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Reviewing circular economy rebound effects: The case of online peer-to-peer boat sharing

Jon Warmington-Lundström⁎, Rafael Laurenti⁎,*

⁎ Department of Earth Sciences, Uppsala University, Villavägen 16, SE- 752 36, Uppsala, Sweden
⁎⁎ Unit of Integrated Product Development, Department of Machine Design, KTH Royal Institute of Technology, Brinellvägen 83, 114 28, Stockholm, Sweden

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ABSTRACT

Renting instead of buying new products may be seen as the most efficient strategies of the circular economy. However, changes in the consumption inevitably liberates or binds scarce production or consumption factors such as raw materials, money and time which can potentially limit the potential to save resources. This phenomenon is known as environmental rebound effect and is currently under-researched in the context of resource sharing. This paper reviews the magnitude and tendency of environmental rebound effects of peer-to-peer boat sharing platform using a double-spending model (i.e. for lessors as well lessees). We found that environmental rebound effect was experienced by every lessee surveyed (n = 104) and in one-third of lessors (n = 29). 60 % of lessees experienced a rebound of over 20 %, losing one-fifth of the potential reductions in emissions through subsequent consumption behaviour enabled by the economic savings created by sharing resources. International air travel and increases in personal use of the boat were the biggest contributing factors towards environmental rebound effect. Users that increased consumption in these ways experienced a backfire effect in which their annual emissions actually increased. This backfire was experienced by 29 % of lessees with the worst scenario increasing emissions by a factor of over eight. We found statistically significant differences in the rebound of lessees and lessees. Greater awareness and non-economic mechanisms (such as symbolic rewards, information provision and nudging) tailored for lessors and lessees are needed to help prevent the likelihood of occurrence and the magnitude of environmental rebound effects from sharing resources.

1. Introduction

The world is increasing its consumption of primary materials and driving climate change through the release of greenhouse gases (IPCC, 2018; Oreskes, 2004; Parmesan and Yohe, 2003). With the global population increasing, predicted economic growth and a developing middle class in emerging markets, many have questioned the current linear economic models ability to protect the climate whilst delivering economic prosperity (Kraussman et al., 2017; Riahi et al., 2017). One potential solution is the adoption of business strategies that enables the (re)circulation of material resources (Sachs et al., 2019).

The greatest efficiency within the circular economy can be gained by maintaining products in their current form, maximising both utilisation of the product and its lifespan (Rashid et al., 2013). Improving the utilisation of products can be achieved by encouraging the extensive use of materials via second-hand sales or transfers, selling services rather than products and consumers granting temporary access to their private goods to others (Tukker, 2015). Within the circular economy, resource-optimisation platforms (referred in this article as internet mediated product-service sharing or reuse) are founded on the principle of maximising the utility of a good through renting, lending and swapping goods (Laurenti et al., 2019).

The modern phenomenon of private consumers sharing resources via the internet is increasingly gaining importance globally (Cherry et al., 2018). This promising trend is usually referred to sharing economy or collaborative consumption (Frenken and Schor, 2017). There is a strong belief that this new mode of sustainable consumption will lead to an overall reduction in CO₂ emissions, resource consumption and other environmental impacts (European Commission, 2016).

Current research, however, also shows that there is a significant potential for environmental rebound effects (Skjelvik et al., 2017). Environmental rebound effects (EREs) occur when the initial environmental benefits are partly or fully offset by the impacts derived from (1) spending the income gained (by lessors) or freed (by lessees) on other goods or services (re-spending effect) and (2) failing to substitute primary production (imperfect substitution) (Makov and Font Vivanco,
2018). Limited empirical evidence exists on the environmental benefits and potential rebound effects from reuse (Makov et al., 2019), specifically regarding derived changes in consumption behaviours from peer-to-peer sharing. Further research is needed into how participation in peer-to-peer initiatives is altering existing consumption in order to maximise the current potential in radically orienting consumption behaviours towards more sustainable practices (Laurenti et al., 2019).

The aim of this article, therefore, is to assess the circular economy rebound (CER) caused by changes in the consumption behaviour of users of a peer-to-peer sharing platform. Inspired by the CER and ERE, we estimated the environmental consequences emanating from two distinct mechanisms: re-spending and substituted consumption. We used a double-spending model where savings as well as gains are considered (i.e. for lessors as well lessees); for estimating the effects of substituted consumption, we investigated the types of consumption activities substituted by the sharing option. By discounting these two rebound mechanisms from the total potential benefit, we could estimate the net realised environmental benefit. With the involvement of a web-based platform facilitating the peer-to-peer leasing of boats in Finland the study has the ability to explore the rebound of products used for leisure and transport.

The study explores the concept of circular economy rebound (Zink and Geyer, 2017) in the context of sharing and provide insight into the utilisation of the rebound effect to answer the following research questions:

- Does participation in the peer-to-peer shared access of boats lead to EREs and net reduction in emissions? If yes, what is the magnitude and likelihood of the EREs? Are there any significant differences concerning the rebound behaviour and emission reduction of lessors and lessees?

2. Rebound effect: concepts and definitions

The concept of rebound effect was first proposed in academic literature by Jevons in 1865 when investigating the increases in energy consumption from coal burning (Jevons 1865). This led to the concept being labelled ‘Jevons paradox’. Further academic research did not become mainstream until the late 1980s when energy economists embraced Jevons ideas following global oil shortages and increasing concerns of climate change (Font Vivanco et al., 2016). The concept has also been termed the ‘Khazzoom/Brookes postulate’ and more recently ‘backfire’ (Broberg et al., 2015).

Thiesen et al. (2008) provide a further explanation stating “the rebound effect deals with the fact that improvements in efficiency often lead to cost reductions that provide the possibility to buy more of the improved product or other products or services” (Thiesen et al., 2008, p.104). From this perspective, a commonly used example is the case of a “driver who replaces a car with a fuel-efficient model, only to take advantage of its cheaper running costs to drive further and more often” (Druckman et al., 2011, p. 3572).

Table 1 compares rebound mechanisms contemplated in the industrial ecology (ERE and CER) and energy economics perspective.

<table>
<thead>
<tr>
<th>Definition/ scope</th>
<th>ERE (Font and Geyer, 2016)</th>
<th>CER (Zink and Geyer, 2017)</th>
<th>Energy economics (e.g. A. Greening et al., 2000; Jenkins et al., 2011)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net gains and savings increase the demand for other goods and services.</td>
<td>Re-spending effect</td>
<td>Price effects</td>
<td>Indirect rebound (or secondary effects)</td>
</tr>
<tr>
<td>Ability to substitute primary production</td>
<td>Imperfect substitution effect</td>
<td>Insufficient substitutability</td>
<td>Not contemplated</td>
</tr>
<tr>
<td>Improvements in efficiency increases the use of the same product or service.</td>
<td>Not contemplated</td>
<td>Price effects</td>
<td>Direct rebound</td>
</tr>
<tr>
<td>Increase in energy efficiency on overall demand after markets adjust and re-equilibrate.</td>
<td>Not contemplated</td>
<td>Broader circular economy rebound</td>
<td>Macroeconomic effects</td>
</tr>
</tbody>
</table>

Within industrial ecology, the perspective of rebound effect has been termed ‘environmental rebound effect’ (ERE), a concept that looks beyond the indicators of energy use to incorporate a wide range of environmental issues such as emissions (Font Vivanco et al., 2015). Font Vivanco et al. (2016, p. 60) provide the following definition of rebound: “the rebound effect is generally defined as the difference between the expected and the actual environmental savings from efficiency improvements once a number of economic mechanisms have been considered, that is, the savings that are ‘taken back’”. Similar to the ERE, other industrial ecologists, coined the term ‘circular economy rebound’ (CER) which takes into account environmental impacts from (a) insufficient substitutability of primary production and (b) price effects. Increase demand due to discounted prices of circular offerings (e.g. recycled materials, remanufactured products, second-hand products) (Zink and Geyer, 2017).

Font Vivanco et al. (2016) argue that by broadening the concept to include economic and behavioural feedbacks into the analysis of rebound effect and utilising applications such as life cycle assessment (LCA) raises questions about where the boundaries to the concept should be defined and without this definition coherent analysis of the term could be jeopardised. The authors call for a greater distinction between the ‘classic rebound effect’ and ERE.

ERE has a number of advantages as an approach over the classic rebound effect calculation. Firstly, traditional rebound studies are biased towards purely technological innovations and focus on fuel efficiency. This has led to organizational innovations, such as sharing economy initiatives being overlooked by research. Furthermore, the narrow presentation of rebound studies, with results offered as a percentage of environmental savings taken back, results in a lack of data into to overall impact of rebound at the macro level. A more holistic approach is crucial in identifying innovations that deserve policy attention (Font Vivanco et al., 2015).

Rebound effect can be defined into two categories ‘direct’ and ‘indirect’ which combined result in the ‘economy-wide rebound effect’ (Broberg et al., 2015). ‘Direct’ rebound is the term accredited to effects calculated by narrow frameworks focussed on energy services. ‘Indirect’ rebound effects consist of the knock-on effects that follow from efficiency gains and can be categorised as “(i) income, output and substitution effects; (ii) general equilibrium effects in terms of long-run structural change following changes in relative prices and (iii) radical changes in the social structure relating to technological development, preferences and institutions” (Broberg et al., 2015, p.27). ‘Backfire’ is a term used to describe situations where the rebound effect is greater than the initial environmental savings (Druckman et al., 2011). Table 1 gives an overview about the meaning and scope of different rebound.
effects. Despite a reasonable number of studies estimating direct rebound effects, there have only been a handful of studies that estimate indirect rebound effects (Druckman et al., 2011). Furthermore, as rebound effects are difficult to quantify, the existing literature is fragmented and focuses only on a subset of effects which are measured over a limited timeframe.

Even fewer studies have examined rebound effects of the circular economy. Makov and Font Vivanco (2018) carried out the first study to quantify the rebound effects of reuse in the circular economy when they explored ERE as a result of second-hand smartphone sales. In their study, it was estimated that, under certain conditions, 100% of emissions savings could potentially be lost due to re-spending and imperfect substitution of the price saving of purchasing a second-hand phone compared to a new device. This result was in line with literature by Zink and Geyer (2017, p.600) who concluded that “circular economy activities can lead to rebound by either failing to compete effectively with primary production or by lowering prices and therefore increasing and shifting consumption”.

Within the sharing economy, a study by Briceno et al. (2005) conducted research on car-sharing schemes to evaluate the changes in behaviour and consumption patterns of the users. The study took existing data from household expenditure to simulate likely scenarios caused by changes in behaviour and surmised that one likely scenario following participation in car-sharing is that users will utilise the cost-saving on international travel. Briceno et al. concluded that users justified additional air travel with a sense that not owning a car was sufficiently doing their part in combating climate change, however, this scenario ultimately led to a rebound effect more detrimental than car ownership (Briceno et al., 2005).

As the Briceno et al. (2005) study was carried out without hypothetical scenarios rather than being based on data directly collected by users of car-sharing schemes, there is a need for further investigation to corroborate the results. Furthermore, the study focused on a product-service system (PSS) approach to sharing economy in which the car was leased out by a private company. In a peer-to-peer sharing scenario rebound effect can be realised by both the lessee and the lessor, the consumption behaviours of both being crucial to a positive rebound result.

3. Material and methods

3.1. Data collection

A survey was used to collect data on the consumption behaviour of users of a peer-to-peer sharing platform. The survey received 134 responses (105 lessees and 29 lessors).

The survey sample was an important consideration for this study. As stated by Punch (2003) the relationship between variables is an important consideration in determining whether the sample should be random or deliberately chosen. As peer-to-peer sharing has yet to become a mainstream activity, random surveying would provide little to no insight into the rebound effect caused by participation. In order to achieve the aims of this study, the survey needed to reach the target audience of individuals currently participating in peer-to-peer sharing initiatives.

A peer-to-peer boat sharing platform based in Finland but also operating elsewhere was identified as a case study for this study. A case study was an important element of the study as “a case study allows an investigation to retain the holistic and meaningful characteristics of real-life events” (Yin, 2009, p. 3). Furthermore, focus on the platform enabled access to an ever-increasing number of users with experience of peer-to-peer sharing who could provide specific details on the changes in consumer behaviour as a result of their participation in the circular economy. An additional further consideration is that access to both lessees and lessors was an important addition to this study calculating rebound effect that has been absent in previous literature.

Two surveys were produced for the study to take place; one for lessees and one for lessors. The need for two separate but similar surveys is to collect slightly varying data sets for both groups. For the lessee, the main focus is on the substitution in spending with some indicator as to whether this is financially more or less than usual. For the lessor survey, the emphasis is much more on what the additional revenue generated from sharing the boat is spent on with questions regarding if the revenue was reinvested into extending the life cycle of the boat through regular maintenance.

Both surveys were quantitative in nature. Punch (2003, p.19) describes quantitative research as to when “reality is conceptualised as variables, and the ultimate objective is to find out how different variables are related to each other”. This style of research is necessary to be able to quantifiably calculate the environmental impact of the consumption substitutions and rebound effects.

The survey was conducted through a self-administered questionnaire which, due to its simplicity to complete, ensured the maximum number of respondents possible in a limited timeframe. Each question came with predefined answers, with the exception of costs which was limited to numerical input, to allow for direct comparisons between the dataset. The survey was sent out to all platform users located in Finland and thus the survey was conducted in Finnish for ease of use for the respondents. Closed responses assisted in allowing for responses to be easily translated into English for analysis and a copy of the survey in both English and Finnish can be found in Supplementary Material 1 accompanying this study. The surveying tool chosen for this survey was ‘Google Forms’ due to its easy to use user interface, unlimited response collection and continuity having been used by the platform to conduct customer surveys in the past.

A self-administered questionnaire was deemed to be the best way to capture the data on personal consumption required for such a study. Although more accurate data on consumer behaviour is theoretically available, the wide number of vendors available to book leisure travel would mean that necessary levels of participation would be almost impossible to achieve. Self-responding was therefore deemed to be the fairest comparison between the consumption associated with the sharing platform and previous consumption patterns in other forms. In order to simplify the reporting process, and given participants will not have exact numbers to hand, options of consumption categories were provided for participants to select the one that applied most closely to their circumstance. These categories were based on actual consumption trends and their formulation is outlined further later in this paper.

The survey itself was framed as studying consumption behaviour rather than environmental impact in an attempt to gain greater honesty and insight. The authors acknowledge that questions directly focussed on an environmental impact may have led to underreporting by participants.

3.2. Data analysis

This study will scrutinize the rebound effect of peer-to-peer sharing practices from the perspective of industrial ecology. The most common approach to calculating rebound within industrial ecology literature is the environmental rebound effect (ERE), a wider interpretation of the traditional notion of rebound effect which allows for a more holistic insight into environmental impact (Font Vivanco et al., 2016). ERE is an appropriate concept for interpreting the rebound of peer-to-peer practices as it goes beyond focussing purely on energy and can instead allow for factors such as emissions and lifecycle of the product. Peer-to-peer exchanges often result in dynamics with more complexity than the simple approach of measuring a change in the ratio of inputs and outputs from manufacturing.

The study will calculate the rebound effect by comparing the maximum potential changes in CO2 emissions based on the user responses against those that were actually realised after additional changes in
spending. A similar approach was taken by Makov and Font Vivanco (2018) in their study of the rebound effect from the reuse of smartphones and is thus an approach that is supported by the literature. In that study, life cycle assessment (LCA) was a core component in calculating the changes in greenhouse gas (GHG) emissions as a result of extending the smartphones life. Similarly, this study will also present the calculation of rebound in terms of GHG emissions.

Rebound effect is the combined result of two distinct forms of rebound; re-spending and imperfect substitution (Makov and Font Vivanco, 2018). Re-spending rebound is the idea that certain price savings as a result of circular economy initiatives effectively increase an individual’s effective income and leads to additional purchasing power. Consumers typically react to this by purchasing additional goods (Zink and Geyer, 2017). In a peer-to-peer sharing dynamic, additional purchasing power can be realised by both parties as the lessee can benefit from the lower costs associated with renting and the lessor receives a financial transaction in return for the temporary access of the property. It is, therefore, crucial to investigate the consumption patterns of both parties.

Imperfect substitution is the idea that circular economy strategies do not lead to the reduction of new product units on a 1:1 basis (Makov and Font Vivanco, 2018). In the context of this study, the lease of a boat via a sharing economy platform does not necessarily equate to one less boat being manufactured. In addition, previous studies such as Makov and Vivanco have studied products that are relatively passive in terms of GHG emissions outside of their primary production, however, in the context of extended use of boats, far greater levels of GHG emissions result in additional use and operation of the boat. Furthermore, the life of the product far exceeds the 36 months (Makov and Font Vivanco, 2018) average lifespan of a smartphone and can be extended further as a result of good maintenance practice (LIFE, 2012).

In order to accommodate imperfect substitution, responders were directly asked whether or not they would be in the market for purchasing a boat if the leasing platform were not an option to them. This provided insight into the extent of potential changes in primary production demand and an annual share of primary production emissions which has been incorporated into the calculation.

The consumption baseline of this survey is taken as the respondent’s leisure travel in the year prior to engaging in the sharing platform. The respondents were then asked to report increases or decreases in consumption based on that baseline of previous activity. As all participants were likely to have been involved in some form of leisure travel previously, the baseline could not be set at zero nor could it have been set at a constant and therefore cannot be defined any more definitively than ‘previous consumption’.

The environmental rebound effect as a result of lessors and lessees partaking in peer-to-peer sharing of boats will be calculated via Eq. 1:

$$\%ELE = \left(1 - \frac{pr - ic}{pr}\right) \times 100$$

(1)

Where $pr$ is the maximum potential reduction from substituted previous consumption and increase in lifecycle and $ic$ is the increased consumption in other areas resulting from additional spendable income.

Both $pr$ and $ic$ are calculations of emissions expressed in kg CO2 eq.

For lessors, the $pr$ is Substituted Travel + Extension of Life; and $ic$ is Additional Use + Additional Spend.

For lessees, $pr$ is Replaced Travel + Replaced Spend + Reduction in Primary Production; and $ic$ is Use of Boat (kg CO2) + Additional Travel (kg CO2) + Additional Spend.

In addition to calculating rebound, we estimated the overall change in emissions via the formulas:

- Lessor Change in Emissions = Additional Use + Additional Spend + Substituted Travel + Extension of Life
- Lessees Change in Emissions = Use of Boat + Additional Travel + Additional Spend + Replaced Travel - Replaced Spend + Reduction in Primary Productions - Replaced Travel - Replaced Spend - Reduction in Primary Productions

As the results depend on the calculation of kg CO2 eq. emissions resulting from consumption indicated in the survey, it is important to further discuss the sources of this emissions data and further explain how the values for each category will be calculated based on the respondents’ survey inputs.

The use of the boat is hugely dependent on the type of boat being used. The type of boats being offered by the sharing platform studied can be placed into three different categories; sailboat, motorboat and Rigid-hulled Inflatable Boat (RIB) (or similar). An LCA was carried out by LIFE (2012) Europe project ‘BoatCycle’ and determined that the average kg CO2 emission per hour of use was; 3.04 for sailboats, 25.47 for motorboats and 13.44 for RIB (LIFE, 2012).

Respondents of the survey were asked to state the number of days they used different forms of boat as this was deemed to provide a more accurate response than requesting the number of hours which some respondents may not have known. For each day of use, it is assumed that the boat is under power for 8 h which equates to a per day kg CO2 eq. emission of; 24.32 for sailboats, 203.76 for motorboats and 107.52 for RIB.

The BoatCycle project also calculated the kg CO2 eq. emissions as a result of the manufacturing stage of the boat’s lifecycle and found that on average the following were emitted; 46,000 for sailboats, 158,000 for motorboats and 31,000 for RIB (LIFE, 2012). In order to provide a calculation of rebound, it is important to consider the lifespan of the boat which was stated as 25 years for both sailboats and motorboats and 15 years for RIB.

Calculating the potential savings as a result of a reduction in primary production, lessees were asked to state whether they would purchase a boat if leasing was not an option for them. In cases where the respondent stated that they would purchase a boat if leasing was not an option then a portion of the average production emissions is subtracted in the rebound calculation. As we will assume that the potential owner will offer average maintenance of the boat over its life span the total production emission is divided by the average lifespan to provide the annual saving of; 1840 kg CO2 eq. for sailboats, 6320 kg CO2 eq. for motorboats and 2067 kg CO2 eq. for RIB.

For lessors, the calculation of emission saving through the reduction in primary production was calculated in a similar manner. As the boat has already been produced, total minimisation in primary production can obviously not be achieved, however, thorough maintenance of boats can significantly increase their lifespan and thus reduce the need for further primary production (LIFE, 2012). Lessors were asked to state whether they used the income from leasing their private boat towards maintenance. Those that respond that the income is not used for this purpose will not gain an extension to the life of the boat as a result of leasing, however, those that do utilise income in that manner are divided into a further two categories. A follow-up question as to whether the income covers the entire costs of maintenance determines the extent of the extension of life. For those that respond that the full cost of maintenance is met, it can be assumed lifespan can be extended by 50 % raising the lifespan of sailboats and motorboats to 37.5 years and RIBs to 22.5. Calculating annual emission saving from the reduction in primary production over the new longer time period gives values of; 613 kg CO2 per annum for sailboats, 2107 kg CO2 for motorboats and 689 kg CO2 for RIB. For those that stated they used the generated income on maintenance but the full costs were not covered, the lifespan increase is calculated at 25 % giving annual emission savings of 362 kg CO2 for sailboats, 1264 kg CO2 for motorboats and 413 kg CO2 for RIB.

Emissions associated with other forms of leisure travel were calculated by a set list of options which included the following; travel within the Nordic region, travel within the Baltic region, travel within Europe and long-haul travel. In the calculation of travel to and from these destinations, it is assumed that the travelling group is equal to the
The average size Finnish family of 2.8 persons (Official Statistics of Finland, 2018) rounded up to 3 individuals for convenience.

The destinations used for the calculation of travel are determined by the popularity of destinations among Finnish travellers as stated by the Official Statistics of Finland (2018). Estonia is the most popular destination for leisure travel both within the Baltic and in general. For the Nordic region, Europe and long-haul, the most popular destinations are Sweden, Spain and Thailand respectively (Official Statistics of Finland, 2018). The GHG emissions created by different transport methods are taken from DEFRA’s GHG Conversion Factors (DEFRA, 2018) and multiplied by the point to point distance, between Helsinki and the capital city of the destination country, as calculated by online tool ‘Distancefromto.net’ (DistanceFromTo, 2019).

The calculations provide the following CO₂ emission levels for the leisure transport options provided for a family of three. Travel within the Baltic is a 164 km return journey taken by ferry emitting 0.12774 kg CO₂ per km totalling 62.85 kg CO₂. Travel within the Nordic region is a 790 km return journey taken by ferry emitting 0.12774 kg CO₂ per km totalling 302 kg CO₂. Travel within Europe is a 5896 km return journey taken by short-haul aeroplane emitting 0.16155 kg CO₂ per km totalling 2857 kg CO₂. Travel long-haul is calculated as a 15,774 km return journey taken by aeroplane emitting 0.2115 kg CO₂ per km, totalling 10,009 kg CO₂. Table 2 summarises the transport mode values used in this study.

Not all users of the platform have made a direct substitution between leisure activities and have instead found either a gain or reduction in income spent on regular living costs compared to previous years. This is an important factor in calculating the rebound from engaging in peer-to-peer access as every unit of currency spent in modern economies leads to carbon emissions of some form. According to World Bank figures, each US dollar worth of spending in Finland resulted in 0.209 kg CO₂ emission in 2014 (The World Bank, 2014). Adjusted into Euros (IRIS, 2019) using the average conversion rate of that same year (IRIS, 2019) gives emissions of 0.268 kg CO₂ per Euro spent. Respondents stated whether their ability to lease a boat came from changes in their regular spending rather than substitution in travel and this figure will be used to calculate the GHG emissions impact of the consumption behaviour change.

In the event that a lessee respondent has stated ‘regular living costs’ as the biggest utilisation of the financial savings but has also indicated an increase in travel, the double calculation will be avoided by including two-thirds of the spending impact and one-third of the travel impact. Likewise, the same ratio will be made in the lessee calculation between maintenance and increased travel or living costs.

### 4. Results

There were 29 responses to the lessor survey and 128 responses to the lessee survey. Of the 128 lessee responses, 23 were not sufficiently complete to include in the calculation dropping the used number of responses to 104. Therefore, 148 users of the peer-to-peer sharing platform have been included in this study.

#### 4.1. Rebound size and tendency

Using the calculations outlined in the material and methods section, the response of each user (both lessee and lessor) enabled the calculation of rebound shown as a percentage of potential gains in emissions reductions that have been lost due to substituted consumption.

Among lessors, 55 % of users did not experience ERE and thus maximised the potential emissions savings from leasing their boat. However, due to the consumption of the remaining 45 % of users, the overall average ERE grows to 46.5 %. Furthermore, 17 % of users experienced backfire, increasing their overall emissions with one user increasing emissions by a factor of 4.8. In order to achieve 100 % of the potential gains, the entirety of the generated income must be reinvested into the upkeep of the boat. Users that did not achieve this full potential either increased their personal use of the boat or utilised the revenue on additional travel.

All lessees experienced ERE in some form with the extent varying greatly. The lowest recorded ERE was just 1 %, however, the highest was 8.4 %. Our results pointed out that there is a large variation in realising the potential emissions savings from participation in the peer-to-peer sharing of boats as a lessee. 27 % of respondents experienced a rebound of 10 % or lower with 40 % experiencing less than 20 % rebound. Amongst users that had a net reduction in emissions, the average ERE stands at 25 %. 29 % of users experienced backfire, increasing their emissions as a result of leasing a shared boat. Of this group, 53 % increased their travel as a result of cost savings. Of the top 10 greatest increases in emissions, 8 of the users had substituted travel within the Baltic or Nordic Regions with the leasing of a boat. Within those that reduced their emissions just 18 % increased their travel consumption.

Fig. 1 illustrates the distribution of ERE among the lessors and lessees surveyed.

#### 4.2. Insight into changes in consumption and emissions

As ERE is a calculation against the maximum potential reduction in emissions, a high ERE can still lead to a significant net reduction in emissions. For example, one user experienced a rebound of 68 % due to taking a flight within Europe limiting the reduction of emissions from less primary production, however, this still resulted in an overall emission reduction over 2 tonnes CO₂. It is therefore important to also consider what changes in consumption realised the largest overall changes to CO₂ emission.

For the lessees, there is a large variation in the generated reductions in emissions as a result of changes in consumption and use of time due to participating in peer-to-peer sharing of boats. The highest calculated reduction in emissions was -11,752 kg CO₂ eq. and the highest calculated increase in emissions was 8339 kg CO₂ eq., thus giving a difference in the result of over 20 tonnes of CO₂. 57 % of responses resulted in a net reduction in CO₂ emissions whereas the remaining 43 % resulted in an increase in carbon emissions. The average change in emissions across the lessees was a -2,503 kg CO₂ eq. reduction in emissions.

Lessees experienced a larger percentage of users gaining a reduction in emissions with 83 % of respondents. However, the combined average change in emissions is an 858 kg reduction CO₂ eq. output which is lower than the combined average of the lessee responses. The difference in the maximum and minimum values for lessees was much smaller than that of the lessees with a range just 8790. The range and average

### Table 2

Comparison of emissions of destinations and transport modes.

<table>
<thead>
<tr>
<th>Destination</th>
<th>Transport mode</th>
<th>Distance, km (return journey)</th>
<th>kg CO₂ per km</th>
<th>Total kg CO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel within the Baltic</td>
<td>Ferry</td>
<td>164</td>
<td>0.12774</td>
<td>62.85</td>
</tr>
<tr>
<td>Travel within the Nordic region</td>
<td>Ferry</td>
<td>790</td>
<td>0.12774</td>
<td>302</td>
</tr>
<tr>
<td>Travel within Europe (short-haul)</td>
<td>Aeroplane</td>
<td>5,896</td>
<td>0.16155</td>
<td>2,857</td>
</tr>
<tr>
<td>Long-haul</td>
<td>Aeroplane</td>
<td>15,774</td>
<td>0.2115</td>
<td>10,009</td>
</tr>
</tbody>
</table>
were skewed by an anomaly in the responses with one user reporting an increase of 4849 kg CO₂ emissions, 3000 kg greater than the next largest increase. However, as the large increase is explained by a seemingly realistic change in consumptive behaviour, namely a 30-day increase in personal boat use due to additional revenue, it was decided to include the value in the dataset to highlight just how much overall effect can be achieved.

Fig. 2 shows the distribution of the differences in emissions among the lessors and lessees surveyed. A comprehensive description of the data is found in Tables 1 and 2 of Supplementary Material 1 of this article.

4.2.1. Lessors

The lessors had the closest range of change caused by their consumption alterations and this group also had a higher percentage of users experience a drop in emissions. One of the biggest factors in that reduction in emissions came from maintenance extending the lifespan of the boat. 96.6 % of those surveyed stated that at least some of the income they generate from peer-to-peer sharing goes towards maintenance of the boat.

However, when asked the follow-up question of whether the income generated covers the full cost of maintenance, 55.2 % responded that it did not. This limits the increase in lifespan within the calculation to a 25 % extension rather than the 50 % increase in lifespan from the full cost of maintenance being covered.

Among those that responded that the full cost of maintenance had not been covered by the income generated, the average received income was €2,468 with an average of 11.3 days of sharing. Among those that responded that the income had covered the full extent of maintenance costs (with the removal of an anomaly response seven times greater than the next closest response), the average received income was €3,554 with an average of 15.8 days of sharing.

Of the users that responded that maintenance costs were not fully covered, the average change in emissions was a 768 kg CO₂ reduction. Among the users that responded that maintenance was fully covered the average change in emissions was 970 kg CO₂ however, this group also included 80 % of the users that experienced a backfire rebound resulting in an increase in emissions, due to increasing spending elsewhere.

Of the five users that experienced an increase in emissions, three increased their personal use of the boat by more than 10 days, one experienced the highest recorded increase in regular spending and one utilised the increase in income by taking a trip to Europe.

Other users indicated that they had taken an additional trip to Europe as a utilisation of the additional income and gained an overall reduction in emissions, however, those users all operate motorboats which, as a result of a more carbon-intensive production process, gain greater reduction in emissions from extending the life of the boat through thorough maintenance compared to the sailboat of the user described above. Despite this insight, the type of boat shared was not the primary factor in determining the rebound effect as 22 % of sailboat users and a comparative 15 % of motorboat users experienced a backfire rebound.

4.2.2. Lessees

Lessees had a far more diverse spectrum of potential changes in consumer activity as participating in peer-to-peer sharing has the potential of both increasing and decreasing spending. Changes in expenditure from leasing a boat were utilised in the following ways.

23.5 % of users surveyed stated that leasing a boat through peer-to-peer sharing had been an additional expenditure compared to consumption in previous years. In order to afford this increase in expenditure towards a leisure activity, 8.4 % substituted other forms of travel and 15.1 % reduced their expenditure on regular living costs.

26.9 % of users stated that their expenditure on leisure had remained consistent with previous years with a simple substitution of other forms of travel allowing for the lease of a boat.

Almost half of those surveyed, at 49.6 %, stated that they had saved money as a result of leasing a peer-to-peer shared boat. This led to an increase in spending in other areas with 31.1 % stating that they had more revenue to go towards regular living costs and 18.5 % stating that they had taken additional travel compared to previous years.

Among users that had substituted other forms of travel, 81 % experienced a reduction in emissions compared to previous years. Across the entire spectrum of those that substituted travel, the average change in emissions was a 3902 kg CO₂. Unsurprisingly, those that gained the biggest reduction in emissions were those that substituted long haul flights with an average saving of 10,199 kg CO₂ amongst this group.

The type of boat leased does not appear to have affected the ability to gain a reduction in emissions with users of each of the three categories of boat experiencing both increases and decreases in emissions when substituting other forms of travel. Nor does the amount of time that a boat was leased with the second-highest reduction in emissions for this category coming from a user that leased a sailboat for 20 days.

Among users that increased their travel as a result of cost savings from peer-to-peer sharing, 91 % experienced an increase in their emissions compared to previous years. Increase in emissions was experienced by users of all three boat types and by increase travel to each of the four destination categories.

However, an increase in travel does not automatically equate to an increase in emissions with one user leasing a motorboat for one week, taking an additional flight to Europe and still reducing emissions by over 2 tonnes CO₂ as a result of leasing rather than purchasing a boat.
causing an overall increase in emissions from the primary production.

Changes in expenditure on living costs do not massively impact the emissions of users. For those that responded that the biggest change in expenditure was an increase in living costs, 38 % experienced an increase in emissions whilst 62 % experienced a reduction. For those that primarily reduced their expenditure on living costs, 39 % experienced an increase in emissions whilst 61 % experienced a reduction.

The greatest factor for those that have predominantly altered their regular living spending is whether or not they are likely to purchase a boat for themselves if leasing was not an option. 43 % or lessee respondents stated that they would be in the market for purchasing their own private boat if leasing were not an option to them. These 51 users alone are saving 232 tonnes of CO2 per year just by leasing rather than creating further primary production. Of those that experienced a reduction in emissions 85 % users indicated that they would be in the market for purchasing their own boat. Of those that experienced an increase in emissions, 100 % of users indicated that they would not be in the market for purchasing a boat.

Indeed the impact of reducing emissions through reducing primary production can be seen clearly when isolating just those users who would be in the market for purchasing their own boat if leasing was not an option (see Fig. 3).

Of all users who indicated that they would be in the market for purchasing a private boat if leasing was not an option, 90 % experienced a reduction in emissions resulting from reducing primary production. Within the top 20 % of reductions 9 of the 10 users also substituted flight travel with the lease a boat. The 10 % of users that did not experience a reduction in emissions all increased their travel as a result of cost savings.

For users that would not be in the market for purchasing a boat if leasing was not an option, the change in emissions was a lot more varied. Overall, 65 % experienced an increase in emissions as a result of leasing a peer-to-peer shared boat with 35 % experiencing a reduction in CO2 emissions. Among this demographic cost savings had a massive impact on whether emissions increased with 97 % of those that saved money by leasing a boat experiencing an increase in emissions. Every user that indicated that had travelled more as a result of the cost savings increased their overall emissions. In contrast, 70 % of those that replaced travel with the leasing of a boat experienced reductions in emissions.

Finally, one-way ANOVAs for the ERE and for reveals that there is a statistically significant difference in the means of the ERE (Fig. 1; F = 4.699; p = 0.0392) and for the differences in emissions (Fig. 2; F = 89.8; p = 4.44e-10) of the lessors and lessees.

### 4.3. On actions for reducing ERE

Policymakers, as well as platform providers themselves, shall consider actions and incentives to minimize the unwanted rebound effect. The effectiveness of respective organizational practices, however, may depend on a deep understanding of the mechanisms that drive behavioural change of lessors and lessees. The current literature appears to lack empirical evidence about the effectiveness of practices and a consideration of the particularities of the sharing economy. Therefore, our current understanding does not provide actionable advice for resource-optimization platform providers in order to adapt their business model to drive a net reduction in resource use and environmental impacts.

New endeavours in this direction shall bring together leading sharing economy players using a change-driven approach. Mechanisms that simultaneously lead consumers to actively engage in the sharing economy and maximise the environmental gains from the use of sharing platforms must be developed and tested. These mechanisms should be tailored to specific users’ groups (i.e. lessors and lessees) based on their particular characteristics (motivations, preferences, consumption behavioural choices, etc.). They might include non-monetary incentives such as symbolic rewards (signifying high social status) and descriptive norms (carrying information about what is typically done in the given situation), information provision about rebound effects targeting the motives of users, or the design of a semi-closed business model, where participants can only spend their gains on products or services that carry a low environmental impact.

A more concrete agenda for future research would be to:

- develop a behavioural framework for analysing sharing behaviours and related spending intentions; why and how lessors and lessees engage in sharing platforms spend their freed/saved money (involving thus dissimilar rebound effects and subsequently, different net environmental impacts)
- increase understanding of the root-causes and quantifications of full environmental behavioural effects addressing the fundamental gap whether, to what extent, and under which conditions rebound effects undermine the environmental gains of resource-optimisation platforms
- generate real-world data from field experiments

### 5. Discussion

The results provide insight into the existence of ERE on the peer-to-peer shared access of boats and show that improved access does not necessarily result in an increase in emissions. However, despite decreases in primary production, substituted consumption behaviour, such as increases flights or increased personal use of a boat, can result in significant rebound and, in almost a third of cases, backfire.

The study shows that peer-to-peer leasing of boats can lead to significant reductions in CO2 with an average saving across all users of 1474 kg CO2. This is in line with literature claiming that the circular economy can be effective in reducing the environmental impact from the consumption of goods.

One of the biggest contributing factors to an overall reduction in emissions comes from extending the lifespan of existing products through good maintenance and from the reduction in primary production. The fact that 96.6 % of lessors indicated that they utilised the additional income on maintenance was surprising and the fact that 55.2 % of lessors are yet to have the full cost of maintenance covered by the income generated by leasing shows that there are potentially greater gains to be made through an increase in leasing.

Among lessees, the 43 % of users that stated they would be in the market for purchasing a private boat if leasing were not an option are saving over 232 tonnes in CO2 emissions per year as a result of the avoidance of primary production. That is a staggering saving from just
51 users of the platform and proves that shared access can successfully prevent primary production at a significant level. None of the users who indicated that they would purchase a boat privately experienced a backfire from their increases in consumption elsewhere resulting in a net loss of emissions. Zink and Geyer (2017) argue that, in order for a circular economy to work, it is fundamental that consumers are drawn away from primary production and the results of this study suggest that this can and does occur in practice.

However, such a high rate in primary production reduction may not necessarily be replicated as access to boats increases through peer-to-peer sharing. One can assume that the individuals with the greatest interest in boating have been the early adopters of sharing platforms such as the one studied and future new users have less interest in owning a boat of their own. The platform studied is still within its first five years of operations and is growing at a rapid rate, therefore, further research is needed to investigate the long-term trends of peer-to-peer sharing and determine if similar reductions in primary production are replicated across increasingly larger pools of users.

Despite the overall reductions in emissions resulting in participation in shared access, it is clear that ERE is very present. Among lessees, the average ERE stood at 46.5 % despite 55 % of the users experiencing no rebound at all. The increase in use and travel by a minority of users wiped out almost half of the overall potential savings across the board showing that the consumption of few can have a huge impact on the success of circular economies.

Among lessees every single user experienced ERE of some extent proving that the potential gains from circular economy can very quickly become eaten into by consumption in other areas. 60 % of users experienced an ERE of over 20 % with 29 % of users experiencing backfire and completely reversing any benefit achieved by their participation in shared access. The potential for peer-to-peer boat leasing to become a net increase on environmental pressures is hugely worrying and greater awareness of this potential is needed to educate consumers that their use of sharing schemes does not inherently lead to an overall reduction in emissions.

Briceno et al. (2005) warn of a scenario in which consumers justify energy-intensive consumption with the fact that they have reduced primary production through participation in shared access schemes. This scenario could well explain the increase in consumption that led to the highest rates of rebound effect. However, this study did not explore the incentive behind increased consumption in other areas and thus fails to provide evidence to fully support the hypothesis.

The ERE average experienced by lessees of the boat sharing platform is higher than the 29 % ERE average found by Makov and Font Vivanco (2018) smartphone reuse. However, with the actual use of the boat during the leasing period contributing to an increase in rebound it is inevitable that the ERE is higher than a relatively passive product to use such as a smartphone. Makov and Vivanco acknowledge that their study only investigates direct replacement between smartphones and therefore does not include an increase in consumption through the use of services such as cloud storage that would result in a situation where the user upgrades from a regular phone (Makov and Font Vivanco, 2018).

Similar to the Makov and Vivanco study, life cycle assessment is a fundamental component of the calculation of rebound (Kjaer et al., 2018). Reduction in primary production was a hugely important factor preventing backfire with the reduction in emissions from production far outweighing increases in consumption in other areas for the vast majority of cases. Lessees similarly experienced a net reduction in emissions caused by an increase in the boats life span, however, the emissions resulting from an increase in maintenance were not considered in the ERE calculation nor the overall impact on emission.

Outside of improvements in life span and a reduction in primary production, the greatest impact on ERE was an increase in air travel. Increased travel occurred in 91 % of users who experienced backfire. This supports the conclusion proposed by Briceno et al. (2005, p.12) that “annual intercontinental air travel leads to worse overall environmental impacts” when funded by cost savings from participation in shared access”.

Lastly, in this study stated responses (rather than actual measurements) were the basis for calculating ERE and therefore the results should, evidently, be interpreted as such. Furthermore, the generalisability of our research findings to other context (e.g. resource type and country) is limited. Further research with a larger sample size for multiple contexts is needed.

6. Conclusion

This paper reviewed the magnitude and likelihood that environmental rebound effects emanating from sharing resources can happen. A survey completed by users of a peer-to-peer boat sharing platform in Finland allowed, for the first time, for the quantitative analysis of environmental rebound effect experienced by the lessors and lessees and also provide insight into the consumption behaviour that created the most negative consequences.

The results of the study show that ERE does exist in the context of peer-to-peer leasing of boats, affecting lessors and lessees in different ways. There is a much lower rebound effect acting on lessees with the majority of users indicating that they are maximising the potential reductions in emissions. Lessees, on the other hand, have much more varied results with consumption changes drastically increasing the rebound effect to the extent that 29 % of lessees experienced backfire and increased their overall emissions output. The largest contributor to the rebound effect was increasing other forms of travel especially when an aeroplane was the mode of transport. Despite a clear indication that rebound effect does exist and limit the potential of resource-optimisation platforms, reductions in emissions were experienced by 63 % of the combined user base with an average reduction of 1474 kg CO₂eq. The two biggest factors contributing to the reduction of emissions were substituting air travel and reducing primary production of boats. Similarly, the largest contributing factors creating ERE were increases in personal use of the shared boat and increases in air travel. Utilising the additional income on air travel has the potential to create a backfire, increasing emissions by a factor of eight in the worst scenario experienced. Moreover, one-way ANOVAs indicated that there are significant differences in the ERE and emission changes of lessors and lessees.

Despite the existence of ERE, reductions in emissions were seen by the majority of users; hence peer-to-peer sharing platforms can remain effective in reducing emissions and primary production. Furthermore, the peer-to-peer sharing of boats can provide a cheaper and more environmentally form of travel compared to continental air travel, however, without adequate recognition and mitigation against ERE, its ability to deliver on these goals becomes limited. Therefore, greater awareness of the consequences of re-spending among users, platform providers and regulatory agents is needed. Non-economic mechanisms (such as symbolic rewards, information provision and nudging) addressing ERE shall be developed, tested and implemented. It is evident that the emphasis must remain on directing the released consumption factors such as money and time towards less impacting choices. With high levels of satisfaction amongst existing users and a massive rise in popularity across the world the mainstream acceptance of sharing schemes is a real possibility.

Declaration of Competing Interest

The authors declare no conflict of interest.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.rcrx.2019.100028.

References


European Commission, 2016. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. A European agenda for the collaborative economy.


Jenkins, J., Nordhaus, T., Shellenberger, M., 2011. Energy Emergence: Rebound and Backfire As Emergent Phenomena. The Breakthrough Institute, Okland, CA, USA.


