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Sharing Economy Rebound- The Case of Peer-2-Peer Sharing of Food Waste

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Abstract: The Sharing Economy is commonly assumed to promote sustainable consumption and improve material efficiency through better utilization of existing product stocks. Yet the cost-savings and convenience of using sharing economy platforms can ultimately stimulate additional demand for products and services. As a result, some or even all of the expected environmental benefits attributed to sharing could be negated, a phenomenon known as Rebound Effect. Relying on a unique dataset covering close to 1.1 million exchanges on a Peer-to-Peer (P2P), food sharing platform, we use a combination of Environmentally Extended Input Output analysis (EEIO), geo-spatial network analysis, and econometric modeling to quantify how much of the expected environmental benefits attributed to sharing are negated via rebound effects. We find that over the 3 years examined, sharing edible yet unwanted food with other peers was associated with nearly 1,800 tons of avoided CO2-eq. However, our results suggest that over 80% of these avoided emissions were negated as platform users re-spent the money saved by sharing on other goods and services. Our results demonstrate the importance of considering the potential implications rebound effects might have on the efficacy of leveraging the sharing economy to elevate environmental burdens.

Introduction

The last few years gave rise to the “Sharing Economy” (SE), a host of platform mediated business models which allow their users to share various goods and services either by giving access, or passing ownership, for free or for pay (Frenken & Schor, 2017; Hamari et al., 2016). Although sharing is a long standing human practice, wide adoption of Internet and Communication Technologies (ICT) and smartphones in particular have lowered the transaction costs of sharing enabling large scale adoption (Hamari et al., 2016; Mair & Reischauer, 2017; Richards & Hamilton, 2018) as well as sharing among strangers. (Schor, 2014).

The SE is generally assumed to improve resource efficiency and reduce demand for new production by increasing the usage of a wide range of existing yet underutilized products (Botsman & Rogers, 2011; Nijland & van Meerkerk, 2017). For example, research on car sharing suggests that participation reduces user’s GHG emissions by up to 51% (Chen & Kockelman, 2016) Similarly sharing unwanted yet edible food can reduce overall food waste, GHG emissions and save users money at the same time (Makov et al., 2020).

Yet if and how SE might affect household consumption more broadly, and the related environmental implications of such changes remain unclear. Specifically the convenience of cost savings offered by many SE products and services can induce added consumption and increase demand for durable goods and services. Car sharing for example, displaces not only single passenger rides, but also more sustainable transport modes such as public transport and walking (Clewlow & Mishra, 2017). Furthermore, SE can also boost demand for durable goods such as new cars (Gong et al., 2017) housing (Horn & Merante, 2017), or tourism (Tussyadiah & Pesonen, 2015). So while products and services might be more environmentally friendly on the single unit basis, there are more units of consumption overall. As a result, some of the expected environmental benefits of the SE are negated- a phenomenon typically studied under “Rebound effects”.

Increased demand might be expected as Recent studies suggest that not all SE business models are sustainable by default, and that environmental impacts vary by business models (Curtis & Mont, 2020; Laukkanen & Tura, 2020; Verboven & Vanherck, 2016) or types of product shared (Schwanholz & Leipold, 2020). Some of the features associated with improved sustainability are: (1) operating as a two sided market, also referred to as person to person networks (P2P) (2) using idle resources or existing stocks (3) promoting access over ownership (4) minimizing economic incentives that could increase consumption (Curtis & Mont, 2020). Laukkanen and Tura examine sharing business models and find that some for-pay business models could lead to increased consumption and rebound effects (Laukkanen & Tura, 2020).

Rebound effect

The rebound effect is a construct used to describe a variety of consumer and market responses to technologically driven improvements in efficiency which increase demand. In brief, improving efficiency effectively reduces the unit usage price leading to increased demand, and increased overall consumption compared to a theoretical bassline in which there was no improvement in efficiency (Chitnis et al., 2014).

Research on rebound effects originated in the work of the economist William Stanley Jevons in 1865. Jevons postulated that efficiency gains in the use of coal would cause an increase in the total demand for coal (Jevons, 1865). In the 1980s, following the energy crisis, energy economics adopted and enhanced Jevon’s argument (Font Vivanco et al., 2016). Leonard Brookes and Daniel Khazzoom proposed and formalized the rebound effect, from macroeconomic and microeconomic respectively (Brookes, 1979; Khazzoom, 1980). Khazzoom outlined how switching to a car with higher fuel efficiency, leads to a drop in the ‘effective price’ of driving a mile, which might increase demand for longer or more frequent drives. Well documented examples of the rebound effect in energy economics include: increased energy demand following household energy efficiency improvements, longer distances driven in response to more fuel-efficient vehicles and cheaper operating costs, and lights left on longer after installation of energy-efficient light bulbs (A. Greening et al., 2000; Chitnis et al., 2014; Schleich et al., 2014). Situations where increased consumption leads to more energy demand compared to before the efficiency measure are termed ‘backfire’.

The literature generally distinguished between three types of rebound effects: direct, indirect, and economy wide rebound. Direct rebound is used to describe increased consumption of a product or service in response to its improved efficiency. In economics these mechanisms are also referred to as the ‘substitution effect’. Indirect rebound effect refers to increased consumption of other goods and services as a result of increased performance of another product. In this case, reduction in the price of a product leads to residual savings, which are used on other goods or services. Also referred to also as the ‘income effect’. Finally, the sum of direct and indirect rebound effects over the population is the economy-wide rebound effect - large scale readjustments to final demand across multiple sectors throughout the entire economy (A. Greening et al., 2000; Sorrell, 2007).

More recently, the construct of rebound effects has been expanded beyond in original field of energy economics to include a multitude of environmental impacts, and researchers have examined rebounds in response to efficiency strategies related to construction materials (Bahn-Walkowiak et al., 2012) dietary changes (Grabs, 2015), food waste (Hagedorn & Wilts, 2019), and consumer electronics (Makov & Font Vivanco, 2018).

While there is growing evidence that the cost savings and conveniences offered by the SE affects consumer behavior and demand, with few notable exception (Amatuni et al., 2020; Cheng et al., 2020; Warmington-Lundström & Laurenti, 2020), data driven research examining SE rebound effects remains surprisingly scarce (Henry et al., 2021).

Case study

One type of SE platform which fits the definitions for sustainable business model, and has received relatively little scholarly attention is of digitally enabled, Peer-to-Peer (P2P) food sharing between strangers. Global food waste is a major environmental issue responsible for 8% of global anthropogenic GHG emissions, 20% of fresh water consumption, and 30% of global agricultural land use(FAO, 2013, 2018). Since both unmet demand and edible yet unwanted food can be found in the same areas, food sharing platforms have been created for both for-free and for-pay redistribution of foods (Davies et al., 2017; Michelini et al., 2018). Yet while past work demonstrates that food sharing has environmental benefits, it can also trigger rebound effects as consumers re-spend the money they saved by collecting free food from others (Makov et al., 2020). If, for example, consumers save money via food sharing only to spend it on flights, or other GHG intensive products well, needless to say that the effort might not lead to a net environmental benefit in terms of GHG emissions. As the popularity of SE continues to grow, a better understanding of its net environmental impacts which account for potential rebound effects is needed.

This work aims to fill this knowledge gap through a data driven analysis of OLIO - a UK-based startup which operates an increasingly popular location-based P2P food sharing platform (https://olioex.com/) . OLIO (also referred to as the platform throughout) provided data on all food exchanges between April 2017 to February 2020, containing close to 1.1 million food listings offered across more than 110 countries. Using OLIO as a case study, we employ a combination of data-science methods with Environmentally-extended input output (EEIO) assessment to quantify the environmental rebound effect associated with food sharing activity in the UK, the largest and most mature network accounting for 70% of all platform activity.

Methodology and Data

The Environmental Rebound Effect (hereafter rebound for short) is defined as the percent of environmental benefits, which are nullified via re-spending and its associated environmental impacts. To quantify rebound effects resulting from P2P food sharing we first created a food sharing database from OLIO's raw data by matching for each food collection data on providing and collecting users. Next, we estimated how much each food item cost as well as the overall sum of money saved by all collecting users across the UK. We then built on these results to examine potential rebound effects using Environmentally Extended Input Output Life Cycle Analysis (EEIO-LCA). Specifically, we (1) estimated the environmental benefits related to avoided food waste (also termed potential savings) (2) calculated how the saved expenditure (i.e. money that would have been spent without taking food items from OLIO) was redistributed among household consumption categories, using the 'Almost Ideal Demand System' (AIDS) consumer demand model (3) estimated the environmental impacts of added consumption and (4) calculated the rebound effect, namely- the share of expected benefits that were offset by re-spending consumption according to the following formula (Font Vivanco et al., 2014):

$$(1)\ \%ERE = \left(\frac{PS - AS}{|PS|}\right) * 100$$

Where PS are the potential environmental savings, and AS are the actual savings when taking into account behavioral responses due to using OLIO (in this case re-spending).

Our model assumed that all food items shared fully displaced the purchase on new, identical food items and led to avoided production. To illustrate, if a user picks up a sandwich via

OLIO, this replaces buying an identical sandwich and ultimately also production of such sandwich .

Dataset construction

Using OLIO's raw data we created a dataset of unique food collections, with details describing the food listings (unique id, text description of the item itself, collection notes, offering date, collection unique id, collection date), and each listing's provider and collector (user unique id, and 'food waste hero' an indication of whether the user collects excess food from local cafes and restaurants and redistributes to other OLIO users). Following the approach outlined in (Makov et al., 2020) all listings were classified into food categories using a supervised deep learning long short-term memory (LSTM) network classifier, aggregating many different food listings into 13 homogeneous categories.

Calculating retail value per food category

Dividing the dataset into subgroups based on the food category and type of providing user (i.e. whether user was an official OLIO volunteer who redistributed foods collected from local shops and cafes or a regular user), we then used a series of Monte Carlo simulations (10^4) to estimate for each subgroup the total monetary value of all food items exchanged. To this end we: (1) Randomly sampled <200 (?) food listings from each sub group, (2) manually examined both listing text and images as they appeared on the platform and estimated their retail price and weight. We then used this empirical sample to calculate a price distribution probability function (PDF) for each sub group using the Scipy Python package (Virtanen et al., 2020). (4) For each sub group's price distribution probability function, we ran a series of Monte Carlo simulations over 10,000 iterations to calculate the overall sum saved in each sub category and overall (for more detail please see Makov et al, 2000).

Environmental analysis of food waste sharing

To estimate the environmental benefits associated with food sharing, we used the Exiobase, an EEIO-LCA tool. EEIO-LCA is a method used to evaluate the relationships between economic consumption and environmental impacts for different sectors and products. It is based on the Input-Output framework (IO), a macroeconomic tool, defined by Nobel prize winner Leontief in the 1930s' (Leontief, 1970; Miller & Blair, 2009). Input output framework uses tables of national sectoral aggregated data with inter-industry relationships to model how change in household and government demand (termed final demand) will affect these inter-industry relationships. Exiobase v3 is a database used for multi-regional Input-Output model the database maps 44 countries and 5 rest of the world regions for environmental analysis (Stadler et al., 2018).

To estimate GHG emissions saved from food waste exchanges, we began by mapping our food categories to EXIOBASE sectors. After converting from the British pound (£) to Euro (€) using european central bank data, we disaggregated the monetary savings representing final household consumption per category to account for imports using Exiobase existing import weighting. The world-wide final demand associated with UK reduced consumption of shared food was set as input for EEIO-LCA environmental calculation, using pymrio python package (Stadler & Didier, 2020).

Calculating added consumption and its added environmental impacts

Quantifying the added consumption was done using a single re-spending model, where all consumption categories were treated equally (Murray, 2013; Salemdeeb et al., 2017). The Marginal Budget Shares (defined as how much of additional income consumers allocate to the respective goods (Matsuda, 2004)) were calculated using a linear approximation of the Almost Ideal Demand System (AIDS), developed by (Deaton & Muellbauer, 1980).

The AIDS model for the i-th consumption category and a given time period t is expressed as:

$$(2)\ w_t^i = \alpha^i + \beta^i ln(\frac{x_t}{P_t}) + \sum_{j=1..n} \gamma^i ln(p_t)$$

where n is the number of consumption categories, x is total expenditures, P is defined here as the Stone's price index, p is the price of a given category and α, β and γ are the unknown parameters.

Consumption categories were taken from the 12 top tier categories of Classification of Individual Consumption According to Purpose (COICOP). Using UK price indices and COICOP expenditure historical data between 1996-2019 from (Eurostat, 2021b, 2021a) and calculation of the MBS was done using (Henningsen, 2017) R package.

The calculated MBS were used to assess re-spending per COICOP category and calculate added environmental burdens using Exiobase.

Results

Between April 2017 to February 2020 User of OLIO in the UK collected food with an estimated retail value of €2.58 million (with 2.54 and 2.64 million being 5 and 95 percentiles respectively) and 1,766 metric tons of avoided CO_2-eq (taking mean values, and assuming perfect substitution), equivalent to the yearly CO2 emissions of more than 300 people within the UK. However, as can be seen in figure 1, taking rebound effects into account, consumption due to re-spending adds 1,481 tons of CO2eq, such that the actual savings is only 295 tons of CO2eq and ERE is 83% due to re-spending.

In figure 2 we can see that 49% of associated GHG emissions (and 22% of expenditure) are due to two consumption categories: 'Food and non alcoholic beverages' and 'Transport'. In figure 3 you compare category expenditures vs, GWP intensity per euro. Notable to see that the third category by GWP emission, 'Housing, water, electricity, gas and other fuels', is so high mostly due to high absolute spending, and not GHG intensity, unlike the first two categories.

Discussion

Using OLIO as a case study for the SE, we quantified the magnitude of the Environmental rebound effect. Our results suggest that up to 83% of the potential climate benefits delivered from avoided food waste are negated when households re-spend saved money. Our results help demonstrate that although sharing food waste at a local level has environmental benefits, a systems' perspective is needed to gage the net environmental benefits of SE products and services. As our results suggest, in the case of food sharing much of these benefits are offset through the unintended impact SE has on household consumption overall.

This research has several important limitations. First, we assume that food items shared displace purchasing of new food items, and subsequently their production at a 1:1 ratio. If without OLIO, users would have purchased less expensive items from the ones received, or items from a different food category then overall saved expenditure might be smaller. Interestingly, however, the rebound might not change, as the smaller amount is redistributed in the same proportions. More critical is if shared foods are not perfect substitutes for new foods and do not lead to their avoided production. In such cases, we would expect the environmental benefits to shrink, while saved expenditure remains the same, causing the rebound effect to increase. Second, we assume that people using OLIO follow the same homogeneous expenditure pattern as the general population used to calculate the MBS. If OLIO users, and food SE users in general have pro-environmental attitudes or belong to low income decile groups, then their expenditure patterns might be substantially different than those of the average household depicted in economic models. Last, this research focuses mainly on GWP and GHG emissions. There are many other relevant and pressing environmental indicators, for which added benefits and burdens might yield meaningfully different results. More research is needed to dive into these questions, as well fine tune the underline calculations.

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Figures and Tables

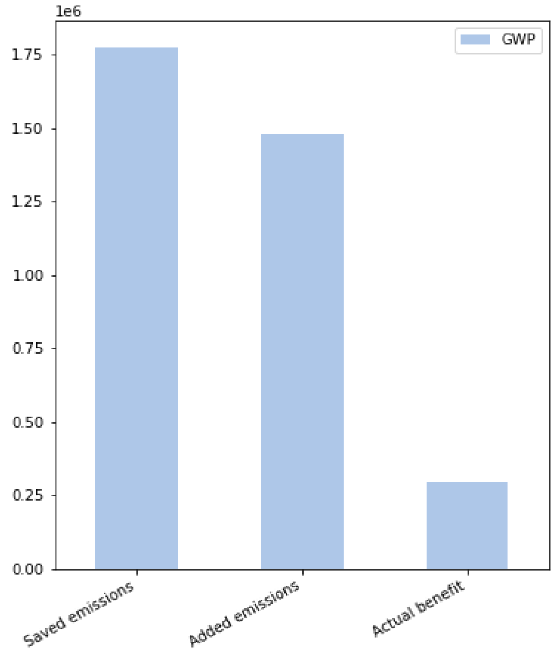

Figure 1. GWP possible savings vs. added emissions and actual savings.

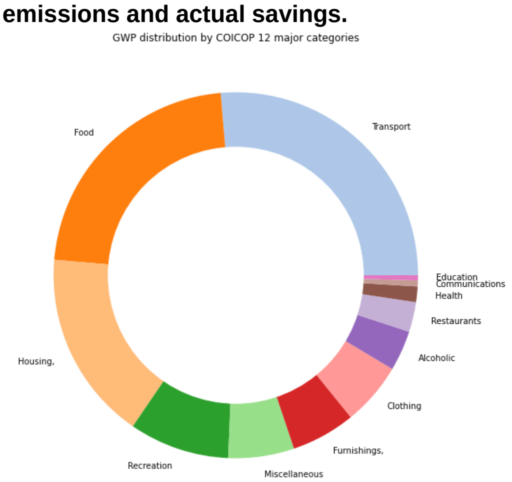

Figure 2. Added emissions by COICOP categories.

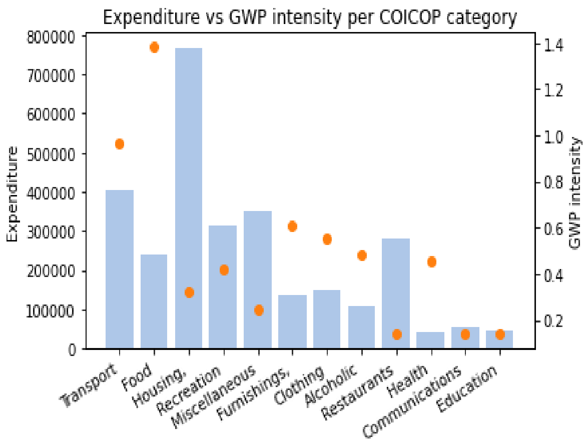

Figure 3. Expenditure vs. GWP intensity of COICOP categories.