What do we know about the climatic impacts of product-service systems? Sharing models unpacked

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Abstract

This paper examines the claim that product-service systems can result in radical reductions in environmental burdens (up to 90%). The study performs a systematic literature review peer-reviewed assessments of use-oriented PSS models that facilitate sharing. Our findings suggest that significant reductions are possible in some cases.

Keywords

Product-service systems, product as a service, sharing, environmental assessment, climate change.

Introduction

Over the last two decades, research on the topic of product-service systems (PSS- also referred to as product as a service) has flourished. Increased interest in PSS is at least in part due to their apparent environmental credentials. Initial seminal works such as those of Tukker (2004) introduced the concept in terms of product-, use- and results-oriented variants and proposed that PSS have the potential to reduce ecological burdens (see also Mont, 2002). Use- and result-oriented PSS were depicted to have the largest sustainability potential (up to 90% reductions), since they provide access to products rather than ownership. Such business models can incentivise manufacturers to shift their focus from linear to circular products, whereby strategies such as material recirculation and product-life extension are the source of environmental betterment. A further means to reduce ecological burdens is through use-oriented PSS models that facilitate sharing. In theory, when products are shared among multiple users, fewer resources are required to meet market demand (Mont, 2004, Kjaer et al., 2019).

Presently, there is a lack of academic work that examines PSS' environmental credentials. Although multiple reviews of the PSS literature exist (see Moro et al., 2020 for an overview), few works comprise actual environmental assessments, and a majority of authors pay lip service to sustainability aspects. Hence in this paper, we attempt to address this shortcoming by examining peer-reviewed quantitative assessments of PSS. We elected to focus explicitly on use-oriented sharing models given to their potential to bring about behavioural changes among private consumers of pollutive products, such as those within transportation, appliances and textiles (Tukker et al., 2016). We also focus on climatic impacts (i.e. emissions of greenhouse gasses, typically measured in kilograms of carbon dioxide equivalents – $kgCO_2e$) due to the salience of the climate issue. In particular, we seek to address two questions:

1) What are the climatic impacts of use-oriented PSS sharing models?
2) What factors influence climatic impacts?

The remainder of this paper is structure as follows. The next section outlines or methodological approach, based on systematic literature review. In section three we present our main findings, and in section four we outline future research opportunities and implications for practice.

Methods

To examine the literature on the climatic impacts of use-oriented sharing models, we performed a systematic literature review based on the recommendations in Xiao and Watson (2019).

First, we developed a review protocol, which comprised a spreadsheet containing lists of keywords and search terms; search results; and framework for screening and analysing data. The protocol was developed following multiple iterations within the research team, using different combinations of search terms (e.g. product-service systems, use-oriented, environmental assessment) as a means to refine the protocol and gauge the scope and content of the literature. We settled on the following selection criteria:

1. Papers should include quantified data on climatic impact, stated in terms of changes in CO_2e emissions, including a baseline upon which to make comparisons.
2. Papers should include empirical data and not be solely based on the assessment of hypothetical scenarios.

3. Papers should be published in scientific journals having gone through a peer review process.

We also settled on the search terms outline in Table 1, which were used as keyword searches in Scopus. We performed out literature search in September 2023 which yielded an initial dataset of 296 papers.

Keyword #1	Keyword #2	Results
"Product-service system"	"Environmental impact"	175 papers
	"Environmental assessment"	9 papers
	"Life cycle assessment"	84 papers
	"Material flow analysis"	3 papers
	"Life cycle impact"	3 papers
	"Sustainability assessment"	22 papers
	Total	**296**

TABLE 1: SEARCH TERMS.

We removed duplicates reducing the dataset to 223 papers and then removed papers that did not fulfil our selection criteria. Our final screening resulted in a dataset containing 10 papers for analysis (Table 3). The final step focused on analysis according to the framework shown in Table 2.

Analytical categories	**Examples**
Product/s in focus	Washing machines, everyday garments
Industry sector/s	Appliances, clothing
Customer segments	Business to consumer, business to business, business to government, peer to peer
Circular strategies	Repair, reuse, refurbish, remanufacture, recycle, takeback, etc.
Assessment method/s	Lifecyle assessment
Method/s for data collection	Questionnaires, interviews, scenario creation
Quantified climatic impacts	Percentage reductions of carbon dioxide equivalents (CO_2e)
Factors that influence climatic impact	Transportation and logistics, energy supply, utilisation

TABLE 2: ANALYTICAL FRAMEWORK

Results

Table 3 shows the reported climatic impacts of use-oriented PSS models focused on sharing. The papers within our dataset conducted assessments of shared laundry machines, clothing, books, tools and vehicles such as cars, bicycles, e-scooters and vans (seven papers). Overall, the results demonstrate that sharing models can result in reduced climatic impacts, with the largest reduction amounting to circa 80% compared to baseline measurements (typically traditional product sales). Six of the papers in our dataset reported climatic impacts using spans, with three papers reporting potential increases in climatic impacts of up to 30%.

PSS that facilitate sharing can lead to reduced climatic impacts due higher product utilisation. In practice, products with a large proportion of climatic impacts generated upstream in the value chain (as opposed to the use phase) will have the greatest potential for reductions in climatic impacts due to sharing models. This is because sharing models can distribute production-related impacts among multiple users compared to a traditional product sales model. This line of reasoning is supported by our findings. The three studies that examine bicycle sharing systems (Amaya et al., 2014; Bonilla-Alicea et al., 2020; Zheng et al., 2019) each report the potential for large reductions in emissions (58-78%, 30-62% and 25-50% reductions respectively).

In addition to the production phase, a significant proportion of cars' emissions arise in the use phase. Hence car-sharing systems can result in significant reductions (up to 50%) but also increases (up to 30%) due to factors related to the use phase (Amasawa et al., 2020). Laundry machines are to some extent similar to cars in that they have significant emissions from both the production and use phases. The two papers within this category demonstrate quite different results, with Amasawa et al. (2018) reporting only a 1.8% reduction, whereas Klint and Peters (2021) reported a much more significant 26% reduction. The main outlier within our findings is shared electric scooters, which were found to increase emissions by 20% (Moreau et al., 2020).

	Author/s	**PSS description**	**Product/s**	**Climatic impacts**
1	Amasawa et al. (2020)	Sharing systems	Cars and books	50% reduction - 30% increase
2	Amasawa et al. (2020)	Communal laundromat	Laundry machines	1.8% reduction
3	Amaya et al. (2014)	Bicycle sharing systems	Bicycles	58-78% reduction
4	Bonilla-Alicea et al. (2020)	Smart bike systems + smart docks	Bicycles	30-62% reduction
5	Firnkorn and Müller (2012)	Car sharing	Cars	5-11% reduction

6	Klint and Peters (2021)	Shared laundromat	Laundry machines	ca 26% reduction
7	Martin et al. (2019)	P2P sharing platform	Multiple products	ca 80% reduction
8	Moreau et al. (2020)	Shared dockless e-scooter system	E-scooter	ca 20% increase
9	Zamani et al. (2017)	Clothing libraries	T-shirts, jeans, dresses	40% reduction - 10% increase 50% reduction - 1% increase
10	Zheng et al. (2019)	Bicycle sharing systems	Bicycles	25-50% reduction

TABLE 3: THE CLIMATIC IMPACTS (KGCO_2E) OF USE-ORIENTED PSS MODELS THAT FACILITATE SHARING.

Numerous factors were listed as influencing climatic impacts among studies of use-oriented sharing models. Of these, use intensity[1] was the most cited factor, appearing in six of the 10 papers within this category (Amasawa et al., 2020; Amasawa et al., 2018; Amaya et al., 2014; Bonilla-Alicea et al., 2020; Zamani et al., 2017; Zheng et al., 2019). It is rather unsurprising that use intensity features significantly within this category, given the potential for sharing models to reduce production-related impacts. To reiterate, lowly utilised products infer a greater need for resources to satiate market demand.

In some instances, however, reductions in climatic impacts due to increased use intensity are counteracted by increased emissions in other aspects of the use phase, such as transportation. For example, Amasawa et al. (2020) show that if drivers in travel more than two kilometres (by car) to collect passengers, then the resultant emissions of ridesharing models are greater than those in a traditional sales model. Similarly, travelling to collect or drop off shared products was cited as a determinant of increased emissions by other authors within the dataset (Martin et al., 2019; Zamani et al., 2017). Notably, increased emissions from transportation applies to multiple product types and may be somewhat universal in sharing models. In some instances, emissions from transportation can be offset by increased "usage per user"[2], as is the case for garments in clothing libraries (Zamani et al., 2017).

[1] For shared products, use intensity may be defined as utilisation throughout the entire product lifespan, and is sometimes referred to as usage frequency. Some studies relate use intensity to factors that influence uptake, such as pricing or willingness to adopt.

[2] The term "usage per user" is not the same as use intensity as reported above, which typically refers to high usage rates among different users. Both terms are part of the broader concept of product utilisation, which is an important determinant of climatic impacts within sharing models.

Several studies within this category target mobility-related sharing models (bicycle sharing, car and ridesharing, electric scooters, etc.), with the implication that users' modal shifts (i.e. the type of transportation modes that are displaced by the PSS offer) are a further determinant of climatic impacts (Amasawa et al., 2020; Bonilla-Alicea et al., 2020; Firnkorn and Müller, 2011; Martin et al., 2019; Moreau et al., 2020; Zheng et al., 2019). Ideally, sharing models for mobility should displace transportation modes with significant use-phase emissions (e.g. automobiles). In practice, a range of factors influence modal shifts, including the pricing of transport alternatives and geographical elements such as city location, size, demographics and mobility cultures (Firnkorn and Müller, 2011).

Other determinants of climatic impacts cited within our dataset include emissions from manufacturing/production and product distribution (Amasawa et al., 2020; Amasawa et al., 2018; Bonilla-Alicea et al., 2020; Klint and Peters, 2021); product maintenance (Bonilla-Alicea et al., 2020); emissions from surrounding systems such as buildings and the energy system (Amasawa et al., 2018; Klint and Peters, 2021); and product lifespans (Amaya et al., 2014). Regarding the latter, extending a product's lifespan is an unsurprising means to reduce emissions from production within a sharing model. In some cases, product lifespans can have significant effects – the main determinant of higher emissions for shared e-scooters (20% more than a traditional sales model) is product lifespan as reported by Moreau et al. (2020).

Conclusions

At the outset, we posed two questions:

1) What are the climatic impacts of use-oriented PSS sharing models?
2) What factors influence climatic impacts?

Our study suggests that use-oriented models that facilitate sharing can result in significant reductions in climatic impacts, as hypothesised by Tukker's (2004) original work on the PSS concept. However, none of the studies in our dataset showed reductions of 90%, and only two of the 10 papers demonstrated that 80% reductions are possible. The presence of spans, which in some cases show that increased climatic impacts are a possibility, suggests that the environmental credentials of this type of PSS are not universal across product categories. Closer analysis reveals that use intensity and transportation are the two most frequently cited determinants climatic impact. This makes logical sense in that use intensity refers to the propensity for sharing models to redistribute upstream emissions among multiple users, and since sharing sometimes additional use-phase transportation to collect and return products. The wider implication is that consumer behaviour is a critical aspect of climatic impact, in that sharing implies novel consumer patterns in many product categories and given the ability to choose among different transportation modes with different levels of emissions (e.g. private car, bus, bicycle).

Our study has three main limitations. First, by focusing on use-oriented sharing models, we targeted a nuanced subset of the academic literature on PSS and a limited dataset of 10 papers. Second, we focused on climatic impacts rather than a broader set of environmental impact categories. Third, we focused narrowly on peer-reviewed academic literature, neglecting other potential sources of data such as industry assessments of their own PSS initiatives. Whilst this choice was made with methodological rigour in mind, our study may have missed other useful datasets. A broader study that targets other types of use- and result-oriented models, with assessments of other impact categories, and which considers a wider range of datasets would likely shed additional light on PSS' environmental credentials and their ability to bring about radical sustainability improvements.

Our overall assessment is that the literature on this topic is relatively sparse and contains several methodological shortcomings. The papers within our dataset demonstrate large variations regarding the presence and quality of judgement calls and assumptions related to, for example use-phase variables that are critical to climatic impacts. In some cases, papers included in-depth methodological considerations, which allowed for careful evaluation of the validity and robustness of the results. Others presented little in the way of a methodological background, making it difficult to gauge the validity of the claims. Also, some papers include assessments of the entire product lifecycle (from cradle to grave) whereas other neglect to include key aspects, such as elements linked to product (Firnkorn and Müller, 2012) and/or the PSS use phase (Amasawa et al., 2018, Klint and Peters, 2021). Taken together, these shortcomings pose additional problems in drawing robust conclusions regarding PSS' potential for environmental betterment.

Overall, our findings indicate that there is a need for further research to quantify the environmental impacts of product-service systems. Ideally quantitative assessments should be complemented by qualitative studies that investigate the use-phase variables linked to consumer behaviour, such as use intensity and transportation. Qualitative work could mitigate the need for guesswork present in existing assessments and shed light on some of the more critical determinants of climatic impacts.

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