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Analysis

Environmental Impact of Consumption by Czech Households: Hybrid Input–Output Analysis Linked to Household Consumption Data

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ABSTRACT

We quantify direct and indirect emissions resulting from Czech household consumption contributing to climate change, acidification and smog formation. We develop a hybrid environmentally extended input–output model that links the single-region input–output analysis on domestic processes with a multiregional input–output analysis to derive the indirect emissions associated with imports and part of the domestic production. We apply Almon's algorithm to transform the domestic emissions from industries to product groups. The indirect and direct emission intensities of more than hundred consumption items are then linked to expenditures of almost 3000 individual households to compute the total emissions for each household.

We find that emissions attributable to households are not distributed evenly — while the first expenditure decile of households is responsible for less than 4% of all emissions, the tenth decile is responsible for 20–24%. Consumption of services and goods is least emission intensive, while use of electricity, heating, and transportation remains responsible for the major part of emissions. The most important factor of emissions attributable to household consumption is total expenditures; the expenditure elasticity of emissions is about 0.8, but we identify consumption groups which emissions are less sensitive to total expenditures (electricity, heating and food) and more sensitive (transportation, goods).

1. Introduction

The environmental burden from air pollution and greenhouse gases (GHG) causes substantial economic costs and considerable adverse health and non-health impacts (OECD, 2014; WHO and OECD, 2015).[1] Household consumption is responsible for two thirds of GHG emissions worldwide (Hertwich and Peters, 2009; Ivanova et al., 2015).

While application of the environmentally extended input–output analysis (EE-IOA) to derive emissions attributable to household demand is not new (see Andrew et al., 2009; Herendeen and Tanaka, 1976; Suh, 2009), only a few studies exist that have computed the total emissions for individual households, or for several different household categories by linking environmental extensions, input–output tables and individual expenditure data. Among these few studies, several papers have focused on emissions attributable to households with different incomes or expenditures (Druckman and Jackson, 2008; Golley and Meng, 2012; Kerkhof et al., 2009b; Steen-Olsen et al., 2016; Weber and Matthews, 2008), or households that differ with respect to other household characteristics (Baiocchi et al., 2010; Lenzen et al., 2004; Peters and Hertwich, 2006). Some papers have aimed primarily at making comparisons of household emissions across countries (Kerkhof et al., 2009a; Peters and Hertwich, 2006). A comprehensive overview of studies dealing with household emissions for different countries has been made by several authors (Di Donato et al., 2015; Hertwich, 2005; Tukker et al., 2010, 2006).

The single-region environmentally extended input–output analysis (SR EE-IOA) may lead to over- or underestimation of emissions related to imported products due to the domestic technology assumption (Weinzettel and Kovanda, 2009). In order to incorporate differences in production technologies between countries, the multiregional environmentally extended input–output analysis (MR EE-IOA) has come into practice in the last decade. A downside of the currently available global multiregional input–output datasets is the lack of the desired level of detail (Steen-Olsen et al., 2014) or quality issues in comparison to the single-region input–output table (Schoer et al., 2013).

The main contribution of this paper to the recent literature is

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[1] The World Health Organisation and OECD (2015) quantified the annual economic cost of the health impact of air pollution in Europe at US$ 1.575 trillion: that is equivalent to more than 1% of the gross domestic product of the region. Emissions of air quality pollutants also cause other non-health problems, including impacts on agriculture crops, building materials, and ecosystems; however, the health impacts contribute more than 90% of the total value of damage (Maca et al., 2012; Ščasný et al., 2015).

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achieved by linking several databases in order to derive the total emissions for individual Czech households and hence to provide a better picture of households' responsibility for their environmental burden. For that purpose, we have developed a hybrid input–output method that links a global environmentally extended multi-regional input–output table, based on EXIOBASE 2 database, with a domestic single-region input–output table (IOT) and domestic emissions data from NAMEA,[2] both for the Czech Republic. We then link input–output results to household consumption data from the consumer expenditure survey (CES) of Czech households. Using this method, we quantify the total indirect emissions for several hundreds of consumed items for each of the nearly 3000 Czech households surveyed, and add them to direct emissions stemming from household fuel combustion. To ease the interpretation of our results, we present the average values and values related to expenditure deciles to present variability between different expenditure levels. Further, we use expenditure elasticities similarly as in several other studies (Golley and Meng, 2012; Kerkhof et al., 2009b; Weber and Matthews, 2008), to depict the dependency of emissions on the total expenditures.

In order to deliver results that better reflect the reality, we have included several additional enhancements compared to common practices. Special effort was devoted to electricity and heat in this regard. In order to obtain accurate values of local emissions from industries, we compile more detailed NAMEA, disaggregate its electricity to electricity from fossil fuels and other electricity, apply Almon's algorithm (Almon, 2000) to avoid negatives in transformation of NAMEA from industries to products and keep the product technology assumption at the same time, and apply the transformation method close to the industry technology assumption for the joint production of electricity from fossil fuels and heat.

An additional added value of our study is the calculation of eleven pollutants induced by household consumption for a country in Central and Eastern Europe, as such an analysis has not yet been performed for this region in such detail.

2. Methodology

Total emissions attributable to the consumption of each household are quantified in our study for eleven different pollutants overall, which are merged into three different environmental impact categories[3]: greenhouse gases that contribute to climate change (including CO_2, CH_4, N_2O, HFCs, PFCs, SF_6), pollutants causing acidification (SO_2, NH_3, NO_X), and precursors of photochemical smog formation (NMVOC, CO).

Direct emissions come from fuels burnt by households to heat their dwellings and to propel their vehicles, whereas indirect emissions stem from industries, agriculture and transportation of goods, including both domestic production and imports. The total emissions are the sum of direct and indirect emissions and are quantified separately using two different calculation processes.

2.1. Direct Emissions

In principle, direct emissions result from fuels burnt by households. In our study, direct emissions are calculated for eight different fuels in total (natural gas, lignite, bituminous coal, coke, fuel wood, gasoline, diesel fuel and LPG), which cover the vast majority of the fuel consumption of Czech households (see Supporting information for particular values). We determine direct emissions from household expenditures (CZSO, 2011a), fuel prices (CZSO, 2014; ERU, 2009; MPO, 2012), emission intensity (Adamec et al., 2005; EEA, 2007; MZP, 2009), and physical properties, such as density (Beranovský and Truxa, 2004; ČEPRO, 2011a, 2011b), calorific value (Beranovský and Truxa, 2004) and sulfur content (Top palivo-teplo, 2015). All direct emissions of NH_3, HFCs, PFCs, and SF_6 as well as emissions of N_2O for natural gas are regarded as negligible.

2.2. Indirect Emissions

We quantify indirect emissions by combining the EE-IOA with household expenditures (Herendeen and Tanaka, 1976). This method virtually re-allocates the emissions from industries to final demand products and it quantifies emissions related to the complete production chain of each product purchased by each household.

In order to cover the full global production chain including imports and their upstream emissions, we combine two input–output datasets. First, the global multiregional environmentally extended input–output database (MR EE-IOT) EXIOBASE 2 (Wood et al., 2015), that describes the financial flows within the global economic system, is applied to estimate the upstream emissions of products imported to the Czech intermediate economy consumption and final demand. Second, we use the domestic single-region CZ-IOT,[4] which describes the financial flows among all product groups within the studied region (country).

We apply this hybrid input–output method because we consider that using the single-region CZ-IOT is more accurate as it describes the economy for the same year in which the CES records the household expenditures, and because using the global MR EE-IOT is a more accurate way to characterize imports than to follow the domestic technology assumption if the CZ-IOT was used. A similar hybrid method was applied earlier by Schoer et al. (2012) and Weinzettel and Kovanda (2009) for selected products.

In order to assure mutual compatibility between different databases used within this paper, several transformations and disaggregations need to be carried out in parallel to the input–output analysis itself. As a general rule, all manipulations are carried out in such a manner as to retain the utmost detail of available information, since it has been shown that a high level of detail can significantly improve the accuracy of the results (Steen-Olsen et al., 2014).

To obtain the resulting indirect emissions for each household, we derive embodied emission intensities of product groups[5] (steps 1 to 5), link them with household expenditures (steps 6 to 9) and calculate individual emissions of eleven pollutants (step 10). Then we add the direct emissions, convert the total emissions to environmental impact categories and group them into six consumption groups (Section 2.3). We carry out this procedure in sequential steps described in the following sections:

1. Disaggregation of nationally recorded emissions to match CZ-IOT

Emissions of domestic industries for 2010 recorded in CZ-NAMEA for 88 industries of NACE rev. 2 classification (CHMI, 2012) are disaggregated into 184 industries (see Supporting information 1 for particular values) of the resolution[6] of 2010 CZ-IOT. For major sources of emissions (larger than 0.2 MW of heat power), we sum emissions of individual enterprises based on the first three digits of their NACE codes (CHMI, 2014). For separately recorded minor stationary and mobile emission sources, where emissions are not assigned to enterprises with NACE codes, emissions are adopted from CZ-NAMEA and subdivided in the ratios of fuel consumption in each industry. This ratio is acquired from the detailed domestic use table of 2010 (CZSO, 2012). Coal and

[2] NAMEA stands for National Accounting Matrix with Environmental Accounts.

[3] The impact categories, see i.e. Kerkhof et al. (2009b), do not translate the impact to damage, as for example, in Weinzettel et al. (2012)

[4] In order to ease the clarity of our method, we denote country specific databases by the prefix CZ further in the text, as our study site is the Czech Republic. Yet this approach can be applied to any country or region for which such data is available. The selection of the year 2010 is determined by data availability: for instance, the detailed version of the CES is available for 1999 and 2010 and EXIOBASE 2 is available for 2000 and 2007 only.

[5] The term product and product group may be used interchangeably.

[6] Resolution stands for a size of the matrix or vector describing the system.