Evaluating the sustainability impacts of the sharing economy using input–output analysis

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1. Introduction

Although sharing has been practised for millennia in different societies, today, the emerging notion of the sharing economy (SE) is regarded as a new social phenomenon. It refers to various forms of transactions between strangers enabling access to goods without ownership, utilizing the capacity of privately owned assets not currently in use and exploiting the benefits of information technologies to reduce transaction costs.

Recent studies define SE as peer-to-peer (P2P) sharing of underutilized assets among strangers without a change in ownership (Botsman and Rogers, 2011; Owyang et al., 2014; Codagnone and Martens, 2016). Such a definition excludes many business-to-consumer (B2C) business models that purposefully acquire assets for sharing (Belk, 2014). Umbrella terms, such as access-based (Bardhi and Eckhardt, 2012), collaborative consumption (Botsman and Rogers, 2011) or the SE (Schor, 2016) are often used to refer to a variety of consumption forms. Frenken (2017), for example, distinguishes four models of collaborative consumption: sharing, on-demand access, second-hand markets and product-service systems. In this chapter, SE is defined as P2P transactions granting access to physical goods and services and facilitated by digital platforms (Frenken and Schor, 2017).

SE is often associated with positive socio-economic and environmental benefits. SE could, for example, provide a step towards cost-effective and resource-efficient livelihoods in less affluent societies. SE can enable access to goods or services to people who currently could not afford to buy or access them. Some of the frequently advertised benefits of SE include resource savings, participatory democracy, better quality of life, access to more goods and services at lower cost, flexible working hours and new earning opportunities.

However, the overall effects of SE on economic growth, employment or the environment are still underexplored and a better understanding of these impacts is needed to support policies that could steer the more sustainable evolution of SE.
Comprehending the complexity of these effects requires the analysis of cross-sectoral interactions and behavioural responses to SE activities. This chapter discusses the methodological and data challenges of analysing the effects of SE using static macroeconomic modelling frameworks, such as environmentally extended economic input–output (EE–I/O) analyses. A hypothetical case of car sharing (CS) will be used as an illustration in this chapter.

2. The multi-faceted effects of sharing economy

The discourse on the sustainability potential of the is SE generally positive and the environmental benefits are often taken for granted and directly associated with resource efficiency. However, much of the existing research lacks insights into consumers’ behavioural responses and the complexities of cross-economic consequences for production value chains (Codagnone et al., 2016a; Goudin, 2016; Frenken and Schor, 2017). A lot of research is largely qualitative and the empirical evidence of the costs and benefits of SE is inconclusive and patchy (Codagnone and Martens, 2016).

Some of the negative impacts of SE highlighted in different studies include the exploitative nature of the labour force (Schor, 2016). Commercial sharing platforms primarily follow an economic rationale and are not always necessarily ‘green’ or ‘fair’. Schor (2017) argues that ‘gig economy’ platforms reduce employment opportunities for less-skilled people since better-educated service providers now take supplementary jobs, such as driving, cleaning and other household errands. There has been increased media coverage about different controversies and legal disputes regarding the impacts of large platforms such as Uber and Airbnb, including labour rights, social protection, wages, property prices and rents and job losses in the incumbent businesses. In SE, participants face poorly defined liability rules and consumer protection. Governments anticipate a potential loss of tax revenues and difficulties in formalizing and enforcing their fiscal policies, and the incumbent formal business actors expect more competition and erosion of their revenues (Miller, 2016). The economic and competitive advantages offered by SE can partly be viewed as due to the non-compliance of current social norms in some countries, as highlighted in several studies on social impacts of SE (for example, Stokes et al., 2014; Katz, 2015; Martin, 2016). This has indeed prompted a regulatory debate which has polarized into a ‘liberal’ side advocating less regulation and a ‘moderate’ side proposing innovative and smart forms of regulation (Codagnone and Martens, 2016). Owing to these concerns, some reviews of different media sources conclude that public rhetoric on the promises of SE is probably changing from generally positive and praising to less optimistic (Codagnone et al., 2016b).

Other SE externalities include the negative environmental and social implications of induced additional consumption (Denegri-Knott, 2011) and their rebound effects (Demailly and Novel, 2014; Verboven and Vanherck, 2016; Frenken, 2017; Frenken and Schor, 2017). The direct rebound effects refer to increased demand
when technological or organizational improvements lead to lower prices of goods and services.\footnote{Indirect effects are secondary increases in consumption of other goods and services when the residual savings from the consumption of primary goods and services are made available. Readjustments to final demand can cause further ripple effects throughout the entire economy by adjusting prices and total outputs in many sectors. These effects can also move across national borders with consequences for employment, economic growth and the environment as the footprints of the additional consumption might be higher than those reduced by sharing.}

Various potential impacts of sharing assets mentioned so far can be illustrated by a simplified causal loop diagram (CLD) as shown in Figure 5.1. CLDs facilitate qualitative understanding of interrelationships between different variables in a system via feedback loops, which can reinforce (R) and balance (B). CLDs connect variables in a system by representing causal relationships between variables and indicate how

![CLD diagram showing various reported and potential impacts of a generic sharing system](image-url)

**Figure 5.1** CLD representing various reported and potential impacts of a generic sharing system

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a causal relationship reacts to a change by using positive or negative polarity. In the case of positive polarity, the variables move in the same direction (increase or decrease) towards a change in the variables and vice-versa (Lane, 2008).

SE has been growing rapidly across many sectors, but the sustainability implications and the rebound effects of SE are still largely unknown. The inconclusiveness of the overall impacts of sharing and the recent controversies surrounding the unintended negative impacts of SE call for systematic evaluations that could guide a more sustainable evolution of SE (Goudin, 2016). A systematic assessment is essential in order to assist possible regulatory interventions to steer a more sustainable development of SE.

Some of the key social, economic and environmental implications of SE can be summarized as in Table 5.1. These implications have varied impacts across stakeholders, value chains and nations, depending on the current structure of regulations and institutions in the society. This implies that some stakeholders or parts of society are more vulnerable (than others) to the negative implications of SE. The following sections provide an overview of different modelling approaches and their strengths and weaknesses for evaluating the impacts of SE.

### 3. Limitations in sustainability evaluations of sharing economy

Although SE exists in several economic sectors, research on its environmental implications has focused mainly on CS and accommodation sharing using case studies of large international sharing platforms like car2go, Lyft, Uber and Airbnb. Many of the existing environmental evaluations of SE are made or facilitated by commercial platforms and they sometimes lack methodological transparency. Moreover, many environmental evaluations have limited scope focusing largely on the direct implications of reduced consumption induced by sharing within a particular product group. Airbnb, for example, has reported environmental gains in energy (78%), water (48%), waste (32%) and greenhouse gas emissions (89%) by comparing a typical occurrence of home sharing with staying in a hotel (Airbnb, 2018). At the same time, studies are often not transparent about methods and system boundaries used or the assumptions made (Codagnone et al., 2016a). Studies conducted by the sharing platforms may overestimate environmental benefits by including only the impacts of sharing and excluding the rebound effects.

Many studies have compared CS to car ownership and explored its environmental impacts (Martin and Shaheen, 2011a; Zhou and Kockelman, 2011; Fagnant and Kockelman, 2014; Santi et al., 2014; Chen and Kockelman, 2016a; Nijland and van Meerkerk, 2017). In many cases CS exhibited environmental gains due to reductions in driving distance, vehicle ownership rates and parking space used. For example, a shared car in the UK removed 3.5 to 8.6 new and second-hand private vehicles from the road (Steer Davies Gleave, 2016), while in the USA, this replacement was
estimated as 9 to 13 cars with a reduction of household driving distance of 27 to 43 per cent (Shaheen et al., 2015; Martin and Shaheen, 2016).

However, overall environmental gains can be different if changes in other systems and the rebound effects caused by sharing are included. As discussed, SE may not necessarily lead to less consumption since access-based consumption models could contribute to significant changes in disposable income and the reallocation of spending (Verboven and Vanherck, 2016). Zipcar, for example, estimates up to USD 5000 in annual savings for car owners who have moved to CS (Zipcar, 2018). Providers of shared assets, for example Uber, Lyft and Airbnb, can attain additional income between USD 2000 and USD 5000 per year (Earnest, 2018). Environmental evaluations also point to data uncertainties that are often based

Table 5.1 Sustainability implications of SE

| Impacts | Social | Economic | Environmental |
|---------|--------|----------|---------------|
| Direct  | • inclusive participatory service democratization using fair rating systems (+) • flexible working hours (+) • social cohesion (+) • access to services to broader societal groups (+) • increase of jobs in sharing sectors (+) • potential exploitation of work force (−) • risks with non-compliance of social norms (−) | • new economic opportunities for providers (+) • lower cost of per unit service for users (+) • revenue generation through taxes for local governments (+) • growth of new sectors (+) • rapid economic depreciation (−) | • dematerialization of per unit service (+) • utilization of idle resources (+) • additional consumption due to lower per unit prices (−) • accelerated asset depreciation (shortened lifetime) (−) |
| Indirect | • reallocation of employment opportunities (−) • could make some workforce more vulnerable (−) • decrease in jobs negatively impacted incumbent sectors (−) | • additional economic growth due to increase in public spending (+) • negative economic impacts on incumbent businesses (−) • revenue losses by competing businesses (−) • may cause unintended negative cross-sectoral impacts (−) | • additional consumption of other products or services due to income effects (−) |

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on self-reported surveys, which are subject to inaccuracies, exaggerated travel behaviour, misestimates of travel distances, induced changes in car ownership and assumptions regarding the use of other travel modes induced by sharing activities.

More accurate estimates require collaboration with CS platforms and companies; however, businesses are often reluctant to disclose this information due to matters of individual privacy and the proprietary nature of the information (Shaheen and Cohen, 2018). Table 5.2 presents some studies that have evaluated the sustainability impacts of SE in the CS sector and which employ different modelling approaches ranging from life cycle assessment (LCA) to EE–I/O analysis as well as hybrid methods.

The main difference between LCA and EE–I/O analyses is the type of data they rely on, that is, bottom-up and top-down data. LCA represents a bottom-up approach that uses environmental assessment based on the life cycle perspective. It requires the collection of data on input materials, energy carriers, land resources and the associated emissions and wastes for each small process unit. As unit process data are usually derived from direct measurements and surveys of companies and facilities manufacturing products of interest, LCAs can potentially be quite accurate and product- and process-specific, if high-quality data is used. However, LCAs are data intensive and time-consuming and require high technological, time and geographical representativeness of data. The lack of process-specific data can often result in the use of data from generic processes based on averages or unrepresentative sampling. Furthermore, the ambition of mapping the details of the entire life cycle system can result in highly complex systems of interlinked unit processes, especially in the upstream sections of the production chain. This often requires introducing upstream system boundary cut-offs, which result in truncation errors (Pomponi and Lenzen, 2018).

EE–I/O is a classic representative of a top-down assessment approach based on economic input–output (I/O) analysis. It uses aggregated sectoral data derived from national statistical accounts describing economic inter-industry relationships, factor inputs and total outputs for final consumption. The I/O framework allows modelling of the way changes in final demand will be reflected in the outputs of regional economic structure in the directly affected sectors and also the indirect changes in other sectors (a very detailed methodological description of I/O is provided by Miller and Blair, 2009). The I/O framework was developed in 1930s by the Nobel Prize winner Wassily Leontief; today, most industrialized countries use it in macroeconomic assessments. In the 1970s, the I/O framework began to be applied to environmental assessments and was formalized as environmentally extended I/O (EE–I/O) models. Here, the economic or physical transactions reflected in I/O tables are combined with satellite environmental accounts (for example, emissions, energy, waste, land use) using Leontief’s premise that any industrial output needs not only the intermediate inputs from other sectors but also ‘requires’ the emissions and other environmental loadings that accompany
| Modelling approach | Impacts analysed | Method employed | Type of data used | System boundaries |
|-------------------|-----------------|-----------------|------------------|-------------------|
| Bottom-up-based model | GHG savings due to: car mileage and car ownership rates (Martin and Shaheen, 2011a) | Different models of car fleet systems, LCA | Online user survey on type of vehicle and vehicle kilometres travelled | Only environmental impacts from driving considered; social and economic rebound impacts excluded. Vehicle depreciation not included |
| | Car ownership rates and extent of private car use (Nijland and van Meerkerk, 2017) | | User survey on changes in mobility pattern | Rebound effects not considered. Vehicle depreciation not included |
| | Changes in mobility patterns, user behaviour, costs, parking and newer vehicles (Baptista et al., 2014) | | User survey of consumer behaviour and life cycle inventory data of the vehicles |
| | Changes in overall mobility pattern (Lane, 2005) | | User survey of changes in modal split due to car sharing |
| Top-down-based model | Material efficiency and employment impacts (Cooper et al., 2016) | Multi-regional input–output (MRIO) model | Material flow inventory and economic data for material efficiency improvements in mobility and construction sectors |
| Hybrid models | Changes in passenger mileage, transport mixes (Briceno et al., 2005) | LCA and EE-I/O | Consumer expenditure on transport sector |
| | | | Direct rebound effect from household spending. Indirect rebound impacts from the consumption of other products excluded |
these inputs (Leontief, 1970). The environmental data are normalized per unit of total output from a particular sector and are treated the same way as other production factors, such as capital and labour, in the I/O framework. As EE-I/O analysis is based on I/O data, it avoids the truncation errors characteristic of LCAs. On the other hand, the I/O-based analyses suffer from high data aggregation, poor capture of post-consumer life cycle stages and the inherent assumptions regarding price homogeneity and uniformity of outputs from each industrial sector. The inherent strengths and weaknesses of LCAs and EE-I/O approaches are summarized in Table 5.3.

A promising way forward is the exploitation of the strengths of LCA and I/O in hybrid-LCA approaches, which are viewed today, at least in academia, as the state of the art in product life cycle assessments (Wiedmann, 2009). Information from the I/O framework allows a more informed selection of system boundaries and the capture of the impacts of upstream processes, whereas LCA-based data allows a more process/product-specific analysis and the capture of the impacts of post-consumer life cycle phases. The International Journal of Life Cycle Assessment has been providing extensive research coverage of LCA, I/O and hybrid approaches since 2003 (Suh, 2003).

Employing LCA, I/O-based and hybrid approach methods to evaluate a relatively new consumption model such as SE presents numerous challenges and creates new research needs. In this chapter, we highlight some of these challenges and new research needs while employing the EE-I/O framework to evaluate the sustainability implications of SE. We will discuss how, in view of the multi-faceted impacts of SE that span value chains and territories, top-down modelling approaches and hybrid models employing input–output analysis can be employed. To illustrate this, we will use the hypothetical example of generic CS without distinguishing between B2C or P2P types of sharing.

4. An example of I/O-based sustainability assessment: The case of car sharing

4.1 Causalities in car sharing

A wealth of studies exist that explore the environmental implications of CS in different countries (Martin and Shaheen, 2011a; Sioui et al., 2012; Clewlow, 2016; Feigon et al., 2016; Martin and Shaheen, 2016; Stapleton et al., 2016; Becker et al., 2017; Livingston and Storer, 2017; Shaheen and Cohen, 2018). These studies indicate that the emergence of CS practice usually leads to direct changes in households’ disposable income, consumption patterns for transport services and of other goods and services, as well as indirect changes in employment and economic outputs of other sectors. The main variables determining the direct environmental implications of CS are changes in the modal split of transport, disposable income, demand for personal vehicles and emission factors of the vehicles used. Figure 5.2 describes different consumption causalities using CLD as well as
| Modelling approaches            | Examples                      | Strengths                                                                 | Weaknesses                                                                                                                                 |
|--------------------------------|-------------------------------|--------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|
| Bottom-up-based models or life cycle-based | Life cycle assessment         | ● Allows high level of data specificity                                   | ● Introduces truncation errors due to system boundary cut-offs                                                                         |
|                                 |                               | ● Better for consequential simulations with marginal data (in case consequential approach is taken for allocation and marginal changes) | ● Not suitable for evaluating cross-sectoral economic implications                                                                       |
|                                 |                               | ● Better for evaluating direct impacts                                    | ● Demands large amount of data                                                                                                          |
|                                 |                               | ● Addresses truncation errors of life cycle-based approaches for upstream processes | ● Prone to random errors due to varying data quality                                                                                   |
|                                 |                               | ● Suitable for evaluating cross-sectoral implications                      | ● Unrealistic assumptions regarding sectoral/commodity homogeneity and price proportionality relative to scale of activities             |
|                                 |                               | ● Availability of databases at various regional and international aggregations of economy | ● Does not reflect well on product end-of-life phase                                                                                     |
| Top-down-based models           | Input–output analysis, general economic equilibrium models | ● Allows reducing the potential errors due to sectoral aggregation         | ● High level of data aggregation                                                                                                        |
| Hybrid methods                  | Hybrid I/O analysis           |                                                                          | ● Requires data specificity, can be data-intensive                                                                                       |
showing the various driving mechanisms of the changes induced by household participation in CS.

One of the main factors influencing changes in original consumption for households participating in CS is the different cost structure compared to car ownership. In the latter, households have to pay for the initial investment, operation, service and maintenance costs, insurance and road taxes. For CS users, all these costs are internalized in the pricing of CS schemes and some of these costs are shared with other users. Although the marginal costs of using CS mobility services are relatively higher than those of private cars, these are much lower than the total ownership costs of private cars. Until a certain threshold of distance driven is reached, the annual costs of CS are lower than those of a private car. Indeed, many studies point to cost savings as the prime reason for participation in CS. Therefore, CS can generate significant economic savings in mobility expenditure (reinforcing the feedback loop: R1 Savings in Figure 5.2). These savings may induce changes in overall transport demand, leading to direct rebound effects (B2, Figure 5.2) due to, for example, longer driving distances or an increased use of public transport and other...
means of transport, as identified in several studies (Martin and Shaheen, 2011b; 2016; Shaheen and Cohen, 2018). In addition, the economic savings could also influence overall consumption patterns, thus resulting in changes in final demand for some of the industrial sectors depending on how and where the savings are spent (indirect rebound effects R2, Figure 5.2).

From the consumer perspective, changes in the personal mobility bundle described by the amount of transport demanded from different transport modes (cars, bus, train, cycling or walking) lead to direct impacts (balancing feedback loop B2: Direct rebounds, Figure 5.2). The reallocation of household expenditure on other products and services can lead to the indirect impacts (reinforcing feedback loop R2: Savings-induced consumption, Figure 5.2). The additional income of CS providers also belongs to this category. However, it is also possible that less money would be available for expenditure on other commodities. Therefore, an evaluation of the sustainability profile of CS also requires information on any changes in demand for new products and services enabled by extra savings/income. This demand can be assumed to be either an elastic function of the savings/income (for instance, the new demand will increase or decrease proportionally for all products and services) or a combination of elastic and inelastic functions (for instance, an increased propensity for demand of certain type of products and services). Furthermore, the broader intersectoral impacts of the changing consumption patterns can include changes in employment (balancing feedback loop B3: Employment, Figure 5.2).

From the producers’ perspective, changes in final demand for private vehicles can result in direct and indirect effects due to the accompanying changes in other supplying sectors (balancing feedback loop B4 and reinforcing feedback loop R3, Figure 5.2). A sustainability evaluation could also include broader systemic ripple effects generated due to overall changes in employment, environmental impacts and economic growth.

4.2 Implications for modelling impacts from changes in consumption patterns

This section describes some implications for modelling changes in consumption patterns and the subsequent impacts on producing sectors.

4.2.1 Profiling users of car sharing

Modelling consumer behaviour in CS schemes requires greater understanding of users. Cervero et al. (2007), for example, suggest that potential users of CS are people who use their cars less frequently, live in higher density areas and have better access to alternative mobility services. With typical car ownership costs and prevailing CS prices, CS is an economically feasible option when compared to car ownership if annual personal car use is less than 12 000 to 15 000 km (Loose, 2010). Understanding users is therefore essential for analysing impacts caused by changes in overall mobility profile, financial savings and expenditure patterns.
4.2.2 Changes in mobility bundle

The shift to CS implies changes in the mobility bundle with regard to modal split and distances travelled. The overall vehicle kilometres of travel (VKT) could be reduced since CS often leads to 10–20 per cent more walking and biking (Lane, 2005; Martin and Shaheen, 2011b). Since the marginal costs of CS use are much higher than those for private cars, CS can significantly decrease their vehicle mileage (10 to 20 times less) and also increase walking/cycling and the use of public transport (up to 10% more) (Lane, 2005). Meanwhile, users who did not own a car could now increase VKT and decrease the use of public transport. The overall effect will be highly contextual and location-specific; however, the majority of studies agree that CS generally facilitates more use of public transport and reduces overall VKT (for example, Chen and Kockelman, 2016b).

4.2.3 Emission factors of vehicles in car sharing

Generally, vehicles used in B2C CS schemes have a better emissions profile than the average national fleet since their vehicles are usually smaller, newer and have a higher share of hybrid or fully electric cars. The difference in average CO2 emissions between private and CS vehicle fleets is estimated in the range of 15–35 per cent (Loose, 2010; Steer Davies Gleave, 2017). Thus, when evaluating the direct environmental impacts of CS, it is important to differentiate between B2C and P2P CS segments. It is likely that vehicles provided by P2P schemes have an emissions profile closer to the national average. P2P providers, on the other hand, largely exploit the underutilized potential of their existing vehicles and want to make extra income from unused resources. Indeed, very few P2P providers share new vehicles so they can recuperate high initial investment. B2C providers, on the other hand, often cooperate with car manufacturers utilizing their premium leasing schemes to facilitate user access to the latest car models with the latest engine technologies and highest emissions standards. Vehicle occupancy rate is another important parameter that must be included when evaluating the emissions factor as this could significantly differ between shared and private cars.

4.2.4 Car ownership effects

It is estimated that CS can lead to car shedding effects of 10–20 per cent (Cervero et al., 2007; Zhou and Kockelman, 2011). However, there is no consensus regarding these estimates. Although CS has been praised for its potential for reducing private car ownership and freeing up parking spaces, this does not necessarily mean that the number of cars in traffic will be reduced. There could also be unintended impacts due to significant numbers of users opting for CS and diverting some users away from public transport. CS can influence overall demand for new cars and therefore the automobile manufacturing industry. Market research suggests this affect could range from mild/positive to neutral in the worst-case scenario (Cornet et al., 2012).
4.2.5 Final consumption bundle

Evaluation of the impacts of CS on final household demand implies the analysis of any changes in final consumption expenditure after a household has begun to engage in sharing activities. In the case of CS, this involves the analysis of new expenditure on CS services, reduced private car ownership expenses and more expenditure allocated to public transport as well as potential savings that are reallocated to the consumption of other products and services (as described in Figure 5.2).

The sustainability implications of the above-mentioned consumption patterns using I/O analysis require an examination of any changes in final (largely household) demand. New final demand requires information about annual savings from removing car ownership costs, annual depreciation, fuel costs, insurance and taxes, and service and maintenance costs. Savings can be counted as extra income available for new mobility demands and/or other products and services. New mobility demand, that is, the modal split between CS, public transport, taxis, walking or biking, could be estimated from household travel surveys, consumer expenditure surveys or complimentary case-based empirical observations. Empirical observations could assist in providing scenarios for disposable income being spent on other products and services.

4.3 Implications for modelling impacts from changes in production sectors

4.3.1 Disaggregating an sharing economy sector

Current input–output tables (IOT) lack detailed information on intersectoral impacts (for instance, the production recipes) of SE sectors. Thus, some sectors may require disaggregation in order to include these impacts. In disaggregation, additional sectors are created by adding rows and columns into the existing IOT. Creating a new hypothetical sector in EE-I/O framework requires data on the intersectoral production inputs required to produce the product or service in question and the environmental burdens of their production process. The economy-wide environmental burdens of one unit output of the sector can then be estimated. Joshi (1999) provides methodological recommendations in the examples of Models II–IV. Existing IOTs may contain the transactions of formal businesses engaged in SE transactions, which, under Standard Industrial Classification (SIC) categorization are likely to be included with the traditional industrial sectors such as ‘taxi services’ or ‘car rental services’. This could present challenges for an estimation of the share of the total output of the CS sector and of the share of different types of business models such as B2C and P2P sharing.

The production recipe for CS (the intermediary industry requirements matrix column, Figure 5.3) can be assumed to be representative of the sectors from which they are drawn (for instance, the original technical coefficient matrix is unaffected by the introduction of the new sector). It can be assumed that CS requires similar
amount of inputs from the same industrial sectors as the rental sector. CS can require different inputs from other sectors such as administrative services, insurances and repair or vehicle capital depreciation due to significant differences in the type of vehicles in the sharing fleet and their depreciation rates. This would require empirical information on sharing business models (design, revenues, pricing and cost structure), factor inputs (capital, labour and taxes), asset characteristics (utilization/replacement rate, energy/material intensity) and environmental data (energy, emissions, materials). Similarly, the new CS sector as a producer (a new row representing a disaggregated new sharing sector in the I/O table in Figure 5.3), requires estimates regarding the outputs of this sector to others. The output to some sectors can be assumed to be proportional to the existing rental sector. However, in the case of a large share of mobility services used by private individuals, the output coefficients must be adjusted using expert estimates and available statistics. Depending on the scale of the disaggregated sector, IOT may require rebalancing. Indeed, this could be the case for some SE sectors, such as shared mobility or accommodation sharing, which can have a significant impact on the incumbent sectors and the entire regional economy. Methodological advancements and alternative methods for matrix balancing are provided, for example, by Lenzen et al. (2009) and Junius and Oosterhaven (2003) with their KRAS and GRAS methods for matrix rebalancing, respectively.

5. Reflections

This section presents some of the key challenges and future research needs in the context of evaluating the sustainability impacts of SE.
5.1 Challenges

The main challenges to evaluating the sustainability implications of SE are not due to lack of methods or assessment frameworks but to lack of data. The challenges include the diversity of SE business models, poor information about sharing activities between individuals and difficulties in measuring potential non-monetary transactions (Office for National Statistics, 2016). Data on the size of various market segments of the SE are unreliable due to the lack of a shared definition for SE.

Existing national economic accounts have been assembled for the SIC where companies in traditional manufacturing and service sectors are clustered by commonly established characteristics of their outputs. SE does not fit within this classification system; indeed, SE is often classified under standard sectoral codes along with other traditional business activities. The fact that SE is not a separate sector, but rather a cluster of transaction models, complicates the collection of statistical information. A shared understanding of SE and its characteristic business models could facilitate the standardization of statistics.

Another issue is that not only companies (for instance, formal economic entities), but also private individuals engage in sharing activities. Estimating the value of SE transactions using current official statistics is difficult because economic exchanges between individuals are not included in gross domestic product or the consumer price index (CPI). At best, in theory, only the formalized part of exchanges could be measured. For example, statistics authorities could track B2B and B2C production, expenditure and income. However, individual revenues from sharing are not accounted for in national statistics due to underreporting or being under the taxable threshold.

It would be feasible for businesses facilitating for-profit platform services to account for sharing revenues. However, many SE platforms offer flat-rate membership fees, not-for-profit services run on donations or free labour input from participants, or there are non-monetary exchanges (for example, reciprocal services).

Assumptions regarding homogeneity and proportionality in the I/O framework could pose challenges. For example, using the existing satellite accounts in environmental evaluations may significantly differ for sharing. Indeed, CS belongs to the ‘taxi, car rental and leasing of personal vehicles’ sector, but the emission factors of vehicles in CS can differ significantly from the average emissions in this sector, due to large share of relatively new and electrical vehicles in the fleet.

Other models, such as econometric or computable general equilibrium (CGE) models, could be suitable for modelling dynamic price–volume relationships in economies of scale. However, these demand much more information about the economic system and rely on assumptions with regard to current and future behavioural responses, which introduces a high level of uncertainty into the results. CGE models would be more suitable for modelling old established economic sectors.
with ample historical data and relatively less dynamics when compared to emerging markets, such as the SE.

6. Need for future research

In order to employ the I/O approach in sustainability evaluations of SE, existing national accounting frameworks would need to accommodate the specifics of emerging SE, including its diverse business models. This would require detailed information on the various inputs and outputs of sharing businesses, for example: total turnover, employment costs, total purchases, profit margins, duties, levies and taxes, the value of acquisitions of a capital asset, shares of imports and exports, and spending on capital assets. Furthermore, data is needed on specific environmental intensities of SE business models, especially in the dominant SE segments such as accommodation, space, mobility and household goods.

Better measurements of labour inputs and annual income in SE are needed (for example, employment status, hours worked, earnings and type of work). Behavioural studies could be devised to better understand consumer responses to the income/savings from sharing activities. Time surveys could be employed to analyse the behavioural changes of households since time can be a limiting factor for emerging consumption patterns and, therefore, the environmental footprint of consumption (ESRC, 2018).

SE is a global phenomenon and analysing it through I/O framework requires a multi-regional perspective. Today significant advancements have been made in the development of multi-regional I/O tables (MRIOTs), including EXIOBASE, GTAP, EORA, WIOD and AIIOT (see Tukker and Dietzenbacher, 2013; Wood et al., 2014; Lenzen et al., 2017). These MRIOTs have varying resolutions and diverse geographical and sectoral coverage. Further work is needed to adapt these datasets to the needs of SE analysis, including the satellite environmental accounts in different databases, such as UNFCC, CDIAC and EDGAR.

NOTE

1 Research on the rebound effect has been extensively covered in journals such as *Energy Policy*, *The Energy Journal*, *Energy Economics* and *Journal of Industrial Ecology*.

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