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What is my Share? Using Market Data to Assess the Environmental Impacts of Secondary Consumption

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Abstract: Growing interest in alternative consumption models (e.g., circular economy, sharing economy) bring forth the need for new methods to better quantify the environmental impacts of reuse and specifically, secondary consumers. In this paper, we suggest using market data and economic depreciation to assess the full lifespan of products and allocate the environmental impacts of consumption across multiple users that reuse or share the same product. We demonstrate our approach using the case of smartphones and cars.

Introduction

Concern over environmental degradation has motivated research into and development of environmental accounting methodologies used to quantify the full life cycle impacts of durable goods (products). Today, companies across the business spectrum use tools such as Life cycle assessment (LCA) and foot-printing to measure and optimize the environmental performance of their products. At the same time, growing interest in circular economy models where multiple agents (users) reuse the same products either in parallel (e.g. Zipcar) or one after the other (e.g., via resale on eBay) creates the need to better track the environmental impacts of each user.

While traditionally, the full life cycle impacts of a product were associated with its producer, in recent years, environmental accounting methods have been slowly converging towards consumption (rather than production) based approaches. Consumption based approaches are based on the premise that demand for new products is the key driver for production. As such, they hold the agents who benefit from the products (e.g. countries, companies, households, consumers) responsible for the environmental impacts associated with their purchases regardless of where such impacts might accrue (Wiedmann et al. 2013; Ivanova et al., 2016; Kanemoto et al. 2016). Consumption based allocations have been instrumental in demonstrating the significant impacts of household consumption as well as the fact that developed countries have essentially outsourced pollution and environmental degradation, yet benefit from the utility delivered from product produced elsewhere.

Critically however, consumption based allocations typically overlook the role that secondary consumers play in driving primary production. This is problematic given that trade volumes in secondary markets (e.g., second hand markets, sharing economy) often surpass those of primary ones. Moreover, in the rare cases where secondary consumption is considered, it is commonly assumed to generate net environmental benefits. Research however, suggest that secondary consumption can also increase (and not only decrease) demand for primary production (i.e. production of new products). Some studies suggest that second hand markets stimulate new production, for example by allowing consumers to sell their older products and use the earnings towards the purchase of new units (Chu and Liao 2010; Waldman 2003; Cooper and Gutowski 2017). In addition, the presence of secondary markets might encourage manufacturers to introduce new products at greater frequency, or to increase prices for new units to capture the surplus of secondary markets as well (Yin et al. 2010).

Furthermore, secondary consumption as well as systemic differences in product design, quality, and branding affect the overall lifespan of products. As a result, even within the same product category, the utility products deliver at each stage of their use phase and their overall lifespan is not uniform. For example, some car models retain their value better and outlast other, similar car models. Additionally, lifespans are not constant and can change over time (REF). Current environmental accounting methods however, seldom take into account within category differences in product lifespans nor do they consider how secondary consumption and reuse, in all its mired forms, can change the environmental performance of products. In sum, to truly link the impacts of production to the agents driving its demand, environmental accounting methods should incorporate secondary consumers as well.

Methods

In this work we explore the following: (1) How to extend consumption base footprint principals when there is more than one user?; (2) How to divide the environmental impacts of new products that were used for very short time by the first user and were them sold to another user;

To this end, we propose a new method to allocate products' environmental impacts across all the users products might have over the course of their full lifespan according to their market depreciation (i.e., value loss). While depreciation is not a direct measure of the way secondary users impact demand, in a free market context, it reflects the amount of utility (i.e. benefit) to be gained from previously owned products. As such we argue that depreciation is well aligned with the basic premise that those benefiting from consumption should be held accountable for its impacts.

Specifically, we suggest using LCA in conjunction with market data on product depreciation to equitably allocate environmental impacts among multiple agents in both primary and secondary markets. Our method suggests that fixed environmental impacts (i.e. those related to materials, production, transport and EoL) be associated with pre-resale and post-resale 'lives' based on economic value retention. For example, if a consumer choses to sell her car after the first year of use, the share of fixed environmental impacts associated with the 1st life period (i.e. pre-resale) will be proportional to the overall share of value lost during that year.

For each product, we demonstrate the equations we used to calculate three parameters: the market depreciation, the climate change impact for the pre-resale stage, and the climate change impact in post resale stage. We also discuss methods to obtain depreciation data then demonstrate how to use LCA data for that purpose.

Modelling Approach: Cell phones

Depreciation model in this case was based on analysis of almost 500,000 listings from eBay from 2015-2016. We have estimated the depreciation curves based on econometric analysis we have done. We then used published life cycle GHG data from Apple Inc. downloaded from their website to calculate the pre and post sales emissions distribution. For full description of this evaluation, please refer to Makov et. al, 2018. The equations are listed below:

Market Depreciation

$$\%\text{VALUE LOSS}_m = 100\% \times (1 - (\text{eBay resale price}_m / \text{U.S. retail launch price}_m)$$

Pre-resale CC impact

$$\%\text{VALUE LOSS}_m \times \text{fixed CC impacts}_m + \text{AGE}_m \times \text{monthly CC impacts}_m$$

Post-resale CC impact

$$(1 - \%\text{VALUE LOSS}_m) \times \text{fixed CC impacts}_m + (\text{maxage}_m - \text{AGE}_m) \times \text{monthly CC impacts}_m$$

Modelling Approach: Passenger Vehicles

Depreciation model in this case was based on available market data. We chose three similar vehicles and for each of them the original retail price at launch (i.e. MSRP) and historical prices were obtained from the official website for the National Automobile Dealers Association (NADA website).

For all models, historical prices represent clean retail prices in California on January 1st of each year between 2001-2018. We chose California since it is the largest car market in the US. The equation is as follows:

$$MARKET\ DEPRECIATION\ it = 100\% \times \left(1 - \frac{resale\ price}{US\ retail\ launch\ price}\right)$$

We then calculated GHG emissions based on LCA we performed for each model according to its specifications. All emissions related to maintenance and fuel consumption (direct and embodied) are considered use phase impacts. All emissions related to the other life stages are considered fixed.

Specifically, impacts associated with pre-sale were derived my multiplying the share of value lost by overall fixed impacts, while impacts associated with post-sale were derived by multiplying the share of value maintained by overall fixed costs. Since average miles driven per year tends to decline with vehicle age, overall mileage travelled by Jan 1st of each year was calculated based on mean miles travelled by passenger vehicle in the US. We then used distance traveled by multiplying emission per km by the sum of km traveled before sale to calculate the use phase impacts.

Results

Cell phones

Our results first show (based on figure 1) that the life time of Samsung and Apple phones can reach five and six years in practice, suggesting that the two-three years use phase estimate used in many LCAs is likely not accurate enough. Second, in the cell phone case, where 80% of the product life cycle emissions are at the production phase, we show that substantial portion of the production related GHG emissions should be allocated to secondary consumers (i.e. post-resale transaction; see Figure 2). In contrast, methods that allocate all production related impacts to the first users, and consider only direct use phase impacts for secondary consumers (e.g. electricity) lead to lower emissions attributed to secondary consumption.

Passenger Vehicles

In the vehicles case, we find that on average in the US people sell new cars after 6.6 years and they reach their end of life stage after 11.6 years (figure 3). Since in vehicles 80-85% of the product life cycle emissions are at the use phase (when burning fuel), our results suggest that allocating the fixed costs of vehicle production to secondary consumers is less critical as production is only a small portion of the total GHG emissions (Figure 4).

Conclusions

In contrast to allocating impacts based on use time alone, our method accounts for the fact that in some cases the functional utility products can provide declines over time. In addition, we propose that use phase impacts be modeled in accordance with product age and location appropriate use patterns. For example, it is well documented that vehicles' annual travel distances decline over time. Thus, we argue that the use phase for the 1st life period be modeled based on average distance traveled during a vehicle's first year of life. Our findings suggest that depreciation based allocation is particularly relevant for products with large production phase impacts, and illustrates the importance of accounting for secondary users' specific use patterns (such as location and use length) in LCA modelling. In addition, our analysis provides insight into the actual lifespan of product with multiple users (for example 5-6 years for cell phones compared with 18-24 months cited in literature). Such analysis provide evidence based use phase data that can help to improve use phase assumptions when conducting or updating LCA data.
If circular and sharing economy will continue to be increasing trend and policy targets, the need to calculate consumption base footprint will grow and therefore our suggested method could be useful and practical. Finally, paralleling economic and environmental methods might help to push managers and policy makers to adopt eco-efficiency measures in a more intuitive way.

Figures and Tables

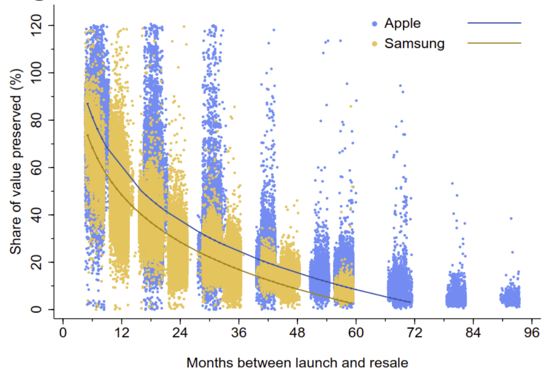

Figure 1. Phones: Smartphone depreciation curves (Adapted from Makov et. al, 2019).

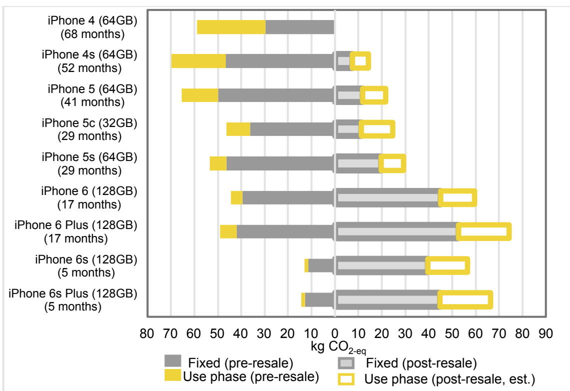

Figure 2. iPhones – Pre-resale and post-resale related emissions.

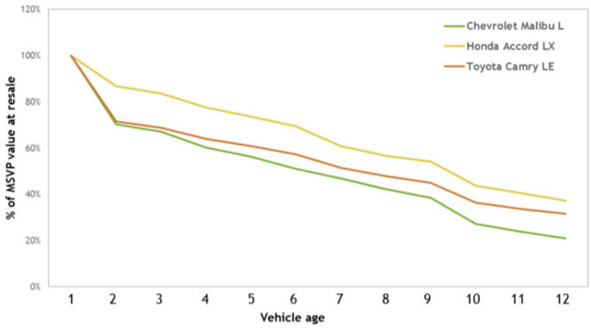

Figure 3. Cars: depreciation curves.

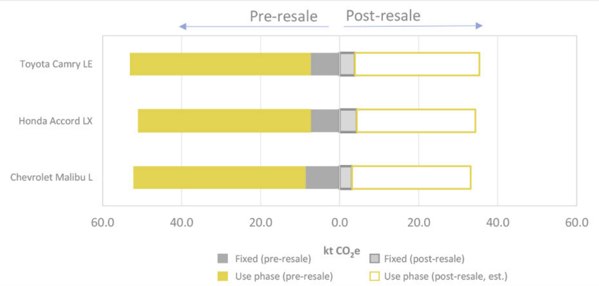

Figure 4. Passenger vehicles – Pre-resale and post-resale related emissions (production + fuel).

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