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WASTE HIERARCHY AND SUSTAINABILITY CHANGES IN THE PERCEPTION OF CONCEPTS OF RELEVANCE FOR A CIRCULAR ECONOMY

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Abstract

The concrete perception of concepts such as "waste hierarchy" or "sustainability" is of the utmost importance for implementing a circular economy. However, these perceptions are changing, which has an impact on long-term circular economy strategies and necessitates adjustments in the corresponding economic and environmental policies. The paper examines these changes with two different methodological approaches. By means of a literature review and empirical observations it is found that waste prevention – as the priority goal of the waste hierarchy – plays an increasingly subordinate role, which contributes to higher quantities of packaging waste, for example. As for sustainability an analysis of the newspapers *taz* (Germany) and *The Guardian* (UK) is used with the latest techniques of text-mining (co-occurrence analysis, volatility analysis, topic modelling). The analysis shows that the perception of the concept is changing with fluctuating external factors such as climate change conferences or social efforts in the context of a pandemic. As a result, for example, sustainability reporting is becoming more and more arbitrary. In conclusion, these shifting perceptions are leaving their footprint in efforts to implement a circular economy, thus transforming into a diffuse concept that needs to attract the attention of policymakers.

Keywords

Circular Economy, Sustainability, Waste Hierarchy, Text-mining Techniques, Environmental Policy

I. Introduction

Languages are living institutions and constantly changing – new words are adopted, old words gradually disappear and concepts, the meaning of words, are changing over time. These processes are well documented in all kinds of dictionaries, in particular etymological dictionaries, and online platforms. Reasons for these observations can likely be found in cultural and technical developments, often driven by societal issues such as globalization, innovations, and economic growth.

In addition to these common long-run changes, we can, however, also observe changes in the perception of certain contexts, which are happening in a comparatively short period of time. This refers to environmental concepts, which have been gaining increasing visibility in the last decades. In this context, there are some interesting questions that are addressed in this paper. There is first the question about the intrinsic reasons for such sometimes rapid adjustments in the perception. Are they, in one way or another, related to economic interests, perhaps even to business interests? Or is there in the sense of environmental behavioral economics rather an attempt of a local or a global moral self-licensing? A second question must refer to possible consequences of these shifts in the perception. If we stay in the environmental arena, what are potential implications for

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environmental issues, for efforts to implement a circular or green economy, for environmental and economic policy in this context?

As examples this paper considers the concepts of the "waste hierarchy" and "sustainability". Both concepts are closely associated with the paradigm of a "circular economy", whose goal is to "sustainably" integrate the fundamental functions of the environment in all kinds of economic activities. Serving as a receptacle for waste is one of these fundamental functions, another one is providing (limited) natural resources for all kinds of economic activities. Thus, the focus on the waste hierarchy with its goals to save resources and protect the assimilative capacities of the environment.

Since many countries are currently preparing their road towards a circular economy, short-run changes in the perception of these concepts could have a significant impact on its implementation.

The discussion starts with the case of the waste hierarchy. First, its origin and its relevance to a circular economy are examined, followed by a short analysis of the perception of waste and waste prevention – in literature, but especially in practice. The reasons for these observations are given and possible consequences for the implementation of a circular economy are addressed. For example, according to EU (2024) the European Commission is already targeting a revision of EU waste rules in view of increasing quantities of food and textile waste. Since terms like "waste prevention" are not much discussed in public, we use a literature review and empirical observations to examine perceptions and their changes.

Whereas the perception of the waste hierarchy is changing slowly, the perception of sustainability is developing more rapidly and more visibly in public, as in the contexts of ESG (Environmental Social Governance) and sustainability reporting. Consequently, many more people are familiar with the concept, and its original meaning in the context of forest management is immediately clear. Nevertheless, the concept is difficult to define in a general context and leaves a lot of room for interpretation – as can be seen in current sustainability reporting.

In order to investigate comparatively frequent shifts in its perception, a literature review alone would not be sufficient. We therefore analyze the use of the concepts in two newspapers over the period 1999 to 2018 and 2019 respectively. The newspapers are the *taz* from Germany and *The Guardian* from the UK. The fact that these newspapers are from different countries allows the additional analysis of the perception of "sustainability" in the UK, and of "Nachhaltigkeit" in Germany. For the *taz* more than 950,000 documents with 14,676 documents with the words "nachhaltig" or "Nachhaltigkeit" were considered in the period 1999-2018. The analysis of *The Guardian* is based on more than 2 million documents in the period 1999-2019, with 52,710 of them containing the words "sustainable" or "sustainability".

The selection of precisely these two newspapers and periods indicated is subject to a certain degree of arbitrariness. Even if the differences in the research results between *The Guardian* and the *taz* are limited, other newspapers could of course lead to different results. Future research should focus on this "arbitrariness".

The period 1999-2018/19, on the other hand, includes many events and policy-making that affect both the waste hierarchy (various EU waste directives, mandatory deposit on single-use beverage packaging in Germany, …) and sustainability (the UN's annual climate conferences, the EU's Green Deal, sustainability reporting, …). This certainly justifies the choice of this period.

The Guardian documents are freely available, the articles from the taz can be purchased on request and subsequently used in a non-commercial context. The empirical analysis is based on the "Interactive Leipzig Corpus Miner (iLCM)", whose development was funded by the German Science Foundation (DFG). It constitutes an integrated research environment to analyze large quantities of text, and it is based on open-source technologies such as docker, R-Shiny, MariaDB, spaCy, Solr.

A co-occurrence analysis is used to reveal relevant shifts in the perception of sustainability. Moreover, other tools of text-mining, such as topic modelling, help to visualize these changes.

A volatility analysis is applied to study the stability of the concept in the course of time. The results point to shifts in the meaning of the concept, leading to a review of its application in the implementation of a circular economy, and ultimately supported by appropriate environmental policy adjustments.

The following section investigates the concept of the waste hierarchy. The next part refers then to the concept of sustainability and sustainable development. A final section summarizes the results.

II. The Waste Hierarchy

This section considers the concept of the waste hierarchy, widely used in environmental regulations. In the following subsections, we examine the origin and relevance of the concept, observe the changes in its perception, and explore reasons and consequences of these changes.

Origin and Relevance of the Waste Hierarchy

Following Van Ewing and Stegemann (2016) there are some indications that the concept of the waste hierarchy emerged in the 1980s – in the context of appropriately managing hazardous waste, stressing prevention and reduction, reuse and recycling instead of landfilling the hazardous substances. It gained increasing visibility with important environmental regulations, such as the EU Waste Directive 2008. According to the EU, "the following waste hierarchy shall apply as a priority order in waste prevention and management legislation and policy: (a) prevention; (b) preparing for re-use; (c) recycling; (d) other recovery, e.g. energy recovery; and (e) disposal". Moreover, the EU emphasizes that the member states "shall take measures to encourage the options that deliver the best overall environmental outcome" when applying the waste hierarchy. For more details on the economics of the waste hierarchy see e.g. Wiesmeth (2020a), Ch. 18.

What are possible reasons for this focus on the waste hierarchy and with waste prevention as priority? There is the relationship between economic activities and the response of the environment. Pearce and Turner (1989) point out that "natural environments are the ultimate repositories of waste products", but there is only a limited capacity of the environment to assimilate waste. This refers to all kinds of waste, with plastic waste and waste electronic equipment prominent examples. If this assimilative capacity is exceeded, as with plastic waste, serious repercussions are to be expected.

Waste can be collected and recycled. But it is obvious that the collection of all the pieces of waste that end up in the environment requires considerable financial resources. The more waste we generate, the more tends to remain in the environment. Therefore, the prevention of waste, which also helps to save resources, is the most plausible reaction to this dilemma and deserves for this reason the first place in the waste hierarchy.

Reusing old commodities such as textiles or electronic equipment can help to prevent waste and save resources because they reduce the quantities of new products entering the markets. Recycling, finally, helps to recover natural resources from the waste products, also energy, and reduces the volume of waste to be landfilled. In the hierarchy, however, reuse and recycling come after waste prevention – in the light of what has been said above.

The waste hierarchy, particularly the priority goal of waste prevention, is immediately related to the "Circular Economy". According to Pearce and Turner (1989), a circular economy respects and sustainably preserves the fundamental functions of the environment. The environment serves as provider of natural resources, as receiver of waste and as direct provider of utility. The waste hierarchy thus reduces the impact of waste on the environment and helps to save natural resources.

The waste hierarchy is of special relevance for all countries, which are currently implementing a circular economy. The details how the waste hierarchy is handled can depend on the framework conditions in these countries, on the geographic, demographic, and the economic conditions. However, the priority of waste prevention is clearly not affected by the concrete local situation.

The Perception of Waste and the Waste Hierarchy in Literature and in Practice

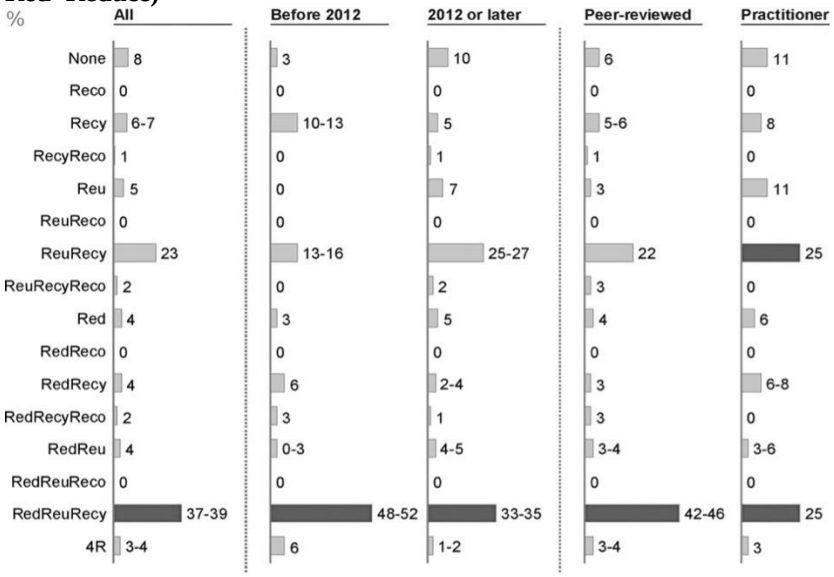
Despite the clarity of the concept and the fact that the waste hierarchy is an integral part of many environmental regulations, there are substantial differences regarding its interpretation and practical handling. These differences exceed by far necessary modifications due to varying framework conditions. Accordingly, the waste hierarchy is perceived differently in different countries, often with significant deviations from the original concept. Moreover, these deviations refer most often to the perception of waste prevention and to the perception of waste itself.

Since compliance with the waste hierarchy is of the utmost importance for the circular economy, the well-documented understanding of the circular economy conveys an idea of the perception of the waste hierarchy. Definitions of the concept of a circular economy are investigated by Kirchherr et al. (2017) "comprehensively and systematically" through the analysis of contributions to the literature – both in peer-reviewed journals as well as in policy papers and reports.

They collected 114 definitions for the circular economy and examined, among other things, "the frequency of the 4R framework" (reduce, reuse, recycle, recover), which is closely related to the "traditional" waste hierarchy with its 3R framework (reduce, reuse, recycle).

Figure 1 shows their results for the 16 combinations of the 4R framework. The 3R framework is the most common, with decreasing frequency in more recent years, however. Interestingly, among practitioners the combination of reuse and recycle is featured as often as the 3R framework (in 25% of the definitions).

Figure 1 Circular economy definitions coded on the 4R framework (Reco=Recover; Recy=Recycle; Reu=Reuse; Red=Reduce)



Source: Kirchherr et al. (2017), Fig. 3. (Licensed CC BY 4.0)

Kirchherr et al. (2017) also find that "waste hierarchies have been featured less frequently more recently and are barely included in practitioner definitions (contained in 11% of practitioner definitions versus 38% of peer-reviewed ones)". If – for the moment – we consider waste reduction as equivalent to waste prevention, the consequence is that waste prevention is not really on the agenda of practitioners, but that the focus has undoubtedly been shifted to recycling.

What are possible explanations for this phenomenon? It is probably necessary to have a closer look at the perception of waste itself and its prevention.

"Waste" is something people want to get rid of, meaning "any substance or object which the holder discards or intends or is required to discard", according to EU (2008). Not so long ago, waste, especially household waste, was simply landfilled in often uncontrolled dump sites or incinerated,

and thus disappeared from people´s perceptions. Landfilled waste was "prevented": it was prevented from having a direct impact on the immediate environment of the households.

In a Eurobarometer survey on waste 92% of households agree that "they make efforts to reduce the amount of household waste that they generate" (EU 2014, p. 16). However, it is likely that most households have not much interest in their waste once it has been collected. They regard their collected waste to be "prevented" in the sense that it does not pollute their immediate environment.

Moreover, the standard procedures of collection and separation of waste can serve as a kind of "moral self-licensing": with separating my waste I have contributed my fair share to protecting the environment. Following Engel and Szech (2020) this moral self-licensing, a concept from behavioral environmental economics, helps to explain the persistence of this perception of waste and the way of dealing with waste in households. This leads to a gap between "real" waste prevention and its perception.

According to EU (2008), waste prevention "means measures taken before a substance, material or product has become waste, that reduce: (a) the quantity of waste, including the re-use of products or the extension of the life span of products; (b) the adverse impacts of the generated waste on the environment and human health; or (c) the content of harmful substances and products". EU (2024) emphasizes this definition with a focus and policy recommendations on food and textile waste.

Wilts (2012) looks at this context and remarks that "defining the prevention of the waste as the top priority of the waste hierarchy … is much more than a simple amendment of ways of dealing with waste but means nothing less than a fundamental change of the socio-technical system of waste infrastructures …" (p. 29). He also points to the increasing amounts of wastes, "although waste prevention has been the paramount objective of both national and EU waste management policies for many years, …" (p. 32). Again, this gap between official definitions and practical views on waste prevention seems to be triggered by this specific perception of waste.

The continuous development of technologies to collect, segregate and recycle waste has not changed the current perception of waste, but the perception of its prevention, also in businesses. The fact that various companies are actively promoting their one-way drinks packaging, justifying this with the promised collection and recycling of empty bottles with appropriate technologies, points in this direction. There is a shift in the perception of waste prevention (in the proper sense) to recycling (as a substitute for prevention). That in Germany, a country with a presumably high environmental awareness, a few hundred million empty bottles are not returned to the collection points every year, shows once again the environmental relevance of waste prevention, but is not much discussed in public. This example shows that a vague perception of waste prevention can lead to more waste. In addition, this situation contributes to the large number of definitions of a circular economy compiled by Kirchherr et al. (2017).

What role do companies play in this context? They design plastic products and electronic devices, they apply new technologies in waste management, such as recycling technologies. Why don't we see more "aggressive" efforts by business to prevent waste?

The Role of Business Companies

The question arises whether there are appropriate business models for the waste hierarchy in general, and waste prevention in particular. The EU Waste Directive 2008 indicates measures which are meant to prevent waste. Some of them, the promotion of an `eco-design´ or a `design for environment´ (DfE) among them, focus on business companies. The objective is to prevent waste through an appropriate design, which could also increase the lifespan of a product, thus saving resources, thereby further preventing waste.

DfEs will take place primarily if it is profitable for the business companies, if, for example, production costs can be reduced by using less resources. But in this case, which is at first glance in line with a circular economy, the main objective of the business company is to stay competitive or to become more competitive and to attract additional customers and sales. The result could be a rebound effect

in the sense that increasing sales partially or completely offset the environmental impact of the DfE. For more information on rebound effects see, for example, Wiesmeth (2020a), Ch. 12.

As the business companies have the knowledge, DfEs need not happen if they lead to higher production costs or design changes that may not find the interest of the customers. Thus, existing and future business models should not be expected to automatically support the prevention of waste. Wiesmeth (2020b) points to the fact that waste prevention by DfE is not always the most important goal of business companies. Similar considerations, with some modifications though, apply to the reuse of old commodities, an issue repeatedly addressed by the EU. According to EU (2024) only 22% of post-consumer textile waste is collected separately for re-use or recycling, while the remainder is landfilled or incinerated (p. 2).

For various reasons, it makes sense to have private companies operating the waste management systems. These companies are expected by their shareholders to generate profits. Recycling of waste can yield profits, if the framework conditions consisting of legal requirements and fees for collecting and recycling waste, and the market prices of the recycled products are appropriate. Thus, there is an obvious focus on recycling activities, showing new success stories with ever-increasing recycling rates. Waste prevention would certainly dampen this success. It is the generation of waste, its (partial) collection and its (partial) recycling that counts more. Van Ewijk and Stegemann (2016) refer in this context again to societal path dependencies.

Thus, we are back at the situation with recycling waste perceived as preventing waste. The fact that recycling is often a profitable business likely strengthens this perception of waste prevention and the waste hierarchy. The final, almost obvious step is then to replace a DfE by a DfR, a “design for recycling”, which is, for example, promoted by the “Green Dot”.

Thus, to solve this dilemma a systemic change is required, a change, which should, however, preserve the advantageous characteristics of a market economy. This should include efforts to change the perception of waste, which is crucial for the proper perception of waste prevention and the waste hierarchy. This likely requires modifying societal path dependencies and creating appropriate social norms – a challenging task. According to Wiesmeth (2020b) appropriate environmental policies based on variations of the principle of extended producer responsibility (EPR), could, to a certain extent, support such modifications to achieve the required systemic change. However, the procedures to successfully bring about such a systemic change still need to be discussed and analyzed.

Whereas this shift in the perception of the concept of the waste hierarchy has gradually taken place in recent decades, the changes in the perception of the similarly important concept of sustainability seem to be much more dependent on fluctuating external factors. This will be investigated in the following section, employing, however, quite different methods and tools.

III. Sustainability

Although the concept of sustainability or of sustainable development has a long history, it became broadly visible only at the occasion of the “Earth Summit” in Rio de Janeiro in 1992 (UNCED). In the following subsections, we explain the origin, the meaning and the relevance of the concept, and investigate possible shifts in its perception. This part of the analysis makes use of tools from text-mining: keyword searches, co-occurrence analysis, context volatility analysis and topic modelling. Some necessary remarks on the consequences of these changes complete this part of the paper.

Origin, Meaning and Relevance of Sustainability

In the literature, for example according to Kirchherr et al. (2017), a circular economy is closely linked to sustainable development, and in fact it is often meant for sustainable development. Not surprisingly then that a variety of other initiatives such as the “Green Deal”, the “Smart City”, or the “Green City” and others are often related to both a circular economy and sustainability.

Important roots of sustainability can be found in forestry. The classical example refers to parts of Germany, particularly Saxony, which were deforested some 300 years ago due to mining activities,

which required large volumes of wood at a time, when coal was not yet much used. As this shortage threatened business and cultural activities, the idea of a “sustainable” harvesting of wood was born – only that volume that can normally regrow should be harvested in a certain period. For some more information on the sustainability concept see e.g. Geissdoerfer et al. (2017).

The modern concept of sustainability is often related to the 1987 report of the World Commission on Environment and Development, the widely known report of the Brundtland Commission, which entered UNCED. According to this report, "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs”.

The report refers to limits: “The concept of sustainable development does imply limits – not absolute limits but limitations imposed by the present state of technology and social organization on environmental resources and by the ability of the biosphere to absorb the effects of human activities. But technology and social organization can be both managed and improved to make way for a new era of economic growth”. And, perhaps even more importantly, “sustainable development is not a fixed state of harmony, but rather a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are made consistent with future as well as present needs”.

These last quotes are of relevance: they reveal some indeterminacies of the concept, which obviously allow for differing and changing perceptions, depending on the “present state of technological and social organization …”. Moreover, the required identification of “future needs” leaves also ample room for appropriate interpretations. It should be noted that these indeterminacies are justifiable – the implementation of a circular economy must consider local conditions – can lead to problems in ESG and sustainability reporting, e.g. if companies can refer to reporting standards that best suit their situation. This section investigates perceptions of the concept of a sustainable development – over time and in different countries.

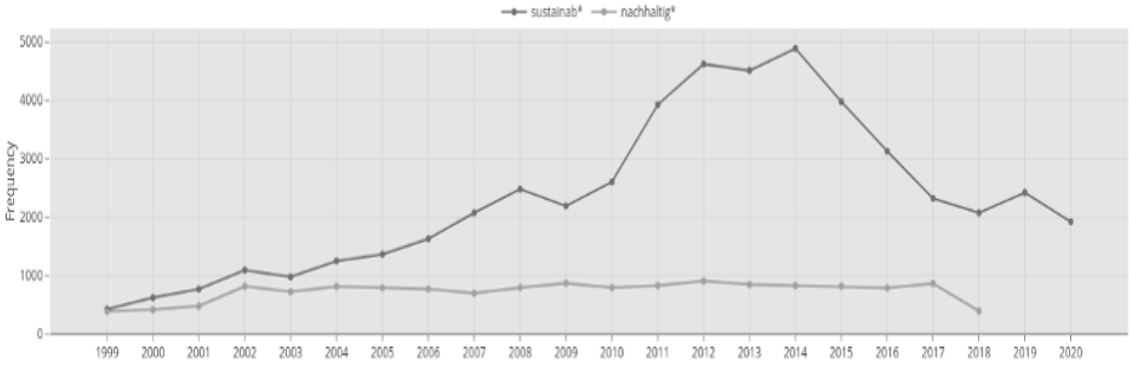
The societal relevance of the concept of sustainability seems to be intuitively clear: according to Geissdoerfer et al. (2017) preserving and maintaining the fundamental functions of the environment in all economic activities requires sustainability. Moreover, the 17 `Sustainable Development Goals´, adopted by the UN in 2015, provide a rather detailed list of actions. Sustainable development is thus an integral part of an economic system, which respects the fundamental functions of the environment, it is therefore an integral part of a circular economy.

Analysis of the Perception of Sustainability in Germany and the UK

Entering the keywords “sustainable” or “sustainability”, yields 52,710 documents in *The Guardian* (1999-2019) and, with the German version of the keywords, 14,676 documents in the *taz* (1999-2018). The documents containing these keywords are now analyzed with various tools of text-mining.

At the beginning, the temporal distribution of the documents containing the given keywords (nachhaltig*, sustainab*) was examined (Figure 2). It turned out that in the *taz* the frequency of use remains almost constant over the entire period. *The Guardian* starts at a very similar level in the early years (1999 to 2003). In the following years, however, the frequency of use increases sharply, peaks in 2014 and then decreases. A closer look shows that between 2009 to 2013, the number of documents found in the section "Business" increased massively. This even led to the establishment of a separate section "Guardian Sustainable Business" between 2009 to 2017, explaining to some extent the higher frequency of the keywords detected in *The Guardian*.

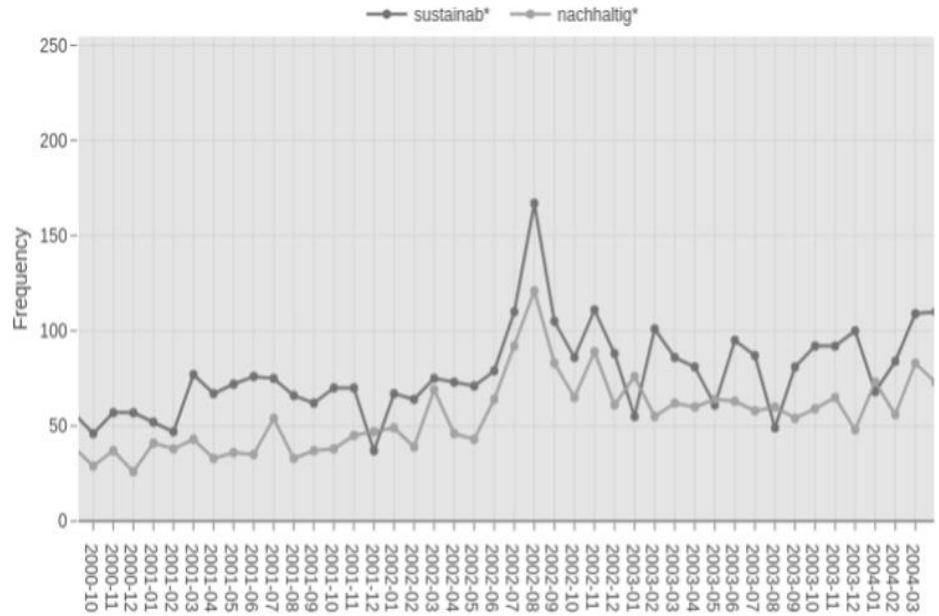
Figure 2 Time series of the number of documents containing the keywords: nachhaltig*, sustainab* in the newspapers The Guardian (bold) and taz



Source: Own drawing based on own calculations

If we look at the values broken down by month instead of the counts for entire years, we find various indications of possible causal events for peaks in the data. The graph shows such a peak in both *The Guardian* and the *taz* in August 2002. These local optima coincide with the World Summit on Sustainable Development in 2002, which took place in Johannesburg. However, simply looking at the number of found documents is not enough to conclude causality from this correlation (Figure 3).

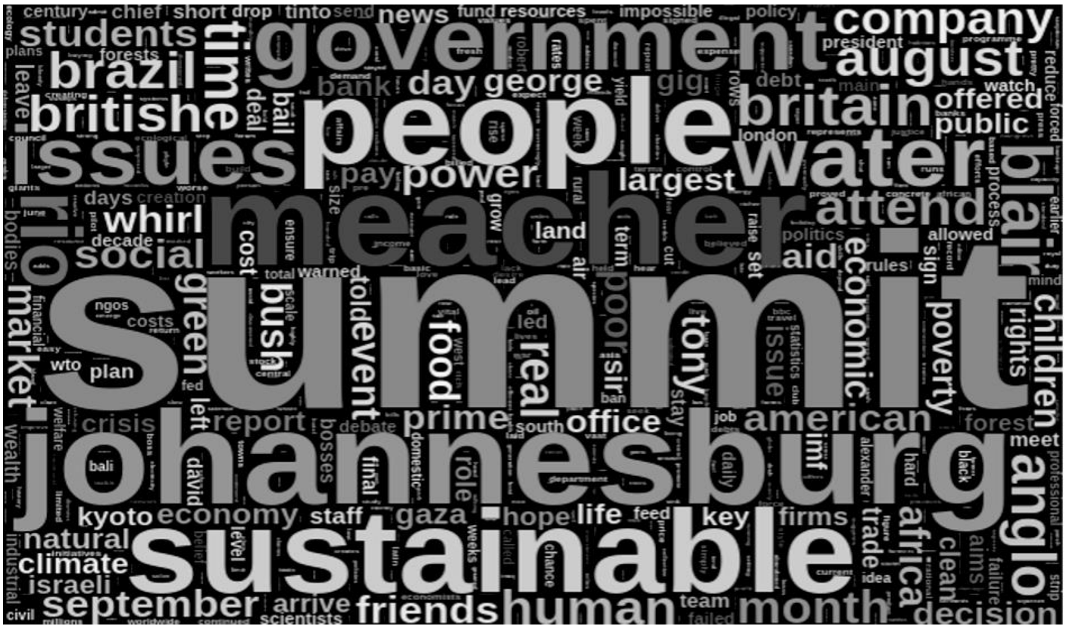
Figure 3 Time series monthly for given keywords; in August 2002 a peak is present in both, The Guardian (bold) and taz



Source: Own drawing based on own calculations

If we instead look at the most frequently used words in the corpora in August 2002, we can visualize the frequency of the words by means of a "word cloud". The frequency of occurrence of a particular word is displayed with font size and color (or shading – in our case). We observe that the coverage of the summit in Johannesburg represents one of the main topics in *The Guardian* (Figure 4). This seems to confirm the association between the Johannesburg summit and the frequency of documents discussing sustainability at that time.

Figure 4 Word cloud, representing the most frequent words in August 2002 in the Guardian Corpus



Source: Own calculations

It is important to note that the temporal perception of “sustainability” is dependent on events, which are related to UNCED, the Kyoto Protocol, or others. Consequently, the context of these events, climate change, mitigation of climate or adaptation to climate change, or social agendas, for example, also affects perception.

Co-occurrence Analysis

To examine the meanings of the term "sustainability" at different points in time, a co-occurrence analysis is carried out. Co-occurrences describe pairs of words that occur together in a defined context window with statistically significant relevance. Knowledge of such co-occurrences allows us to understand the context and thus the meaning of the keywords.

We divided the corpora into four time periods and used the significance measure log-likelihood of Dunning (1993) to calculate the most relevant co-occurrences for each period for the word "sustainable" as shown Figure 5.

Table 1 Most relevant co-occurrences for “sustainable” in the different time periods

Rank	1999 -2004	2005 - 2009	2010 - 2014	2015 - 2020
1	development	development	development	development
2	communities	communities	business	goals
3	environmentally	energy	future	future
4	summit	environmentally	Unilever	business
5	growth	future	living	environmentally
6	term	term	growth	energy
7	convergence	growth	awards	footing
8	energy	commission	financially	food
9	Johannesburg	ensure	economic	fashion
10	environment	transport	products	seafood

Source: Own calculations

For the texts in *The Guardian*, the four time periods show quite different emphases, which are also reflected in other developments:

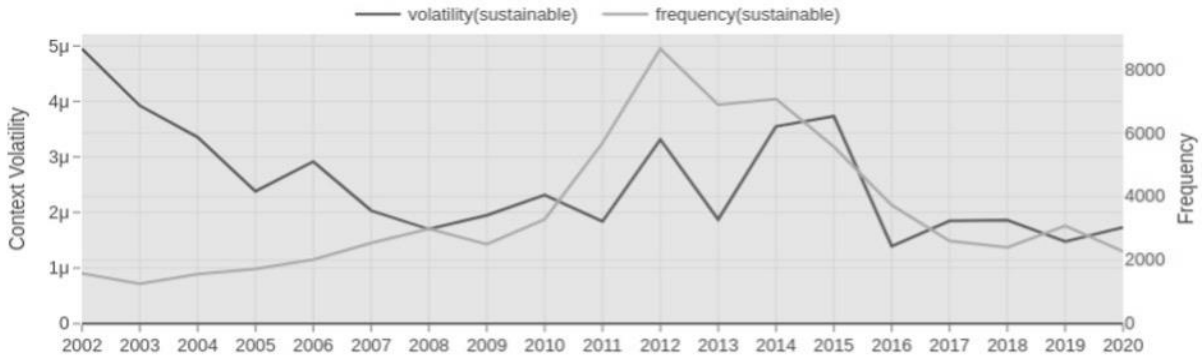
- 1999-2004: The high relevance of "communities" seems to point to the social aspects of a sustainable development, as highlighted, for example, in the "Agenda 21", the action plan set out in UNCED.
- 2005-2009: After the Kyoto Protocol came into effect in 2005, the "flexibility mechanisms" (International Emissions Trading, Clean Development Mechanism, Joint Implementation) brought countries, even communities together in their efforts to reduce greenhouse gas emissions.
- 2010-2014: The financial crisis in the years from 2008 onwards has clearly shifted the focus to the economic aspects of a sustainable development. This is also the time when other business models emerged, which were closely linked to sustainability: smart city, green city, ….
- 2015-2020: With concepts such as sustainable fashion, sustainable food, sustainable consumption, …, the focus is again on business, always with an eye on environmental aspects, not only on greenhouse gas emissions.

Context Volatility Analysis

Context volatility as investigated in Kahmann et al. (2017) describes a method for quantifying context change. In a sliding window approach, a diachronic co-occurrence analysis is performed with the aim of capturing the degree of change in the contexts of key terms. The resulting change trajectory provides an indication of possible controversial discussions or semantic shifts and dynamics in individual thematic areas. To investigate the dynamics of the terms used in discussions about sustainability, the context volatility values of these terms were calculated.

To calculate context volatility, for selected key terms (here "sustainable") the available texts are divided into individual sub-corpora based on their year of publication. Co-occurrence statistics are then calculated for these individual sub-corpora. Subsequently, the procedure provides for the determination of an expected significance value for the co-occurrences of the target words based on a predefined number of time points. In this analysis, the three years preceding the point in time under consideration were used. This results in a vector of expected values for the co-occurrences of the target word, which must be compared with the actual co-occurrence significances for the period under consideration. If there is a high discrepancy between the expected values, it can be assumed that there is a large context change. This procedure is applied in a sliding-window approach over all available time periods, which finally results in a curve of the context change over time.

Figure 5 Frequency and context volatility (bold) curve for the word `sustainable´ calculated using the corpus of the Guardian



Source: Own drawing based on own calculations. "1µ" means one millionth

Figure 6 shows both the frequency curve and the volatility curve (bold) of the word `sustainable´ in the period between 2002 and 2020. In the early 2000s, there is a comparatively low frequency of use for the term. At the same time, a high context volatility can be observed. This could indicate that in this period, not long after the Kyoto Protocol was concluded, the context of use of the term is not yet dominated by a few special topic areas. Rather, it is the case that a variety of contexts can be observed. In concrete terms, for example, the top 50 co-occurrences in 2002 include the words: environment,

energy, government, business, earth, farming, food, economic, industry, transport, tourism and poverty, which all play a role in the years after UNCED in 1992.

In the following years, the frequency of the term increases significantly. However, this is accompanied by a relatively constant low volatility. The reason for this seems to be a strong focus of the term `sustainable´ in economy and business (possibly triggered by the European financial crisis).

Only from 2015 onwards, a change in this situation can be observed due to a local maximum of the volatility curve. Increasingly, terms associated with climate protection, food production and national strategies of individual countries for the implementation of sustainability goals appear in connection with sustainability. Words that appear significantly more often together with sustainable in 2015 than in 2012 are, for example: SDGs (Sustainable Development Goals), energy, fashion, food, city, climate and poverty and others. Words that have lost significance, on the other hand, are business, economic, economy, growth and innovation.

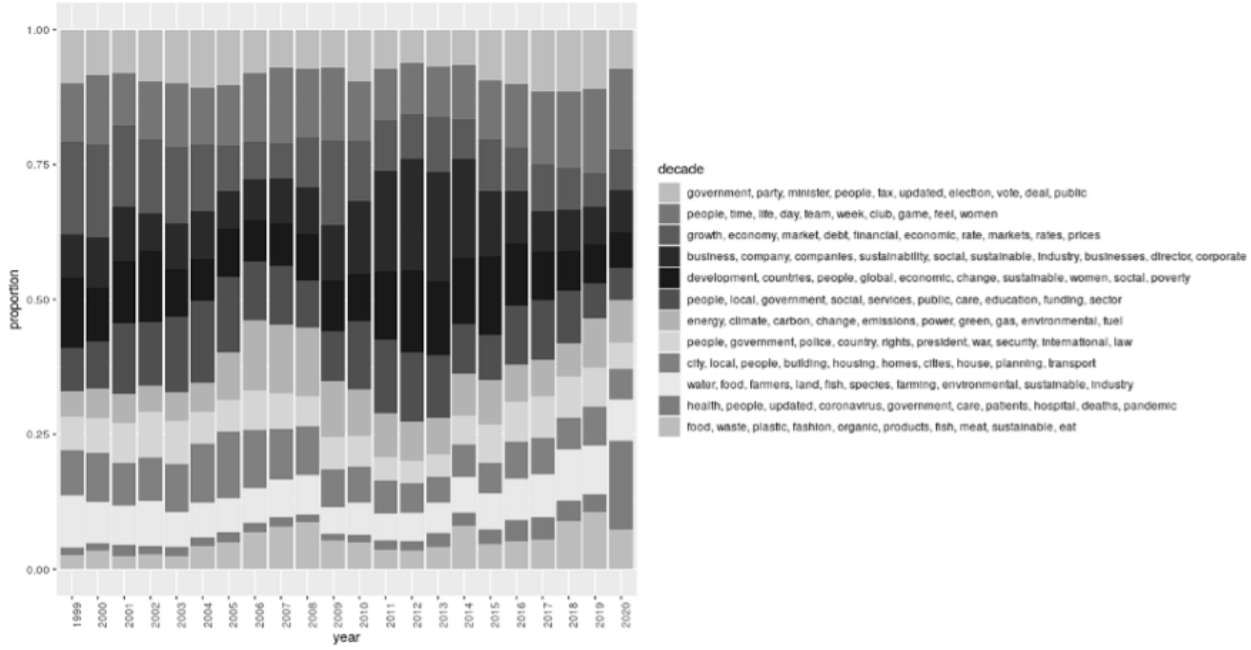
However, this pattern seems to remain constant in the years thereafter, which in turn results in low volatility for the years 2016 to 2020. The extent to which individual key events, such as the Paris Climate Conference in 2015 or the financial crisis, are the cause of the measured context changes must be evaluated in further studies.

Moreover, the fact that periods of high frequency of `sustainability´ occur simultaneously or alternatively with periods of high volatility, indeed deserves special attention in future research. This could help to improve our understanding of changes in the perception of sustainability.

Topic Modelling

Following Blei (2003) topic modelling describes a method for the unsupervised classification of documents into automatically found semantic topics. Each document is assigned a distribution of a fixed number of topics. A "topic" then describes a probability distribution over the entire vocabulary of the corpus. By looking at the topics found and their distribution over time, conclusions can be drawn about the most relevant topics in the documents and their development of meaning over time. Applied to the corpus of *The Guardian*, this results in the following topics, with the size of the topic showing its relevance in the year under consideration:

Figure 6 Diachronic topic distribution as the result of an LDA (Latent Dirichlet Allocation) applied to the Guardian Corpus



Source: Own calculations

- *Topic 3* ~ Economy: growth, economy, market, debt, financial...
- *Topic 4* ~ Business: business, company, companies, sustainability, industry...
- *Topic 7* ~ Energy/Environment: energy, climate, carbon, change, emissions, power, green...
- *Topic 11* ~ Health/Corona: health, people, coronavirus, care, patients, hospital, deaths.

The noun "sustainability" is predominantly used in the context of business (topic 4). In contrast, the adjective "sustainable" is used in almost all different topic fields: we are talking about sustainable growth, cities, fashion, food, consumption, agriculture, packaging, just to name a few. Thus, it appears as if "sustainable" is sometimes used as a marketing device.

The hypothesis of a strong focus on economic and business topics in the years around 2010 and a subsequent decline in the importance of these topics, which we established already through the application of context volatility, can be confirmed by topic modelling. If we look at the temporal course of the importance of the individual topics, we can clearly see in Figure 7 that the topics on economy and business have a very high importance in the period between 2009 and 2013. However, this decreases significantly in the following years. In this study, too, the influence of Covid-19 is not absent, as in 2020 it causes the discussion about sustainability in the context of health issues in general and corona in particular to become the predominant topic (topic 11).

What is the Meaning of Sustainability?

From these investigations a transformation in the meaning of the term sustainability can be documented. Particularly for the texts of *The Guardian*, a strong focus on individual topics can be identified for individual periods. These often coincide with events that may have caused them (e.g. the summit in Johannesburg, the financial crisis, etc.) and thus also have a close connection with certain aspects of environmental and economic policy. It also became clear that the term sustainability is used in various thematic fields in both German and English texts. These start with energy policy and economic discussions, but also include health issues, urban planning and sustainable food production. The differences between German and English texts are comparatively small.

These shifts in the perception of sustainability are, in principle, consistent with sustainable development not "a fixed state of harmony, but rather a process of change …", as indicated in the Brundtland-Report in 1987. However, it seems that there is an inflation of sustainability contexts, which sometimes also serve as a tool for marketing, but which also affect the perception of the concept. It seems as if there is a direct correlation between economic (policy) issues and the perception of sustainability.

While perceptions of the waste hierarchy in general and waste prevention in particular are gradually changing and often related to the introduction of new waste management technologies, changes in the perception of sustainability, are much more frequent and refer to very different aspects of societies and economies.

Again, this intrinsic nature of the concept can create problems for the implementation of a circular economy, or the Green Deal, for example. The reason for this is that the road to a circular or green economy takes a long time. It can make a difference whether "sustainability" refers more to business or more to social aspects in a pandemic, whether certain SDGs play an important role, or technical aspects of a smart city, for example.

Following Wiesmeth (2020a) the concept of a circular economy must be adapted to the local framework conditions, and so there is always room for a specific local sustainability concept. But the problem is this constantly fluctuating perception of the concept, which obviously depends on external factors, which can hardly be controlled.

The consequence is probably that the implementation of a circular economy should be based on a concept of sustainability, which allows adjustments to future requirements of society without violating relevant local conditions – again a challenging task.

IV. Conclusion

The results of this paper revealed significant changes in the perception of concepts, which are of relevance for implementing a circular economy. Such changes are quite common, and they can be related to quite different contexts. In the case of the waste hierarchy or rather waste prevention, available waste management technologies seem to influence the perceptions, while perceptions of sustainability occur more frequently and can depend on all kinds of external developments.

The consequences of these observations include occasional changes in environmental policy. Often, however, these regulations affect the economy. Regarding the waste hierarchy, an example of this is the mandatory deposit on disposable beverage packaging in Germany: an increase in one-way plastic bottles led to the mandatory deposit. Due to a misleading perception of waste prevention, this mandatory deposit induced even more one-way plastic bottles and increased recycling activities. Following policy measures could relate to the packaging industry and/or to the recycling industry. Likewise, the vagueness around sustainability requires more and more fine-tuning of ESG and sustainability reporting with additional burdens on the economy.

In addition to expanding the database, further research should focus on ways to modify the societal perception of waste to stimulate efforts to prevent waste in the true sense of the word. In addition, it is necessary to look for concepts of sustainability that are, on the one hand, general enough to allow for subsequent adjustments, but also specific enough to the local conditions in a country on the way to a circular or green economy.

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