Bridging the Gap between Micro-Consumption and Macro-Input-Output: A Systematic Assessment of Biases in Environmental Footprinting and a Path towards Integrated Microsimulation-IO Modelling in MEDUSA

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The integration of household consumption microdata into multisectoral economic models has become essential for understanding the distributional implications of environmental and social policies. However, the methodological pathway from raw survey data to a coherent vector of final demand suitable for input-output (IO) analysis is fraught with potential pitfalls that can introduce biases in subsequent impact assessments. This paper provides a comprehensive quantification of the biases arising from incomplete or incorrect implementation of the four-step harmonization procedure described in Cazcarro et al. (2022); TomÃ¡s and Cazcarro (2024): (1) alignment of consumption microdata with National Accounts (NA) principles; (2) conversion from the consumption classification (COICOP) to the production-based classification (CPA) using bridge matrices; (3) transformation from purchasers' prices to basic prices through the systematic treatment of taxes and trade/transport margins; and (4) when required by the model structure, adaptation from product to industry classification (e.g., for industry-by-industry tables such as WIOD or OECD-ICIO).
We firstly use Spain as a case study, initially for the year 2019â€”selected as the last pre-COVID year with stable consumption patterns and consistent micro-macro data (the work plans to advance also for other years and countries, e.g. UK). We systematically test alternative scenarios that omit each step individually and in combination. These scenarios replicate common practices in the literature (especially in the past), including naÃ¯ve one-to-one COICOP-NACE matching, failure to scale survey totals to National Accounts aggregates, and neglect of valuation adjustments. We employ both FIGARO (Full International and Global Accounts for Research in Input-Output Analysis) and the environmentally extended FIGARO-E3 database, allowing us to also assess the impact of aggregation bias when moving from detailed national tables to multi-regional frameworks. Our results reveal that omitting any of the four steps introduces not only significant errors in aggregate carbon footprint estimates (which we guess could be ranging from 10% to over 60% in weighted average percentage error for specific demand vectors), butâ€”more critically for distributional analysisâ€”alters the ranking of households by environmental pressure.
A central contribution of this work is the development of open-source R code that automates the entire four-step transformation process, making it replicable and adaptable to different countries and years. The code is designed to interface directly with microsimulation tools, and we demonstrate its integration with the MEDUSA (Microsimulation for Energy Demand and User Sustainable Analysis) R package (Alonso-Epelde and Al., 2026), developed by the Basque Centre for Climate Change. MEDUSA enables highly disaggregated distributional analyses accounting for socioeconomic and demographic characteristics (income, rural/urban location, household composition, gender of the main breadwinner) and incorporates indices of energy and transport poverty.
Crucially, we implement and compare two alternative integration strategies within MEDUSA. The first approach (forward method) applies the complete four-step transformation to each household's expenditure data, generating household-specific vectors of final demand in the classification of the IO table (products or industries), which are then multiplied by sectoral COâ„‚ multipliers to obtain carbon footprints. The second approach (reverse method) pre-multiplies the entire IO structureâ€”including environmental coefficients, the Leontief inverse, and the full transformation chainâ€”into a compact vector of COICOP-level multipliers. This approach, mathematically equivalent to the forward method, offers substantial computational advantages for microsimulation involving tens of thousands of households, as footprint calculations reduce to simple dot products while maintaining full macroeconomic consistency. We provide the exact matrix algebra for both

approaches and discuss their respective advantages in different analytical contexts.
While currently implemented for Spain, our code and methodology are designed for scalability to all EU countries, contingent on the availability of Household Budget Surveys, Supply-Use Tables (from which bridge matrices, margins, and tax rates can be derived), and National Accounts aggregates. We position this work at the frontier of research linking survey microdata with IO models, complementing recent initiatives such as GreenEUROMOD (Dreoni et al., 2025) and contributing to the broader agenda of distributional environmental policy analysis. By making our code open-source and integrated into MEDUSA, we provide the research community with a rigorous, accessible, and computationally efficient tool for incorporating household heterogeneity into IO-based footprinting and policy simulation.