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From linear to circular economy: PSS conducting the transition

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Abstract

It is a consensus that we are passing by a period of severe natural resource depletion. Our current linear socioeconomic system, characterized by the product discard at the end of product life, is one of the main causes of this natural depletion. Some governs and institution, as European Union [3] and The Ellen MacArthur Foundation [1], are calling for a new economic model, as can be seen on the Europe 2020 strategy [4]: "the Europe Union has no choice but to go for the transition to a resource-efficient and ultimately regenerative circular economy". This highlights the trend for a circular economy, characterized by restoration and circularity of product components. It is a response to the inefficient management of the resources in the traditional linear model. To support this transition from a linear to a circular economy, business managers rely on new business models be developed. Product-Service System (PSS) is considered a business model that integrates products and services with the aim of fulfilling customer's needs. The objective of this study is to identify if PSS can be used as a business model for firms achieve resource-efficiency through circular economy. This study constitute a literature review and a bibliometric analysis about PSS and circular economy.

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Keywords: PSS; sustaintable business model; circular economy; product-service systems

1. Introduction

The current socioeconomic system is based on a linear economy, in which firms make products and the consumers use and dispose. Material flow is understood as the conceptual logic of value creation in which only virgin material enters in the beginning of value chain. This linear production model incurs unnecessary resource losses in several ways: production chain and end-of-life waste, excessive energy use and erosion of ecosystems [1]. With these resource depletion proliferation signs, the call for a new economic model is getting louder [2]. The European Union (EU) has designated resource-efficiency as one of the flagships of its Europe 2020 strategy [3], as 'the EU has no choice but to go for the transition to a resource-efficient and ultimately regenerative circular economy'[4].

The circular economy has been defined as an industrial system that is restorative or regenerative by intention and design [5], which principles are three [1]: preserve and enhance natural capital, optimize resource yields and foster system effectiveness. The circular economy brings the idea of restoration and circularity in order to replace the traditional concept of end-of-life, shifting towards the use of renewable energy, eliminating the use of toxic chemicals, and aims for the elimination of waste through the superior design of material, products, systems and business models.

In business model literature, circular economy has been recently emerged, proposing feasible ways to business innovation linked to sustainability concerns [6]. This is an attempt to change the product-oriented business models - in which firms have the incentive to maximize the number of products sold - to a service-oriented business model in which

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firms make money by the service offered [3]. With this change, firms will have an incentive to prolong the service life of products, to ensure they are used as intensively as possible, to make them as cost and material-efficiently as possible, and to re-use parts as far as possible after the end of the product's life [3].

Product-service system (PSS), defined as a business model focused toward the provision of a marketable set of products and services with the aim of fulfilling customer's needs [6], has been labelled as an environmentally friendly business model, mixing the two main themes of sustainability and business models [3,6–11]. PSS can increase reused, repurpose, remanufactured and recycled at its end-of-life thus increasing resource productivity and minimizing waste generation [11].

The aim of this study is to identify if PSS can be used as a business model for firms to achieve resource-efficiency through circular economy. This study consists in a literature review and a PSS and circular economy bibliometric analysis.

2. Method

The aim of this study is to give a holistic view and help identifying opportunities for further researches. It also aims to determine the main authors in the literature that considers PSS as a business model that helps firms to achieve resource-efficiency through circular economy. The Scopus database was used to collect the papers. The selected papers were read and analyzed through a coding system and bibliometric analysis software's.

2.1. Selection of references

The literature review was conducted throught a search in the Scopus database. Falagas et al. [12] suggests that compared to alternatives databases like the Web of Science and Google Scholar, Scopus, due to a wider subject and journal range, is probably currently the best tool available for electronic literature search, particularly for articles published after 1995.

In order to improve the search string, the papers [3] and [6] were used as reference alongside with specifics searches in the Scopus database. The resulting string is: *"PSS" OR "Servitization" OR "Industrial product service system" OR "Industrial product service systems" OR "Product Service Systems" OR "Product Service System" OR "Integrated service product" OR "Industrial Product Service System" OR "Product-Service Systems" OR "Product-Service System" OR "ISP" OR "IPS2" AND "Circular Economy"*. The search using this string yielded 17 papers, showing that the relation between PSS and Circular Economy are a recent theme in the literature point of view. The titles and the abstract of these 17 papers were read to determine whether they link PSS and Circular Economy or not. If they do, they were selected for further analysis, and if they do not, they were discarded.

From the 17 previous yielded papers, ten papers were selected for further analysis, they are listed in Table 1. The coding and bibliometric analysis tools allowed to understand if PSS can be used as a business model to conduct the transition to circular economy and find gaps and opportunities for further researches.

Table 1. Selected papers

Paper reference
[14] Pialot O, Millet D, Bisiaux J. "Upgradable PSS": Clarifying a new concept of sustainable consumption/production based on upgradablility. J Clean Prod 2017;141:538–50.
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3. Analysis of references

Bibliometric is a term presented by Allan Pritchard on the article entitled "Statistical Bibliography or Bibliometrics", published in 1969 [13]. This term was used to identify the field of study that uses mathematical and statistical methods to investigate and quantify the written communication processes. The bibliometric research can be used in many fields of study and helps to improve and analyze research trends. One of the most important aspects of Bibliometrics, according to [13], is that this term will be used in all the studies which seek to quantify the processes of written communication.

To reach the goal of this article, the Scopus search considered the years between 2008 and 2017 because that is when the publications started. The following items were analyzed:

- Percentage of papers per subject area;
- Affiliations by country;
- Citation co-occurrence.

Table 2 shows the authors countries and affiliations of the selected papers. It can be noticed that the majority of papers that relate PSS with Circular Economy comes from Europe. This effort is still concentrated in this part of the world. We can conclude that Asia, represented by China, and the North

America, represented by the United States already gave its first steps towards this subject. Besides that, the Institutes and Universities currently studying this subject are very mixed among the countries.

Table 3 shows the number of papers per Scopus subject area. It can be seen that, after Business and Engineering areas, the results concerning PSS and Circular Economy are studied in Environmental Sciences. This shows that the environment is a strong factor for the authors even with the focus being in business models and innovation. The same paper may cover more than one area, so the percentage take this in account and it is not excluding.

In the 10 papers analyzed, the only author with more than 1 publication was Vogtländer, J., with two papers.

Table 2. Papers' countries and affiliations (one paper can have more than one affiliation depending on its authors)

Country	Institute/University	Area/Laboratory
France	Supmeca	QUARTZ
	Université de Toulon	COSMER
	UTC Compiègne	COSTECH
Sweden	KTH Royal Institute of Technology	Industrial Ecology
		Environmental Strategis Research
	IVL Swedish Environmental Research Institute	-
	Viktoria Swedish ICT AB	-
	Volvo Construction Equipment	-
	Blekinge Institue of Technology	Department of Mechanical Engineering
Netherlands	Delf University of Technology	Faculty of Industrial Design
	Netherlands Organisation for Applied Scientific Research TNO	-
	Leiden University	Institute of Environmental Sciences
	TU Delft	-
Norway	Norwegian University of Science and Technology	Industrial Ecology Program
UK	University of Oxford	-
USA	Stanford University	Center for Design Research
China	Tongji University	College of Design and Innovation
India	University of Strathclyde	Design Manufacture and Engineering Management
	Cranfield University	Manufacturing Department
Poland	Jagiellonian University	Institute of Public Affairs

Table 3. Publications per Scopus subject area (status on 27 December 2016; the same paper may cover more than one subject area)

Area	Percentage
Business and Management	50%
Engineering	50%
Environmental Sciences	40%
Energy	30%
Social Sciences	30%
Arts and Humanities	10%
Computer Science	10%
Decision Science	10%
Mathematics	10%
Multidisciplinary	10%

3.1. Co-citation

The softwares Bibexcel® and Pajek® were used to map and draw the citation co-occurrences (co-citation). The co-citation is defined as the frequency with which two documents are cited together by other documents [18].

In Fig. 1, the lines connects the papers that were co-cited. These lines have three levels of thickness. The thicker the line, the higher the number of co-occurrences. Therefore, the thickest line means a co-citation index of 3; the intermediate line a index of 2; and the thinnest line a index of 1.

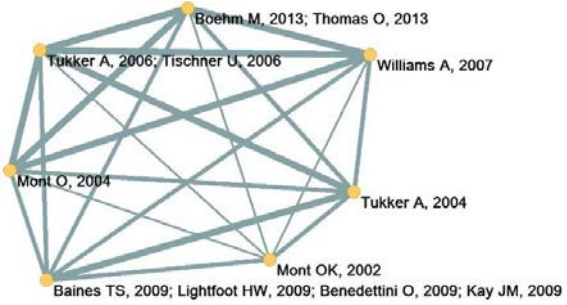

Fig. 1. 7 top citation co-occurrences (Pajek)[19–25]

The 7 most frequent citations by the 10 selected papers were used in this analysis. With this result, it was possible to find similarity between them, based on [18] that says documents featuring high numbers of co-citations are regarded as more similar. The documents used in Fig. 1this analysis are the most relevant cited references of the papers.

The papers selected for this analysis are mainly about PSS and have little relation with the Circular Economy idea. That shows that the subject of the link between PSS and Circular Economy is still very recent and there is not yet enough authors

working on this relation. Besides that, it shows that PSS authors are looking towards Circular Economy, and not the opposite.

PSS and resource-efficiency authors have shown interest in inserting Circular Economy in its works. This is not reciprocal in the Circular Economy point of view, since not all of its authors are aware of PSS and usually looks for general sustainable business models.

4. PSS conducting the transition to circular economy

4.1. Does the literature agree that PSS business model can be used by firms in the transition for a circular economy?

The current socioeconomic system is based on a linear economy, in which firms make products and consumers use and dispose. The conceptual logic of value creation is the material flow, in which only virgin material enters in the beginning of value chain. With little focus on environmental and social issues, which are two of the three dimensions of sustainability [26], our current economy is not sustainable [14].

All authors in the analyzed literature agree that circular economy is an alternative to the traditional linear economy (make, use, dispose) because allows us to keep resources in use for as long as possible, extract the maximum value from them whilst in use, then recover and regenerate products and materials at the end of each service life.

Recent reports made by business community [1,27] and by governs [4] has introduced the circular economy for firm's resource-efficiency. Although this importance exists, managers rely on the development of new business models to support this transition from the old, linear and unsustainable systems towards new and circular systems [7,8,11,15].

PSS has been labelled as an environmentally friendly business model that mixes the themes of sustainability and business models [3,6–11]. PSS can increase reuse, repurpose, remanufacture and recycle at products end-of-life thus increasing resource productivity and minimizing waste generation [11].

Although some authors recommend PSS business model for circular economy [3,7,8], PSS needs to be implemented with great care [7]. There is no guarantee PSS will reduce environmental impacts, unless be intentionally designed [3,8,11].

4.2. Does PSS business model agree with circular economy principles (provided by Ellen MacArthur Foundation)[1]*?*

4.2.1. Principle 1: Preserve and enhance natural capital by controlling finite stocks and balancing renewable resource flows

In PSS business models for circular economy, firms will have an incentive to prolong the service life of products and to make them as cost and material-efficiently as possible [3,11,16]. From the three types of PSS (product, use or result-oriented [28]), authors claim that only the result-oriented PSS have real contributions to resource-efficiency and circularity, while product-oriented PSS do not change the incentive to maximize product sales and use-oriented could prompt less careful use, making the circularity difficult to happen [3,7,29]. The result-orientated model is more sophisticated and represents the most popular interpretation of the features of a PSS [28]. The circularity of products and consequently the resource-use efficiency can be achieved through implementation of result-oriented PSS, because the customer will pay only for the provision of desired results, which is also considered as a service, and not for the consume nor product ownership.

4.2.2. Principle 2: Optimize resource yields by circulating products, components and materials in use at the highest utility at all times in both technical and biological

There is a great expectation of shifting from firms offering a manufactured product to offering a combination of products and services [9,11]. This movement is also viewed as a shift from product-oriented to service-oriented business model [3] and from consuming products to using services [11]. In this new paradigm, firm's profit comes from the selling "units-of-service" and not by the number of product sold [11]. Firms then make money by being paid for the service offered to users.

In PSS business model for circular economy, firms re-use parts (also modules and product components), as far as possible after the end of the product's life [3,7,8,10,11,15,16,29]. This is possible because the producer retains the ownership of the product [3,7,10,14,16].

4.2.3. Principle 3: Foster system effectiveness by revealing and designing out negative externalities

The environmental problems caused by the old and linear economy model are not resolved only through PSS business model. PSS is not the sustainability panacea [3,7]. There is no guarantee PSS will reduce environmental impacts, unless be intentionally designed [3,8].

For this reason, life cycle assessment (LCA) is considered an important tool to design the PSS business model for circular economy, in order to get some important insights about how products must be designed for continuous recovery and reutilization of product components [7–9]. LCA is also a product benchmarking tool, which considers the material flow into the "cradle-to-cradle" system [9].

4.3. Being PSS a business model for circular economy, what are the main challenges on this transition?

During the literature review, some challenges for firms were identified in the transition from linear to circular economy. Firstly, from the costs perspective, some authors believe that circular economy products are expensive to build from the producer point of view due to high labor intensity [3], required return logistics [16] and expensiveness of design processes when using EcoDesign [9]. Costs per item are often higher for circular business due to the higher complexity in designing for refurbishing and remanufacturing [16]. Secondly, from the revenue side, it is very difficult for managers to estimate the unit-of-service that will be sold by the new PSS business model [16]. High innovation speed – when brought by competitors – can make re-use impossible. At the same time, leased products tend to be used less carefully than products that are owned [16].

5. Conclusions

In this work, it was discussed if PSS can be an alternative for companies to achieve resource-efficiency coupled with circular economy. The aim was to bring the discussion about the transition from linear to circular economy, in which firms no more sells for make profit, but sells units of services.

A literature review and a bibliometric analysis were performed. It was possible to know if the literature agree that firms in the transition from linear to circular economy can use PSS. The method yielded a small amount of papers, indicating that this subject is still very recent. However, some important insights were collected in order to guide the further researches about this theme.

Our research found that all authors in the analyzed literature agree that circular economy is a trend in response to the inefficient management of the resources in the traditional linear model. Governs have claimed this change and the business community is seeking new business model to conduct them on this transition.

Although some authors recommend PSS business model for circular economy, PSS needs to be implemented with great care. To reduce the environmental impacts, PSS needs to be intentionally designed. Although there are three different types of PSS, authors have defined that just the result-oriented PSS type have real contributions to resource-efficiency and circularity. The main explanation is that the customer will pay only for the provision of desired results, which is also viewed as a service, and not for the product ownership. When the service finishes, the product return for the producer, who can manage its components and module to offer different kind of services, enabling the circular economy.

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