Technology and
Innovation Management
at Hamburg University
of Technology

Working Paper

Frugal Sustainability – A New Perspective to Foster Corporate Sustainability

Timo Achtelik, Cornelius Herstatt and Rajnish Tiwari

February 2022 (updated: April 2022)
Working Paper 112

Hamburg University of Technology (TUHH)

Institute for Technology and Innovation Management

Am Schwarzenberg-Campus 4
D-21073 Hamburg, Germany

Tel.: +49 (0)40 42878 3777
Fax: +49 (0)40 42878 2867

timo.achtelik@tuhh.de
www.tuhh.de/tim

Frugal Sustainability

A New Perspective to Foster Corporate Sustainability

By

Timo Achtelik[1,2], Cornelius Herstatt[1] and Rajnish Tiwari[1,3]

[1] Center for Frugal Innovation, Institute for Technology and Innovation Management,
Hamburg University of Technology

[2] Volkswagen AG, Wolfsburg, Germany

[3] Chair for Business Management and Global Innovation,
Hochschule Fresenius – University of Applied Sciences

Abstract

Frugal innovations are increasingly considered in the context of sustainability and are seen to have promising potential for the realization of global sustainability goals. So far, the discourse has focused on the question of whether and how frugal innovations contribute to sustainable development without presenting concrete guidelines and principles. Through a systematic literature review guiding principles are therefore derived, conceptualized in the motivational context of emerging and industrialized economies and empirically illustrated using the example of Western automotive companies. The principles can be used to further substantiate the link between frugal innovations and corporate sustainability as well as to use them for the development of green(er) innovation.

Keywords: Frugal Innovation, Frugal Sustainability, Corporate Sustainability, Automotive

Update: This working paper underwent some minor editorial corrections on April 25, 2022.

A revised and peer-reviewed version of this paper with the title "Frugal Sustainability: A Novel Way to Promote Corporate Sustainability" has been accepted for presentation at the Innovation and Product Development Management Conference (IPDMC) 2022.

Contents

1 Introduction

> *"[...] where economic growth has led to improvements in living standards, it has sometimes been achieved in ways that are globally damaging in the longer term. Much of the improvement in the past has been based on the use of increasing amounts of raw materials, energy, chemicals, and synthetics and on the creation of pollution that is not adequately accounted for in figuring the costs of production processes" (World Commission on Environment and Development, 1987).*

Almost 35 years have passed since the United Nations published the report "Our Common Future" (so-called "Brundtland Report") and significantly shaped the definitions and implications of sustainable development. Together with the model of the triple bottom line, published in 1994, it was possible to establish a first basic understanding of the concept and dimensions of sustainability (Dyckhoff and Souren, 2008; Elkington, 1997; Sitnikov, 2013).

Sustainability is understood as a 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). According to Elkington (1997), the three dimensions of sustainability are ecological, economical and social issues, which must be fulfilled holistically despite their sometimes conflicting requirements. Companies need focus "not only on the economic value they are supplementing, but also on the environmental value and on the social value they are supplementing – and eliminating" (Sitnikov, 2013, p. 2563).

Despite many years that the concept of holistic sustainability is now gaining conceptual acuity[1], the state of the world in 2021 is described by the "Intergovernmental Panel on Climate Change" (IPCC) with the words "climate change widespread, rapid, and intensifying" (IPCC, 2021, p. 1). Negative changes in the areas of "wetness and dryness, to winds, snow and ice, coastal areas and oceans" (IPCC, 2021, p. 2) are direct consequences of a global temperature increase, to name but a few at this point.

Given these circumstances, it is hardly surprising that the so-called efficiency strategies of sustainability management are coming under increasing criticism (Braungart and McDonough, 2002; Hauschild et al., 2017; Schmidt, 2008; Young and Tilley, 2006). Braungart and McDonough (2002) sum up the problem when they describe eco-efficiency in their book *"Cradle to Cradle: Remaking the Way We Make Things"* as "less bad is no good" and a "destructive system". Several researchers point out that methods of environmentally oriented product development need a more absolute and holistic perspective on global sustainability (Hauschild et al., 2017; Schmidt, 2008). Nevertheless, in view of today's prevailing basic linear economic paradigm of "take, make, waste", the orientation towards circular economy design of products is associated with major implementation challenges on a wide range of levels[2]. In particular, the rather long implementation period is, among other challenges, the cause of a sufficiency-driven discussion. Taking Linz (2002) as an example, personal consumption renunciation, modesty as well as a new culture of prosperity are seen as elementary and necessary components of a functioning environmental policy. On the other hand, sufficiency is considered to have a too little saving potential and a lack of social acceptance. As a result, pure sufficiency strategies are therefore not considered efficient and effective by some scholars (Huber, 2000; Schmidt, 2008).

[1] More than 10 years before the Brundtland Report, the "Club of Rome" had already pointed out the need for a necessary paradigm shift in economic policy in its publication *"The Limits to Growth"* (Meadows et al., 1972).

[2] A comprehensive overview of barriers for circular innovation and circular business models is provided e.g. by (Hansen et al., 2021).

1.1 Connecting the Dots: Frugal Innovation and Sustainable Development

As companies have an impact on the environment due to their activities and can contribute to solve sustainability challenges at the societal level it becomes necessary to include the role of corporate sustainability within the overall discourse of sustainable development (Dyllick, 2003). Several frameworks of "corporate sustainability" or "sustainable entrepreneurship" provide a first orientation which levels have to be considered for a (more) sustainable orientation of companies (Belz and Binder, 2015; Dyllick and Hockerts, 2002; Hockerts, 2003; McDonough and Braungart, 2002; Young and Tilley, 2006).[3] Within these frameworks the strategies of efficiency, sufficiency and effectiveness are all understood as part of a holistic sustainable orientation. By referring to the "fractal triangle", McDonough and Braungart (2002) mention that "every business decision is connected to and has an impact upon all three value systems [– equity, economy and ecology –], all of which carry equal weight and require equal consideration" (Young and Tilley, 2006, p. 407).

Within this debate a research field of innovation management is opening up, which has gained remarkable and increasing interest in recent years: frugal innovations (Herstatt and Tiwari, 2015; Radjou and Prabhu, 2015; Tiwari and Kalogerakis, 2016).

Frugal innovations originated in price-sensitive and unsaturated markets of emerging economies, primary India, where so-called "bottom of the pyramid" (BoP) consumers developed an increased demand for "good enough" products and services (Bhatti, 2012; Brem, 2017; Prahalad and Mashelkar, 2010; Tiwari and Herstatt, 2020). Thus Mashelkar (2014) introduced the term "affordable excellence", which describes affordability in the monetary sense on the one hand, and a technologically appropriate "good enough" solution without over-functionality on the other.

Often closely linked to constraint-based conditions like scarce financial or material resources (Agarwal et al., 2021; Prahalad and Mashelkar, 2010), frugal innovations are increasingly gaining attention and popularity in developed nations as well, especially in the context of sustainability (Albert, 2019; Brem, 2017; Brem and Ivens, 2013; Herstatt and Tiwari, 2020; Rosca, Reedy and Bendul, 2017; Tiwari et al., 2016; Tiwari and Herstatt, 2020; Wohlfart et al., 2021).

1.2 Research Questions and Research Design

In his extensive literature review on the positive and negative connection between frugal innovations and sustainability, Albert (2019, p. 11, table 6) states that frugal innovations are "inherently green", "create value from waste (waste as resource)" or "improve energy and material efficiency". In contrast to this "frugal innovation does not have an inherent sustainability impact, the ecological impact of frugal innovation is rather a spill-over effect, the economic and ecological impact is not always given clearly" (Albert, 2019, p. 10) who refers to Rosca, Arnold and Bendul (2017). Based on this debate, two research gaps arise which – to the best of the author's knowledge – have not been explicitly addressed in the literature.

The first gap concerns the transfer of frugal innovation principles to corporate sustainability in developed markets. It seems crucial not only to emphasize *whether* frugal innovations are (not) sustainable, but *how* frugal innovations can promote sustainability and *which* basic innovation perspectives Western companies can follow to foster green(er) innovation. Already today – despite the generally criticized lack of empirical research (Albert, 2019; Brem and Ivens, 2013; Rosca, Reedy and Bendul, 2017) – some in-depth case studies present in detail *how* frugal innovations support

[3] Within the scope of this paper, the framework of corporate sustainability developed by Dyllick and Hockerts (2002) and based on the "six criteria of corporate sustainability" is taken for further analysis.

sustainable product development, e.g. Busch et al. (2018), Dressler and Bucher (2018) or Molina-Maturano et al. (2020). However, in order to further establish a link between frugal innovations and corporate sustainability in Western markets, it is important to create a broader and hands-on overview to guide companies and decision-makers. For these reasons, the first research question is:

> **RQ1:** Can frugal innovations support corporate sustainability? If so, which principles can be applied?

Further, this paper will be based on the assumption that frugal innovation principles addressed in the first research question can improve sustainability performance *without* the need to develop a frugal product. Due to numerous barriers to the implementation of frugal innovations (Niroumand et al., 2021), it seems necessary to underline the trade-off between frugal, but not inherently sustainable, and sustainable, but not inherently frugal. As a result, companies do not necessarily have to develop a frugal product to increase their sustainability performance. Consequently, there is a need for a more in-depth conceptual consideration of frugality and sustainability. Hence the second research question is:

> **RQ2:** How can these principles be conceptualized in the discourse of frugal innovations and sustainability?

A comprehensive literature review will be conducted to answer the first and second research question. The findings will be classified by means of a qualitative content analysis along the categories of corporate sustainability proposed by Dyllick and Hockerts (2002) and translated into guiding principles afterwards.

Both research questions remain on a conceptual level and build on existing literature. For this reason, a first empirical investigation of the proposed concepts should be carried out. The automotive industry will serve as an example as the link to frugal innovations is already subject of numerous research papers (Bergmann and Tiwari, 2017; Midler et al., 2017; Nielsen and Wilhite, 2015; Palepu et al., 2010; Prabhu, 2017; Singh et al., 2020; Sridharan, 2021; Tiwari and Bergmann, 2018; Tiwari and Herstatt, 2014; Tiwari and Kalogerakis, 2017). Within the scope of this paper, sustainability publications of Western car manufacturers will be analyzed systematically with regard to the principles derived in research question one and two. In addition, cases from the automotive industry will clarify the conceptualization. Finally, the third research question is:

> **RQ3:** How far are frugal innovation principles incorporated in the sustainability strategies of Western automotive companies?

The structure of the paper is as follows: Chapter 2 provides a theoretical background to corporate sustainability as well as to frugality and frugal innovations. Chapter 3 outlines the literature review, derives principles of frugal innovations to promote sustainability and conceptualize the findings. In chapter 4, the implications are transferred to the automotive industry. The paper concludes with a summary, limitations and the need for further research in chapter 5.

2 Theoretical Background

First, this chapter discusses the theory of corporate sustainability followed by a comprehensive taxonomy of frugal innovations in chapter 2.2.

2.1 Corporate Sustainability

According to Schaltegger (2013) sustainability management is a management discipline that runs through the entire company and supports the various business functions in minimizing negative environmental and social impacts. In order to achieve a holistic approach, management activities are based on the understanding of the triple bottom line framework. However, an important distinction should be made between the two basic philosophies that consistently characterize the corporate sustainability debate: (eco-)efficiency and (eco-)effectiveness.

Eco-efficiency has become the underlying paradigm of economic activities for companies (Braungart and McDonough, 2002). The understanding of eco-efficiency is closely linked to the concept of business efficiency and economic performance. As a consequence eco-efficiency is oriented towards the relationship between a target or output variable (e.g. economic value creation) and an environmental reference variable (e.g. environmental impact added) (Schaltegger and Lüdeke-Freund, 2013; Schaltegger and Sturm, 1990). By adopting this understanding, any environmental protection investment must reduce the environmental impact of the output. This could be done in several ways, e.g. the reduction of materials used for a product or through the use of renewable energy for the production of goods. The influence of the ecological and social orientation of companies on economic performance can be illustrated by the business case for sustainability. In this sense, it is crucial for a company "how profit increasing social and environmental activities, rather than cost increasing measures, can be identified and realised" (Schaltegger and Lüdeke-Freund, 2013, p. 248).

By taking a broader perspective, it also becomes clear that "the business case for sustainability is embedded within the wider notion of corporate sustainability" (Schaltegger and Lüdeke-Freund, 2013, p. 249). As soon as a company (in the logic of eco-efficiency and the business case for sustainability) does not create economic added value through an ecological or sustainable action, this action is no longer carried out on a voluntary basis. There is a need to take an absolute perspective on sustainability – a perspective that makes products "less bad" and creates not only incremental improvements (Braungart and McDonough, 2002; Dyllick and Hockerts, 2002; Gladwin et al., 1995; Hauschild et al., 2017; McDonough and Braungart, 2002; Schaltegger and Lüdeke-Freund, 2013). As the proponents of eco-efficiency, Braungart and McDonough (2002, p. 62) describe this strategy as "little more than an illusion of change" and "it works within the same system that caused the problem in the first place".

Within the debate of efficiency and effectiveness Dyllick and Hockerts (2002) adopt a three-part view of corporate sustainability – divided into the business, natural and societal case for sustainability. The authors provide six criteria of corporate sustainability that can serve as "clear indicators for firms to use in their strategy development" (Dyllick and Hockerts, 2002, p. 138), i.e. eco-efficiency and socio-efficiency as drivers for the business case for sustainability, eco-effectiveness and sufficiency as drivers for the natural case of sustainability and socio-effectiveness and ecological equity as drivers for the societal case of sustainability. A detailed explanation of the individual cases and drivers is given in table 1. This basic understanding will be further used in the following part of this paper by establishing the connection to frugality and frugal innovations.

Level	Overall Definition	Drivers
Business Case	*"Economically sustainable companies guarantee at any time cashflow sufficient to ensure liquidity while producing a persistent above average return to their shareholders."* (Dyllick and Hockerts, 2002, p. 133)	– ***Eco-Efficiency:*** Ensuring corporate competitiveness while minimizing negative environmental impacts along the entire life cycle of the product or service. – ***Socio-Efficiency:*** Improving the social value of a product or service and minimizing associated negative social impacts.
Natural Case	*"Ecologically sustainable companies use only natural resources that are consumed at a rate below the natural reproduction, or at a rate below the development of substitutes. They do not cause emissions that accumulate in the environment at a rate beyond the capacity of the natural system to absorb and assimilate these emissions. Finally they do not engage in activity that degrades eco-system services."* (Dyllick and Hockerts, 2002, p. 133)	– ***Eco-Effectiveness:*** Development of products and services that adopt an absolute perspective on ecological sustainability, rather than focusing on relative, incremental improvements. – ***Sufficiency:*** Creation of a new, conscious way of consuming, primarily through abandoning consumption and questioning the habits of consumption.
Societal Case	*"Socially sustainable companies add value to the communities within which they operate by increasing the human capital of individual partners as well as furthering the societal capital of these communities. They manage social capital in such a way that stakeholders can understand its motivations and can broadly agree with the company's value system."* (Dyllick and Hockerts, 2002, p. 134)	– ***Socio-Effectiveness:*** Development of products and services that adopt an absolute perspective on social sustainability, i.e. that add social value to society as a whole. – ***Ecological Equity:*** Ensuring that future generations are not negatively impacted by today's economic activities or the exploitation of (natural) resources.

Table 1: Levels of corporate sustainability, adopted by Dyllick and Hockerts (2002)

2.2 Taxonomy of Frugality and Frugal Innovation

The origin of the word "frugal" and "frugality" can be traced back to the 16th century – where the Latin term "frugalis" can be translated as "economical", "thrifty", "suitable" (Oxford Advanced Learner's Dictionary, 2021; Wohlfart et al., 2021). It is assumed that the term "frugal" made its way into innovation management for the first time in 2009 in the context of low-cost innovative medical technology and – as already described – generated significant research interest (Herstatt and Tiwari, 2015; The Economist, 2009). However, mainly discussed in the fields of innovation management and business research, some other disciplines that are directly related to the term must not go unmentioned (Tiwari et al., 2016). To provide a comprehensive introduction into "frugality" and "frugal innovation" table 2 can serve as a first orientation.

Frugality in Philosophy

Due to the focus of the working paper on innovation management, the philosophical aspect of frugality will only be briefly touched. Nevertheless, Tiwari et al. (2016, p. 7) note "the importance of investigating the history and geography of frugality, especially when aiming to better understand its relation to questions of innovation, progress, and sustainability". The basic understanding of frugality is already thousands of years old and has always been the cause of philosophical and nowadays increasingly business-relevant debates.

Subject	Keywords	Exemplary Sources
Philosophy	Golden mean ("middle path"), modesty and prudence	Bouckaert et al. (2007); Tiwari et al. (2016)
Innovation (wider sense)	Bottom-of-the-pyramid (BoP), global and disruptive innovation, affordable (green) excellence	Brem (2017); Herstatt and Tiwari (2017); Prahalad and Hart (2002); Radjou and Prabhu (2015); Zeschky et al. (2011)
Innovation (narrower sense)	(Frugal) Mindset	Krohn and Herstatt (2018); Krohn et al. (2019, 2020); Soni and Krishnan (2014)
	(Frugal) Process/ Engineering	Beise-Zee et al. (2021); Knizkov and Arlinghaus (2020); Sissoko and Castiaux (2018); Weyrauch (2018)
	(Frugal) Outcome/ Product	Rao (2013); Singh et al. (2020); Weyrauch and Herstatt (2016)

Table 2: Taxonomy of frugality

In philosophical writings that deal with the question of "how we should live" we observe various connections to frugality and frugal lifestyles. Taking the example of Confucius and Aristotle both philosophers speak of "the mean" and "moderation" – a path without extreme positions, which is also called the "golden mean" (Lawrenz, 2020, p. 2).

In Epicurus' philosophy, too, restraint and modesty are important virtues in order to experience pleasure – the ultimate goal of a human being.[4] Even if the philosophy of the Stoa is basically different from Epicurus' view, both share the conviction of a sufficiency-oriented way of life. In this conception, luxury and consumption are not fundamentally rejected, but it is nevertheless recommended to consume as little as possible, not to become dependent on external things or to ascribe too significant value to them (Schnor, 2015).

Restraint is also found in Buddhism, which has "not to multiply but to simplify desires" as one of its principles (Tiwari et al., 2016, p. 9). Song (2020, 2021), based on Buddhist teachings and cultures, explores the need to discard today's win-win paradigm of corporate sustainability and adopt an alternative path. The author proposes the "Buddhism-based sustainability framework" with three principles that serve as an orientation for more corporate sustainability, i.e. moderation, reasonableness and prudence.

Herstatt and Tiwari (2020) emphasize how (over)consumption in Western society does not inevitably lead to a more satisfying way of life. The involuntary renunciation that society is now experiencing in the Covid-19 pandemic, however, has the potential to question and recognize that consumption alone does not bring happiness: "People experienced that 'less can be more' and that one can be even happier with much less spending for things, we eventually do not need anyway. [...] Frugal lifestyle [...] does not mean bare renunciation of everything possible, but conscious consumption" (Herstatt and Tiwari, 2020, p. 12).

Particularly in the context of developed countries, renunciation and prudence as represented by Aristotle, Epicurus, the Stoa, but also Immanuel Kant, Adam Smith or Adam Weishaupt[5] are becoming increasingly important in the context of environmental challenges and overconsumption.

Frugality in Innovation Management

In order to derive a taxonomy for the concept of frugal innovations, the division into an innovation mindset, innovation process and innovation outcome proposed by Kahn (2018) proves useful. Other taxonomies of frugal innovations that have already been published, such as the one by Soni and Krishnan (2014) or Knizkov and Arlinghaus (2020), are also based on this threefold division. However,

[4]See the famous writing "Letter to Menoeceus" (Epicurus, 2021).

[5]See Tiwari et al. (2016) and Bouckaert et al. (2007) for a more comprehensive overview.

since frugality is often also understood as an overarching philosophy as well as provides links to several other theories within innovation management this section will focus on ***frugal innovations in a wider sense*** at first. Afterwards, the focus will shift to the frugal mindset, process and outcome – or in other words – ***frugal innovations in a narrower sense***.

In order to provide an introduction to frugality in innovation management, a historical perspective seems to be a suitable approach. Therefore the "undergoing contextual shift" (Brem, 2017, p. 39) within the theory of frugal innovation is taken as a basic frame for this purpose. A similar historical outline is presented by Tiwari and Herstatt (2020), which describe the different phases of traditional frugality as "frugality 1.0" to the modern understanding of "frugality 4.0".

Starting with the theory of the "bottom-of-the-pyramid" (BoP)[6] it is important to note that Western companies are overlooking the unsaturated markets of emerging economies. Even though products and services in emerging markets have relatively low profitability, the aggregate purchasing power of the BoP is far greater than that of the upper segments. In spite of this, companies are increasingly focus on more profitable market segments and thus overlooking the economic opportunities of the lower market segments "due to the limited purchasing power of its customer base" (Brueckner, 2013, p. 1149).

This hesitation and the ignorance on the low-end segments offer from the perspective of the theory of disruptive innovation by Christensen (1997) a great potential for disruptors to enter precisely this market and, from there, possibly become a threat to incumbents. "Products based on disruptive technologies are typically cheaper, simpler, smaller, and, frequently, more convenient to use" (Christensen, 1997, p. xv). The theory of disruptive innovation provides one answer, why Western MNCs struggle to penetrate BoP markets – despite their outstanding growth potential.

Prahalad and Hart (2002, p. 3) outline that "doing business with the world's 4 billion poorest people [...] will require radical innovations in technology and business models. [...] Companies will be forced to transform their understanding of scale, from a 'bigger is better' ideal to an ideal of highly distributed small-scale operations married to world-scale capabilities." The result of this (re-)orientation are so-called affordable, low cost, sustainable – in short frugal – innovations.[7]

Moreover, the scientific debate about "low-cost-high-quality" innovations makes a reorientation of the lead market theory necessary. In particular, Tiwari (2017, p. 55) points out that India is "a very attractive market for frugal innovations, which can be then introduced in other markets with comparable socio-economic conditions or even in the industrialized world." Empirical investigations within the Indian automotive industry shows that India is "in a position to lead the demand for (low cost) small cars for price-sensitive customers [...], for whom cost of ownership is a key criterion of decision making in regard to any such purchase of relatively large magnitude" (Tiwari and Herstatt, 2014, p. 192). Ultimately, the interest of Western MNCs in unsaturated markets as well as the increasing diffusion of innovations from new lead markets such as India contribute to the fact that frugal innovations must be interpreted as a multinational, global phenomenon (Agarwal and Brem, 2021, part III). As a result, the context in which frugal innovations have been investigated in research is changing (Brem, 2017). Initially, the focus was on the understanding how domestic companies in emerging markets manage to bring affordable and technologically well-developed products ("affordable excellence" (Mashelkar, 2014)) to market under difficult marginal conditions, such as low purchasing power or resource scarcity. Especially in saturated markets

[6] See Prahalad and Hart (2002) and Prahalad (2005)

[7] For the purposes of this working paper, a precise distinction between frugal innovations and, for example, jugaad or reverse innovations will not be made.

in Western economies, the BoP markets appear to be a promising opportunity for companies to generate a win-win situation with innovations "that are profitable as well as help solve social and environmental problems in low-income countries" (Brueckner, 2013, p.1149).

But frugal innovations are also seen as having great potential in industrialized nations. What is also called "frugality 4.0", "affordable green excellence" or "frugality by choice" is the consistent orientation of society towards conscious consumption with a focus on environmental sustainability (Tiwari and Herstatt, 2020). The key motives for pursuing a frugal life style are thus partly different from the predominantly financially driven motivation in emerging markets.[8] Interestingly, years before the term "frugal innovation" appears in the academic (global) discourse, Prahalad and Hart (2002, p.12) recognized that "many of the innovations for the bottom can be adapted for use in the resource- and energy-intensive markets of the developed world".

In this contextual shift, the conceptualization based on Rosca, Arnold and Bendul (2017) and presented in fig. 1 provides a more comprehensive overview. A distinction is made between the origin of the frugal discourse, product or service (from emerging or industrialized nations) and the target market (to emerging or industrialized nations).

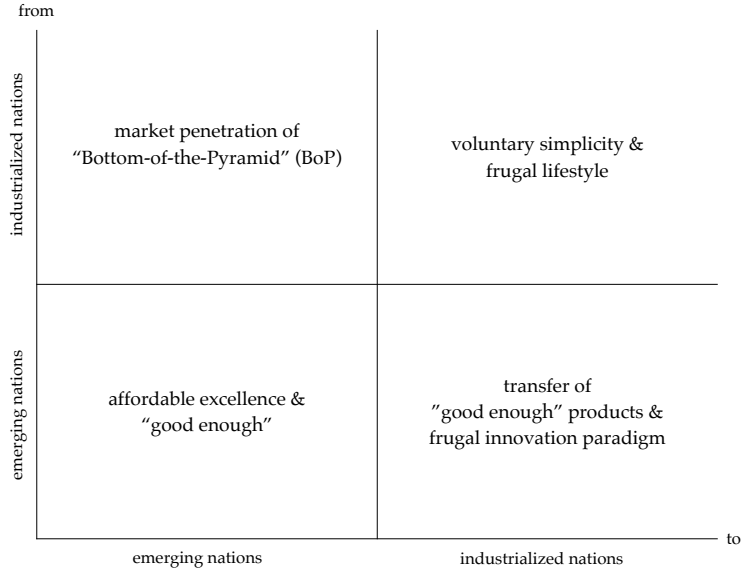

Figure 1: Conceptualisation of frugal innovation in innovation management, adopted by Rosca, Arnold and Bendul (2017) and further modified by the author

By adopting a narrower sense on frugal innovations, questions arise about the prevailing innovation mindset within organizations to promote frugal thinking and innovate frugally. Since "reverse product innovations are fundamentally different from advanced products developed for Western markets, the existing structures of Western MNCs' international R&D organisation may not be designed to meet the requirements of frugal innovations [...]" (Zeschky et al., 2014, p. 259). Based on the theory of "Action Phases and Mindsets" by Gollwitzer (1990) as well as the "Theory of Planned Behavior" by Ajzen (1991) researchers investigate the ***frugal mindset*** both on a conceptual as well as empirical level (Krohn and Herstatt, 2018; Krohn et al., 2019, 2020). Quoting the

[8] Again, in the context of lead market theory Tiwari (2017, p. 55) mentions that "the acceptance [in India] seems to be, however, primarily motivated by financial considerations and in that it varies from their global counterparts, who also put emphasis on environmental aspects in their pursuit of frugality."

authors "a frugal mindset describes a cognitive orientation, which results in questioning current assumptions, re-evaluating current approaches and implementing effective actions to develop frugal innovations" (Krohn and Herstatt, 2018, p. 13). The authors present nine core characteristics of a frugal mindset (Krohn and Herstatt, 2018) and propose a way how to operationalize it – resulting in a research model that quantifies different influencing factors of behavioral intention (Krohn et al., 2020). Accordingly, organizations and managers with a frugal mindset are able to develop a deep and precise understanding of customer needs and translate these into frugal outcomes (Krohn and Herstatt, 2018).

Knizkov and Arlinghaus (2020) provide a comprehensive overview of the state of research about the processual characters of frugal innovations. ***Frugal processes*** are "understood and defined in relation to their desired outcome, frugal products" (Knizkov and Arlinghaus, 2020, p. 6).[9] Despite the direct link between frugal processes and outcomes, scholars point out the need to conceptually separate the two terms (Bhatti and Ventresca, 2013; Soni and Krishnan, 2014). Knizkov and Arlinghaus (2020, p. 6) emphasize that "frugal processes do not necessarily need to result in frugal products, [but] frugal products require all processes associated with them to be frugal as well". However, according to Knizkov and Arlinghaus (2020) literature about frugal processes is still undertheorized. The researcher underline that most of the papers published provide a strong focus on product and outcome level. Eventually the authors develop a set of nine (frugal) process characteristics, e.g. simplified, localized, iterative and flexible. Also Weyrauch (2018) finds within a 19 months action research project, that frugal innovation processes needs to be flexible and partly iterative. A market-pull philosophy, i.e. consistent orientation to customer needs, must therefore be emphasized early on in product development.

The term ***frugal engineering*** can be defined as "a clean-sheet approach to product development that aims at maximizing value for the customers while minimizing non-essential cost" (Soni and Krishnan, 2014, p. 9). In this context Beise-Zee et al. (2021), Weyrauch (2018) and Herstatt and Tiwari (2015) provide an overview of possible methods for the frugal (engineering) process. Examples include the value analysis, analogy method, TRIZ[10] or contradiction-oriented innovation strategy as well as target costing. The resource-constraint characteristic of frugal innovations is also subject of recent research as a major factor influencing the frugal engineering and innovation process (Agarwal and Brem, 2021; Agarwal et al., 2021; Beise-Zee et al., 2021).

In order to be able to distinguish a ***frugal product*** from a non-frugal product, Weyrauch and Herstatt (2016) propose the three criteria often cited in academia. According to these, a frugal product is characterized by (1) substantial cost reduction, (2) concentration on core functionalities and (3) optimized performance level. It is important to underline that the cost reduction is always achieved from the customer's perspective, thereby emphasizing the criterion of affordability. However, the decisive factor which classifies an innovation as (not) frugal, are the total costs of ownership (Tiwari and Herstatt, 2012; Weyrauch and Herstatt, 2016). In meeting the core functionalities and the required level of performance, various attributes, like "affordable", "robust", "user-friendly",

[9] The reader should be made aware of the conceptual vagueness of frugal process and frugal engineering, see also Soni and Krishnan (2014) who classify "frugal engineering" in the category "process". However, the term "frugal engineering" is often treated as independent concept within the theory of frugal innovation. Beise-Zee et al. (2021, p. 649) note that "we are still far from being able to flesh out a sophisticated and theory-driven constraint-based engineering". As a reason of that, frugal engineering is also understood as part of the innovation process and not further conceptualized in this paper.

[10] Translated from the Russian **t**eoriya **r**esheniya **i**zobretatelskikh **z**adatch as "theory of inventive problem solving".

"scalable", "sustainable", "resource-efficient" or "social" are used to describe a frugal outcome more in-depth (Albert, 2019; Herstatt and Tiwari, 2015; Radjou and Prabhu, 2015; Singh et al., 2020; Weyrauch and Herstatt, 2016).

Researchers also point out that the "good-enough" philosophy must always be contextualized and interpreted in a situation-specific way.[11] As a result, the market-geographical context needs to be taken in account when analyzing frugal innovations – an insight that is particularly important in the research and diffusion of frugal innovations in developed nations. In this sense Wohlfart et al. (2021, p. 160) state that affordability "is an important factor in all markets but has a different meaning in a high-income country compared to a middle- or low-income one".

3 Frugal Sustainability in Academia

After the theoretical background of corporate sustainability as well as frugal innovations has been presented, the multifaceted relationship between sustainability and frugal innovations will be discussed in this chapter which is structured as follows: first, the method and the results of the systematic literature review (SLR) are described. Subsequently, the result of the SLR is analyzed with a content analysis based on predefined (a-priori) categories. The iterative process of inductive categorization finally leads to the development of specific principles to foster sustainable innovation based on frugality. The chapter concludes with the conceptualization and discussion of the proposed term "frugal sustainability".

3.1 Systematic Literature Review

As mentioned in the introduction, there are numerous studies of frugal innovations in the context of sustainability. While some authors see a strong correlation between frugal innovations and sustainability (Brem and Ivens, 2013) others are more critical (Rosca, Arnold and Bendul, 2017). A comprehensive overview of the positive as well as negative connections is presented by Albert (2019) on the basis of an extensive literature review conducted in April 2017. Because of the growing interest in frugal innovations in literature and in the global business context as well as due to the increasing urgency of sustainable development, it seems to be reasonable to conduct a current SLR of both disciplines. With the method of the SLR "all empirical evidence that fits the pre-specified inclusion criteria to answer a particular research question or hypothesis" (Snyder, 2019, p. 334) can be determined.

The first step was to define the search keywords, which were set as "frugal innovation*" and "sustainab*" (to ensure both "innovation" and "innovations" as well as "sustainability" and "sustainable"). In order to achieve a precise focus on the two mentioned disciplines, the query was limited to headings in which both keywords had to appear. Further, only (conference) reports, articles and book chapters in English language were considered. On September 2, 2021, the literature search was carried out in the following databases: Web of Sciece (17 findings), EBSCO Business Source Premier (9 findings), Google Schoolar (42 findings) and BASE (63 findings). The results are presented in table 5. After duplicates were removed, 48 findings remained. 9 reports were not included as not relevant to the content, not accessible or due to Spanish language. Ultimately, 39 findings were considered in the final database and therefore taken into account for the content analysis.

[11] A car horn in India can serve as an example, which must be particularly robust due to its frequent use (Herstatt et al., 2008).

Interestingly, an analysis of the publication dates shows that approximately 50% of all findings appeared in 2019 or later. On this basis, an increasing attention to frugal innovations and sustainability can be identified, underlining the continued focus on frugality in innovation management.

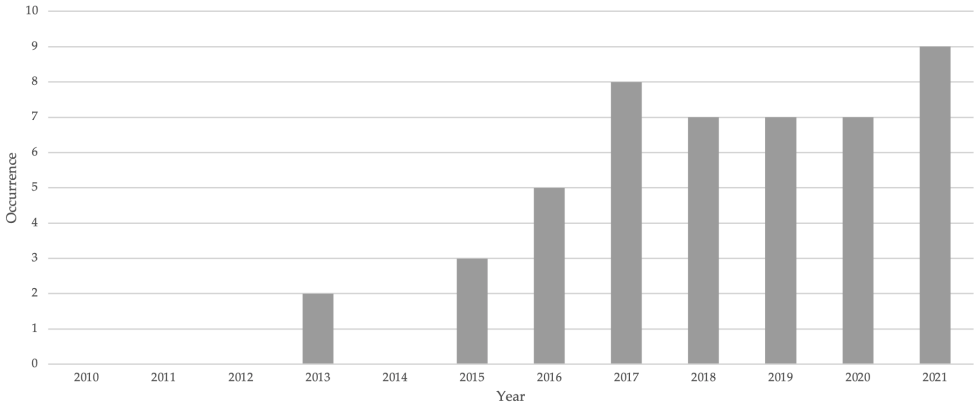

Figure 2: Result of the SLR, ordered by publication date (own illustration)

3.2 Frugal Innovation and Corporate Sustainability

In order to determine the relationship between frugal innovations and corporate sustainability, a qualitative content analysis was conducted within this study following the approaches proposed by Kuckartz (2018). According to Kuckartz (2018) qualitative content analysis is characterized in particular by its structured, code-guided approach.[12]

Therefore, the sources identified in the SLR were first coded using a-priori (deductive) codes. These codes were based on the structure of corporate sustainability already proposed by Dyllick and Hockerts (2002) and presented previously. Thus, this categorization goes beyond the classification based on the triple bottom line as it is carried out for example in Albert (2019) or Levänen et al. (2016). Furthermore, the characteristics of frugal innovations can be classified along efficiency, effectiveness and sufficiency. A summary of the results is given below. For the sake of better readability, only a limited number of sources are given.

(1) Business Case – the eco-efficient perspective

The efficiency paradigm of frugal innovations expressed in the principle "do more with less" (Radjou and Prabhu, 2015) can also be found in numerous sources of the SLR. Efficiency is defined in various ways, but can often be referred back to the concept of reduction. In this context, Brem and Ivens (2013, p. 41) note the reduction of "input resources required for the production of a market offering" of a frugal product. The reduction of complexity in frugal processes and products as well as the resulting cost savings are stressed by several scholars (Brem and Ivens, 2013; Busch et al., 2018; Hossain, 2018; Khan and Le Bas, 2019; Le Bas, 2016; Levänen et al., 2016; Pansera and Sarkar, 2016; Rosca, Arnold and Bendul, 2017). As a consequence, frugal innovations can lead to a reduction of negative externalities, like emissions or waste and therefore reduce the ecological footprint (Albert, 2019; Brem and Ivens, 2013; Busch et al., 2018; Khan, 2016; Yousaf et al., 2021).

[12]Due to issues of conceptual differentiation between "code" and "category", the recommendation of Kuckartz (2018) is also followed here and both terms are used synonymously.

In addition to the promotion of environmental sustainability, frugal innovations are often positively linked to the corporate growth to improve and maintain economic orientation and business opportunities (Albert, 2019; Basu et al., 2013; Brem and Ivens, 2013; Le Bas, 2016; Molina-Maturano et al., 2020). The realization of new market potentials can be achieved through the radical and disruptive nature of frugal innovations, which forces companies to rethink products, processes and business models (Brem and Ivens, 2013; Iqbal, Ahmad, Li and Li, 2021; Le Bas, 2017). Scholars emphasize that new, customized innovations have been developed in particular *due to* constraints and restrictions within the innovation environment (such as the scarcity of materials or financial resources). In this context numerous case studies from different countries, like Brazil (Busch et al., 2018), India (Chhabra, 2016; Hossain, 2021), South Africa (Dressler and Bucher, 2018; Johnsson, 2020), Kenya (Musona, 2021), Mexico (Molina-Maturano et al., 2020) or Mali (Sissoko and Castiaux, 2018) provide valuable insights.

(2) Business Case – the socio-efficient perspective

In particular, the socio-efficient sustainability perspective of frugal innovations is one of the most frequently found in the literature. This seems not surprising as frugal innovations, as described, originate from the debate of customers of the BoP. In this context, Pansera and Sarkar (2016, p. 19) emphasize the role of the BoP as "poor-as-consumers, poor-as-co-producers and poor-as-innovators". Khan (2016, p. 21) summarizes that "frugal innovators pull poor customers into the mainstream, innovate for them and provide affordable and viable solutions to their needs. Therefore, businesses that innovate frugally contribute towards societal goals alongside economic ones". The social value of frugal innovations can be illustrated in particular by the empirical studies just cited above and manifests in a wide variety of forms (Johnsson, 2020; Khan, 2016; Yousaf et al., 2021). Examples include the fight against poverty and hunger as well as the promotion of prosperity, economic development, digitalization and knowledge creation, to name just a few. Frugal products are optimized precisely for the local and social infrastructure and shortcomings. Numerous authors point out the need for local value creation, for example through local development, manufacturing and distribution as well as use of locally available resources (Busch et al., 2018; Khan, 2016; Pansera and Sarkar, 2016; Rosca, Arnold and Bendul, 2017; Sissoko and Castiaux, 2018).

Finally, affordability is central to the debate on social-efficiency of frugal innovations. Through affordability frugal innovations enable low-income populations with (very) low purchasing power to consume and ultimately promote prosperity and social development. Despite numerous similarities to sustainable and reverse innovation, the characteristic of affordability is the central distinctive feature of frugal innovations (Le Bas, 2016).

(3) Natural Case – the eco-effectiveness perspective

A number of sources show evidence of a correlation between frugal innovations and circular economy approaches. This refers to the orientation towards the "R-principles" (e.g. reuse, recycling or reduce), focus on closed-loop activities, the avoidance of toxic and hazardous ingredients or the use of renewable energy (Busch et al., 2018; Iqbal, Ahmad, Li and Li, 2021; Le Bas, 2016; Rosca, Arnold and Bendul, 2017). Based on Tiwari et al. (2014), Albert (2019, p. 13) states that "practices of planned obsolescence are incompatible with frugal innovation, since frugal innovation, [...] need to cope with various infrastructural shortcomings such as voltage fluctuation, abrupt power-cuts, dust, and extreme temperatures".

However, with a few exceptions, e.g. Busch et al. (2018), the link towards circularity remains mostly at a conceptual level. Authors criticize the lack of an absolute perspective of sustainability. In this sense Levänen et al. (2016, p. 10) emphasize that "despite frugal innovations being more ecologically sustainable in a local context, it is especially difficult to estimate their material effi-

ciency from the global life-cycle perspective". To conclude, the discrepancy between relative and absolute sustainability perspectives in the context of frugal innovations remains one of the many under-researched issues in this field.

(4) Natural Case – the sufficiency perspective

The sufficiency nature of frugal innovations is one of its core characteristics, reflected for example in the philosophy of "good enough". The avoidance of unnecessary product features as well as overengineering and a significant simplification of the products or services can be categorized as sufficiency-oriented strategies (Basu et al., 2013; Hossain, 2018; Le Bas, 2017; Rosca, Arnold and Bendul, 2017). Frugal innovations are also highlighted in the context of voluntary simplicity and post-growth opportunities, which also promote critical reflection on product features and conscious consumption (Albert, 2019; Carrera and MacDonnel, 2015; Rosca, Reedy and Bendul, 2017).

Since complexity reduction in an eco-efficient sense as well as simplification in a sufficiency sense are closely related to each other, the conceptual distinction between sufficiency and efficiency is not always obvious; a characteristic of frugal innovations that Rosca, Reedy and Bendul (2017, p. 149) notes as "combination of efficiency and sufficiency approaches".

Despite closely linked sufficiency approaches, the "excellence" characteristic of frugal innovations should be emphasized again at this point. Although frugal innovations have a reduced range of functions, their quality attributes precisely meet customer needs and – by definition – do not produce poor or cheap quality (Weyrauch and Herstatt, 2016).

(5) Societal Case – the socio-effectiveness perspective

The BoP context in which frugal innovations originate focuses on economically and socially marginalized population groups. Frugal innovations consider society as a whole and are seen as drivers for social equality, environmental justice and social inclusiveness (Dressler and Bucher, 2018; Khan, 2016; Khan and Haldar, 2015; Le Bas, 2016; Pansera et al., 2017). With that, consumption and well-being, as well as research, development and production, are shifting more and more to other regions and markets in the world, thus promoting the global fight against poverty and social inequality (Albert, 2019; Bhatti and Prabhu, 2019; Hossain, 2018; Rosca, Reedy and Bendul, 2017).

(6) Societal Case – the ecological equity perspective

The final aspect of the corporate sustainability framework is also the one for which by far the least content could be found. As long as ecological equity is conceptually separated from eco-effectiveness, only Rosca, Reedy and Bendul (2017, p. 151) mention frugal innovations in the context of future generations. Due to the ecological characteristics of frugal innovations it is possible "to meet the needs of the current generation and the future ones" – a wording that recalls the definition given in the Brundtland Report which also emphasizes the intergenerational aspect of sustainability (World Commission on Environment and Development, 1987).

Further, if responsible innovations or corporate social responsibility (CSR) are explicitly considered in the context of intergenerational and environmental justice, a link to frugal innovations can be established as well (Albert, 2019; Le Bas, 2017). Otherwise, this point remains vague and more in-depth investigations should be carried out, for example on the basis of other search criteria of the SLR.

3.3 Principles of Sustainable Frugal Innovation

After the sources of the SLR were classified into the predefined criteria, these were refined into inductively generated categories. This iterative process resulted in the principles shown in table 3.

Case	Driver	Principle	Exemplary sources
Business Case	Eco- Efficiency	Reduce input resources, negative externalities and product/service complexity ("do-more-with-less-paradigm")	Brem and Ivens (2013), Khan and Le Bas (2019), Albert (2019), Levänen et al. (2016), Busch et al. (2018) , Khan (2016), Rosca, Arnold and Bendul (2017)
		Rethink and redesign products, processes and business models in a radical and/or disruptive way in order to increase and maintain economic growth and market performance	
		Balance innovation contradictions, constraints and scarcities and treat them as opportunities rather than barriers	
	Socio-Efficiency	Create local value and preserve user proximity with a deep understanding of customer needs	Khan (2016), Sissoko and Castiaux (2018), Rosca, Arnold and Bendul (2017), Le Bas (2016)
		Create social value by addressing and tackling social challenges	
		Foster affordability through consistent reduction of total cost of ownership	
Natural Case	Eco-Effectiveness	Take an absolute perspective on sustainability through circular economy approaches	Busch et al. (2018), Iqbal, Ahmad, Li and Li (2021), Levänen et al. (2016)
		Prevent (planned) obsolescence through robustness, durability and reuse	
	Sufficiency	Renounce unnecessary features by fostering simplification and a "good-enough-philosophy"	Basu et al. (2013), Hossain (2018), Rosca, Reedy and Bendul (2017)
		Consume and procure consciously with voluntary simplicity	
Societal Case	Socio-Effectiveness	Promote social equity and justice through inclusive and social innovation	Dressler and Bucher (2018), Khan (2016), Bhatti and Prabhu (2019)
		Consider society as a whole through increased focus on BoP	
	Ecological Equity	Address ecological ethics and intergenerational awareness with responsible innovation	Rosca, Reedy and Bendul (2017), Albert (2019), Le Bas (2017)

Table 3: Principles of frugal sustainability based on SLR

The procedure follows the process of a "structuring content analysis" according to Mayring (2015) and Kuckartz (2018), which is based on a mixed form, also called "deductive-inductive category formation" (Kuckartz, 2018, pp. 95-96). The final categories were reformulated into the form of a principle that can be used as a strategic orientation for sustainable product and process development.

The principles shown present a combination of theoretical contributions as well as empirical studies based on the literature shown in table 5. They do not answer the question whether frugal innovations are (inherently) sustainable or not. Rather, these principles can be used for the development of sustainable and green(er) innovation *without the intention of developing a frugal innovation in the definitional sense* according to Weyrauch (2018). Given these considerations, the conceptualization of the principles within the overall academic discourse becomes necessary and will be therefore discussed in the next chapter.

3.4 Discussion: Frugal Sustainability and Sustainable Frugality

In addition to the positive contribution of frugal innovations to sustainability, there are also a number of reports that are more critical in this context. For example, Albert (2019) presents features and characteristics of frugal innovations that have a negative or even counterproductive impact on sustainability. Examples include rebound effects or a lack of adequate end-of-life-treatment. Numerous authors point out that frugal innovations are not developed for ecological reasons and

that positive contributions to sustainability are (incidental) side effects. Thus, Rosca, Arnold and Bendul (2017) speak of a spill-over effect of ecological advantageousness. Both Wohlfart et al. (2016) and Weyrauch (2018) state that environmental aspects are not the primary motivation and focus of frugal innovations. As a consequence, Akbar and Subramaniam (2019) (who refers to Lelivelda and Knorringab (2017) as well as Hyvärinen et al. (2016)), underline the need to adopt a wider and long-term perspective on frugal innovations that is not limited to the product-level. Iqbal et al. (2020, p. 6) notes that "frugal innovation is inherently sustainable but does not result in sustainable performance in and of itself". Finally, for Le Bas (2016), the lack of a primary focus on sustainability is the key difference between frugal and sustainable innovation, even if frugal innovations basically support the sustainability orientation of technology.

The discussion about positive and negative impacts of frugal innovations on sustainability can be summarized with the question "*How much sustainability is inherent in frugal innovation?*". Some features of frugal innovations have no impact on the promotion of sustainability goals while others can actively contribute to an improvement in many aspects. The lack of a holistic view of sustainability in frugal products can be explained by the fact that frugal innovations have mainly been considered in the context of developing countries and thus the focus is more on social and economic aspects rather than achieving ecological improvements (Albert, 2019; Busch et al., 2018; Khan, 2016; Tiwari and Kalogerakis, 2016; Wohlfart et al., 2016). But even in industrialized nations, the focus of frugal innovations is not necessarily holistic. As Wohlfart et al. (2021) point out, there is a different understanding of the term "affordability" compared to emerging nations. Further, Albert (2019) highlights that the motivation for simplification and complexity reduction is a also different. Consequently, the social aspect is not at the forefront of frugal innovations in developed markets and the focus shifts more to an economic-ecologic motivation.

With respect to Brem (2017) and Tiwari and Herstatt (2020) who emphasize the global character of frugal innovations it seems necessary to strengthen the focus on the two following aspects:

First, the motivating background of frugal innovation approaches in different countries is too multifaceted to draw a single and final conclusion about the sustainability impact. Some authors underline the need to operationalize sustainability effects in order to be able to better compare and evaluate progress caused by frugal innovations (Albert, 2019). Others propose a reference point against which the (local) sustainable benefits can be measured (Busch et al., 2018). However, as shown in the SLR, it is revealed that frugal innovations contribute to sustainable development at different levels of corporate sustainability. Dressler and Bucher (2018, p. 276) point out that "if frugal innovations can at least be called more sustainable than other innovative solutions, they could have a great impact on the economic future". This potential makes it particularly interesting, especially for Western companies, to pay more attention to the innovation principles of frugality.

The second aspect concerns a more explicit conceptual separation of frugal innovations and sustainability. In a globally intensifying discussion about ecological sustainability, Western companies in particular are forced to come up with eco-innovations. Despite increasing interest in economically growing BoP markets and local frugality movements (Herstatt and Tiwari, 2020; Wohlfart et al., 2021), there are, so far, numerous barriers to frugal innovations, especially in Western (high-tech) environments (Krohn and Herstatt, 2018; Niroumand et al., 2021; Tiwari and Bergmann, 2018). Fear of product cannibalisation, lack of knowledge or the inhibiting organizational mindset are just a few examples why Western companies struggle to innovate frugaly. As long as Western companies are only partially taking up the development of frugal innovations, a second question arises: *"How can corporate sustainability be supported through frugality?"*.

Consequently, frugality is perceived as an enabler and new perspective to support the primary goal of (corporate) sustainability. The principles shown in table 3 do not have to result in a frugal

outcome *per se* – an implication that Soni and Krishnan (2014) and Knizkov and Arlinghaus (2020) also emphasize in the context of frugal processes. As described, frugal processes do not have to end in frugal products. The following terminology, "frugal sustainability" and "sustainable frugality", is intended to clarify the conceptual separation.

- ***Sustainable frugality*** describes the debate on whether and how frugal innovations are sustainable and can thus contribute to the sustainable development goals. The starting point of the discussion is a frugal product or business model, with the aim of fostering social value in BoP markets while realizing economic growth opportunities. Social and economic sustainability complement each other, ecological effects are a by-product.
- ***Frugal sustainability*** describes the debate on how far frugal principles can be used to improve the sustainability performance of companies, both on efficiency and effectiveness levels. The starting point of the discussion is the goal of ecological sustainability with simultaneous integration of economic goals into the value creation process. Economical and ecological effects complement each other, social aspects are a by-product.

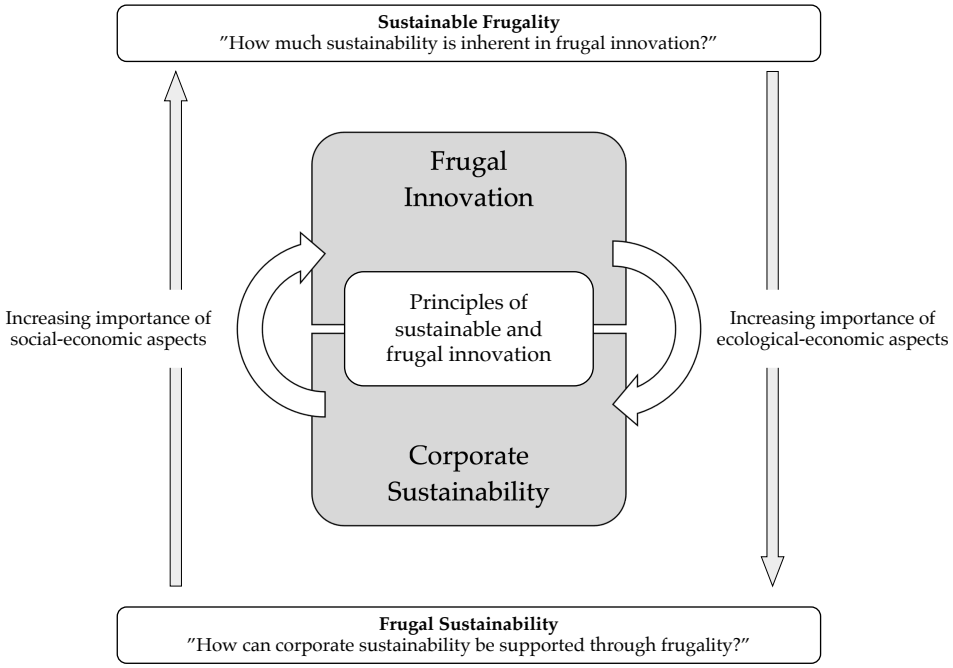

Figure 3: Frugal sustainability and sustainable frugality [own illustration]

The framework shown in fig. 3 supports the broader discussion and conceptionalization. For companies, the question arises whether (corporate) sustainability should be achieved through the development of a frugal product or whether the sustainability strategy should be supported with the principles of frugality. The framework illustrates the trade-off between a frugal (but ultimately not fully sustainable) innovation and a sustainable (but ultimately not fully frugal) innovation.

Finally, the authors want to state the following proposition: If frugal innovations are to be given greater consideration in Western nations and high-tech environments, an increasing focus on frugal sustainability will be essential. The following case studies will therefore serve to confirm the proposition and to show that "environmental sustainability can only be achieved when it is married to the concept of frugality" (Herstatt and Tiwari, 2020, p. 20).

4 Frugal Sustainability in Automotive

As already mentioned in the introduction, the automotive industry is often cited in connection with frugal innovations. The case of the "world's cheapest car", the Tata Nano, serves as an suitable example of a frugal innovation, despite its ultimate inability to become a commercial breakthrough (Nielsen and Wilhite, 2015; Palepu et al., 2010). But also within developed and industrial nations, the example of the German automotive component supplier industry shows that frugality is as an overarching innovation paradigm of modern technology development (Bergmann and Tiwari, 2017). In this respect, the (Western) automotive industry will also serve as an example for a more in-depth examination of frugal sustainability.

4.1 Frugal Sustainability in Automotive Sustainability Strategies

In the following analysis, the concept of frugal sustainability is further outlined using quantitative content analysis. For this purpose, the sustainability resp. annual reports of eight Western and globally operating automotive companies for the years 2016-2020 were analyzed for predefined keywords. Companies with different market positioning, e.g. from the volume, premium or sports segment, were selected for a more substantiated overview, see table 4. Together, they represent more than 37% of the global automotive sales market in 2020, with approximately 29 million vehicles sold (Statista, 2021c,d,f).[13] The keywords were derived from the principles shown in table 3 and are presented in table 6. Using MAXQDA software, the number of words in all reports was provided. The processed output is shown and analyzed in more detail in the following sections.

Company	Country	Sales in millions (2020)	Share of global car sales (2020)
Volkswagen (without Porsche)	Germany	8,89	11,46%
General Motors	USA	6,8	8,76%
Ford	USA	4,19	5,40%
Renault	France	2,95	3,80%
Daimler	Germany	2,84	3,66%
BMW	Germany	2,33	3,00%
Tesla	USA	0,5	0,64%
Porsche	Germany	0,27	0,35%
$\sum$	/	28,77	37,07%

Table 4: Automotive companies included in the case (Statista, 2021c,d,f)

Absolute and Relative Frequency of Keywords

In total, 23585 hits were returned for the defined keywords. The hits per keyword are shown in fig. 4. The graph shows that only a few keywords make up the majority of the hits. More precisely, the words (and their variants) "emission*", "responsib*", "reduc*", "efficien*", "waste", "local*" and "recycl*" already account for approx. 80% of all hits.

Subsequently, the keywords were reassigned to the corresponding (sub)category (namely "case"

[13]Since not all manufacturers publish their sustainability reports at the same time and in the same format, the following aspects are be pointed out: In 2020, BMW's sustainability report was merged with the annual report for the first time and therefore the latter was analyzed. Ford has published sustainability reports of two half-years each until 2019. In order to start the analysis from 2016, the 2016/2017 report was added to the year 2016 (subsequent years equivalent). In 2020, Ford published a report for the whole year. Porsche has combined the annual and sustainability report in one document. Similar to Ford, Renault has also published reports of two half-years each. For the analysis, the annual report 2016/2017 was added to the year 2017 (subsequent years equivalent). The 2015 financial year was included in a report for 2015 only, so that 2016 could not be analyzed separately. Lastly, Tesla has only been publishing the so-called "Impact Report" since 2018 – therefore, the years before could not be included in the analysis.

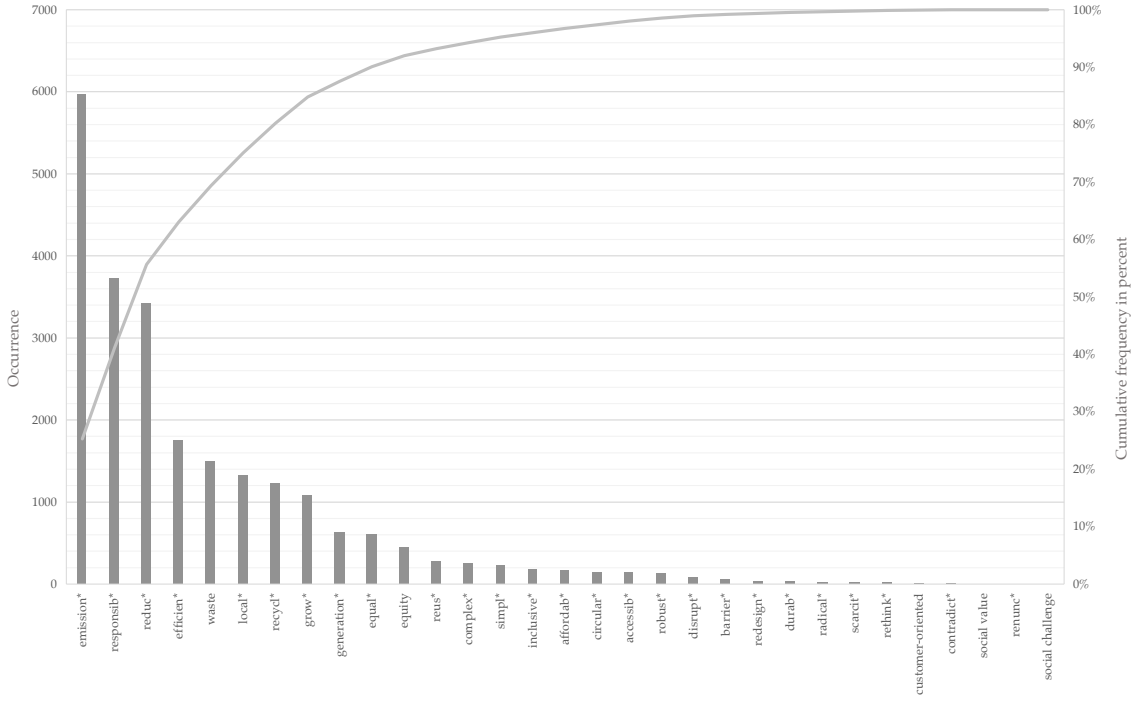

Figure 4: Occurence and cumultative frequency of selected keywords (own illustration)

and "driver") of the framework of Dyllick and Hockerts (2002) shown in table 1 resp. table 3. Since some subcategories have a higher number of keywords, the absolute number of hits per subcategory was divided by the number of corresponding keywords per subcategory. The result – the relative number of hits per subcategory – is shown in fig. 5.

The presentation of the relative number of hits per subcategory allows some initial insights to be made. First, the subcategory "ecological equity" is by far the most frequent. Even if this subcategory was classified by Dyllick and Hockerts (2002) in the "societal case", the result does not appear surprising in the context of frugal sustainability. Ultimately, the efforts of the economy and society to promote sustainability as well as environmental awareness can be traced back to intergenerational justice. As already stated in the definition of sustainable development published by the UN (World Commission on Environment and Development, 1987), in which intergenerational equity is a core element, this focus can also be confirmed in the reports examined.

However, eco-efficiency (excluding ecological equity for the moment) outweighs the orientation of the sustainability strategies of the companies studied. This confirms the *primary* focus of frugal sustainability on economic-ecological interests and a secondary focus on eco-effective and socio-effective levels. Even if the latter two do mark a certain number of hits, sufficiency-based strategies do not show a particular high level of attention. This confirms the fundamental criticisms of sustainability strategies that are based on sufficiency (cf. introductory part of this paper).

Since, as shown, frugal sustainability is not clearly centered in one of the six groups, but rather has numerous overlaps, it is necessary to take a closer look at the specific keywords over the years for a deeper analysis. The longitudinal representation is therefore described below.

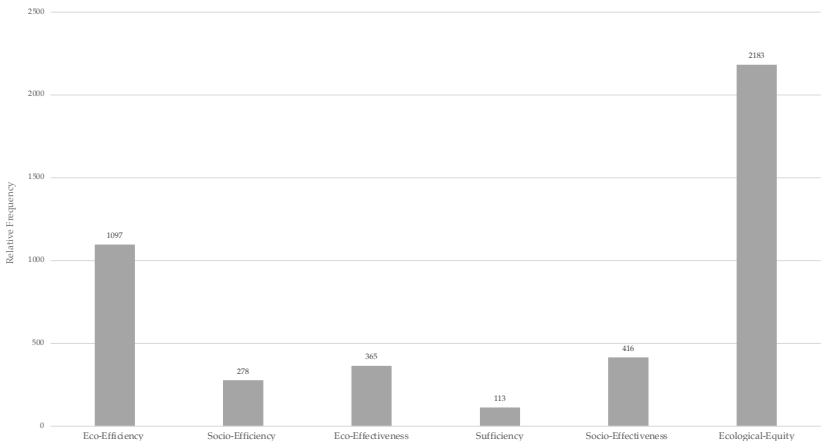

Figure 5: Relative number of hits per subcategory based on Dyllick and Hockerts (2002) (own illustration)

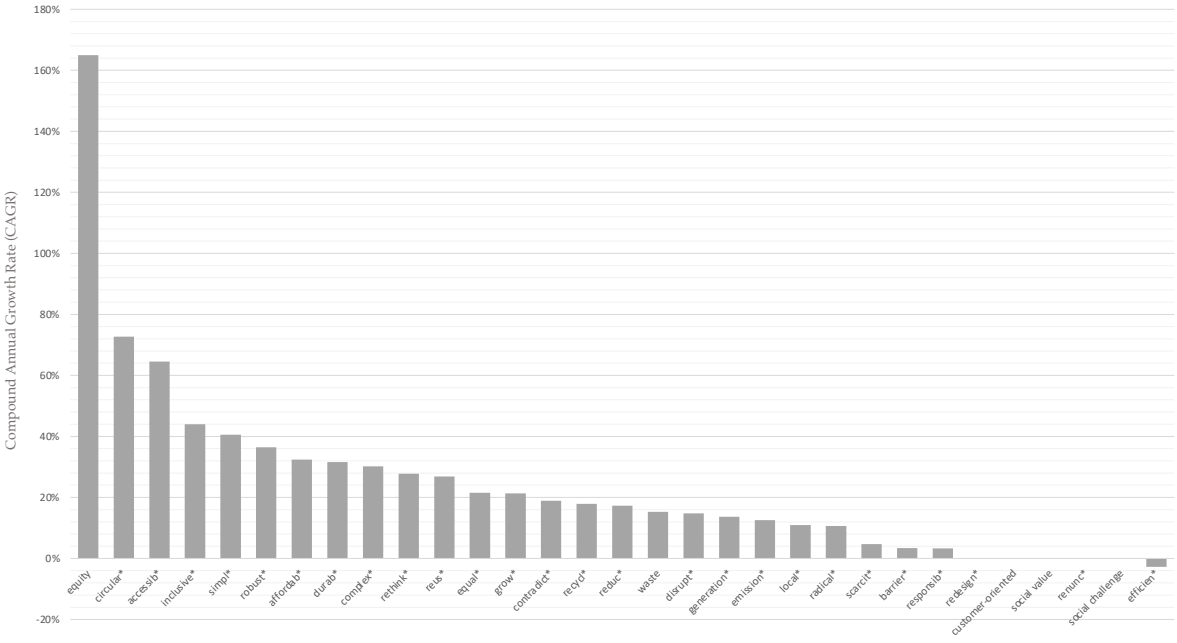

Figure 6: Compound annual growth rate (CAGR) 2016-2020 of keywords (own illustration)

Longitudinal Analysis of Keywords

For the longitudinal analysis, the compound annual growth rates (CAGR) of the corresponding keywords were examined and are shown in fig. 6. Again, there is an observable difference between the individual words. Interestingly, the most frequently mentioned words in absolute terms – "responsibility*" and "emission*" – experience low or even negative growth rates. The first ten words with the highest growth rates, none of which is smaller than 28%, are: "equity", "circular*", "accessib*", "inclusive*", "simpl*", "robust*", "affordab*", "durab*", "complex*" and "rethink*". Analyzing these words, the clear connection to frugality becomes apparent. Core characteristics such as affordability and accessibility as well as words underlying the modern understanding of frugality such as circularity and rethinking can be identified. It can therefore be argued that the derived principles

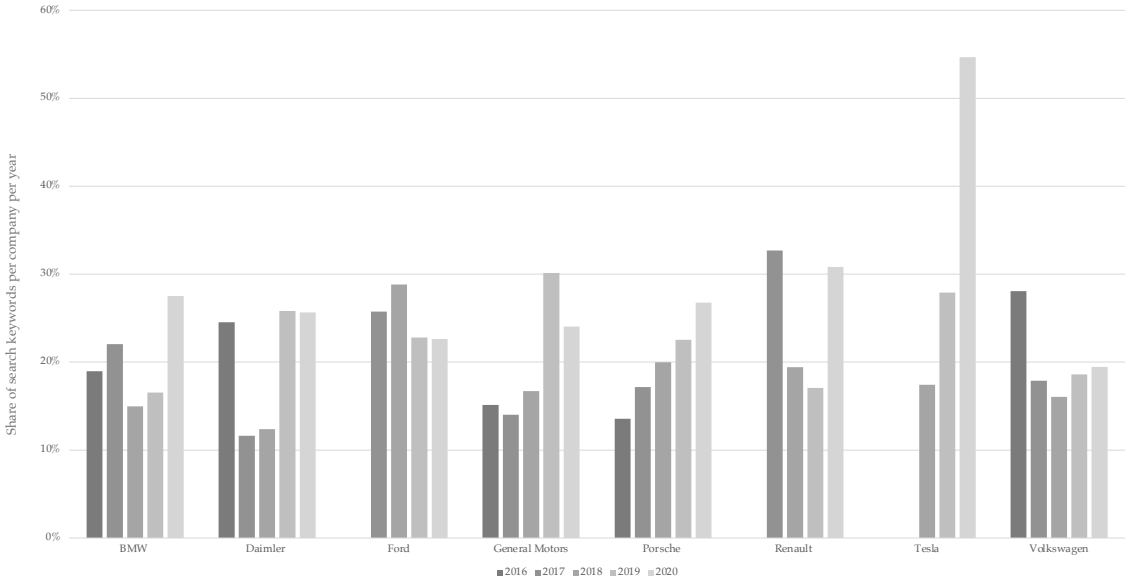

Figure 7: Analysis of the percentage use of the keywords by year and company (own illustration)

are not only found in today's strategies, but are showing outstanding growth rates. This underlines the raising phenomenon of frugality which has been mentioned frequently in the literature.

Analysis of the Percentage Use of Keywords by Year and Company
Finally, the percentage distribution of the keywords found in the reports for the individual companies is described in more detail. For this purpose, the percentage of the total hits of *all* words of a certain car manufacturer in one year was analyzed. This makes it possible to determine any trends over the years. For example, of all the hits found for the Tesla company, 55% were used in the 2020 report.

First of all, it should be noted that no clear trend can be identified between the brands, neither in general nor with regard to individual segments, e.g. exclusively within the volume or premium segment. Some manufacturers show rather constant hits over the years while for some others the value in 2016 is lower than the value in 2020 (e.g. Ford or Volkswagen). Others again show a continuous increase (e.g. Porsche or Tesla). Nevertheless, even without a clearly recognizable overall trend, an interesting connection can be identified, which ascribes a wide spectrum of applications to the concept of frugal sustainability: *Frugality and frugal sustainability must be seen as a new perspective to foster corporate sustainability, regardless of previous market, brand or product positioning.* This again disproves that frugal innovations are only to be found in low-tech sectors due to their "good enough" character and thus run the risk of delivering inferior quality. Frugality must therefore be seen as having a wider range of applications that go far beyond BoP markets and low-income segments.

4.2 Sustainable Frugality and Frugal Sustainability in the Automotive Industry

Finally, the following section will further illustrate frugal innovations in the context of the automotive industry with the example of a few specific vehicle projects.

Despite the limited commercial success of the Tata Nano, often referred as the "cheapest car in the world", this case provides an example of how frugal innovations can be developed but eventually not commercialized (Nielsen and Wilhite, 2015; Palepu et al., 2010). Tiwari and Herstatt (2014, p.

31) note that "customers have generally acted in a reserved manner while accepting products that were specifically designed and marketed as 'low-cost products'". On the other hand, the radical rethinking of the entire development process and supply chain becomes apparent in the case of Tata Nano even more so (Palepu et al., 2010). Also other models by Tata Motors Limited (TML) consistently pursue frugal approaches and enjoy great popularity in price-sensitive markets. One good example is the Tata Ace, a mini truck, which "cost[s] 50% less than any other four-wheeled commercial vehicle in India" (Tiwari and Herstatt, 2014, p. 71). Unlike the Tata Nano, the Tata Ace is a major commercial success with over 100,000 produced trucks just 22 months after the launch in May 2005 (Tiwari and Herstatt, 2014). One of the key features of the Tata Ace is the use of about 40% vehicle components that "are shared with other TML products to generate additional savings through bulk purchasing" (Tiwari and Herstatt, 2014, p. 72).

A similar approach, the so-called "carry-over method", has been used by the Romanian manufacturer and carmaker "Dacia", part of the French "Renault Group", for many years with outstanding success in global markets (Knörle and Esch, 2013). By using this method, components are specifically used that have already completed the development effort and have been successfully established in the market (in this case parts from other Renault Group brands). This has made it possible to significantly reduce development costs and successfully offer cars by Dacia not only for emerging markets but also for price-sensitive markets in Western industrial nations.

Another example is the Renault Kwid which exemplifies the great potential of frugal cars on the Indian market and in this case manufactured by a Western company. According to Singh et al. (2020), the great success in the Indian market can be explained in particular by the fact that the Renault Kwid emphasizes not only affordability but also "other attributes such as functionality, usability, performance, aesthetics, robust, [and] accessibility" (Singh et al., 2020, p. 10).

The growing importance of affordable cars is also evident in the world's largest automotive sales market, China. For years, the share of German passenger cars sold in China in total sales has been increasing (Statista, 2021b). China's share of global passenger car production is also growing at the global level (Statista, 2021a). Nevertheless, recent media reports indicate that the best-selling electric car, with a market share of almost 20%, is the Wuling Hongguan Mini EV from the joint venture manufacturer SGMW (Car News China, 2021; Spiegel, 2021; Tagesschau, 2021).[14] Available for a price of around 5,000 euros, it once again points out the importance of affordability, for both economic success and social added value – in this case mobility. These examples are typical representatives of ***sustainable frugality***, offering a good or good-enough quality to neglected customers mainly in emerging markets and thus significantly promoting social prosperity and development. At the same time, these models represent solid sales opportunities, both for domestic and foreign companies, and secure shares in growth markets that are difficult to realize, especially for Western companies (Knörle and Esch, 2013). Apart from the numerous simplifications and the elimination of non-essential functions the advantageousness of ecological sustainability is not explicitly mentioned in the cases just quoted.

The German automotive industry also provides its first examples of ***frugal sustainability***, as shown by the example of the "BMW i Vision Circular", a concept car that was first presented at the "Internationale Automobil-Ausstellung" 2021, or IAA for short. With the introduced model, the premium manufacturer BMW wants to demonstrate the vision of a fully circular and sustainable car and at the same time highlight the underlying philosophies of the entire development process published in an extensive press release (BMW Group, 2021). Not only does it emphasize the reduction

[14]SGMW is a joint venture of the companies "SAIC Motor Corporation Limited", "GM China" and Liuzhou "Wuling Motors Co Limited" (SGMW, n.d.). In 2020 the company already ranked fourth in the number of electric cars sold worldwide – behind the manufacturers Tesla, Volkswagen and BYD (Statista, 2021e).

of the use of primary raw materials, but it also literally addresses the "more with less" mentality in the innovation process. For BMW, the development of the "i Vision Circular" "[...] meant scrutinising processes and manufacturing technologies and thinking differently" (BMW Group, 2021, p. 2). Once again, the rethinking and scrutinizing character of frugal sustainability is underlined at this point – a strategy that has also worked well with the Tata Nano (Palepu et al., 2010). Durability and robustness are important characteristics, since "[...] the vehicle's life cycle can also be extended by refurbishing and redesign" (BMW Group, 2021, p. 3). Finally, even some sufficiency influences become apparent, which are characterized, for example, by a significantly reduced variety of materials and parts (BMW Group, 2021, p. 2 and 4).

This large number of cases supports the view that frugal innovations are a global phenomenon and should not be linked to just one product class or customer group. As shown, the principles of frugality can be found in products with drastically reduced functionality, as well as in the premium segment.

5 Summary, Limitations and Further Research

The report contributes to two main aspects of innovation research on frugality and sustainability.

First, based on an extensive literature review, principles were derived according to which frugal innovations can contribute to sustainable development on the levels of efficiency, effectiveness and sufficiency. Due to different motivational backgrounds of companies depending on their geographical location and market conditions, the terms "frugal sustainability" and "sustainable frugality" were introduced. While "sustainable frugality" emphasizes the sustainable character of frugal innovations in general, "frugal sustainability" tries to promote sustainability in companies without ultimately developing a frugal product. Therefore, frugal sustainability should be understood more as a new overarching innovation perspective.

Second, in order to gain first empirical insights into the concept of frugal sustainability, a quantitative content analysis was conducted on the basis of sustainability resp. annual reports by Western automotive companies. The results show a clear emphasis and positive development over the years of keywords that correlate closely with the principles derived earlier. Case studies of different companies and diverse product segments – from low-price to premium – underline the increasing importance of the introduced innovation principles.

Finally, the limitations of the studies will be discussed. First, it should be noted that the literature search was limited to keywords in the headings of the sources. Nevertheless, there are a large number of publications that also deal with the sustainability aspect of frugal innovations without having the keywords mentioned in the headline. Furthermore, the selection of reports in the quantitative analysis was limited to the Western automotive industry. It would be interesting to examine other sectors as comparative cases in order to be able to identify similar trends.

Moreover, the limitations of quantitative content analysis should not be ignored. While it is useful to identify overarching trends, it is not possible to examine a single word in its individual context in detail. For this reason, the keywords should be analyzed, e.g. with the help of a qualitative content analysis, for a more in-depth validation of the results.

On the theoretical and conceptual level, the principles of frugality and frugal sustainability show great potential for promoting corporate sustainability. However, as many authors note, the lack of empirical evidence should also be highlighted here. Despite its theoretical suitability, there are no empirical studies on whether and how the principles of frugal sustainability can be successfully applied in Western environments. In subsequent studies, the transferability to the entrepreneurial level must therefore be investigated.

A Appendix

Source	Included	Web of Science	EBSCO BSP	Google Scholar	BASE
Akbar and Subramaniam (2019)	✓			✓(2 entries)	✓
Albert (2019)	✓	✓	✓	✓	✓
Arnett and Claas (2015)	✓			✓	✓
Basu et al. (2013)	✓				✓
Bhatti and Prabhu (2019)	✓				✓(2 entries)
Brem and Ivens (2013)	✓			✓	✓
Brodhag (2021)	X				✓(6 entries)
Busch et al. (2018)	✓			✓	✓(4 entries)
Carpentier and Rang (2021)	✓			✓	✓
Carrera and MacDonnel (2015)	✓			✓	✓
Chhabra (2016)	✓			✓	
da Silva et al. (2020)	✓			✓(2 entries)	✓(2 entries)
Dressler and Bucher (2018)	✓	✓		✓	✓
Dubey et al. (2021)	✓			✓	✓
Hassani et al. (2019)	X	✓		✓	
Hossain (2018)	✓			✓	
Hossain (2021)	✓	✓		✓	✓
Hossain et al. (2021)	✓	✓	✓	✓	✓(2 entries)
Ibarra Baidón (2018)	X				✓
Iqbal et al. (2020)	✓	✓		✓	✓
Iqbal, Ahmad and Li (2021)	✓	✓		✓	✓
Iqbal, Ahmad, Li and Li (2021)	✓	✓	✓	✓	✓
Johnsson (2020)	✓			✓	✓
Khan (2016)	✓	✓		✓(3 entries)	✓(2 entries)
Khan and Haldar (2015)	✓				✓(2 entries)
Khan and Le Bas (2019)	✓			✓	✓
Kim et al. (2020)	X			✓	✓(5 entries)
Kunamaneni (2017)	X			✓	
Le Bas (2016)	✓	✓		✓	✓(2 entries)
Le Bas (2017)	✓			✓	✓(3 entries)
Levänen et al. (2016)	✓	✓			
Mishra and Saini (2017)	X			✓	
Molina-Maturano et al. (2020)	✓	✓	✓		
Musona (2021)	✓			✓	✓
Pansera and Sarkar (2016)	✓	✓			
Pansera et al. (2017)	X				✓(2 entries)
Quevedo et al. (2018)	✓			✓	✓
Rodríguez and Da Cunha (2017)	✓			✓	✓(2 entries)
Rosca and Bendul (2017)	X				✓
Rosca, Arnold and Bendul (2017)	✓	✓	✓	✓	✓(2 entries)
Rosca, Reedy and Bendul (2017)	✓	✓	✓	✓	✓(2 entries)
Schneider (2020)	✓		✓		
Sehnem et al. (2020)	✓			✓	✓
Shibin et al. (2018)	✓	✓	✓	✓	✓(2 entries)
Sissoko and Castiaux (2018)	✓			✓	✓
Ulz and Winkler (2019)	X		✓	✓	
Valsamidis (2019)	✓			✓	✓
Yousaf et al. (2021)	✓	✓		✓(2 entries)	✓
$\sum$	**39**	**17**	**9**	**42**	**63**

Table 5: Detailed result of systematic literature review

Case	Driver	Principle	Keywords (Quantitative Analysis)
Business Case	Eco- Efficiency	Reduce input resources, negative externalities and product/service complexity ("do-more-with-less-paradigm")	efficien*, reduc*, emission*, complex*, waste
		Rethink and redesign products, processes and business models in a radical and/or disruptive way in order to increase and maintain economic growth and market performance	rethink*, redesign*, radical*, disrupt*, grow*
		Balance innovation contradictions, constraints and scarcities and treat them as opportunities rather than barriers	scarcit*, barrier*, contradict*
	Socio-Efficiency	Create social value by addressing and tackling social challenges	social value, social challenge
		Create local value and preserve user proximity with a deep understanding of customer needs	local*, customer-oriented
		Foster affordability through consistent reduction of TCO	affordab*, accessib*
Natural Case	Eco-Effectiveness	Take an absolute perspective on sustainability through circular economy approaches	circular*, recycl*, reus*
		Prevent (planned) obsolescence through robustness, durability and reuse	robust*, durab*
	Sufficiency	Renounce unnecessary features by fostering simplification and a "good-enough-philosophy"	simpl*, renunc*
		Consume and procure consciously with voluntary simplicity	
Societal Case	Socio-Effectiveness	Promote social equity and justice through inclusive and social innovation	equal*, equity, inclusive*
		Consider society as a whole through increased focus on BoP	
	Ecological Equity	Address ecological ethics and intergenerational awareness with responsible innovation	responsib*, generation*

Table 6: Derived keywords for quantitative content analysis

Bibliography

Agarwal, N. and Brem, A. (2021). *Frugal Innovation and Its Implementation: Leveraging Constraints to Drive Innovations on a Global Scale*, Springer.

Agarwal, N., Oehler, J. and Brem, A. (2021). Constraint-Based Thinking: A Structured Approach for Developing Frugal Innovations, *IEEE Transactions on Engineering Management* **68**(3): 739–751.

Ajzen, I. (1991). The theory of planned behavior, *Organizational Behavior and Human Decision Processes* **50**(2): 179–211.

Akbar, S. and Subramaniam, N. (2019). "Linking Frugal Innovation and Sustainable Development: Leveraging Corporate Accountability Mechanisms", *in* A. J. McMurray and G. A. de Waal (eds), *Frugal Innovation: A Global Research Companion*, Routledge, pp. 196–211.

Albert, M. (2019). Sustainable frugal innovation – the connection between frugal innovation and sustainability, *Journal of Cleaner Production* **237**: 1–15.

Arnett, D. K. and Claas, S. A. (2015). "Frugal innovation: Solutions for sustainable global cardiovascular health", *in* J. Andrade, F. Pinto and D. Arnett (eds), *Prevention of Cardiovascular Diseases: From current evidence to clinical practice*, Springer, pp. 251–260.

Basu, R. R., Banerjee, P. M. and Sweeny, E. G. (2013). Frugal Innovation: Core Competencies to Address Global Sustainability, *Journal of Management for Global Sustainability* **1**(2): 63–82.

Beise-Zee, R., Herstatt, C. and Tiwari, R. (2021). Guest Editorial: Resource-Constrained Innovation and Frugal Engineering, *IEEE Transactions on Engineering Managment* **68**(3): 643–652.

Belz, F. M. and Binder, J. K. (2015). Sustainable Entrepreneurship: A Convergent Process Model, *Business Strategy and the Environment* **26**(1): 1–17.

Bergmann, S. and Tiwari, R. (2017). Innovationspfade in der deutschen Automobilzuliefererindustrie: Eine Untersuchung aus der Frugalitätsperspektive, *Technical report*, Working Paper No. 97 – Hamburg University of Technology (TUHH), Institute for Technology and Innovation Management.

Bhatti, Y. A. (2012). What is Frugal, What is Innovation? Towards a Theory of Frugal Innovation, *Technical report*, Working Paper Saïd Business School and Green Templeton College.

Bhatti, Y. A. and Ventresca, M. (2013). How can 'frugal innovation' be conceptualized?, *Technical report*, Saïd Business School Working Paper Series, Oxford.

Bhatti, Y. and Prabhu, J. (2019). "Frugal Innovation and Social Innovation: Linked Paths to Achieving Inclusion Sustainably", *in* G. George, T. Baker, P. Tracey and H. Joshi (eds), *Handbook of Inclusive Innovation: The Role of Organizations, Markets and Communities in Social Innovation*, Edward Elgar Publishing, pp. 354–376.

BMW Group (2021). *The BMW i Vision Circular*, BMW Group Corporate Communications (media information September 6, 2021), retrieved December 31, 2021, from `https://www.press.bmwgroup.com/global/article/detail/T0341253EN/the-bmw-i-vision-circular?language=en`.

Bouckaert, L., Opdebeeck, H. and Zsolnai, L. (2007). *Frugality: Rebalancing Material and Spiritual Values in Economic Life*, Peter Lang Academic Publishers.

Braungart, M. and McDonough, W. (2002). *Cradle to Cradle: Remaking the Way We Make Things*, 1 edn, North Point Press.

Brem, A. (2017). Frugal Innovation—Past, Present, and Future, *IEEE Engineering Management Review* **45**(3): 37–41.

Brem, A. and Ivens, B. (2013). Do Frugal and Reverse Innovation Foster Sustainability? Introduction of a Conceptual Framework, *Journal of Technology Management for Growing Economies* **4**(2): 31–50.

Brodhag, C. (2021). Frugal innovation in sustainable construction, *Smart and Sustainable Cities 3rd International Conference*.

Brueckner, M. (2013). "Fortune at the Bottom of the Pyramid (Prahalad)", *in* S. O. Idowu (ed.), *Encyclopedia of Corporate Social Responsibility*, Springer, pp. 1149–1154.

Busch, H.-C., Dauth, T., Fischer, L. and Souza, M. (2018). Frugal innovation approaches to sustainable domestic energy: two cases of solar water heating from Brazil, *International Journal of Technological Learning, Innovation and Development* **10**(3-4): 231–257.

Car News China (2021). Beating Tesla in China, Wuling plans global with the new Xingchen model, retrieved October 20, 2021, from `https://carnewschina.com/2021/05/05/beating-tesla-in-china-wuling-plans-global-with-the-new-xingchen-model/`.

Carpentier, C. L. and Rang, W. (2021). Achieving the SDGs through Green, Blue, Orange, Purple Economies and Frugal Innovation: New Economics for Sustainable Development, *Cadmus Journal* **4**(4): 45–46.

Carrera, P. M. and MacDonnel, M. (2015). The "great moderation" in healthcare and frugal innovation: Toward sustainable health systems, *Technical report*, Working Paper (no further information available).

Chhabra, G. K. (2016). Case study of Coca Cola's ekocool solar Cooler; A frugal innovation serving as a source of sustainable competitive advantage in Rural markets of Northern India, *International Journal of Marketing and Technology* **6**(7): 119–129.

Christensen, C. M. (1997). *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail*, Harvard Business School Press.

da Silva, I. M., Borini, F. M., de Miranda Oliveira Junior, M., Quan, I. X. and von Zedtwitz, M. (2020). "An indirect metric of frugal innovation from product, open, cost, and sustainable innovation scales", *in* A. McMurray and G. de Waal (eds), *Frugal Innovation – A Global Research Companion*, Routledge, pp. 241–257.

Dressler, A. and Bucher, J. (2018). Introducing a Sustainability Evaluation Framework based on the Sustainable Development Goals applied to Four Cases of South African Frugal Innovation, *Business Strategy and Development* **1**(4): 276–285.

Dubey, R., Bryde, D. J., Foropon, C., Tiwari, M. and Gunasekaran, A. (2021). How frugal innovation shape global sustainable supply chains during the pandemic crisis: Abstract lessons from the COVID-19, *Technical report*, Supply Chain Management (Vol. and No. ahead-of-print).

Dyckhoff, H. and Souren, R. (2008). *Nachhaltige Unternehmensführung: Grundzüge industriellen Umweltmanagements*, Springer.

Dyllick, T. (2003). "Konzeptionelle Grundlagen unternehmerischer Nachhaltigkeit", *in* G. Linne and M. Schwarz (eds), *Handbuch Nachhaltige Entwicklung: Wie ist nachhaltiges Wirtschaften machbar?*, Springer Fachmedien Wiesbaden, pp. 235–243.

Dyllick, T. and Hockerts, K. (2002). Beyond the Business Case for Corporate Sustainability, *Business Strategy and the Environment* **11**(2): 130–141.

Elkington, J. (1997). *Cannibals with Forks: The Triple Bottom Line of 21st Century Business*, Capstone.

Epicurus (2021). "Letter to Menoeceus", *in* M. Cholbi and T. Timmerman (eds), *Exploring the Philosophy of Death and Dying: Classical and Contemporary Perspectives*, Routledge, pp. 67–69.

Gladwin, T. N., Kennelly, J. J. and Krause, T.-S. (1995). Shifting Paradigms for Sustainable Development: Implications for Management Theory and Research, *The Academy of Management Review* **20**(4): 874–907.

Gollwitzer, P. M. (1990). "Action phases and mind-sets", *in* E. T. Higgins and R. M. Sorrentino (eds), *Handbook of Motivation and Cognition: Foundations of Social Behavior*, Guilford Press, chapter "Action phases and mindsets", pp. 53–92.

Hansen, E. G., Fichter, K., Lüdeke-Freund, F. and Jaeger-Erben, M. (2021). Circular Business Models: Overcoming Barriers, Unleashing Potentials, *Technical report*, acatech/Circular Economy Initiative Deutschland/SYSTEMIQ.

Hassani, Y., Ionescu, R. C. and Mansour, J. (2019). Contribution of Frugal Innovation to Sustainable Development, *Quality-Access to Success* **20**(2): 302–306.

Hauschild, M., Herrmann, C. and Kara, S. (2017). An Integrated Framework for Life Cycle Engineering, *The 24th CIRP Conference on Life Cycle Engineering* **61**: 2–9.

Herstatt, C. and Tiwari, R. (2015). Frugale Innovation: Wissenschaftliche Einordnung eines neuen Innovationsbegriffs, *Technical report*, Working Paper No. 88 – Hamburg University of Technology (TUHH), Institute for Technology and Innovation Management.

Herstatt, C. and Tiwari, R. (2017). *Lead Market India: Key Elements and Corporate Perspectives for Frugal Innovations*, Springer.

Herstatt, C. and Tiwari, R. (2020). Opportunities of Frugality in the Post-Corona Era, *Technical report*, Working Paper No. 110 – Hamburg University of Technology (TUHH), Institute for Technology and Innovation Management.

Herstatt, C., Tiwari, R., Ernst, D. and Buse, S. (2008). India's national innovation system: key elements and corporate perspectives, *Technical report*, East-West Center Working Papers, Economics Series, No. 96.

Hockerts, K. N. (2003). *Sustainability Innovations: Ecological and Social Entrepreneurship and the Management of Antagonistic Assets*, PhD thesis, Universität St. Gallen, Hochschule für Wirtschafts-, Rechts- und Sozialwissenschaften (HSG).

Hossain, M. (2018). Sustainable Business Model for Frugal Innovation at the Grassroots Level in Emerging Markets, *Technical report*, MIOIR / MBS Working Paper Series – Working Paper 83, Alliance Manchester Business School, University of Manchester.

Hossain, M. (2021). Frugal innovation and sustainable business models, *Technology in Society* **64**: 1–7.

Hossain, M., Levänen, J. and Wierenga, M. (2021). Pursuing Frugal Innovation for Sustainability at the Grassroots Level, *Management and Organization Review* **17**(2): 1–8.

Huber, J. (2000). Industrielle Ökologie: Konsistenz, Effizienz und Suffizienz in zyklusanalytischer Betrachtung, *in* U. E. Simonis (ed.), *Global Change*, Nomos.

Hyvärinen, A., Keskinen, M. and Varis, O. (2016). Potential and Pitfalls of Frugal Innovation in the Water Sector: Insights from Tanzania to Global Value Chains, *Sustainability* **8**(9): 1–16.

Ibarra Baidón, C. (2018). Bien común, innovación frugal y empresas con propósito: movimientos emergentes orientados a la sostenibilidad empresarial (english title: Common good, frugal innovation and companies with purpose: emerging movements oriented towards business sustainability), *Realidad Empresarial* **6**: 52–54.

IPCC (2021). *Climate change widespread, rapid, and intensifying – IPCC*, IPCC Press Release (August 9, 2021), retrieved August 10, 2021, from `https://www.ipcc.ch/2021/08/09/ar6-wg1-20210809-pr/`.

Iqbal, Q., Ahmad, N. H. and Halim, H. A. (2020). Insights on entrepreneurial bricolage and frugal innovation for sustainable performance, *Business Strategy and Development* **4**(3): 237–245.

Iqbal, Q., Ahmad, N. H. and Li, Z. (2021). Frugal-based innovation model for sustainable development: technological and market turbulence, *Leadership & Organization Development Journal* **42**(3): 396–407.

Iqbal, Q., Ahmad, N. H., Li, Z. and Li, Y. (2021). To walk in beauty: Sustainable leadership, frugal innovation and environmental performance, *Technical report*, Managerial and Decision Economics (online version of record before inclusion in an issue).

Johnsson, S. (2020). *Scaling Frugal Innovation Based Startups to Accelerate Sustainable Development: A Minor Field Study in Cape Town, South Africa*, Master's thesis, Degree Project in the field of technology design and product realisation and the main field of study mechanical engineering, KTH School of Industrial Engineering and Management (ITM).

Kahn, K. B. (2018). Understanding innovation, *Business Horizons* **61**: 453–460.

Khan, R. (2016). How Frugal Innovation Promotes Social Sustainability, *Sustainability* **8**(10): 1–29.

Khan, S. and Haldar, O. P. (2015). Frugal Innovation: How Meager Resources and Idealistic Goals Lead To Sustainable Development, *IOSR Journal of Business and Management (IOSR-JBM)* **17**(4): 1–6.

Khan, S. and Le Bas, C. (2019). "Ethics and sustainability in frugal innovation", *in* A. J. McMurray and G. A. de Waal (eds), *Frugal Innovation – A Global Research Companion*, Routledge, pp. 275–288.

Kim, B., Chrin, P., Pietrzak-David, M. and Maussion, P. (2020). Frugal innovation for sustainable rural electrification, *2020 22nd European Conference on Power Electronics and Applications (EPE'20 ECCE Europe)*.

Knizkov, S. and Arlinghaus, J. C. (2020). Frugal Processes: An Empirical Investigation Into the Operations of Resource-Constrained Firms, *IEEE Transactions on Engineering Management* **68**(3): 667–684.

Knörle, C. and Esch, F.-R. (2013). "Wachstumsstrategien in neuen Märkten", *in* F.-R. Esch (ed.), *Strategie und Technik des Automobilmarketing*, Springer Gabler, pp. 381–408.

Krohn, M. and Herstatt, C. (2018). The Question of a Frugal Mindset in Western MNCs – Exploring an Emerging Phenomenon with a Systematic Literature Review, *Technical report*, Working Paper No. 103 – Hamburg University of Technology (TUHH), Institute for Technology and Innovation Management.

Krohn, M., Petersen, F. and Herstatt, C. (2019). Understanding Managers Perspectives in the Face of Global Socio-Economic Shifts – Towards an Instrument to Measure the Recognition of Opportunities for Frugal Innovation, *R&D Management Conference 2019*.

Krohn, M., Petersen, F., Hochmuth, D. and Herstatt, C. (2020). The Deliberative Frugal Mindset - A Model of Managerial Opportunity Recognition for Frugal Innovation, *Technical report*, Working Paper No. 109 – Hamburg University of Technology (TUHH), Institute for Technology and Innovation Management.

Kuckartz, U. (2018). *Qualitative Inhaltsanalyse. Methoden, Praxis, Computerunterstützung*, 4 edn, Beltz Juventa.

Kunamaneni, S. (2017). Low-Cost Innovation Capability development in Emerging and Transition countries: An Institutional Perspective, *Frugal Innovation for Sustainable Global Development, Session 3: Frugal Innovation & Society*.

Lawrenz, J. (2020). Confucius, Aristotle, and the Golden Mean. A Diptych on Ethical Virtues, *The European Legacy* **26**(2): 149–169.

Le Bas, C. (2016). Frugal innovation, sustainable innovation, reverse innovation: why do they look alike? Why are they different?, *Journal of Innovation Economics & Management* **3**(21): 9–26.

Le Bas, C. (2017). Sustainable innovation and frugal innovation: Exploring the relationships between Innovation and sustainability, *Revue d'économie industrielle (3e trimestre 2017)* **159**: 113–137.

Lelivelda, A. and Knorringab, P. (2017). Frugal Innovation and Development Research, *The European Journal of Development Research* **30**(1): 1–16.

Levänen, J., Hossain, M., Lyytinen, T., Hyvärinen, A., Numminen, S. and Halme, M. (2016). Implications of Frugal Innovations on Sustainable Development: Evaluating Water and Energy Innovations, *Sustainability* **8**(1): 1–17.

Linz, M. (2002). "Warum Suffizienz unentbehrlich ist", *in* Wuppertal Institut für Klima, Umwelt, Energie (ed.), *Von nichts zu viel: Suffizienz gehört zur Zukunftsfähigkeit*, Wuppertal Papers, pp. 7–14.

Mashelkar, R. (2014). Accelerated inclusive growth through inclusive innovation. Organisation for Economic Cooperation and Development (OECD), retrieved August 12, 2021, from `https://www.oecd.org/sti/inno/Session_3_Mashelkar_Keynote.pdf`.

Mayring, P. (2015). *Qualitative Inhaltsanalyse. Grundlage und Techniken*, 12 edn, Beltz.

McDonough, W. and Braungart, M. (2002). Design for the Triple Top Line: New Tools for Sustainable Commerce, *Corporate Environmental Strategy* **9**(3): 251–258.

Meadows, D. H., Meadows, D. L., Randers, J. and Behrens III, W. W. (1972). *The Limits to Growth: A Report for the Club of Rome's Project on the Predicament of Mankind*, Universe Books.

Midler, C., Jullien, B. and Lung, Y. (2017). *Rethinking Innovation and Design for Emerging Markets: Inside the Renault Kwid Project*, Taylor & Francis Ltd.

Mishra, R. and Saini, A. K. (2017). Business Intelligence for Frugal, Reverse and Sustainable Innovation Success, *International Conference on Strategies in Volatile and Uncertain Environment for Emerging Markets. At: IIT, New Delhi* **1**: 1–9.

Molina-Maturano, J., Bucher, J. and Speelman, S. (2020). Understanding and Evaluating the Sustainability of Frugal Water Innovations in México: An Exploratory Case Study, *Journal of Cleaner Production* **274**.

Musona, J. (2021). "New Business Models for Frugal Innovation: Experience from an Enterprise Supporting Sustainable Smallholder Agriculture in Kenya", *in* N. Agarwal and A. Brem (eds), *Frugal Innovation and Its Implementation. Leveraging Constraints to Drive Innovations on a Global Scale*, Springer, pp. 165–190.

Nielsen, K. B. and Wilhite, H. (2015). The rise and fall of the 'people's car': middle-class aspirations, status and mobile symbolism in 'New India', *Contemporary South Asia* **23**(4): 371–387.

Niroumand, M., Shahin, A., Naghsh, A. and Peikari, H. R. (2021). Frugal innovation enablers, critical success factors and barriers: A systematic review, *Creativity and Innovation Management* **30**(2): 348–367.

Oxford Advanced Learner's Dictionary (2021). Definition of frugal adjective from the Oxford Advanced Learner's Dictionary, retrieved August 19, 2021, from `https://www.oxfordlearnersdictionaries.com/definition/english/frugal?q=frugal`.

Palepu, K., Anand, B. and Tahilyani, R. (2010). Tata Nano – The People's Car, *Technical report*, Harvard Business Review Case Study.

Pansera, M., Hermann, R. R. and Narvaez-Mena, H. (2017). Frugalidad e innovación popular: nuevos caminos para la sustentabilidad y la inclusión social en Ecuador; Grassroots And Frugal Innovation: New Pathways Towards Sustainability And Social Inclusion In Ecuador, *Revista Iberoamericana de Ciencia, Tecnología y Sociedad* **12**(35): 131–152.

Pansera, M. and Sarkar, S. (2016). Crafting Sustainable Development Solutions: Frugal Innovations of Grassroots Entrepreneurs, *Sustainability* **8**(1): 1–25.

Prabhu, J. (2017). Frugal innovation: doing more with less for more, *Philosophical Transactions of the Royal Society A* **375**(2095): 1–22.

Prahalad, C. and Hart, S. L. (2002). The Fortune at the Bottom of the Pyramid, *Strategy+Business (first quarter 2002)* (26).

Prahalad, C. K. (2005). *The Fortune at the Bottom of the Pyramid*, Wharton School Publishing.

Prahalad, C. and Mashelkar, R. (2010). Innovation's Holy Grail, *Harvard Business Review* (July-August 2010).

Quevedo, M. F., Silkina, N. and Rapp, T. (2018). Analysis of the Relationship between Frugal Innovation and Sustainable Development, *Technical report*, HFU Business School Final Report, retrieved September 6, 2021, from `https://opus.hs-furtwangen.de/frontdoor/index/index/docId/4813`.

Radjou, N. and Prabhu, J. (2015). *Frugal Innovation: How to do more with less*, The Economist.

Rao, B. C. (2013). How disruptive is frugal?, *Technology in Society* **35**(1): 65–73.

Rodríguez, L. and Da Cunha, C. (2017). Effects of dynamic capabilities on frugal innovation: A conceptual framework for sustainable supply chain application, *24th International Conference on Production Research (ICPR 2017)*.

Rosca, E., Arnold, M. and Bendul, J. C. (2017). Business models for sustainable innovation – an empirical analysis of frugal products and services, *Journal of Cleaner Production* **162**: 133–145.

Rosca, E. and Bendul, J. (2017). Conceptualizing synergies between economic, social and ecological sustainability: The case of frugal innovation in the sanitation sector, *RWTH Publications*.

Rosca, E., Reedy, J. and Bendul, J. C. (2017). Does Frugal Innovation Enable Sustainable Development? A Systematic Literature Review, *The European Journal of Development Research* **30**: 136–157.

Schaltegger, S. (2013). "Sustainability Management", *in* S. O. Idowu (ed.), *Encyclopedia of Corporate Social Responsibility*, Springer, pp. 2384–2388.

Schaltegger, S. and Lüdeke-Freund, F. (2013). "Business Cases for Sustainability", *in* S. O. Idowu (ed.), *Encyclopedia of Corporate Social Responsibility*, Springer, pp. 245–252.

Schaltegger, S. and Sturm, A. (1990). Ökologische Rationalität: Ansatzpunkte zur Ausgestaltung von ökologieorientierten Managementinstrumenten, *Die Unternehmung* **44**(4): 273–290.

Schmidt, M. (2008). "Die Bedeutung der Effizienz für Nachhaltigkeit – Chancen und Grenzen", *in* S. Hartard, A. Schaffer and J. Giegrich (eds), *Ressourceneffizienz im Kontext der Nachhaltigkeitsdebatte*, Nomos, pp. 31–46.

Schneider, S. (2020). Combining the characteristics of sustainability, frugal innovations and washing machines in the industrial nations –A literature-based analysis of the common features for future sustainable developments, *Journal of Economic Development, Environment and People* **9**(2): 50–59.

Schnor, J. (2015). Suffizienz und die Frage nach dem guten Leben. Betrachtungen von Suffizienz mithilfe von Konzeptionen des guten Lebens von Epikur und der Stoa, *Technical report*, Leuphana Schriftenreihe Nachhaltigkeit und Recht, Nr. 11.

Sehnem, S., Sarquis, A. B., Netto, D. D. P., Martignago, G. and da Conceição, D. A. (2020). "Towards an Analysis of Frugal Innovation: An Important Way to Achieve Sustainability", *in* W. L. Filho and J. B. S. de Andrade Guerra (eds), *Water, Energy and Food Nexus in the Context of Strategies for Climate Change Mitigation*, Springer, pp. 211–224.

SGMW (n.d.). SGMW Overview, retrieved October 20, 2021, from `https://www.sgmw.com.cn/en/SGMWOverview.aspx`.

Shibin, K., Dubey, R., Gunasekaran, A., Luo, Z., Papadopoulos, T. and Roubaud, D. (2018). Frugal Innovation for Supply Chain Sustainability in SMEs: Multimethod Research Design, *Production Planning and Control* **29**(11): 908–927.

Singh, R., Seniaray, S. and Saxena, P. (2020). A Framework for the Improvement of Frugal Design Practices, *Designs* **4**(3): 1–12.

Sissoko, M. and Castiaux, A. (2018). How does frugal innovation emerge and lead to sustainability in developing countries? A case study in Malian agricultural areas, *European Association of Agricultural Economists, 166th Seminar*.

Sitnikov, C. S. (2013). "Triple Bottom Line", *in* S. O. Idowu (ed.), *Encyclopedia of Corporate Social Responsibility*, Springer, pp. 2558–2564.

Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines, *Journal of Business Research* **104**: 333–339.

Song, H.-C. (2020). Sufficiency economy philosophy: Buddhism-based sustainability framework in Thailand, *Business Strategy and the Environment* **29**(3): 1–11.

Song, H.-C. (2021). Buddhist approach to corporate sustainability, *Business Strategy and the Environment* **30**(7): 1–13.

Soni, P. and Krishnan, R. T. (2014). Frugal Innovation: Aligning Theory, Practice, and Public Policy, *Journal of Indian Business Research* **6**(1): 1–30.

Spiegel (2021). Dieser Winzling hängt Tesla in China locker ab, retrieved October 20, 2021, from `https://www.spiegel.de/auto/saic-wuling-mini-ev-dieser-winzling-haengt-tesla-in-china-locker-ab-a-281d558a-7ca3-4b31-a202-9d45c484a9b1`.

Sridharan, B. K. (2021). *German automotive industry and frugal innovations in India*, Master's thesis, TU Delft Technology, Policy and Management, retrieved August 12, 2021, from `https://repository.tudelft.nl/islandora/object/uuid:45ed8ad9-9113-4ca0-9ee1-1a8575158d8f`.

Statista (2021a). Anteil Chinas an der weltweiten Produktion von Personenkraftwagen und Nutzfahrzeugen von 2010 bis 2020, retrieved October 20, 2021, from `https://de.statista.com/statistik/daten/studie/514726/umfrage/china-kfz-produktion-marktanteile/`.

Statista (2021b). Anteil der in China verkauften Personenkraftwagen am Gesamtabsatz deutscher Automobilhersteller von 2011 bis 2021, retrieved October 20, 2021, from `https://de.statista.com/statistik/daten/studie/1084191/umfrage/absatz-deutscher-premium-modelle-in-china/`.

Statista (2021c). Anzahl ausgelieferter Fahrzeuge von Porsche weltweit von 2010 bis 2020, retrieved December 29, 2021, from `https://de.statista.com/statistik/daten/studie/235144/umfrage/fahrzeugabsatz-von-porsche-nach-modell/`.

Statista (2021d). Anzahl produzierter Kraftfahrzeuge weltweit von 2000 bis 2020, retrieved December 29, 2021, from `https://de.statista.com/statistik/daten/studie/151749/umfrage/entwicklung-der-weltweiten-automobilproduktion/`.

Statista (2021e). Anzahl verkaufter Elektroautos weltweit nach Marken in den Jahren 2019 und 2020, retrieved October 20, 2021, from `https://de.statista.com/statistik/daten/studie/561568/umfrage/die-groessten-hersteller-von-elektroautos-nach-absatz/`.

Statista (2021f). Größte Automobilhersteller weltweit nach Fahrzeugabsatz im Jahr 2020, retrieved December 29, 2021, from `https://de.statista.com/statistik/daten/studie/173795/umfrage/automobilhersteller-nach-weltweitem-fahrzeugabsatz/`.

Tagesschau (2021). Deutsche E-Autos fahren hinterher, retrieved October 20, 2021, from `https://www.tagesschau.de/wirtschaft/unternehmen/deutsche-autokonzerne-geschaeft-china-101.html`.

The Economist (2009). Health care in India: Lessons from a frugal innovator, retrieved August 19, 2021, from `https://www.economist.com/business/2009/04/16/lessons-from-a-frugal-innovator`.

Tiwari, R. (2017). "Frugality in Indian Context: What Makes India a Lead Market for Affordable Excellence?", *in* C. Herstatt and R. Tiwari (eds), *Lead Market India: Key Elements and Corporate Perspectives for Frugal Innovations*, Springer, pp. 37–61.

Tiwari, R. and Bergmann, S. (2018). What pathways lead to frugal innovation? Some insights on modes and routines of frugal, technical inventions based on an analysis of patent data in German auto components industry, *Technical report*, Working Paper No. 105 – Hamburg University of Technology (TUHH), Institute for Technology and Innovation Management.

Tiwari, R., Fischer, L. and Kalogerakis, K. (2016). Frugal Innovation in Scholarly and Social Discourse: An Assessment of Trends and Potential Societal Implications, *Technical report*, Working Paper, as a part of the project "PFI - Potentiale Frugaler Innovationen".

Tiwari, R. and Herstatt, C. (2012). Assessing India's lead market potential for cost-effective innovations, *Journal of Indian Business Research* **4**(2): 97–115.

Tiwari, R. and Herstatt, C. (2014). *Aiming Big with Small Cars: Emergence of a Lead Market in India*, Springer International Publishing.

Tiwari, R. and Herstatt, C. (2020). "The Frugality 4.0 paradigm: Why frugal innovation are transcending beyond emerging economies", *in* A. J. McMurray and G. A. de Waal (eds), *Frugal Innovation: A Global Research Companion*, Routledge, pp. 40–53.

Tiwari, R. and Kalogerakis, K. (2016). A Bibliometric Analysis of Academic Papers on Frugal Innovation, *Technical report*, Working Paper No. 93 – Hamburg University of Technology (TUHH), Institute for Technology and Innovation Management.

Tiwari, R. and Kalogerakis, K. (2017). Innovation Pathways and Trajectories in India's Auto Component Industry, *Technical report*, Working Paper No. 98 – Hamburg University of Technology (TUHH), Institute for Technology and Innovation Management.

Tiwari, R., Kalogerakis, K. and Herstatt, C. (2014). Frugal innovation and analogies: some propositions for product development in emerging economies, *Technical report*, Working Paper No. 84 – Hamburg University of Technology (TUHH), Institute for Technology and Innovation Management.

Ulz, A. and Winkler, T. (2019). Frugal Innovation as a trigger for sustainable regional development in Austria, *The ISPIM Innovation Conference – Celebrating Innovation: 500 Years Since daVinci*.

Valsamidis, S. (2019). "Best Practices for Frugal and Sustainable Innovation", *in* A. Theodoridis, A. Ragkos and M. Salampasis (eds), *Innovative Approaches and Applications for Sustainable Rural Development. 8th International Conference, HAICTA 2017, Chania, Crete, Greece, September 21-24, 2017, Selected Papers*, Springer, pp. 37–57.

Weyrauch, T. (2018). *Frugale Innovationen: Eine Untersuchung der Kriterien und des Vorgehens bei der Produktentwicklung*, Springer Gabler.

Weyrauch, T. and Herstatt, C. (2016). What is frugal innovation? Three defining criteria, *Journal of Frugal Innovation* **2**(1): 1–17.

Wohlfart, L., Bünger, M., Lang-Koetz, C. and Wagner, F. (2016). Corporate and Grassroot Frugal Innovation: A Comparison of Top-Downand Bottom-Up Strategies, *Technology Innovation Management Review* **6**(4): 5–17.

Wohlfart, L., Groganz, J., Manefeld, S. and Fröhlich, F. (2021). "Frugal Innovation for Developed Markets: Target Customers, Characteristics, Success Factors", *in* N. Agarwal and A. Brem (eds), *Frugal Innovation and Its Implementation: Leveraging Constraints to Drive Innovations on a Global Scale*, Springer, pp. 141–164.

World Commission on Environment and Development (1987). *Our Common Future*, Oxford University Press.

Young, W. and Tilley, F. (2006). Can Businesses Move Beyond Efficiency? The Shift toward Effectiveness and Equity in the Corporate Sustainability Debate, *Business Strategy and the Environment* **15**(6): 402–415.

Yousaf, Z., Radulescu, M., Sinisi, C. I., Serbanescu, L. and Păunescu, L. M. (2021). Towards Sustainable Digital Innovation of SMEs from the Developing Countries in the Context of the Digital Economy and Frugal Environment, *Sustainability* **13**(10): 1–28.

Zeschky, M., Widenmayer, B. and Gassmann, O. (2011). Frugal Innovation in Emerging Markets, *Research-Technology Management* **54**(4): 38–45.

Zeschky, M., Widenmayer, B. and Gassmann, O. (2014). Organising for reverse innovation in Western MNCs: the role of frugal product innovation capabilities, *International Journal of Technology Management* **64**(2/3/4): 255–275.