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The Carbon Footprint of European Households and Income Distribution

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ABSTRACT

This paper calculates the carbon footprint of private consumption in the EU27 by five groups of household income, using a fully fledged macroeconomic input-output model covering 59 industries and five groups of household income for the EU27. Due to macroeconomic feedback mechanisms, this methodology – besides induced intermediate demand – also quantifies: (i) private consumption induced in the other household groups, (ii) impacts on other endogenous final demand components, and (iii) negative feedback effects due to output price effects of household demand. The carbon footprint is calculated separately for the consumption vector of each of the five income groups. The simulation results yield a non-linear income elasticity of direct and indirect emissions at each income level: the value of the direct footprint income elasticity decreases from 1.32 (first quintile) to 0.69 (fourth quintile). The value of the indirect footprint income elasticity is always below unity and decreases from 0.89 to 0.62. The results in general reveal a relative decoupling effect: the share of the top income group in income (45%) is much larger than its share in the carbon footprint (37%) and *vice versa* for the bottom income group (6% in income and 8% in footprint).

1. Introduction

The environmental impact of inequality in the income distribution has been the object of many theoretical and empirical studies. The main question was, if reducing inequality and rising incomes along the growth process might "automatically" decrease environmental pressure. The "strong" version of this hypothesis where environmental pressure (emissions, energy/resource use) per head is even reduced with income growth, is the "Environmental Kuznets Curve" (EKC). The general result of the literature is that some relative decoupling of environmental pressure from income can be identified, but that does not suffice to reduce absolute environmental pressure. The empirical studies comprise econometric studies in the spirit of the EKC literature (Ravallion et al., 2000; Borghesi, 2000) as well as studies that combine input-output (IO) or life-cycle methods with others to quantify the footprint of different income groups (Weber and Matthews, 2008, and more recently Chancel and Piketty, 2015).

Since the seminal paper of Boyce (1994), most authors find a negative relationship between inequality and emissions, i.e. higher inequality leads to lower emissions. Borghesi (2000) discusses these findings in the light of the literature and concludes with mixed evidence: positive effects of inequality on emissions (poor households using less efficient equipment and more energy/resources) and negative effects (rich households consuming more aggregate energy/resources) might balance.

The studies that use input-output (IO) analysis for calculating the footprint usually calculate direct and indirect emissions of households, and often yield the result that indirect emissions have a higher share in total footprint for high income households than for low income. Parikh et al. (2009) as well as Weber and Matthews (2008) show that for top income households the share of indirect carbon (CO_2 equivalents, i.e. GHG emissions, including CH_4 and N_2O) emissions is significantly higher than for households at the bottom of the income distribution.

One objective of the literature consists in deriving an income elasticity of carbon emissions, either from a cross section or an aggregate time series dataset. Weber and Matthews (2008), who combine IO analysis with econometric estimation find an expenditure elasticity between 0.6 and 0.8 and an income elasticity between 0.35 and 0.52. Lenzen et al. (2006) review this work on elasticities and derive a similar range, but conclude that the literature exhibits a large heterogeneity of estimated elasticity values. It must be noted that the methodology consists of calculating the carbon footprint in a first step and then applying econometric analysis on these results in a second step. The econometric analysis, which attempts to identify the households' reactions, therefore is not integrated with the IO analysis used for calculating the footprint. Another study (Duarte et al., 2015) also uses a CGE model to calculate the full macroeconomic impact of household behavior, but the consequences for emissions are attributed from outside from the results of an IO model (though the IO database is the same as the one for the CGE model). The recent study by Chancel and Piketty (2015) combines footprint calculations from a MRIO analysis with income distribution data via income elasticity values taken from the literature.

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The existing literature has not yet used IO approaches that integrate household behavior for deriving the footprint of different income groups, from which the income elasticity can be derived directly, without any further econometric analysis. This paper attempts to fill this gap and derives an income elasticity that incorporates macroeconomic (or general equilibrium) feedbacks and therefore is not limited to the ceteris paribus condition that needs to hold for the elasticity values estimated in the literature. This study finds that the income elasticity of the carbon footprint considerably decreases when moving from bottom to top income. The income elasticity of the direct carbon footprint is 1.32 for the first quintile and still above unity for the second quintile and then decreases to a value of 0.69. The income elasticity of the indirect carbon footprint is always below unity and decreases from 0.89 for the first quintile to 0.62 for the fourth quintile. Another result that is found and is not in line with the established literature is that indirect emissions play a more important role (in relative terms) for bottom income households. The main reason for this seems to be the CH_4 emissions from agricultural products.

The model used is a hybrid between an econometric IO and a CGE model and splits the consumption block into five groups of household income (quintiles). Aggregate consumption depends on income, wealth and liquidity constraints, consumption by commodity on prices as well. Production is modeled via a Translog model that is fully integrated into the IO structure. Besides that, the model also comprises a block for the labor market and one for the public sector. The analysis in this paper extends the existing literature by the following features: (i) consumption of each household group induces consumption in the other groups via an income and wealth multiplier, (ii) consumption of each household group induces wage and price effects due to the demand pull, and (iii) consumption of durables reacts in a non-linear form, so that energy consumption linked to the durable stock shows non-linear reactions with respect to income as well.

These effects partly magnify the carbon footprint (comprising the carbon equivalent of all GHGs) compared to traditional static IO analysis ((i)) and partly diminish it ((ii)). The non-linear property ((iii)) yields a heterogenous income elasticity of the footprint across income groups. This is an *ex post* elasticity from model simulation results, including all macroeconomic feedbacks.

The paper is organized as follows: Section 2 describes the methodology of calculating direct, domestic indirect and imported indirect carbon footprint for the five household income groups. Section 3 reports the results for the carbon footprint by quintile and calculates the model simulation income elasticity. In Section 4 some conclusions are drawn. A detailed model description with an emphasis on consumption, production and trade can be found in the Appendix.

2. Methodology and Data

The DYNK (DYnamic New Keynesian) model approach applied in this study is a hybrid between an econometric IO and a CGE model and is characterized by the integration of rigidities and institutional frictions. These rigidities include liquidity constraints for consumers (deviation from the permanent income hypothesis), and wage bargaining (deviation from the competitive labor market). In the long-run the model works similarly to a CGE model, and explicitly describes an adjustment path towards a long-run equilibrium. The model describes the inter-linkages between 59 industries as well as the consumption of five household income groups by 47 consumption categories and covers the EU 27 (as one economy).

The IO core of the model is based on Supply-Use tables for Europe (EUROSTAT) and intermediate demand is split into domestic and imported commodities. Instead of deriving a technical coefficient matrix (inputs of intermediate commodities per unit of industry output) from the use matrix, this modeling step is split into two parts in the DYNK model. First, vectors of total input coefficients per unit of industry output for domestic and imported commodities (v_D and v_M) are defined. The commodity structure below this level is then in a second step defined by use structure matrices S^m and S^d with column sum equal to unity. A further distinction within the use matrix is between non-energy and energy commodities. The commodity balance for non-energy commodities is then defined by applying the use structure matrices $\mathbf{S}_{NE}^{m}$ and $\mathbf{S}_{NE}^{d}$ as well as the diagonal matrices of the factor shares defined above, $\hat{\mathbf{V}}_D$ and $\hat{\mathbf{V}}_M$. Multiplying the use structure matrix with the corresponding factor share matrix and with the column vector of output in current prices gives the sum of intermediate demand by commodity. The procedure for energy commodities is the same, with use structure matrices $\mathbf{S}_{E}^{m}$ and $\mathbf{S}_{E}^{d}$ (where the column sum over both matrices yields one), and diagonal matrix $\hat{\mathbf{V}}_E$. The full commodity balance is given by adding the column vectors of domestic consumption (c^d), capital formation (cf^d) and public consumption (cg^d). Capital formation is endogenous as well and derived from capital demand by industry in the Translog model, applying the capital formation matrix (for details see the Appendix). The (column vector) of the domestic output of commodities in current prices, $\mathbf{p}^D\mathbf{q}^D$, is transformed into the (column vector) of output in current prices, $\mathbf{p}_Q\mathbf{q}$, by applying the market shares matrix, C (industries ∗ commodities) with column sum equal to one:

$$\mathbf{p}^D\mathbf{q}^D = \left[\hat{\mathbf{V}}_D\mathbf{S}_{NE}^{d}\right]\mathbf{p}_Q\mathbf{q} + \left[\hat{\mathbf{V}}_E\mathbf{S}_{E}^{d}\right]\mathbf{p}_Q\mathbf{q} + \mathbf{c}^d + \mathbf{cf}^d + \mathbf{ex}^d + \mathbf{st}^d + \mathbf{cg}^d \qquad (1)$$

$$\mathbf{p}_Q\mathbf{q} = \mathbf{C}\mathbf{p}_D\mathbf{q}_D \qquad (2)$$

These two equations describe the core IO model of the system and can be solved in a loop for equilibrium values of output (p_Qq and p^Dq^D), once final demand categories (c^d, cf^d, ex^d, st^d and cg^d) and matrices ($\hat{\mathbf{V}}_D$, $\hat{\mathbf{V}}_E$, $\mathbf{S}_{NE}^{d}$ and $\mathbf{S}_{E}^{d}$) are given.

The final demand categories (c^d, cf^d, ex^d, st^d and cg^d) comprise energy and non-energy commodities, are all in current prices and are all – except stock changes (st^d) – endogenous. The export vector ex^d is calibrated with price elasticity of unity for all commodities and therefore is constant in current prices. The vector of public consumption cg^d is determined in the public sector block of the model in order to close the model with a predetermined public deficit.

2.1. Household Demand and Direct Carbon Footprint of Households

The consumption block differentiates between different stages and separability is assumed between these stages. The separability assumption in that context also implies that the dynamic decision process is disentangled as lined out in Attanasio and Weber (1995). At the first stage, the demand for durables (real estate property and vehicles) is modeled in a way consistent with the version of the buffer stock model described in Luengo-Prado (2006). Further, total nondurable demand is also specified in a way consistent with the main properties of the buffer stock model (excessive smoothing, excess sensitivity). All model parameters are based on dynamic estimation of panel data for Europe (1995–2011), in the first stage for 14 EU countries (Belgium, Czech Republic, Denmark, Germany, France, Italy, Cyprus, Lithuania, Austria, Poland, Portugal, Romania, Slovakia, Finland). The data for the estimation of consumption demand functions are mainly taken from EUROSTAT's National Accounts. The capital stock of housing property was estimated for one year, based on the Household Financial and Consumption Survey (HFCS) of the ECB. By applying property prices from the Bank of International Settlement (BIS) and EUROSTAT population data, a time series of owned houses was constructed for the 14 EU countries. A crucial variable at this first stage of consumers' demand is the down payment for durable purchases (see the Appendix for details). Once the full model is set up with the integrated consumption block, the property of ‘excess sensitivity’ can be tested. Excess sensitivity describes the empirical fact that the growth rate of consumption – partly – reacts to the lagged growth rate of disposable (or labor) income. The full model presented here is run until 2050, so that endogenous