Driving Impact? How Imperfect Substitution Shapes Heterogeneous Rebound in Carsharing

Topic: Input-Output Analysis: Sustainable Production and Consumption policies (4)
Author: David Font Vivanco
Co-Authors: Tamar Meshulam

Rebound effects remain a persistent challenge in the environmental assessment of resource-efficient innovations. Within inputâ€“output analysis, most empirical rebound studies continue to assume perfect substitution between new and displaced activities, thereby imposing behavioural homogeneity and potentially biasing impact estimates. This paper advances environmentally extended inputâ€“output (EEIO) modelling by operationalising imperfect substitution and user heterogeneity within a demand-driven IO framework. Using carsharing as an empirical case, we integrate micro-level survey data on mobility behaviour with an EEIO model based on EXIOBASE to quantify both potential emission savings and economy-wide rebound effects.

The analytical framework proceeds in three steps. First, we estimate expected emission reductions under the conventional assumption of one-to-one displacement of private car travel. Associated expenditure savings are allocated across consumption categories using an Almost Ideal Demand System calibrated on household expenditure data. These marginal consumption changes are then translated into economy-wide environmental impacts through a standard Leontief demand model, linking behavioural adjustments to sector-specific emission intensities. Second, we relax the perfect substitution assumption by incorporating empirically observed modal shifts across transport modes. This enables a consistent recalculation of both direct rebound from altered transport demand and indirect rebound from re-spending effects within the same IO accounting structure. Third, we introduce density-based clustering to segment users according to observed substitution patterns and compute rebound effects for each segment, thereby embedding behavioural heterogeneity directly into the EEIO framework.

Results indicate that aggregate rebound metrics conceal substantial distributional variation. Under perfect substitution, rebound appears moderate and uniform. Once empirically observed substitution patterns are incorporated, rebound estimates range from net environmental savings to backfire. Users replacing private car ownership exhibit moderate rebound, while those shifting toward lower-impact modes generate negative rebound. A smaller segment increasing car dependence produces backfire effects. These findings demonstrate that substitution across competing consumption activities, rather than expenditure reallocation alone, is a decisive determinant of rebound magnitude and direction.

Methodologically, the paper contributes to IO research by formalising a procedure to integrate micro-behavioural evidence and demand-system estimation into a macro-consistent EEIO model without modifying the core Leontief structure. The approach preserves accounting identities while enabling heterogeneous final-demand shocks derived from survey data. This extends the analytical capacity of EEIO models for ex ante and ex post policy evaluation, particularly in contexts where multiple service alternatives coexist and behavioural responses shape environmental outcomes.

More broadly, the study addresses ongoing efforts within the IO community to enhance the behavioural realism of consumption-based footprinting. By embedding imperfect substitution and user segmentation within a demand-driven IO framework, the analysis improves the interpretability of rebound estimates and provides a transferable modelling architecture applicable to energy services, circular economy strategies, and digital service substitution. In doing so, it reinforces the role of inputâ€“output analysis as a bridge between micro-level behavioural evidence and

economy-wide environmental assessment.

In addition, the paper contributes to the discussion on the integration of microdata into macro-consistent accounting structures, demonstrating how behavioural parameters can be incorporated without violating IO identities. This opens avenues for future research linking IO models with agent-based or microsimulation approaches, as well as for improving scenario analysis of demand-side policies. By explicitly modelling substitution across multiple consumption options, the framework helps reconcile bottom-up behavioural evidence with top-down footprint accounting, reinforcing the role of IO analysis as a bridge between behavioural insights and economy-wide environmental assessment.