

Implicit CES Nesting in CDE-Based Demand Systems

Overview Abstract

This paper introduces an implicit CES nesting approach, implemented via an EP-matrix formulation, to improve the representation of price-driven household demand responses in the MAGNET computable general equilibrium model. The approach addresses well-known limitations in the price elasticity structure of CDE-based demand systems, which affect both the standard GTAP CDE and its adjusted variants used for long-run analysis. By replacing the EP and EY matrices while preserving the underlying CDE demand equation, the implicit approach improves substitution behaviour without altering income specifications. Substitution patterns are calibrated directly from uncompensated own-price elasticities, reducing unintended complementarity and enhancing policy transmission, particularly in food systems. The method is transparent, internally consistent, and directly comparable with existing GTAP demand specifications. Implemented using GTAP 11c data and SSP2 baseline assumptions, the new system yields more credible price responses and more robust policy results.

Extended Abstract

Motivation

Household consumption is the largest component of final demand in most economies and plays a central role in shaping long-run structural transformation, diet transition, and environmental outcomes. In global computable general equilibrium (CGE) models, the transmission of relative price signals through household demand is particularly important for analysing policies targeting consumption behaviour, such as food taxes, carbon pricing, and sustainability standards. Distortions in price responses can propagate through the economy, affecting sectoral allocation, trade patterns, welfare outcomes, and environmental indicators.

While CGE models rely on well-established demand systems, it has long been recognised that simulation results are sensitive to the way household demand is specified (Cranfield et al., 2003; Britz, 2021). These sensitivities are especially relevant in food systems, where price and income effects interact across multiple layers of aggregation. This paper focuses on improving the price-driven behaviour of household demand in the MAGNET model, while deliberately not addressing broader issues related to income responses, such as the representation of Engel's and Bennett's laws.

Limitations of the Existing CDE Demand System

MAGNET, like most GTAP-based models, relies on a demand system from the CDE family, using either the standard GTAP CDE formulation or an adjusted variant in which income elasticities are calibrated using PPP-adjusted income to improve long-run baseline behaviour. While these adjustments represent an improvement over the default specification for certain applications, both versions share common structural limitations with respect to price responses.

First, CDE-based systems provide limited control over relative price responses at detailed commodity levels. The interaction between the CDE structure and calibrated price elasticities often produces excessive complementarity among goods that are empirically substitutes, particularly within food categories. When prices change, negative income effects can dominate substitution effects, leading to overly strong own-price responses and muted cross-price substitution. These issues are present in both the standard and adjusted CDE systems and are not resolved by recalibrating income elasticities alone.

Second, CDE price responses are difficult to diagnose and validate. Small changes in elasticities or expenditure shares can generate qualitatively different outcomes, while it is often unclear whether unexpected results stem from price effects, income effects, or their interaction. Although adjustments

based on PPP-calibrated income help regulate aggregate consumption growth, they do not address these underlying price-response issues.

These limitations motivate a reformulation of the price elasticity structure (EP) within the CDE framework, rather than a broader redesign of income behaviour or utility representation.

Implicit CES Nesting via the EP-Matrix Approach

To address these issues, this paper introduces an implicit CES nesting approach, implemented through an EP-matrix formulation, which replaces the price elasticity structure of the CDE demand system while leaving the underlying demand equation unchanged. The approach is compatible with both the standard GTAP CDE and its adjusted variants, making it suitable for a wide range of CGE applications.

Rather than specifying explicit CES nesting equations, substitution relationships are encoded directly in an EP matrix derived from uncompensated own-price elasticities. This allows substitution behaviour to be calibrated transparently and systematically, without imposing strong structural restrictions through nesting trees. Complementarity conditions can be imposed explicitly, ensuring that similar goods behave as substitutes and that substitution strength reflects observed price responsiveness rather than arbitrary nest membership.

Calibration proceeds top-down. Aggregate price responses remain anchored to GTAP-consistent CDE elasticities, while disaggregated substitution patterns are calibrated to preserve relative price responsiveness across commodities. The focus is on relative magnitudes of elasticities rather than their absolute values, reducing the risk of unintended interactions between price and income effects.

Beyond behavioural improvements, the implicit CES approach offers several practical advantages. It ensures consistency, as no new demand equations are introduced and only EP and EY are replaced. It enhances checkability, as the Engel aggregation check provides a powerful diagnostic tool to identify issues arising from formulas, coding, parameter settings, or commodity splits during the EP derivation process. It improves comparability, as the resulting EP and EY matrices are directly comparable with alternative specifications, including default and PPP-based CDE variants. Finally, it offers compactness, substantially reducing code complexity relative to explicit nesting implementations.

Importantly, the implicit CES nesting is not intended to resolve known issues related to income responses, such as the representation of Engel's or Bennett's laws. Any changes in income-related outcomes arise only indirectly, through more credible price-driven adjustments.

Implications for Food Systems and Policy Analysis

The implicit CES nesting approach is particularly relevant for modelling food systems, where realistic substitution patterns are crucial for analysing nutrition, sustainability, and trade impacts. By improving price-driven responses within the CDE framework, the new system better captures substitution between staples and non-staples, across animal products, and between food consumed at home and food services, without imposing additional assumptions on income behaviour.

The approach is implemented in MAGNET using GTAP version 11c with 2017 as the base year. Baseline projections follow Aglink/SSP2 assumptions to 2050. Stylised scenarios focus on policies that internalise food system externalities, such as consumption or carbon taxes on red meat. Relative to CDE-based benchmarks, the implicit approach yields stronger and more interpretable substitution towards less carbon-intensive and healthier foods, improving policy effectiveness while avoiding exaggerated welfare losses.

Trade responses are also smoother and more transparent, as relative price signals are transmitted more consistently across domestic and imported goods. These results demonstrate that improving price elasticity structures alone can materially affect policy conclusions, even when income responses remain unchanged.

Contribution and Scope

The contribution of this paper is mainly methodological. It demonstrates that well-known weaknesses in CDE-based demand systems, present in both standard and adjusted variants, can be traced in part to their price elasticity structure. By introducing an implicit CES nesting through an EP-matrix formulation, the paper provides a transparent, robust, and GTAP-compatible way to improve price-driven demand behaviour without increasing structural complexity or altering income specifications.

At the same time, the paper does not claim to resolve outstanding issues related to income behaviour, such as the simultaneous representation of Engel's and Bennett's laws. Addressing these challenges remains an important area for future research. The present contribution should therefore be seen as a complementary step toward more credible long-run CGE analysis of food systems, sustainability policies, and structural change.