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The structure of socio-economic metabolism and its drivers on household level in Hungary

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ABSTRACT

The joint examination of input flows and the stocks of households provides novel perspectives for socio-economic metabolism (SEM) research. Our study aims to compare household level material flows and stocks, and economy-wide material inputs, and to explore influential factors affecting the level of metabolism at household level.

Household diaries and inventories (n = 73) were used to assemble household-level data regarding material flows and stocks. The mean value of the extrapolated annual material inputs 2.16 tons per household member, while household stocks represented 1.17 tons per household member excluding building stocks, and 46 tons if buildings were considered in the estimation. According to our results, material inputs and stocks are depending on household size and income exclusively.

Amount of the direct input flows of the economy exceed the direct input flows of households significantly. Household inputs represent 10.3% of the Hungarian direct material consumption (DMC). For better understanding, the material balance of Hungary was compiled and extended using an additional layer of the flows' functions. With regard to input flows, every increment in direct inputs evokes multiple increment on macroeconomic scale. Since several input flows are assumed to be driven by the amount of stocks, an increment in material stocks will add further material consumption surplus to this effect. Improvements in production processes can narrow multiplicative effects especially in food supply chains and construction activity. Similar characteristics in material flow and stock relations of three countries (Japan, Germany and Hungary) highlight that the decoupling is not possible without accumulation of lower amount of material in the societies.

1. Introduction

Human societies are using, forming and occupying the Nature from ages, to control the environmental processes was a prior requirement for safety and development. The colonization of natural processes began when human beings change several significant parameters of the natural systems. These changes led to plausibly irreversible effects in the bio-geosphere, such as climate change or biodiversity loss, when societies have started to manage 'extended metabolism' already, i.e. the material input and the output of the processes exceed the range of actual biospheric cycles (Fischer-Kowalski and Haberl, 1997). The colonization is intensifying all the time, which process is determined by the population growth, technological and economic development (Grünbühel et al., 2003).

Hence the extensive usage of natural resources evokes the ecological problems on both input and output side, the driving forces and the strategic interventions can be discussed in a context which includes all human-nature interactions. Doing so, studies of socio-economic metabolism (SEM) focuses on exchange of material flows and stocks of energy, matter and information between the Nature and the society.

Analyses aiming to assess macro-scale requirement on natural resources have previously dominated the research field of SEM; still, the environmental impacts of resource use and waste management are significantly influenced by household consumption patterns (Di Donato et al., 2015; Hertwich, 2011; Lenzen and Peters,

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2009). Household consumption is a key driver of increasing environmental impact of the society. The current ecological crisis is first of all global; however, the examination of lower scales of socio-economic metabolism is crucial, as these scales represent the basic scope of decision-making (Pauliuk and Hertwich, 2016).

In social sciences (e.g. in economics), different aspects of a phenomena can be observed in macro and in micro scale; accordingly, the SEM frame is also able to interpret different issues connected to sustainability among different levels of examination. Analysis of lower economic scales is promising due to the relation to microeconomic theory and sectoral policies towards efficiency (Fischer-Kowalski and Hüttler, 1998; Delahaye and Nootenboom (2008)). Nevertheless, studies on small scale SEM are diverse regarding their scope and object. However, analytical frame fits the methodology and indicators of the macro scale SEM in the majority of the cases.

Until now, relatively few studies have examined socio-economic metabolism at the household level, which was probably caused by the lack of available data. Baccini and Brunner (1991) in their fundamental book compared prehistoric and modern Man's material turnover. Main human activities (e.g. to nourish, to reside) required negligible amount of material stocks and 6 tons of material input each year by the prehistoric Man, while 260 tons of stock and 89 tons of input of modern Man. Additionally, Harder et al. (2014, 2016) provide reviews of scientific fields associated with the investigation of SEM on household levels, and suitable methods are introduced as well. Several studies have examined household metabolism with qualitative analysis on samples of material flows in a few (6–27) households (Kotakorpi et al., 2008; Lettenmeier et al., 2014; Haas and Krausmann, 2015; Leray et al., 2016); while Moll et al., 2005 used top-down method to assign the macro-scale material flows to the household consumption. Our aim was to extend the sample size towards quantitative analyses and to involve material stocks into the examination.

Material stocks contain distinct artifacts built up by the societies (infrastructure, dwelling stock, machinery, etc.), and they provide services for the society itself (shelter, production, and mobility). Material stocks generate material flows during construction, operation and demolition, so they are key issues for sustainability. Stocks cause path dependency in resource use and emission due to its long lifespan (Baynes and Müller, 2016; Krausmann et al., 2017).

Assessments of material stocks in SEM research focus on urban areas in general (Inostroza, 2014) or buildings and transportation networks in particular (Hashimoto et al., 2007; Hu et al., 2010; Müller, 2006; Ortlepp et al., 2015; Schiller et al., 2017). Furthermore, Oguchi et al. (2008) examined at the micro level the 'product flows'. Fishman et al. (2014) and Tanikawa et al. (2015) provide valuable reviews of stock accounting in addition to estimations of the total stocks of socio-economic system of Japan.

In this study, several comparisons of household level metabolism with macro scale metabolism results are provided, with the aim of extending the analysis of direct flows and stocks. We have compiled the material balance of Hungary, in which the amount of directly household-driven flows and changes in stocks are embedded.

Additional aim of our analysis was to reveal the significance of the influential factors of material consumption at the household level. The level of natural resources' requirement is affected by distinct macro-scale factors, e.g., wealth, cultural context, urban structure and climate (see for instance Steinberger et al., 2010). These factors substantially influence living conditions and individual factors, as income, household size, location, car ownership, housing and diet, which are essential in terms of environmental impact (Tukker et al., 2010). However, other micro-level factors, such as environmental consciousness, personal income, qualification and knowledge, as well as individual needs may also affect characteristics of socio-economic metabolism. In the Hungarian context, significant effects of household size, type of settlement, dwelling type and income were assumed.

2. Database and methods

2.1. General characteristics of the applied methodology

Regarding the classification of basic methods used for material stock and flow accounting, there are two features of both flows and stocks analysis: temporal range (static/dynamic) and calculation approach (top-down/bottom-up). Dynamic studies are also suitable for retrospective or prospective investigations; however, static studies are frequently more detailed, which allows deeper analysis of the system structure and effective interventions (Augiseau and Barles, 2016).

The material flow accounting (MFA) conceptualizes the context of socio-economic metabolism. The analyses conducted by MFA methodology have to meet the material balance principle (Fischer-Kowalski et al., 2011). Macro scale studies (Economy-wide MFA, EW-MFA) are compiled typically on the basis of existing data on country level, regarding the used materials (raw materials and traded commodities), as well as wastes (Schandl and Schulz, 2000; Matthews et al., 2000; Grünbühel et al., 2003; EUROSTAT, 2013; Krausmann et al., 2015). Nevertheless, investigation of socio-economic systems at a lower level (settlements, companies, processes or households) frequently requires data generation, of which suitable methods are surveys based on questionnaire, diary and observation (Harder et al., 2014). The former approach is top-down, while the latter is bottom-up, since total flows of a socio-economic entity are aggregated from single data points of each material input (Augiseau and Barles, 2016).

Examinations regarding material stocks follow four approaches: the (i) bottom-up method constructs physical inventory of man-made capital on the specified level, the (ii) top-down method applies the range of accumulated flows to estimate changes in stocks and then the total amounts. In the (iii) demand-driven modelling several socio-economic variables are included for the better fit of the top-down calculation, while different tools of (iv) sensing provide sufficient dataset about stocks at high level of cost and time efficiency with the usage of aerial images, GIS or other maps (Tanikawa et al., 2015).

Our study applies static, mainly bottom-up methods; while top-down calculations were used for the compilation of material balance of Hungary and the estimation of metallic stocks. Fig. 1 represents the pathway of our research, while data sources and processes are described in the next two subsection in details.

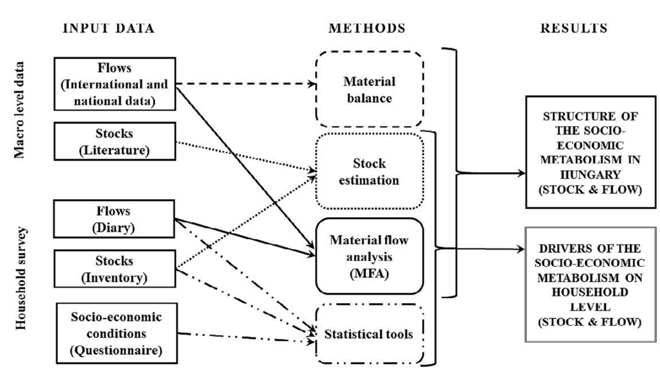

Fig. 1. Study design.