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Review

Bibliometric Analysis of a Product–Service System's Rebound Effect: Identification of a Potential Mitigation Strategy

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Abstract: A product–service system (PSS) is a concept concerning sustainability, as it offers the opportunity to decouple economic success from material consumption, thereby reducing the environmental impact of economic activities. However, researchers have identified significant barriers frequently impeding sustainability potential, which are called rebound effects. Unfortunately, the existing studies are insufficient, and there are few published studies on the actual avoidance of the rebound effect, which is a significant limitation for practical applications for decision-makers and policymakers. Therefore, this study aims to conduct a comprehensive bibliometric review of the relationship between the rebound effect and PSSs, including its drivers and mitigation strategies. This study incorporates multiple perspectives to map and analyze the landscape of rebound effect research in the context of PSSs and used 152 articles from a systematic literature review covering all publication years. Using the Scopus and Web of Science database, journals, citations, authors, and keywords were identified. This study identified the annual trend of research, listed the most influential articles, and uncovered six research topic clusters related to the rebound effect and PSSs. As an innovative feature of this study, it categorised the identified drivers based on their contextual dependencies to elucidate their interrelationships. This study also presents a categorisation of mitigation strategies based on the type of approach. This study is expected to support decision-makers and practitioners in developing sustainable PSS implementation strategies.

Keywords: product–service system; rebound effect; sustainability; mitigation strategy; consumer behaviour; nurture; bibliometric review

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1. Introduction

The origin of the product–service system (PSS) concept is a concern for sustainability. The discipline of PSS has evolved, and its focus has expanded beyond the environmental dimension to include economic and social dimensions. It is currently recognised as a potential catalyst for transitioning to a more sustainable society. Bocken et al. [1] described the significance of PSSs to the sustainable business model archetype as 'deliver functionality rather than ownership'. The nature of this altered relationship is crucial, as not all PSSs inherently result in sustainable solutions [2,3].

The achievement of sustainability is contingent upon a multitude of influencing factors. It is assumed that non-ownership modes of consumption are collaborative, prosocial, altruistic, and environmentally sustainable [4]. Nevertheless, previous research has shown that this is not always the case [5]. The change in ownership can make PSSs more sustainable by encouraging companies to produce superior products and reducing the number of products required to meet the same number of consumers [6,7]. However, this change in ownership has also been identified as a potential source of rebound effects (REs) [2,8].

Furthermore, this study defines the product–service RE as a phenomenon where the expected more sustainable benefits are not partially or entirely attained due to changes in consumer behaviour or other factors that reduce or eliminate the expected beneficial effects. In particular, based on the findings of the preliminary investigation compiled through this bibliometric approach, existing strategy tools to evaluate the RE of PSSs do not provide a comprehensive overview [9]. REs appear in various shapes and sizes and can be initiated by various drivers at various levels and types, making them difficult to identify and measure [10]. Similarly, Hüer et al. [11], who conducted a literature review of 71 scientific publications, found that the existing literature broadly discusses the benefits and risks of PSSs but usually fails to provide adequate drivers and strategic solutions for sustainability-related problems, such as REs.

Several literature review studies have revealed the concept of RE in terms of its definition, mechanism, and relationship with the concept of sustainability. As one of the prominent literature reviews in this study, Castro et al. [12] did not specify and tended to equate the concepts of the circular economy (CE) and PSSs, but they stated that PSSs could consume more energy and produce more emissions than product offerings. Although Castro et al.'s [12] study provides a clear definition and mechanism of the RE, there are limitations in the study, as outlined in future research directions, that prevent identifying the underlying causes/drivers of the RE in PSSs. In their study of RE and sustainability, which includes sustainability concepts, Vivanco et al. [13] argued that 'the explicit links between RE research and sustainability concepts, however, have not been drawn, and the RE has been studied through a narrow framework that may ignore complexity, resulting in inappropriate conclusions and policy recommendations'. This is strongly related to the insufficient identification of causes, such as ignoring behavioural effects, which leads to ineffective mitigation strategies.

Similarly, Biewendt et al. [14] found that research on the RE has not been exhaustive and that little has been published on the actual avoidance of the RE, which is a significant limitation in the practical application of decision-makers and policymakers. This is due to the absence of exhaustive root cause/driver identification studies that address the problem. Metic and Pigosso [15] identified the determinants of the RE in CE. However, it appears that this study has not yet addressed the feasible mitigation strategies that could be proposed. In addition, the PSS is absent from the article's keywords and inclusion criteria, and there is not a single mention of PSS in the article itself. This makes it difficult to establish a direct correlation between this and the case of the RE in PSSs. This study intends to fill a gap in previous research by investigating RE research on PSSs.

This study proposes more in-depth bibliometric research on the RE in PSSs because, without such a study, it would be challenging to identify the particular drivers of the RE in the PSS and to devise effective mitigation measures. Consequently, it is essential to investigate the potential relationship between the RE and PSSs for a more nuanced understanding of this phenomenon. By addressing this gap in the literature, we can develop a more thorough comprehension of the effect of PSSs on sustainability and, ultimately, identify effective strategies for reducing the RE. To address the issue of the RE in PSSs in terms of how to mitigate the possibility of failure and the strategies that can be used in PSS implementation to enable sustainable PSSs, we present a bibliometric analysis pertaining to the PSS-RE.

The following research questions guided this study:

(1) What is the clusterisation and network influence of the PSS rebound?
(2) What are the identified drivers based on the records studied?
(3) What mitigation strategies can be proposed as possible alternatives?

The study is expected to have significant implications for economists, managers, engineers, sustainability studies researchers, practitioners, and decision-makers across disciplines. Due to its interdisciplinary scope, it can provide a comprehensive perspective on the challenges and opportunities associated with sustainable product–service systems. The current study caters to the concerns and interests of those dedicated to fostering

sustainable industrial practices by providing insights into the underlying drivers of the rebound effect (RE) and strategies for mitigation. Incorporating an exhaustive bibliometric analysis contributes to the present body of knowledge concerning REs within product–service systems (PSSs). Employing a holistic methodology, this approach contrasts with previous research that predominantly concentrated on specific facets of the RE. Through bibliometric approaches, the study's primary objective revolves around charting and scrutinizing the landscape of RE research within the context of PSSs. This exhaustive analysis serves as a foundation for identifying the root causes of the RE and proposing effective mitigation strategies. By addressing this deficiency, this study is expected to support decision-makers and practitioners in developing sustainable PSS implementation strategies.

This paper is organized as follows. Section 2 describes the theoretical foundation, and Section 3 presents the methodology adopted in this study. Sections 4 and 5 present and examine the findings and discussion, respectively. Section 6 presents the conclusions of this study.

2. Theoretical Foundation

2.1. RE

To reduce carbon emissions, the majority of governments seek to increase energy efficiency in all economic sectors. In general, it is presumed that such enhancements will reduce overall energy consumption, at least in comparison to a situation in which no such enhancements are made. However, economists have learned that various mechanisms, typically grouped under REs, can reduce the energy savings obtained over time. RE and its theoretical arguments can be traced to Jevons and Brookes' work. Some economists contend that introducing certain energy-saving technologies in the past has increased overall energy demand. This outcome is known as a 'backfire'.

If this RE is significant, energy and climate policy will be profoundly affected [16]. Although cost-effective energy efficiency improvements should increase welfare and enhance economic outcomes, they may be ineffective or even counterproductive in combating climate change in certain instances.

The current debate on RE began with Khazzoom's [17] assertion, which was supported by theoretical logic and empirical evidence, that changes in fuel efficiency would lead to changes in the implicit price of energy services. Therefore, as long as the price elasticity of the demand for energy services is typically negative, it is reasonable to anticipate that efficiency improvements will contribute to upward pressure on the demand for energy services through increased usage levels.

Brookes added a macroeconomic viewpoint, monitored greenhouse gas and CO_2 emissions, and discovered that the RE theme responded to the green surge. Researchers have noted the complexity of the RE, with direct or first-order effects causing indirect or second-order effects [18]. Furthermore, the literature identifies three categories of REs: direct, indirect, and economy-wide [19–21]. Classical theory states that the RE is only concerned with energy issues. However, Giampietro and Mayumi [22] asserted that the RE is valid not only in relation to energy efficiency but also to resources in general, while other scholars, such as Vezzoli et al. [23] and Alfarisi et al. [24], argued that the RE should be extended to include systems involved in the life cycle.

Conversely, Hopkinson and James concluded that three distinct categories of REs (inside PSSs) had been observed: direct, indirect, and platform [25]. Platform effects emerge when new services are made available, influencing the underlying factors that determine production and consumption levels and patterns. REs have been extensively studied in economics and are typically defined as those resulting from changes in relative prices: when a product or service becomes more efficient, its operating costs per unit decrease, which may lead to greater utilisation [18].

Based on a search of the Scopus and Web of Science databases using the search terms 'rebound effect' and 'literature review', 72 documents were obtained. The first study in the

literature review on the RE was discovered in 1968, disappeared, and then returned in 2010. In 1968, the term 'rebound effect' appeared in the health and medicine category for the first time, specifically in the pharmacology subject titled 'Chemistry, pharmacology, and clinical pharmacology of oral contraceptives'. At that time, the RE in the health and medical categories was defined as a secondary reaction of an organism to drug stimuli [26], and the withdrawal effect was defined as the development of new symptoms that are a temporary return of the prescribed drug's symptoms. Subsequently, this research buzzword ceased until it reappeared in 2010. While the REs in natural and environmental science and in engineering and technology overlap and are frequently used interchangeably to refer to an increase in demand for products due to a rise in efficiency [24], the terms are often used interchangeably in economics. The overall or economy-wide RE of energy efficiency improvements is the sum of direct and indirect effects [16].

This study categorises the literature review on the RE into four fields: engineering and technology, natural and environmental science, social science, business and the humanities, and health and medicine. Each of these categories falls under a related subject. Environmental science, biochemistry, genetics and molecular biology, material science, agricultural and biological science, and neuroscience comprise the natural and environmental science category, which accounts for 23% of all publications. About 30% of the engineering and technology category comprises engineering, energy, and computer science. The category of social science, business, and humanities, which includes business, management, accounting, economics, econometrics, finance, decision science, arts and humanities, and social science, has a 33% share. The final category, health and medicine, which includes medicine, pharmacology, toxicology and pharmaceutics, veterinary science, and neurobiology, has a 14% portion. Figure 1 illustrates the total percentage of each category.

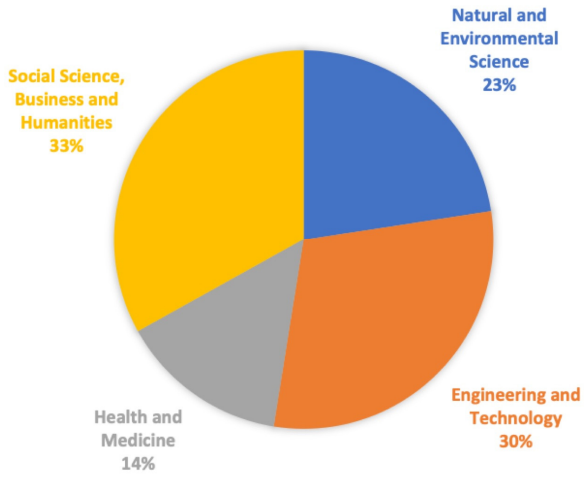

Figure 1. Categorisation of the RE's published articles.

2.2. PSSs

Companies increasingly integrate their products and services into today's globally competitive business environment [7]. This phenomenon is significant for product and service providers [27,28]. Consequently, the prospective benefits of offering integrated product and service solutions have economic, social, and environmental effects as firms increase resource utilisation and competitiveness [29–32]. PSSs are a generic term for research on this emerging phenomenon [27,29]. When defining PSSs, most articles cite Goedkop et al. [33], who define them as a set of marketable products and services that can satisfy customer needs cost-effectively and sustainably.

Product–service systems were inspired by environmental issues. PSSs are viewed as catalysts for the transition to a more sustainable society. Therefore, the concept of sustainability must be clarified for each PSS dimension. Mont [7] described how PSSs offer integrated products and systems of products and services to reduce environmental impacts

through alternative product usage scenarios. PSSs consist of (i) products, (ii) services, in which an activity is executed without the need for tangible goods or systems, and (iii) the combination of products, services, and their relationships [33]. Environmental sustainability is attained when the PSSs' production and consumption patterns limit the depletion of natural resources and decrease pollution from existing products. Economic sustainability occurs when PSSs can sustainably maintain their economic objectives. Social sustainability occurs when PSSs can maintain quality of life without sacrificing social rights. Most authors view PSSs merely as competitive proposals to satisfy consumer demand [7,27,30]. Nonetheless, according to some authors [27,34], PSSs strive for sustainability by striking a balance between environmental, economic, and social concerns. In general, products are created in response to consumer demand and can be modified to incorporate services. Therefore, PSSs represent a competitive opportunity, which is significant because they can alter consumption standards.

In other words, PSSs aim to enhance competitiveness and establish an equilibrium between social, economic, and environmental concerns [35]. Manzini [2] defined a PSS as a strategic design integrating product, service, and communication systems based on new organizational forms, reconfiguring roles, consumers, and other stakeholders.

2.3. PSS-RE

Implementing PSSs does not guarantee sustainability; thus, PSSs must be meticulously designed, developed, and implemented. The emergence of REs in PSSs has been demonstrated to be a valid concern [23,24,36]. Jenkins et al. [37] defined the RE as the difference between anticipated and actual energy gains and broader environmental benefits due to a given efficiency improvement.

Although PSSs are a potential pathway to sustainable resource consumption, they necessitate a significant transformation at the value chain and industry levels for product- and service-oriented businesses [38]. Implementing effective and environmentally favourable PSSs is still limited [39]. Alfarisi et al. [24] found that PSSs have introduced numerous features that function well in one dimension but lead to other issues. This trade-off phenomenon has prompted a broader study of the RE, which is not limited to energy efficiency but encompasses the energy, materials, and transportation sectors and all sectors associated with the cycle. PSSs that are not developed with caution carry the risk of having their environmental potential mitigated by REs and less responsible behaviour [5,40]. The terminology of REs, as described in energy economics, is insufficient to indicate the various secondary effects of sustainable consumption that focus on technological measures to improve efficiency and behavioural changes. Several researchers have incorporated the concept of PSSs into the integrated study of REs, while others have incorporated the concept of REs into the concept of PSSs. These effects are defined as 'ecologically damaging second-order effects that sometimes originate from PSS' [41] and 'unintended impacts of PSS' [42]. Recent studies have emphasised several potential PSS benefits. However, comprehension of the causes and mitigation strategies for PSS-REs remains very limited.

In the context of PSSs, the RE occurs when production and consumption increases offset efficiency and production/service adequacy enhancements. This occurrence is known as the PSS-RE [43]. Systemic REs are unavoidable when implementing PSSs. Vezzoli et al. [23] referred to these as negative consequences. Unfortunately, stakeholders have employed the RE as an excuse for inaction. Managing the RE is crucial when designing a PSS because it entails complex trade-offs that affect the system's overall direction. In addition, the change in ownership affects REs related to consumer behaviour. When consumers are no longer the owners of a product, they may behave irresponsibly with regard to it [2,5]. These types of behaviours can impede the long-term viability of the entire PSS and should be avoided. The premise is that adding a service to a product that focuses exclusively on a shift in property rights, responsibility, or the temporality of possession can decrease the (perceived) value of the product to the user, resulting in REs. Figge and Thorpe [44] identified the production system as a potential aspect of generating a RE. According to Figge and Thorpe [44],

the changes in production, the price of items, materials, or commodities, the operational efficiencies, and the company's relationships are the primary factors contributing to the RE. However, as it overlaps with the concept of CE, the concept of a RE in PSSs has been underdeveloped. Even though they are distinct concepts, CE aims to create the highest possible value and sustain it for as long as possible using the fewest resources [45], and PSS is viewed as one of the approaches to accomplishing this objective [46]. Several studies have demonstrated that PSSs are one of the business model approaches that fall within the CE domain [47], and PSSs are expected to facilitate the accomplishment of CE. Nonetheless, other studies have contended that these two strategies are in accordance with Haber [48]. The consequence of this statement is that the phenomenon that occurs between the two, such as the RE, is considered identical. In this study's literature review, the most cited article is Kjaer et al.'s [49] 'Product/Service systems for a circular economy: The route to decoupling economic growth from resource consumption?', which demonstrates the interrelationship between PSS, CE, and RE. In addition, the research uncovered a significant increase in interest in the topic, as the number of publications increased from 1 in 2010 to 39 in 2022.

3. Methods

This study examines the phenomenon of the RE in PSSs through a systematic literature review. The analysis and discussion of the existing literature on the RE of PSSs serve as the foundation for achieving new theoretical results based on evidence, synthesizing the current state of knowledge, and providing new insights into the subject. This systematic literature review method is based on Briner and Denyer et al. [50] and adheres to scientific procedures and transparency in order to minimize bias through a thorough evaluation of published works. Based on Briner and Denyer et al. [50], the following five stages are suggested: (1) Review questions; (2) Locating the studies; (3) Critical appraisal; (4) Analysis and synthesis of the findings; (5) Dissemination of the findings.

3.1. Review Questions

This literature review is guided by three primary questions. (1) What is the RE phenomenon in the PSS field? (2) What drives contribute to the emergence of the RE in PSS implementation? (3) What mitigation strategies can be employed to minimize the RE during PSS implementation? In order to identify the actual concepts, this study analyzed the literature on the RE and PSSs separately during the initial phase. Later, a typology particular to each field was obtained. This enabled the capture of the nuances of the relationships between concepts, the comprehension of perspectives, and the creation of article search strings.

3.2. Locating the Studies

Before conducting the review and searching for relevant studies, setting up a protocol that relies on and incorporates the review questions is necessary. The protocol ensures that the review is systematic, transparent, and feasible, all essential characteristics of systematic reviews. Based on the results of the evaluation of the review questions, deciding which database to utilize is a crucial query that will largely determine the search strategy. This study used the Scopus and Web of Science databases to ensure the accuracy of the data and reduce the possibility of neglecting important information on this topic.

Moreover, the final form of the search string includes the keywords 'rebound effect', 'product-service system', and 'circular economy'. Each article uncovered must be subjected to inclusion and exclusion criteria to determine its relevance to the review. At this point, all studies regarded as pertinent to the review question will be chosen. The comprehensive search protocol is detailed in Table 1.

Table 1. Research protocol.

Research Protocol	Description
Database	Scopus, Web of Science
Search field	Title-Abstract-Keywords
Search string	'rebound effect' AND 'product-service system' OR 'circular economy'
Language	English-only
Publication type	Peer-reviewed journals and conference papers
Inclusion criteria	Papers that addressed the fields of PSSs and the rebound effect (even if one of the topics was not the primary focus)
Exclusion criteria	Papers that did not address topics related to the RE and PSS or related synonymous concepts or did not report the pertinent perceived effect

3.3. Critical Appraisal

The critical evaluation of each study about the quality criteria established as part of the protocol for the systematic review is a crucial component of the systematic literature review. This enables the review's findings to describe the included studies's quality precisely. A list of 76 articles was chosen for thorough review. A snowballing strategy resulted in excluding 39 articles and adding 3 additional articles (Figure 2). The final sample contained 31 articles. The search was performed in iterations. This iteration permitted the inclusion of newly published papers and ensured that the analysis continued without the risk of omitting pertinent articles. The newly inserted articles provided a new set of examples but did not affect the proposed results or framework. As a result, we find that the selected articles adequately address the proposed questions.

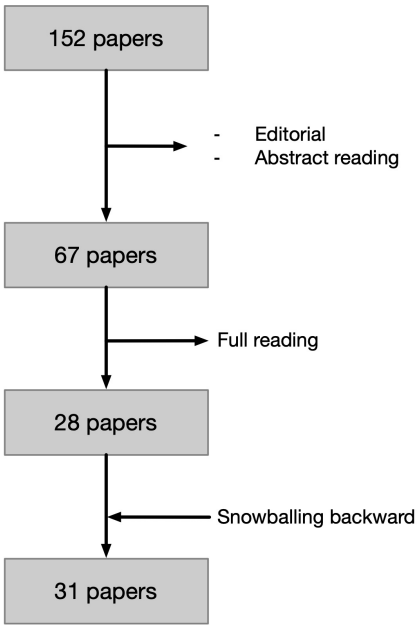

Figure 2. The result of data retrieved.

3.4. Analysis and Synthesis of the Findings

After all studies relevant to the review query have been gathered and evaluated, the systematic review proceeds to analysis and synthesis. The analysis aims to examine and dissect each study and investigate the relationships between its components. In contrast, synthesis is the process of combining the findings from each study into a new or distinct arrangement and developing knowledge that is not apparent from reading the studies separately. This study utilises the articles using bibliometric mapping, such

that the data produced are visual data using mapping tools to gain full perspective and topic relationships. Due to its useful characteristics, this study picked VOSviewer version 1.6.18 over alternative visualization tools for analysis. Users can construct co-occurrences network, density and overlay visualizations, clustering, and text mining analyses using its simple methodologies [51]. It also allows for visualization of dimensions not achievable with manual methods or old software [52]. Using VOSviewer, the text mining technique generated a network map of co-occurrence keywords extracted from the abstracts and contents of the selected research papers. In comparison to other computer software tools, VOSviewer prioritizes the graphical representation of bibliometric maps [53]. Furthermore, big bibliometric maps can be shown and comprehended with simplicity. The outcome of this synthesis study is the identification of RE occurrence drivers (Section 4.2) and mitigation strategies (Section 4.3).

3.5. Dissemination of the Findings

One of the main purposes of systematic literature reviews is to make research findings more accessible to practitioners; the dissemination of review findings is essential to conducting systematic literature reviews, regardless of whether the practitioners are other researchers, organizational managers, or decision-makers. This study considers that publication in a scientific article is one of the most effective methods for disseminating the results of a systematic literature review.

4. Findings

In this section, the results of the bibliometric analysis are presented and discussed. Mendeley and VOSviewer were utilised to facilitate data processing. Specific software was also used to facilitate bibliometric analysis for this study. Bibliometric analysis is based on pertinent scientific publications/literature data [54]. Essential data, such as identification sources (title of journal/literature, volume, and pages), author's name, institution's address, references, document type, title, keywords, abstract, and subject, can be used.

4.1. Cluster and Network Analysis of PSS and RE

When the mapping was completed, it was imprecise and did not demonstrate a strong correlation between PSS and RE due to the large number of keywords that also had a strong relationship. As stated previously, this may occur due to the fact that RE is a broad term; thus, we divided it into four categories in Section 2.1. Consequently, it is possible that the relationship between the RE and the related keywords obscures the clear relationship between the RE and PSSs. Therefore, we attempted to refine the mapping by limiting the keywords and adding exclusion criteria for papers that did not address concepts related to the RE and PSSs. The authors conducted bibliometric mapping using the comprehensive counting method of PSS and the RE divided into database-stored keywords. To explain in detail each keyword that appears in the selected articles, the authors set a minimum number of keyword occurrences to 1 to ensure that all 53 recorded keywords can appear in the bibliometric map, which produced six clusters (Figure 3).

Cluster 1 (blue) consists of nine items, with PSS and residual effect being the primary focus. Demyttenaere [55] and Alfarisi et al. [56] emphasized the importance of this study. Using system dynamics to identify the RE, both studies highlighted the effect of ownership, a unique property of PSSs, on the dimension of sustainability. Sustainability, system dynamics, ownership, product design, nurture, life cycle, and dematerialization are the subsequent keywords.

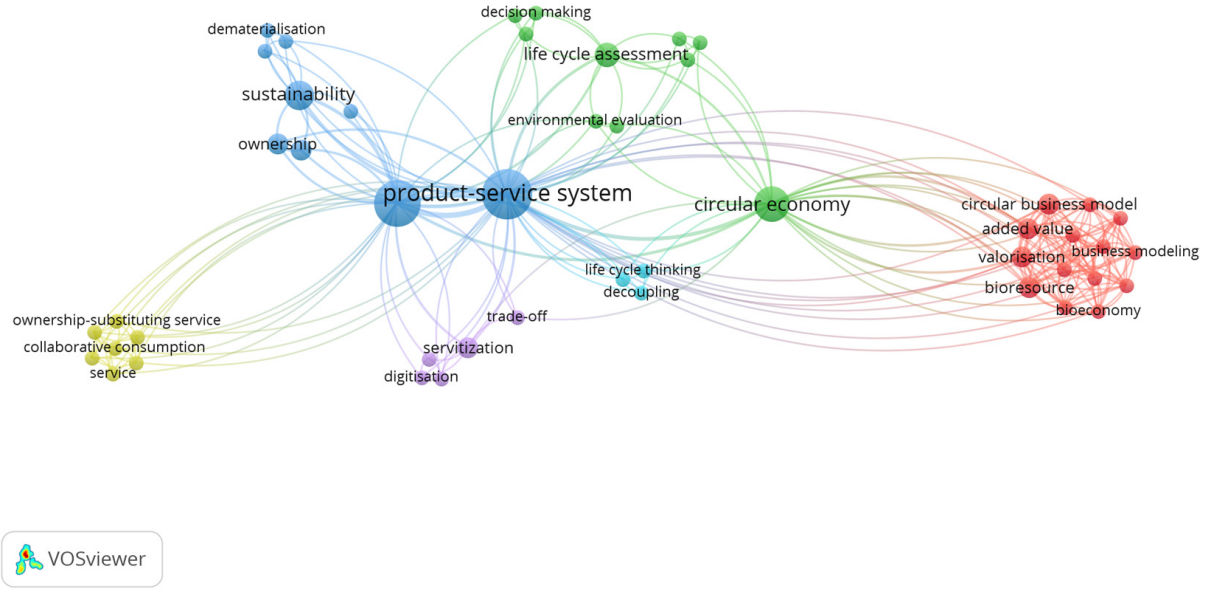

Figure 3. Cluster and network data.

Cluster 2 (green) contains seven products, with CE as the central keyword. This cluster is represented by the studies of Loon [57] and Salvador [58]. The research titled 'Circular products and business models and environmental impact reductions: Current knowledge and knowledge gaps' concludes that current environmental assessments may not accurately quantify circular products/offers and that their environmental performance is an advantage in CE. The results indicate that there is an imperative need for more LCAs that capture the benefits and drawbacks of circular products more accurately [57]. Consumer products, environmental evaluation, environmental impact, greenhouse gas emission, life cycle assessment, and use phase modelling are some additional keywords that are closely related to the principal keywords.

Cluster 3 (yellow) includes seven items: collaborative consumption, ownership-substituting services, product sharing, resource efficiency, resource-saving potential, service, and sustainable consumption. This emphasis is reflected in Leismann's [59] paper titled 'Collaborative consumption: Towards a culture of resource-conscious consumption'.

Cluster 4 (purple) includes the keywords digitisation, servitisation, and trade-off. This cluster is supported by research associated with other keyword clusters, including PSS and circular economy. Widmer et al.'s [60] 'Defining value creation in the context of circular PSS' is the basis of this cluster; it demonstrates how CE principles, which govern a company's decision-making, are applied to supply chain network architecture. Value creation for multiple stakeholders and mobility as a service is used to illustrate the need for systems and life cycle thinking to prevent residual effects and fully comprehend circular PSS trade-offs.

The keywords added value, bioresource, circular business model, and bioresource are recorded in Cluster 5 (red), which comprises low-frequency terms. The main study in this cluster is by Chierici and Copani [61], 'Remanufacturing with upgrade PSS for new sustainable business models'.

The keywords decoupling, industrial ecology, and life cycle thinking comprise Cluster 6 (light blue). This cluster is also closely related to the PSS cluster and the CE cluster, as demonstrated by Kjaer et al.'s [49] study 'Product/service systems for a circular economy: The route to decoupling economic growth from resource consumption?'.

4.2. Driver of the RE

PSSs offer an opportunity to decouple economic achievement from material consumption, thereby reducing the environmental impact of economic activity [27]. Researchers

have conducted a more rigorous review of the issue and have argued that the PSS is not a panacea for sustainability [36,62]. Studies have demonstrated that the PSS business model does not always determine the acquisition of environmental benefits [63]. In the current study, the authors attempt to summarise some of the drivers of REs that hinder the sustainability potential of PSS based on the literature selected during the previous stages of comprehension. This study examines the drivers identified in the category of RE: direct, indirect, and economy-wide factors.

4.2.1. Direct RE

Alfarisi et al. [24] demonstrated that non-ownership is the primary driving force behind the emergence of the RE. Non-ownership is considered to influence product attachment, which is the intensity of consumers' emotional affinity to a particular product [64]. Demyttenaere [55] defined attachment as a strong emotional connection or attachment between a consumer and an object. Therefore, when product attachment is low, there is a possibility of careless behaviour, which shortens the product's lifespan [24]. Moreover, Alfarisi et al. [56] observed that user behaviour during the use phase tends to shorten the product life cycle and the effect of this behaviour on sustainability outcomes using a system dynamics simulation.

Sustainable patterns cannot be accomplished through technological efficiency innovations alone [65]. Numerous product–service innovations with high potential for sustainability fail as a result of consumer disfavour or negative REs [44,66]. Argued that the potential for PSSs to alter production and consumption systems in a manner that enables a sustainable transition must be carefully evaluated. The most important factor is unanticipated user behaviour or inappropriate implementation of potentially sustainable efficiency innovations [67]. Tukker [40] identified 'functional outcomes' as having the greatest potential for environmental advantages in the PSS typology. To realize fundamental system transitions, PSSs that genuinely integrate technological change and concentrate on behavioural changes in usage patterns are required and are believed to be the driving force behind the emergence of REs [65]. Gains in residential energy efficiency for space heating/cooling, personal transportation, household appliances, and illumination are estimated to range from 10 to 30% for direct effects [16,19,68]. This number may be higher for developing country households and manufacturers [43].

Mylan [69] examined a specific factor, attitude, which can influence user consumption behaviour during the consumption phase or socio-psychological factors.

Kjaer et al. [49] provided a broader understanding of REs, which occur when the actual resource reduction of an enhancement is less than anticipated due to behavioural or systemic responses. Kjaer [70] considered that adaptive user behaviour is a common cause of the RE, such as when fuel-efficient automobiles encourage drivers to drive more. Other consumption factor variations, such as variations in time or space, do not account for adaptive user behaviour. According to Kjaer [70], the viability and capacity of PSSs to reduce environmental impacts cannot be guaranteed. PSS alternatives are not inherently more certain than non-PSS alternatives. For user-oriented PSSs in which the solution is provided to users as a platform, but the provider does not own or has limited control over which users choose to use the system or how they conduct it, uncertainty can be greater [70]. A bike-sharing system is an example of a use-oriented PSS because, from the consumers' perspective, there is no alternative to a shared bicycle. User acceptability, contextual dependencies, and the possibility of residual effects are crucial to a project's success. According to Kjaer [70], changes in consumption practices are known to generate REs, which is supported by other PSS researchers [5,41,71], as well as the LCA literature [72,73].

4.2.2. Indirect RE

Laurenti [74] criticised conventional assessment methods and proposed an evaluation based on system behaviour resulting from ripple effects propagating throughout the system's structure. Laurenti [74] identified the RE driver as an incremental enhancement in

material and energy efficiency that increases material consumption based on the premise that a system's behaviour results from its structure (consumption REs). Using a causal loop diagram, the study determined that the cycle of incremental innovation and obsolescence is a reinforcing feedback loop: incremental innovation leads to shorter product lifespans, which increase consumption.

Vivanco et al. [75] asserted that efforts to reduce environmental burdens by promoting energy or resource efficiency usually fall short of expectations. This is partially attributable to the RE, which is a result of behavioural and economic demand responses. Changes in efficiency result in changes in consumption and production factors due to changes in price elasticity [75].

4.2.3. Economy-Wide RE

According to Maxwell and McAndrew [76], REs are unanticipated increases in consumption caused by environmental efficiency interventions, which can occur as a result of price reductions (e.g., efficient products become less expensive and are subsequently consumed at a higher rate) or other behavioural responses. There is substantial evidence that interventions in energy efficiency have resulted in REs in transportation (commercial and passenger vehicles), energy services (commercial and domestic), household heating/cooling, appliances, and lighting.

The economic-wide RE for energy efficiency advancements is estimated to be approximately 10% less than the direct RE, although some cases show >30%, with one case for energy efficiency interventions in the Scottish energy sector demonstrating a long-term boomerang effect [66,77,78].

The authors summarised the drivers of the RE based on the literature recorded in this study, including incremental improvements [74], efficiency change [75], environmental efficiency interventions [76], non-ownership [56], user behaviour [65], change in consumption practice [70], socio-psychological [69], and adapted user behaviour [49]. In addition, this study examined the drivers identified in the categorical category of the RE, namely direct, indirect, and economy-wide factors. Based on these data, the customer behaviour-related factors that contribute to the emergence of the RE during the implementation of PSSs were outlined. An increase in efficiency that causes price elasticity has occurred since the classic RE theory and has been a topic of discussion well before the advent of PSSs. According to the authors' perspective, the preponderance of PSS problems are user-oriented. This is paradoxical because user-oriented PSSs are considered to have the greatest potential to promote sustainability. Conversely, a user-oriented PSS, which precludes ownership, results in changes in user consumption behaviour, which has a negative effect that outweighs the potential benefits that can be obtained by supporting sustainability efforts.

The identified drivers of the RE provide valuable insights into the complexities and difficulties of implementing PSSs in a sustainable manner. Fortunately, clusterisation is distinctive in that it enables the identification of the interdependencies and relationships between concepts so that these interdependent concepts can provide a complete picture of a mutually influential relationship between concepts that cause a RE in PSS implementation. Table 2 provides a categorisation that serves as an overview of the major points discussed in this subsection to facilitate a better comprehension of the various PSS-REs-related aspects. The categorisation was conducted by synthesising the contextual dependencies and determining the time of occurrence and type of RE that could result from each driver.

Table 2. Drivers' categorisation.

Type of RE	Driver	Time of Occurrence	Contextual Dependencies	Reference
Direct	Non-ownership and low product attachment	During the usage phase of the PSS	Influence of user behaviour and emotional affinity with the product	[24,56,64]
	Adapted user behaviour	Along the implementation of the PSS	Adaptive response to resource reduction or enhancements	[44,65,66]
	Changes in user behaviour, consumption practices, and attitudes	During the usage phase of the PSS	User behaviour and socio-psychological factors	[70]
	Socio-psychological factors	During the usage phase of the PSS	Influence of attitudes on user consumption behaviour	[69]
Indirect	Incremental enhancements in material and energy efficiency	Along the implementation of the PSS	System behaviour resulting from a reinforcing feedback loop	[74]
	Changes in efficiency, consumption, and production factors	Along the implementation of the PSS	Changes in price elasticity and behavioural responses	[75]
Wide-Economy	Increase in efficiency causing price elasticity	Along the implementation of the PSS	Effect on consumption patterns and potential benefits	[44,76–78]

4.3. RE Mitigation Strategies in PSSs

Earlier studies have made efforts to mitigate the RE in the implementation of PSSs to optimise the potential achievements of PSS sustainability. However, these works have not been compiled into a single study, which would make it simpler for future researchers to determine the initial foundation for mitigating the RE. The authors summarised some of the strategies that have been published and recorded in this study's document selection procedure. This study discusses mitigation strategies based on the identified approaches.

4.3.1. Taxation Approach

Saunders [79] proposed the use of appropriate taxes, such as energy and carbon taxes, as a taxation strategy to reduce the magnitude of REs. This strategy was supported by Vivanco et al. [75], who identified product- or sector-specific taxes and transversal taxes as two categories in the rebound literature. Transversal taxes aim to enhance the environmental intensity of the entire economy by reducing both direct and indirect effects. Product- or sector-specific taxes aim to reduce the direct effects of particular products or industries.

4.3.2. Market-Based Approach

In addressing REs, Durning et al. [80] discussed cap-and-trade schemes as a market-based approach. These schemes set an upper limit for a particular environmental stress, allowing the market to determine the price of the associated stress and the price of the product. Hovi and Holtsmark [81] emphasized that cap-and-trade programs could be more viable than tariffs due to various factors. Alcott and van den Bergh [82,83] argued that cap-and-trade programs are preferable because they prioritise desirable outcomes, such as absolute environmental stress reductions.

4.3.3. User-Centred Approach

Liedtke et al. [65] identified user behaviour as a significant contributor to the RE and proposed a user-centred approach to mitigate it. They highlighted the significance of incorporating users and stakeholders into the PSS innovation process. By involving consumers, PSS distribution has a greater chance of success and reduces REs.

4.3.4. Evaluation Approach

Kjaer [70] proposed an evaluation method called the assessment of differences in value outcomes through LCA. During the PSS design phase, this approach identifies differences in value outcomes. By incorporating the reference system, functional unit, and system boundaries, the evaluation assessment provides a more appropriate perspective for identifying value and minimising the RE.

4.3.5. Value-Focused Approach

Consistent with the initiative of Kjaer [70], Maxwell and McAndrew [76] proposed a value-focused approach that capitalises on technology and innovation. They used SMART metres to measure energy/resource usage and provide information to consumers, thereby promoting sustainable behaviours and a cognizant evaluation of actions in relation to their environmental impact. This value-oriented strategy seeks a significant transition in consumer consciousness and priorities.

4.3.6. CE Approach

Scheepens et al. [84] advocated for a CE approach to reduce the RE in PSSs. They suggested eco-efficient value-creation strategies that simultaneously consider reduced environmental costs and increased value. By implementing circular business models and focusing on end-of-life products, the CE strategy seeks to avoid the risks and negative social and environmental outcomes associated with REs. The circular transition framework identifies implementation challenges and opportunities, such as business models and government policy coordination. Circularity necessitates a focus on end-of-life products, which Siderius and Poldner [85] referred to as 'secondary production'.

Based on the literature, this study highlights at least seven mitigation strategies, including energy and carbon taxes [79], bonus–malus schemes [75], cap-and-trade schemes [80–83], user- and stakeholder-integrated settings [65], assessment of differences in value outcomes through LCA [70], eco-efficient value creation [76], and secondary production [84,85]. Finally, the mitigation strategies were categorised to structure the discussion using categorising approaches. The approaches discussed include the taxation approach, the market-based approach, the user-centred approach, the evaluation approach, the value-focused approach, and the CE approach. However, to adjust between the drivers of the emergence of the RE and the selected strategy, a more in-depth examination of strategy selection is required. Similarly, integrating multiple strategies is a viable option for achieving optimal results. Nonetheless, additional research should be conducted in a more comprehensive framework so that the effect of the strategy can result in improved performance across the three dimensions of sustainability.

Unavoidably, the implementation cannot be conducted immediately; thus, we analyse the potential problems that may arise from each mitigation strategy. The categorisation includes the strategy's approach and implementation phases. To perform categorisation, this study synthesised the identified mitigation strategies. Categorisation aids in organising and structuring mitigation strategies according to their characteristics, approaches, and appropriate implementation phases. It also allows for the identification of patterns and relationships among various mitigation strategies. It facilitates the sharing and transmission of knowledge among researchers, practitioners, and policymakers. When mitigation strategies are categorised and documented in a structured manner, they are easier to communicate and disseminate to a variety of stakeholders. However, as emphasized by Zink and Geyer [86], mitigation strategies are often unattractive because they can reduce profits. Consequently, it is expected that companies should not only focus on opportunities to reduce environmental and social impacts. Table 3 presents the categorisation of mitigation strategies.

Table 3. Categorisation of mitigation strategies.

Approach	Mitigation Strategy	Phase of Implementation	Typical Problems	Reference
Taxation approach	Energy and carbon taxes	Policy development and enforcement	Resistance from industries, potential economic impacts	[79]
	Bonus–malus schemes	Policy development and enforcement	Designing effective incentive structures	[75]
Market-based approach	Cap-and-trade schemes	Policy development and implementation	Setting appropriate emission limits, market stability	[80–83]
User-centred approach	User- and stakeholder-integrated settings	Design and implementation phase	Balancing diverse stakeholder interests	[65]
Evaluation approach	Assessment of differences in value outcomes through LCA	Design and development phase	Identifying relevant criteria, data availability	[70,87]
Value-focused approach	Eco-efficient value creation	Long-term strategic planning	Balancing environmental and economic objectives	[76]
Circular economy approach	Secondary production	Implementation and operational phase	Establishing efficient collection and recycling systems	[84,85]

5. Discussion

This section discusses and extracts important information from the selected and mapped publications on the RE and PSS research to derive significant findings. This section also responds to the research questions.

5.1. Observations and Answers to the Research Questions

RQ1: What is the clusterisation and network influence of the PSS-RE?

This study utilised VOSviewer software to visualise and cluster keywords associated with the RE in PSSs. Clustering and network analysis provided insights into the relationships and effects of numerous PSS-RE concepts. This study's clustering analysis was instrumental in pinpointing specific research areas in which PSSs and the RE intersect. This enables researchers to better comprehend their intricate dynamics. Four keywords, namely product–service system, sustainability, RE, and circular economy, demonstrated strong relationships and high relevance to the PSS-RE. These terms frequently co-occur and are close to one another in the visualisation, indicating their close interconnection. The lines represent the degree of association between keywords.

This visualisation illustrates seven colour-based clusters. Each colour represents a distinct subject or category. This analysis illustrates both direct and indirect connections between keywords. For example, system dynamics are not directly related to the RE, PSS, or user/consumer behaviour, but they are associated with sustainability. This indirect relationship suggests that a systemic comprehension of system dynamics and PSS system behaviour can contribute to addressing the RE's sustainability challenges. By investigating the relationships between keywords from different clusters, researchers can better understand the causes and mitigation strategies underlying the RE in PSSs. For example, understanding how consumer behaviour and attitudes interact with the design and implementation of a PSS can inform the development of interventions that promote sustainable consumption patterns and reduce the RE.

RQ2: What are the identified drivers based on the records studied?

The identified drivers explain the numerous contributors to the RE during PSS implementation. These determinants have significant implications for PSSs' sustainability potential and highlight areas with challenges and trade-offs.

Based on the reviewed literature, the authors summarised the causes of the RE during PSS implementation, emphasising the role of consumer behaviour-related factors. Although

PSSs have the potential to promote sustainability, issues associated with user-oriented PSSs, such as lack of ownership and changes in consumption behaviour, seem more prevalent and may outweigh the potential sustainability benefits. For example, non-ownership emerged as a significant driver of the RE in PSSs. When consumers do not own a product and have no emotional attachment, they may behave irresponsibly, resulting in a shortened product life and increased consumption. These findings show the significance of understanding the function of ownership and emotional attachment in influencing consumer behaviour within the PSS framework.

Similarly, user behaviour is a significant factor that can impede or promote the potential sustainability of PSSs. Unanticipated user behaviour and improper implementation of innovations in sustainable efficiency can undermine the intended results. Changes in user consumption patterns caused by PSSs or other factors must be carefully evaluated to prevent unintended residual effects.

The identified drivers of the RE provide valuable insights into the challenges and complexities of implementing PSSs sustainably. Contributing to the emergence of the RE are incremental improvements [74], efficiency changes [75], environmental efficiency interventions [76], non-ownership [56], user behaviour [65], changes in consumption practice [70], socio-psychological [69], and adapted user behaviour [49]. Understanding these drivers and their interactions can guide the development of mitigation strategies and decision-making processes to increase PSSs' sustainability potential.

Despite their sustainability potential, the authors observed that PSSs introduce challenges related to user behaviour and consumption patterns that negatively affect sustainability efforts.

RQ3: What mitigation strategies can be proposed as possible alternatives?

Prior research has attempted to resolve the RE in PSSs and enhance their sustainability potential. However, these efforts have not been compiled into a single study, which could facilitate the identification of fundamental strategies to mitigate the RE. This study provided a summary of the published strategies that were identified during the article selection procedure.

At least seven mitigation strategies were highlighted in the literature: energy and carbon taxes, bonus-malus schemes, cap-and-trade schemes, integrated arrangements between users and stakeholders, assessment of different value outcomes through LCA, environmentally friendly value creation, and secondary production. To effectively address the causes of the RE, a more thorough evaluation of strategy selection is necessary. Moreover, integrating multiple strategies can be an effective method for achieving optimal results.

For example, Vivanco et al.'s [75] strategy is to use appropriate tariffs to reduce the RE's magnitude. Specifically, energy and carbon taxes have been proposed as effective solutions. In the literature on resurgence, two categories of taxation approaches have been identified: product- or sector-specific taxes and taxes across environmental sectors. The first strategy aims to reduce the direct effects of particular products or industries. Conversely, the second strategy aims to increase the environmental intensity of the entire economy by reducing both direct and indirect effects.

However, addressing the RE through this strategy presents some challenges. One difficulty is the need for cautious strategy selection and context-specific adaptation. Each strategy has its own benefits and limitations, and determining the optimal combination of strategies requires a thorough study. In addition, effective implementation of these strategies necessitates the cooperation and participation of stakeholders and the adoption of enabling policies and regulations. To address these challenges, policymakers, businesses, researchers, and consumers must collaborate.

Furthermore, continued research is required to assess these mitigation strategies' real-world impacts and effectiveness across the environmental, economic, and social dimensions of sustainability. This study can aid in the refinement of strategies, identify potential synergies between them, and develop a comprehensive framework for strategy selection

and integration. Research must focus on the behavioural factors influencing the RE and how to address them through targeted interventions.

5.2. Research Limitations

Despite the extensive analysis conducted in this study, it is necessary to acknowledge certain limitations. This bibliometric review was restricted to peer-reviewed journal articles accessible using scientific databases. Other sources, such as reports, book chapters, and grey literature, were excluded, which could have caused the omission of pertinent studies and alternative perspectives on the RE in the context of PSSs. Therefore, it is prudent to interpret the findings by recognizing that they pertain specifically to the surveyed literature and may not be universally applicable across the entire spectrum of research on this topic.

VOSviewer software was used to visualise and analyse the relationship between keywords and to generate clusters. Although VOSviewer is a popular bibliometric analysis instrument, it has limitations. For example, the interpretation of keyword relationships and clustering was based on co-occurrence and frequency, which could not have captured nuanced associations or provided a thorough comprehension of the underlying research themes. Additional qualitative analysis or alternative approaches may be required to gain a more nuanced understanding of the relationship between keywords and research areas.

In addition, meticulous consideration was given to the selection of pertinent publications and the application of inclusion criteria. We acknowledge the potential for subjectivity and bias to influence the selection process, but our rigorous methodology was designed to minimize such influence. The inclusion and exclusion criteria for relevant publications were meticulously devised to ensure a comprehensive coverage of the research landscape. It is crucial to note that our research methodology adheres to a rigorous structure that ensures its credibility and validity.

In conclusion, there are some limitations to this study. To gain a complete understanding of the RE in the context of PSSs, it is necessary to conduct additional research and analyses on these limitations.

5.3. Further Research Direction

Although significant points have been addressed in this research, some limitations must be considered in future studies. As shown by the mapping in Figure 3, other keywords from various concepts, such as CE, are closely related to this concept. The concept of CE defies its definition and even its main purpose [41,46,87]. Ghafoor et al. [47] found that the PSS is one of the business model approaches included in the CE domain, consistent with Kjaer's [46] finding in which the PSS is viewed as one of the approaches to achieve the objectives of CE. Due to the close relationship between the two concepts, this method makes distinguishing between them difficult. CE is an overarching economic model that promotes sustainable practices. Conversely, the PSS is a business model that can be utilised to attain these practices within CE.

Consequently, the scope of this investigation is limited to the RE and PSSs. Although attempts have been made to identify the RE in other literature at the outset of this study, the objective was to determine the frequency with which the term RE appears across various subject areas and categories. The study then attempted to synthesise information from keywords and inclusion and exclusion criteria to obtain specific information on the relationship between the RE and PSSs, including identifying drivers and mitigation strategies.

From a different perspective, the authors realised that although the concepts of CE and PSS are distinct, there are often overlaps between the two. As a result, the method of mining databases from published articles that do not include CE as keywords or inclusion criteria overlooks important information, such as potential drivers of the RE and mitigation strategies. Thus, future research should expand the use of keywords and inclusion criteria so that published articles discussing the RE in relation to CE and its mitigation strategies can be investigated further. In addition, whether the research satisfies the inclusion criteria

should be examined so that it can be synthesised and serve as additional findings for existing studies.

6. Conclusions

This study concludes by examining the complex relationship between the rebound effect (RE) and sustainable product–service systems (PSSs). Although the PSS is viewed as a concept concerned with sustainability, as it offers the opportunity to decouple economic success from material consumption, thereby reducing the environmental impact of economic activities, researchers have identified significant obstacles that frequently impede the achievement of sustainability potential and cause REs.

This study identifies seven critical drivers that contributed to the emergence of the resource environment and its associated obstacles. Previous researchers have made similar efforts to mitigate the RE using various methods. This research uncovered at least seven mitigation strategies with differing benefits and drawbacks. The insights derived from this comprehensive analysis offer a clearer understanding of the current state and breadth of research and serve as a valuable resource for future researchers embarking on similar inquiries.

Moreover, this study's findings have relevance for practitioners and decision-makers beyond the academic community. We acknowledge the necessity of transforming our research into practical applications. Therefore, this study presents the following managerial applications: (1) Business enterprises should consider adopting integrated strategies that incorporate economic, management, and engineering perspectives to address the challenges posed by the resource environment in PSSs; (2) Decision-makers can use the identified mitigation strategies to inform their choices, navigating the trade-offs inherent to each approach and tailoring solutions to their particular contexts; (3) The results of this study's visualization and clustering provide a foundation for innovative approaches, such as employing dynamic system methodologies to investigate the complex relationship between the RE and PSSs.

In conclusion, this study contributes to a deeper comprehension of the dynamic interactions between PSSs and the RE. Considering academic and practical implications, this study expects to promote sustainable practices and decision-making in a rapidly changing landscape.

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