NanoGrid	It is a system that allows the distribution of energy to remote areas through a 30 KW solar plant. Its meters and sensors collect data on energy usage and system status, which is fed into SunMoksha's cloud-based control system.
2015 / Thomas Winkler, Anita Ulz, Wolfgang Knöbl, Hans Lercher	Cellphone Emporia	Telephone focused on the special needs of the elderly segment. Elements or functions that the target group considers insignificant are not part of the final product. On the contrary, they prioritize features such as phone function, large buttons and good sound quality, instead of focusing on the Internet connection, an MP3 player or a high-quality camera.
2007 / Jaideep Prabhu	M-Pesa	Mobile phone-based money transfer service that allows users to deposit, withdraw, transfer money and pay for goods and services, transfer money and pay for goods and services easily with a mobile device and without branches. Users are charged a small fee for the use of the service.
2007 / Thomas Winkler, Anita Ulz, Wolfgang Knöbl, Hans Lercher	Airbnb	Application that offers an alternative to traditional lodging, leveraging technology to economically empower millions of people around the world by unlocking and monetizing their spaces their spaces, passions and talents to become hotel entrepreneurs hoteliers.

Source: Own elaboration

The innovations mentioned in Table 6, above, allow us to identify that, despite being created to meet different kinds of needs, they share the same purpose: to provide access to products that are unattainable for people whose resources are limited, to create value for those who use them and to enable the development of entire communities. Similarly, it is possible through manufacturing to create affordable solutions without sacrificing quality.

Figure 12 shows that the productive sector with the highest participation in the development of frugal innovations corresponds to the industrial sector with 36%, followed by the energy manufacturing sector with 27%, however, the sector with the lowest contribution of frugal products corresponds to the financial services and hospitality sector with equal values of 2%.

Figure 12. Frugal innovation by manufacturing sector



Source: Own elaboration

5. DISCUSSION

According to this article, frugal innovation represents a challenge in terms of thinking, creating and offering affordable products/services for populations with limited resources (Ebolor, 2023). This turns out to be a novel topic and becomes a valuable contribution within emerging economies that gives the possibility to include local tools, formulate simple designs and identify just enough details of a product to meet the needs of a population (Wang & Li, 2023). This is achieved without having to sacrifice the quality and functionality of the product, so that the ultimate goal is to combat the scarcity of resources, to achieve the evolution and development of less favored markets (Rossetto *et al.*, 2023; Onsongo *et al.*, 2023).

From a business perspective, frugal innovation is a proposal that allows taking advantage of the opportunities offered by emerging markets, taking into account the wide variety of unsatisfied needs that drive the creation of unlimited innovation ideas (Berndt *et al.*, 2023). Thus, frugal innovation emerges as an alternative for those entrepreneurs, who do not have sufficient resources, to materialize their innovation project by focusing on the essentials at a lower cost (Ebolor *et al.*, 2022). However, the application of the frugal philosophy presents some limitations in terms of its restricted application in developed countries such as North America and Europe, among others, because the research only took place in emerging countries in Africa, Asia and Latin America. In other words, the results obtained in the research only contribute to the knowledge of underdeveloped regions related to the conceptual elements, evolution,

applied tools of frugal innovation in the emerging manufacturing sector (Tselepis & Nieuwenhuizen, 2023).

This study has several significant contributions. Firstly, we provide a deeper understanding of the concept of frugal innovation and show different products developed in emerging countries. Furthermore, the study also unveils the challenges faced by such factory in implementing such an innovation. Secondly, by providing empirical evidence that frugal innovation can be conducted in a competitiveness-rising. To the best of our knowledge, rarely researchers have presented such a comprehensive theoretical. The majority of the researchers have presented conceptual viewpoints related to the area (Brem & Ivens, 2013; Díaz-García *et al*, 2015; Khan, 2016; Pansera, 2016, Pansera, 2018). Finally, the study provided a holistic results and variety products of the challenges of frugal innovation better to understand the concept from an academic and practical perspective.

Taking into account the results and limitations of the research, interested authors are invited to continue exploring in future lines of complementary work related to the new difficulties, challenges and challenges faced by organizations to promote the frugal philosophy in developed competitive markets that are being affected by the current post-pandemic global economic slowdown. Likewise, it is recommended for future research, to analyze new variables in which the correlation of the needs for new goods and services versus the limitations of financial capital in the business sector is determined, with the purpose of making decisions and designing strategies of digital marketing, eco-innovation, process innovation, etc., that tend to increase the innovation of new frugal products and services in the competitive global market.

6. CONCLUSIONS

Frugal innovations present a significant factor in the face of hostile contexts, with few opportunities and limited resources. In this way, new solutions emerge that involve new ways of thinking to respond to the essential needs of consumers at the base of the pyramid. In this sense, this type of innovation philosophy manages to create affordable, robust and easy-to-use alternatives in communities with scarce resources. However, the application of the frugal philosophy presents some limitations in terms of its restricted application in developed countries such as North America and Europe,

among others, because the research only took place in emerging countries in Africa, Asia and Latin America.

Considering the above, frugal innovations become an excellent tool that allows producing more with fewer resources without sacrificing quality; on the contrary, they add value and establish a point of connection between the markets they target, offering goods that satisfy their needs and boost the economic and social development of the geographic area where they are applied. In this sense, consumers can acquire goods/services that would be out of reach in their conventional design. An example of this is the 40 product-companies that resulted from this research, which demonstrate their multiple advantages in terms of social development, relief of manual labor and creation of opportunities, thus facilitating the life of the less favored population.

The frugality described throughout this research provides a hopeful outlook for those regions where access to services such as electricity, drinking water or basic goods for a dignified life are lacking. Likewise, it represents significant advances for manufacturing processes and the optimization of productive processes, given that all of them went through a disruptive design, manufacturing and distribution process that in some cases implied changes in business models, market segmentation and decision making.

Likewise, the methodology with which the research was approached allowed the development of a systematic literature review whose results provided answers to the problem question posed, as well as to the research objectives. The use of search equations, the application of principles of inclusion and exclusion, and the use of databases of high quality indexed journals, allowed the approach of information from authors from different parts of the world where the phenomenon of frugal innovation is responding to the needs of goods and services in emerging countries.

Finally, the purpose of this paper is to explore the influence of frugal innovations in the manufacturing sector of emerging economies through a qualitative study that employs a systematic review analysis of empirical studies. The main novelty of this study lies in its meticulous coding of each article, comprehensively examining the innovation features, the products involved, the considered emerging countries, and the resulting outcomes. This approach allows for the consolidation of fragmented literature, the

quantification of prevailing insights in empirical research, and the facilitation of interpretation and analysis. The ultimate goal is to identify existing research gaps and develop a comprehensive understanding of the potential of frugal innovation in promoting sustainable development.

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