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Carbon mitigation in domains of high consumer lock-in

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ABSTRACT

As climate policy needs to address all feasible ways to reduce carbon emissions, there is an increasing focus on demand-side solutions. Studies of household carbon footprints have allocated emissions during production to the consumption of the produced goods, and provided an understanding of what products and consumer actions cause significant emissions. Social scientists have investigated how attitudes, social norms, and structural factors shape salient behavior. Yet, there is often a disconnect as emission reductions through individual actions in the important domains of housing and mobility are challenging to attain due to lock-ins and structural constraints. Furthermore, most behavioral research focuses on actions that are easy to trace but of limited consequence as a share of total emissions. Here we study specific alternative consumption patterns seeking both to understand the behavioral and structural factors that determine those patterns and to quantify their effect on carbon footprints. We do so utilizing a survey on consumer behavioral, attitudinal, contextual and socio-demographic factors in four different regions in the EU. Some differences occur in terms of the driving forces behind behaviors and their carbon intensities. Based on observed differences in mobility carbon footprints across households, we find that the key determining element to reduced emissions is settlement density, while car ownership, rising income and long distances are associated with higher mobility footprints. For housing, our results indicate that changes in dwelling standards and larger household sizes may reduce energy needs and the reliance on fossil fuels. However, there remains a strong need for incentives to reduce the carbon intensity of heating and air travel. We discuss combined effects and the role of policy in overcoming structural barriers in domains where consumers as individuals have limited agency.

1. Introduction

Scientists and policy makers are increasingly calling for demand-side solutions for mitigating climate change (Creutzig et al., 2018; Wood et al., 2017). Shelter, transport, food, and manufactured products have been identified as high-impact consumption domains (Hertwich and Peters, 2009; Ivanova et al., 2016) and mitigation actions and targets have been suggested (Girod et al., 2014). However, targeting consumer behavior poses its own challenges (Barr et al., 2011; Dietz et al., 2009; Klöckner, 2015). Behavioral scientists have questioned the presumption of control consumers have over their consumption in the context of systematic barriers (Akenji, 2014; Sanne, 2002). Environmental footprints depend to a significant degree on external factors such as infrastructure and technology, institutions (e.g. social conventions, power structures, laws and regulations), and unsustainable habits, creating lock-ins (Jackson and Papathanasopoulou, 2008; Liu et al., 2015; Sanne, 2002; Seto et al., 2016). Such lock-ins reinforce existing social structures and may hinder a transition towards more sustainable systems (Geels, 2011), although opportunities for positive lock-ins have also been explored (Ürge-Vorsatz et al., 2018).

Here we explore the carbon footprints of mobility and housing, and the factors that may explain their variation. Mobility and shelter stand out among the highest contributors to the household carbon footprint (CF) in the EU (Ivanova et al., 2017, 2016), making their de-carbonization a high priority. While previous work has addressed some of these concerns in parts, this study integrates the investigation of attitudinal, structural and socio-economic factors of consumption choices and their CF in four EU regions, thereby enhancing policy relevance of the

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results.

The importance of context for behavior has been a longstanding theme in consumer behavior research, where studies have broadly explained behavior through individual and contextual factors (Ertz et al., 2016; Newton and Meyer, 2012; Stern, 2000). According to the low-cost hypothesis, attitudinal variables have less influence when a behavior is too difficult to perform (e.g. due to high structural barriers). Mobility and energy behaviors are identified as typical high-cost domains (Diekmann and Preisendörfer, 2003; Klöckner, 2015) as complex decisions, such as location of residence and vehicle ownership, define the use-patterns for a long time (Klöckner, 2015).

Most research effort on sustainable consumption focuses on either the physical dimension (technology, supply chains, urban form) or the social dimension (attitudes, behavior) (Banister, 2008; Thomsen et al., 2014). For example, studies on behavioral drivers generally do not introduce footprint controls and instead rely on measuring pro-environmental behavioral proxies. This may introduce a behavior-impact gap (Csutora, 2012) and lead to targeting the most visible, or easy, rather than the most environmentally relevant behaviors (Klöckner, 2015). In contrast, studies that focus only on the technical characteristics leave out important factors for consumption change, such as attitudes, habits, and behavioral plasticity (Dietz et al., 2009; Thøgersen, 2013). The importance of socio-economic effects such as expenditure and income (Ivanova et al., 2017; Minx et al., 2013; Wilson et al., 2013a), household size (Ala-Mantila et al., 2014; Minx et al., 2013; Wilson et al., 2013b), urban-rural typology (Ala-Mantila et al., 2014; Heinonen et al., 2013; Minx et al., 2013), demographics (Baiocchi et al., 2010) and car ownership (Minx et al., 2013; Ornetzeder et al., 2008) for the household CF has been widely discussed (see Supplementary Information (SI) table 15). However, prior work differs in fundamental ways in terms of unit of analysis (Ivanova et al., 2017, 2016), consumption detail (Newton and Meyer, 2012), and geographical coverage (Heinonen et al., 2013; Minx et al., 2013).

Here we examine individual-level behavior and carbon intensity determinants separately, which is not a common practice; we do so to uncover potential differences in their driving forces. Determinants may also be significantly interrelated, e.g. with urban cores exhibiting different incomes and household types (Ottelin et al., 2015). Therefore, we explore combined effects and their footprint implications. Furthermore, we evaluate potential emission trade-offs from other consumption areas. Focusing on a single consumption domain may overlook substantial rebound effects, e.g. where lowering of emissions in one domain causes emission increases in another (Hertwich, 2005; Ornetzeder et al., 2008; Wiedenhofer et al., 2013). For an adequate mitigation of greenhouse gas (GHG) emissions from the consumption side, we argue that several main facets need to be considered:

- lifecycle emissions from various consumption domains
- technical and social dimensions of mitigation potential
- lock-in effects

Our study is the first one, to our knowledge, to combine these considerations in an analysis of carbon emissions that integrates consumption-based accounting with determinants studies in a policy-relevant framework.

2. Data and method

We examined consumption patterns through a survey on behavioral, attitudinal, contextual and socio-demographic factors in a survey sample of four European regions: Galicia (Spain), Lazio (Italy), Banat-Timis (Romania) and Saxony-Anhalt (Germany). The total sample included 1617 respondents, of which 1399 (85%) and 1407 (87%) provided enough detail for mobility and shelter-specific calculations, respectively. Details about survey design, sampling and distribution can be found in the SI "Survey design".

Below we present the CF calculator used as an input to our statistical analysis. The design of the calculator was informed by prior product-level input-output assessments of household consumption (Ivanova et al., 2017, 2016) and mixed approaches to cover emissions and behavioral aspects (Birnik, 2013; West et al., 2016). We focus on the domains of mobility and shelter, with an additional estimation of food and clothing consumption, to capture most of the GHG emissions of European households. For survey background information, uncertainty and validation on footprint calculations, see the SI "Carbon footprint calculations".

2.1. Mobility footprint calculations

We collected data on transport means and distance of regular return trips, including active transport (walk, bicycle, e-bicycle), private motorized transport (car, motorbike) and public transport (bus, tram, underground, train). Regular travel distance (bottom-up) was validated with the annual top-down estimate that car users provided. Additional adjustments were made in the cases of carpooling. We assumed regular travel of 35 weeks/year for work purposes and 40 weeks/year for private purposes. Observations with annual land travel above 80000 km/year (or 220 km/day) were treated as outliers, conforming to the upper limit of the top-down car-travel range. Air travel was based on annual number of short- and long-haul return flights with assumed distance of 2300 and 8000 km/return trip, respectively. See SI "Carbon footprint calculations" for a detailed discussion of the distance assumptions. We treated observations with a number of return flights above 365 in a year as outliers.

The total carbon intensity of mobility results from dividing the mobility footprint by the total distance travelled. Lifecycle (indirect) emissions from cradle-to-gate and direct tailpipe emissions were based on lifecycle assessment (LCA) studies and the Ecoinvent database (GWP100 in $kgCO_2eq$/passenger km (pkm)) (Frischknecht et al., 2005). The emission intensity of electricity mix was considered where relevant (GWP100 in $kgCO_2eq$/kWh, Ecoinvent). We utilized car- and fuel-specific intensities where additional car and fuel data were available. We allocated emission factors for air depending on flight length (see Ross, 2009). Fig. 1 visualizes our sample's mobility CF as a function of distance travelled (x-axis) and carbon intensity (y-axis).

The mean and median of annual land-based travel was about 9500 km (26 km/day) and 4900 km (13 km/day), respectively (Table 1). About 13% of the land-based distance was travelled actively, with an average daily return trip of 6 km (for sub-sample estimates see SI Fig. 1). Our sample had active travel with annual emissions of 4 $kgCO_2eq$/cap. About 29% of distance on land was travelled by public transport, with an average trip of 19 km/return trip. Private motorized travel was 5500 km/cap on average (or 22 km/daily return trip), with a footprint of 1.2 tCO_2eq/cap. About 36% of respondents owned a car and used it alone, while 51% shared the car with other members of the household.

With about 47% of respondents travelling to short-haul destinations, air travel was the largest contributor to mobility emissions (Fig. 1). Air transport brought about an annual CF of 2.4 tCO_2eq/cap on average, compared to 1.5 tCO_2eq/cap for land-based travel (Table 1). These estimates seem higher than prior MRIO assessments, which may be due to the lack of consistency in reporting standards for air transport calculation (Usubiaga and Acosta-Fernández, 2015).

2.2. Shelter footprint calculations

Energy use covers use of electricity (ELEC), space heating (SH) and water heating (WH). Annual electricity consumption was derived from reported monthly payments in winter and summer, discounting any space and water heating powered by electricity to avoid double-counting. Physical energy demand for space and water heating was modelled using the TABULA methodology based on Europe-