Bayesian Balancing of (hybrid) Supply-Use Tables: Towards an uncertainty-aware BONSAI climate footprint database

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This paper asks whether a fully Bayesian, MCMC-based balancing approach can reconcile the large, multi-property hybrid supplyâ€“use table (HSUT) underlying the BONSAI Climate Footprint Database while delivering uncertainty information that can be propagated to downstream footprint results.

We formulate HSUT balancing as probabilistic reconciliation in which all supply and use flows, as well as conversion factors that couple flows between different property layers are treated as random variables centred on the initial table. Core accounting identities (product balances, activity balances, and cross-layer consistency across physical and monetary layers) are imposed through soft log-ratio constraints with tolerances that encode heterogeneous reliability. Posterior inference is performed with the No-U-Turn Sampler (NUTS) in Stan, and prior scales for the high-dimensional flow vector are calibrated in an empirical-Bayes inspired way from observed supplyâ€“use and activity imbalances to stabilise sampling at scale.

The approach is demonstrated on the BONSAI HSUT with approximately 1700 products and 1500 activities in 49 regions, comprising more than 1.8 million non-zero flows across four property layers (tonnes, million EUR, TJ, items), and is executed on high-performance computing infrastructure.

The novelty is a proof-of-concept that Bayesian balancing with MCMC can be made computationally feasible for BONSAI-scale hybrid HSUTs while providing a joint posterior that captures both uncertainty and the dependence induced by multi-layer constraints, enabling principled downstream uncertainty propagation beyond point-estimate balancing.