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Methodological and Ideological Options

A Household's Burden – The Embodied Resource Use of Household Equipment in Germany

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ABSTRACT

The paper describes patterns of resource use related to German households' equipment. Using cluster analysis and material flow accounting, data on socio-demographic characteristics, and expenditures on fuel, electricity and household equipment allow for a differentiation of seven different household types. The corresponding resource use, expressed in Material Footprint per person and year, is calculated based on cradle-to-gate material flows of average household goods and the related household energy use. Our results show that patterns of resource use are mainly driven by the use of fuel and electricity and the ownership of cars. The quantified Material Footprints correlate to social status and are also linked to city size, age and household size. Affluent, established and/or younger families living in rural areas typically show the highest amounts of durables and expenditures on non-durables, thus exhibiting the highest use of natural resources.

1. Introduction

It is widely accepted nowadays that private households contribute greatly to the overall environmental impacts of nations (see Stocker et al., 2014, p. 59; Ferrara and Serret, 2008 and Hertwich, 2010, p. 48). Ivanova et al. (2015) for example show that in 2007, 65% of the global Carbon Footprint and 48% of the global raw material use (not accounting unused extraction) were directly associated with household consumption. Traditionally, studies analysing household consumption use multiregional input-output (MRIO) models based on national statistics (see e.g. Hellweg and i Canals, 2014 and Hertwich, 2005). Miehe et al. (2016) for example, recently analysed greenhouse gas (GHG) emissions of German households in 2004 regarding spatial and financial influences. They found regional differences at federal-state level and particularly differences between urban cores and suburban areas.

However, MRIO models show several shortcomings, when it comes to the analysis of household consumption and its environmental impacts (see e.g. Kitzes, 2013 and Moran et al., 2016 on the limitations). While the national and global trade statistics used for MRIO models allow for numerous ways to evaluate global linkages between production and consumption, they are also highly aggregated and aggregated differently for different MRIO tables. The level of detail in sectoral aggregation for example, directly influences output multipliers for consumption-based environmental accounting (see Steen-Olsen et al., 2014). Further shortcomings stem from the underlying assumption of an arbitrary demand that passes throughout all sectors, because it is not necessarily a direct reflection of what households actually consume. In addition, household characteristics cannot be directly drawn from MRIO tables, which in turn would allow to differentiate between household types and their consumption patterns.

Some researchers tackle these problems by combining MRIO models with additional data sets to link environmental load factors to activities, groups or spatial distribution (see for example Jalas and Juntunen, 2015 or Lenzen and Peters, 2009). Nonetheless, the use of MRIO datasets is limited to current or past production recipes, while other methods such as Life Cycle Assessment, can also be used to quantify potentials for environmental improvement based on the technological development of household goods.

In terms of the socio-demographic characteristics, most studies conclude that income, household size and location are the main influencing factors for private consumption (see e.g. López et al., 2017; Tukker et al., 2010). Other than that, behavioural and cultural aspects also seem to play an important role (see Birch et al., 2004 for a collection of articles on driving forces of and barriers to sustainable consumption). Overall, we still miss studies considering the relation of lifestyles, their typical consumption patterns and the associated environmental burden.

In contrast to studies analysing *ecological or Carbon Footprints*

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according to household characteristics (see for example Druckman and Jackson, 2009 and Chitnis et al., 2014), only a few studies have tried to elicit and differentiate the use of natural material resources or the *Material Footprint* of and among private households. While comparative research on the Material Footprint among *nations* has grown in the past decade (for example Wiedmann et al., 2015; Bringezu, 2015; Bringezu et al., 2004; Giljum et al., 2008), comparative empirical research on the Material Footprint among *private households* remains limited.

These research gaps – the use of endogenic production recipes as well as missing disaggregated data on household types, consumption patterns and corresponding use of natural resources – cannot be closed by usage of trade statistics and extended input-output (I-O) tables alone. Instead, the method described in the paper combines a different statistical basis with methods from the Life Cycle Assessment (LCA) methodology to differentiate profiles of households and their natural resource use.

By doing so, we seek to find out if there are typical consumption patterns of natural resource use related to household goods in Germany. The answer to this question depends on whether empirical (micro) data on household equipment and expenditure is sufficient to identify different representative household types and whether bottom-up accounting of natural resources enables us to equip these types with current and future resource profiles. If so, the method could provide beneficial input for existing holistic models or even used directly in future research to measure the success of policies towards sustainable consumption.

The starting point for our analysis is a recent study on behalf of the Federal Environmental Agency in Germany, which quantifies the sustainability limits for the raw material demand of German households in 2050 (Ahlert et al., 2015). While the quantification in Ahlert et al. (2015) focused on prioritized raw materials, we extend the research methodology by quantifying all life cycle-wide material and energy flows of household goods.

2. State of Research

There are several studies that combine input-output tables with other data sets to quantify different environmental impacts by households and link it to their consumption.

Ivanova et al. (2015) used the EXIOBASE database, which is already supplemented with additional environmental load intensities for different sectors (sourced from different databases). They calculated the direct and embodied Carbon Footprint (GWP 100a) and Material Footprint (Domestic Extraction) on a global and per capita scale of 43 countries. The United States for example "contribute to 4.9 times higher GHG emissions than the world average from a consumption perspective and to only 3.9 times higher emissions from a production perspective" (Ivanova et al., 2015, p. 528). On average, 80% of the GHG emissions are embodied in purchases such as shelter or manufactured products. For the Material Footprint, 40% of the extracted materials can be linked to foreign trade. Both indicators show a high correlation with the national GDP.

In another study, Jalas and Juntunen (2015) combined a single I-O table of Finland with datasets of household expenditure and time use to analyse the changes in embedded and direct energy consumption over a period of 22 years (1987 to 2009). The researchers identified which changes in activity patterns, energy intensities and demographics lead to an increase in energy consumption. They showed that, "in the case of Finland, increases in energy consumption are mostly due to housing-related consumption and to the intensity effect" (Jalas and Juntunen, 2015, p. 55) such as increase in living space or the increase in consumption of products and services for human activities. Further decomposition analyses revealed, that demographic changes cancelled each other out to some extent, because groups with high energy use (couples without children) and low energy use (elderly households) alike, have higher shares in the overall population in 2009 than 1987.

Using similar types of data sets, Barrett et al. (2013) analyse whether "[…] people in lower socio-economic groups have lower environmental impacts […]" and how "[…] changes in the distribution of socio-economic groups impact resource consumption[…]" (Barrett et al., 2013, p. 248). The researchers combine the environmental accounts of the Office of National Statistics (ONS) with socio-economic data on the UK using ACORN (A Classification of Residential Neighbourhoods) and COICOP (Classification of Individual Consumption According to Purpose) classifications. One of their preliminary results is that the ecological footprint from car and van use is up to three and a half times higher in the highest socio-economic group compared to the lowest group. The authors also acknowledge the fact, that money spent on products is not necessarily proportional to physical flows of materials, as certain products might be more expensive in order to consume less material and energy.

There are also empirical studies about resource use in private households and relevant socioeconomic factors in this regard.

Lähteenoja et al. (2008) compared the Material Footprint of 27 Finnish households and Kotakorpi et al. (2008) provided an in-depth analysis of these results in terms of levels and distribution of Material Footprints and some analysis of socioeconomic factors of the households involved. According to Kotakorpi et al. (2008), household goods (excluding their energy use and excluding mobility products) represent 7.5% of the Material Footprint for an "average Finn" and range from 3 to 14% of the overall Material Footprints of the households studied (0.6 to 5.9 metric tons per person in a year).

Greiff et al. (2017), applying a similar methodology, analysed the material and Carbon Footprints of 16 different households in Bottrop, Germany. For small and large electronic devices, the researchers calculated a Material Footprint between 0.3 and 4.3 tons per person and year, ranging from 2 to 10% of the overall Material Footprint. In comparison, Carbon Footprints for the same devices ranged from less than 1% to 4% of the overall Carbon Footprints.

In a transition experiment study, Laakso and Lettenmeier (2015) described the Material Footprints of five Finnish households and reported on the experiments of these households in order to reduce their footprints. For household goods, the reduction in Material Footprints ranged from zero to 37% of the respective Material Footprint for household goods.

Although the share of household goods in the overall expenditure (also see Wiedmann et al., 2006) and overall environmental impact is relatively low, this category appears relevant due to high amounts of stored resources and critical raw materials. As the use of household goods causes the main electricity and fuel use of households, there is also a direct link to the fields of mobility and housing. In terms of the environmental burden of household good production, especially electrical and electronic goods are characterized by fast changing supply chains, rapid technological development, falling prices and high rate of exchanges for new technologies before the old ones fail as a subject of fashion (Reichel et al., 2014, p. 77).

While studies relying on small samples can provide a deeper insight and understanding of consumption patterns and the resource use (Material Footprint) of individual households, they do not yet estimate more general consumption patterns of certain population groups. Those can only be derived by studying larger samples of households and their statistical distributions.

Buhl (2014), for example, shows the resource use of private households for food, housing and mobility broken down among deciles of net household income from representative data for Germany. On average, overall resource use rises as income rises. When splitting the sample based on average net household income, higher incomes show a resource use 1.5 times higher than that of lower incomes. Focusing in even more, the lowest decile shows an average total material requirement of a total of 22.1 tons, whereas the highest decile shows an average total material requirement of 57.2 tons. Thus, the highest decile shows a resource use that is 2.6 times higher than the lowest