# Input-output micro-macro twins*

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**Abstract**

This paper contributes to two broad strands of literature: demand estimation from survey data and the integration of consumer demand with macro-models. In the first part, we estimate and analyze the EU-wide and country-specific results of the intra-budget regressions, which are the building blocks of Taylor's (2014) consumer expenditure model. This provides insights into the internal structure and interdependencies of European households' consumption expenditures. We modify Taylor's framework to account for income effects when incorporating the household budget constraint, and derive closed-form expressions for price and income elasticities. In the second part, we integrate the modified Taylor micro-model with an open input-output (IO) quantity framework, analyzing both the resulting non-linear and linearized IO micro-macro systems. The linearized framework enables the integration of any demand system into an IO model, and supports the analysis of consumer price impacts within a demand-driven IO setting. We discuss and empirically examine novel multiplier matrices, which capture the impacts of price changes on consumption, income, and production. As an empirical illustration, we analyze the effects of consumer price increases in the EU.

**Keywords:** household expenditure model, intra-budget coefficients, micro-macro modelling, micro-macro twins, distributional analysis

**JEL Classification Codes:** C51, C63, C67, D12

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# 1 Introduction

Lester D. Taylor, a renowned scholar in the field of demand analysis and consumption behavior, in his recent book *The Internal Structure of US Consumption Expenditures* (Taylor, 2014) has developed and extensively studied a new empirical approach to the analysis of household consumption behavior for the US case.[1] Distinct from the traditional utility maximization-based approach to demand derivation and estimation, the proposed approach focuses on the direct interrelationships between all consumption categories in households' budget. In particular, for an exhaustive set of consumption categories, each category's expenditures are sequentially related to household expenditures on the remaining categories through a series of regression equations. The so-called "*intra-budget*" coefficients – estimates of the direct inter-linkages/dependencies among expenditure categories – become "the engine of analysis" and capture the "conjunctive effects" of tastes and preferences, income, prices, and household characteristics. One of the main conclusions of this book is that "[s]ufficient stability exists in expenditure interrelationships that intra-budget coefficients can be taken as *stable characteristics* of household consumption behavior" (Taylor, 2014, p. 165, italics added).

The empirical stability of intra-budget coefficients makes the resultant microdata-based, meso-level consumer expenditure model suitable for all kinds of analysis. As the approach is "almost entirely statistical and mathematical", its outcome may be consistent with a variety of preference structures, "in that tastes and preferences can be as postulated in traditional [neoclassical demand] theory or they can be lexicographical, hierarchical, or whatever" (Taylor, 2015, p. 34). Subsequent studies, mostly by Taylor himself, applied this basic framework or its extended versions[2] in calculations of full array of price and income elasticities (Taylor, 2017, 2018, 2020, 2021), and evaluation of the distributional impacts on consumption expenditures of drinking water surcharges (Cory and Taylor, 2017), of carbon taxes with income offsets (Rappoport and Taylor, 2020), and of inflation accompanying the COVID-19 pandemic (Taylor, 2022, 2023*a*).

In the first part of this paper, we estimate the Taylor consumption expenditure model for the EU as a whole and each individual EU country.[3] When focusing on the EU as a whole, we modify the Taylor model to account for country-specific factors and relative size, which allows for a more accurate estimation of the interrelationships among European households' expenditures and income variables. To the best of our knowledge, this is the first empirical work with such a non-traditional focus on the EU households' consumption behavior. Our estimation results give deeper insights into the working and implications of the internal structure of EU consumption expenditures. We compare the

[1] The analysis is based on forty Quarterly Consumer Expenditure Surveys of the US Bureau of Labor Statistics, spanning the period from 1996Q1 through 2005Q4.

[2] To be able to calculate income effects, Taylor (2018) included after-tax income as additional regressor in the intra-budget regressions. Recently, Taylor (2024) proposed another extension of his basic framework, where saving is included as an explicit category of consumer expenditure, which thus also allows for calculations of own/cross effects of changes in the "price" of saving.

[3] Except for Italy due to missing income data in the micro-dataset used in this study.

matrix estimates of the direct and total (direct plus indirect) intra-budget interrelationships between household expenditures for the reference years of 2010 and 2015, with and without consideration of household sample weights in the estimation process. Finally, we elaborate on the proper incorporation of the household budget constraint into the basic Taylor expenditure framework and derive closed-form formulas of price and income elasticities. The estimated EU-wide elasticities for ten income groups of households are presented and briefly discussed.

In the second part of our paper, the modified Taylor consumption expenditure model is integrated with the Leontief open input-output (IO) quantity framework. The micro-macro two-way feedback linkages between the two models allow us to properly account for the economy-wide demand-driven income and consumption multiplier effects. Thus, the proposed integrated micro-macro framework incorporates into the analysis the circular consumption demand, production, and income propagation impacts, drawing on the empirical regularities of the country-specific internal structure of the EU households' consumption expenditures.

To get a better understanding of the inner workings of the proposed IO micro-macro model, we linearize the system as the underlying micro-model is highly non-linear in prices and income. We show that the linearized micro-macro model extends the well-known approach of Miyazawa and Masegi (1963) in two key ways. First, it enables the integration of the IO macro-model with *any* micro-model of consumption demand. Second, the proposed framework supports analysis of consumer price impacts within the IO demand-driven framework. As such, we also discuss novel multiplier matrices that capture the impacts of consumer price changes on income, consumption, and production. The quantitative results of such multiplier matrices are also elaborated upon for 26 EU countries in our empirical section.

As an illustrative empirical application, we additionally study the consumption and income impacts of consumer price changes derived from one of the climate policy scenarios analysed in Weitzel et al. (2023) for reaching a 55% reduction in EU greenhouse gas emissions by 2030 compared to 1990 levels. Specifically, the selected scenario incorporates the effects of both regulatory measures and price-based policies, which come closest to the policy package now in place. Our modelling exercises suggest that the Taylor consumer expenditure model can be used within an integrated micro-macro modelling setting to get further insights on household-level consumption and distributional impacts of policies.

Given that our IO micro-macro framework allows for incorporation of any demand system, the (modified) Taylor micro-model can be used alongside other widely-used consumption demand models, such as e.g. the linear expenditure system (Klein and Rubin, 1947-48; Stone, 1954), the Rotterdam model (Barten, 1964; Theil, 1965), the translog (Christensen et al., 1975), the almost ideal demand system (Deaton and Muellbauer, 1980), and/or the exact affine Stone index demand (Lewbel and Pendakur, 2009). Then one would be able to better account for modelling uncertainties that are implied by the various assumptions underpinning each micro-framework. The IO micro-macro framework discussed here lacks supply-side reactions, making it more suitable for impact analyses of economies with unused capacities and far from full employment of resources. For a more comprehensive integration of demand, supply, and prices in commodity and factor markets, alternative approaches are more appropriate (see e.g. Kratena, 2005; Kim et al., 2015; Kratena et al., 2013; Pollitt et al., 2021; Clements et al., 2022; Weitzel et al., 2023).

The remainder of this paper is organized as follows. Section 2 presents the derivation of the Taylor expenditure model and provides an interpretation of its various components. Section 3 examines the implications and country-specific comparisons of the results of the model application, including its modified version for the overall EU case, using the EU household budget surveys for the reference years of 2010 and 2015. The issues of budget constraint incorporation and derivation of income and price elasticities are detailed in the final part of this section. Section 4 details the integration of the considered micro-model with the IO quantity framework, analyzing both the resulting non-linear and linearized micro-macro frameworks. We demonstrate how linearization errors can be eliminated when using the corresponding linearized system, and elaborate on the different multiplier matrices obtained from this framework. The empirical section (Section 5) examines income- and price-related multiplier matrices, and the impacts of increased consumer prices on EU countries, additionally using the FIGARO inter-country IO table for 2015. Finally, Section 6 gives concluding remarks.

## 2 Taylor's consumer expenditure model

Let us denote $e_{hi}$ as household $h$'s expenditure on consumption category $i = 1, 2, \dots, g$, which includes the exhaustive list of consumption expenditure items. The following ordinary least-squares (OLS) regression[4]

$$e_{hi} = \zeta_i + \sum_{j \neq i} \beta_{ij} e_{hj} + \gamma_i y_h + u_{hi} \quad \text{for all } i = 1, \dots, g \tag{1}$$

relates each $i$-th consumption spending of household $h$ to its expenditures on the remaining $(g - 1)$ consumption categories and disposable income $y_h$, with $u_{hi}$ being the error term.

In the next step, the results of the OLS regressions (1) for all consumption categories are written jointly as a system of linear equations, wherein the regressands and regressors are evaluated at their observed mean values. Thus, one ends up using the following compact matrix forms of the variables and coefficients' estimates obtained from regres-

[4] In order not to cause confusions with the well-established input-output notation, for the microdata-based model of household expenditure we generally use different notation from those that appear in Taylor's work.

sions in (1):[5]

$$\mathbf{e}=\begin{bmatrix}\bar{e}_1\\ \bar{e}_2\\ \vdots\\ \bar{e}_g\end{bmatrix},\ y=\bar{y},\ \boldsymbol{\zeta}=\begin{bmatrix}\hat{\zeta}_1\\ \hat{\zeta}_2\\ \vdots\\ \hat{\zeta}_g\end{bmatrix},\ \mathbf{B}=\begin{bmatrix}\hat{\beta}_{11} & \hat{\beta}_{12} & \cdots & \hat{\beta}_{1g}\\ \hat{\beta}_{21} & \hat{\beta}_{22} & \cdots & \hat{\beta}_{2g}\\ \vdots & \vdots & \ddots & \vdots\\ \hat{\beta}_{g1} & \hat{\beta}_{g2} & \cdots & \hat{\beta}_{gg}\end{bmatrix},\ \text{and}\ \boldsymbol{\gamma}=\begin{bmatrix}\hat{\gamma}_1\\ \hat{\gamma}_2\\ \vdots\\ \hat{\gamma}_g\end{bmatrix}, \tag{2}$$

where $\bar{e}_i = \left(\sum_h e_{hi}\right)/n_h$ and $\bar{y} = \left(\sum_h y_h\right)/n_h$, with $n_h$ being the number of households in the sample. Equations (1) and (2) jointly imply the following *structural* and *reduced-form* representations of the Taylor's consumer expenditure model, respectively:[6]

$$\mathbf{e} = \boldsymbol{\zeta} + \mathbf{B}\mathbf{e} + \boldsymbol{\gamma}y, \quad \text{and} \tag{3}$$

$$\mathbf{e} = (\mathbf{I}-\mathbf{B})^{-1}\left(\boldsymbol{\zeta} + \boldsymbol{\gamma}y\right). \tag{4}$$

We will be using the reduced-form framework in (4), wherein $\boldsymbol{\zeta}$ is considered as the vector of exogenous (or autonomous) expenditures. The latter together with (mean) net income $y$ determine through (4) the vector of endogenous total (mean) expenditures $\mathbf{e}$, given $\mathbf{B}$ and $\boldsymbol{\gamma}$.

Based on the size and corresponding ordering of the estimated exogenous expenditures in (4), Taylor (2014, pp. 118-119) gives one possible interpretations of $\boldsymbol{\zeta}$ as being in line with the Maslovian hierarchy of needs, namely, physiological needs, security, love, self-esteem, and self-actualization (Maslow, 1943, 1954). For example, expenditure categories such as housing, food, transportation, health, and personal insurance make the top list of $\boldsymbol{\zeta}$ in Taylor's empirical studies presumably because these can be seen as basic needs for survival and security, hence displaying the greatest expenditure autonomy. On the other hand, endogenous expenditures would reflect the overlaps and interactions across the Maslowian hierarchy of needs, at least partly, due to Taylor's finding that "endogeneity is greatest for the categories that one would associate with the higher-order needs of love, self-esteem, and self-actualization" (Taylor, 2014, p. 119).[7]

Alternatively, one could also regard the exogenous expenditures $\boldsymbol{\zeta}$ in (3) and (4) akin to the "necessary/minimum required/committed/subsistence expenditures" within the Linear Expenditure System (LES) of Klein and Rubin (1947-48).[8] Within the Taylor frame-

[5] Matrices are given in bold, capitals; vectors in bold, lower cases; and scalars in italics, lower case letters. Vectors are columns by definition, row vectors are obtained by transposition, indicated by a prime ($'$). $\boldsymbol{\imath}$ is a summation vector of ones of appropriate dimension. $\hat{\mathbf{x}}$ denotes a diagonal matrix with the entries of $\mathbf{x}$ on its main diagonal and zeros elsewhere.

[6] Note the disappearance of the vector of OLS residuals $\hat{\mathbf{u}}$ from (3) and (4). Obviously, this is due to the fact that OLS residuals are orthogonal to all the regressors (or, generally, to the subspace spanned by the regressors). Thus, residuals in any regression with a constant term, such as (1), will necessarily sum to zero.

[7] For a detailed discussion of the relevance of Maslowian needs for consumption behavior, see Taylor and Houthakker (2010).

[8] The LES demand system was further elaborated and empirically applied to an analysis of the structure of British demand by Stone (1954). For extensive historical and technical details of the LES model, see e.g. Temursho and Weitzel (2024).

work, the exogenous expenditures would constitute the necessary consumption expenditures that are independent of household income *and* of the inherent interdependencies among endogenous expenditures, here formalized and driven by the the so-called *intra-budget coefficients* in $\mathbf{B}$. The only issue is how to interpret negative $\zeta_i$, which is not well explained even in the case of the LES demand system.[9]

Our interpretation of negative $\zeta_i$'s within their perception as necessary expenditures is as follows. If consumers do not have sufficient financial resources to acquire their basic needs, then these ultimately have to be "funded" by "selling" their non-basic needs, leading to negative expenditures on these "non-vital" or more luxurious goods and services. Here "selling" can have both literal and figurative meaning. In the first case, to obtain extra funding for purchasing basic goods, a household could sell some non-basic goods at its disposal or ocasionally provide services, such as transportation on personal transport equipment.[10] The metaphorical meaning of negative exogenous expenditures, on the other hand, has to do with spending on basic needs *at the expense* of certain non-basic consumption. As such, the "necessary expenditure" interpretation of $\boldsymbol{\zeta}$ is also ultimately related to its interpretation from the perspective of Maslovian hierarchy of needs.

However, it is important to note that the estimate of the constant term in a linear regression incorporates (at least) three elements: the true constant coefficient, the constant impact of any specification errors such as that of the omitted variables, and a non-zero mean stochastic term for the correctly specified equation (Studenmund, 2017, p. 208). As such, "any of these three components could make the estimate [of the constant term] negative. ... To improve the [intercept] estimate reliability, instead of using econometric techniques, the researcher should instead be as theoretically inclusive as possible so that the estimated model approximates as much as possible the true model" (Allen and Stone, 2005, p. 382-383).

The matrix of intra-budget coefficients $\mathbf{B}$ produces complex spillover and feedback spending effects among all categories of consumption, hence is considered the "engine of analysis" in models (3) and (4). Interestingly, the mathematical form of (4) is equivalent to the open input-output (IO) model of Leontief (1941), which was also mentioned in Taylor (2014, p. 90). We take up the discussion of the similarities and differences between these two models in the next sections. An important empirical property of $\mathbf{B}$, which represents the "*internal structure of consumption*", is that it embodies a "pressure" or "*self-energy*" that "continually pushes consumption beyond the total expenditure that is available" (Taylor, 2014, p. 164). This "pressure" could be seen as akin to the assumptions of unbounded utility in traditional demand theory. To keep such "self-energy in check", (often) budget constraints need to be explicitly imposed in quantitative assessments based on the Taylor

[9] In fact, some researchers chose to restrict subsistence quantities of consumption to be positive in their estimation of the LES model, following Samuelson (1947-48).

[10] This later case is, in fact, a widely used practice in developing countries. For example, while driving to work, car owners often take passengers for a fee. Although perhaps not as common, in developed countries many people also use such community-based travel platforms as BlaBlaCar, connecting drivers and passengers that are willing to travel together between cities, sharing the cost of the journey. In particular, these travel networks are often used by "drivers" who commute (not at daily basis) long distances to work.

expenditure frameworks (3) and (4). However, the self-energy regulating function is also partly played by the internal structure of consumption, as evidenced by Taylor's findings that the eigenvectors of the matrix $\mathbf{B}$ of intra-budget coefficients all have modulus less than one, which maintains system stability. This is the consequence of how the model has been constructed from the OLS estimation results, which ultimately guarantees the existence of the inverse matrix $(\mathbf{I} - \mathbf{B})^{-1}$ in equation (4).

Formally, the pressure or self-energy of increasing consumption is captured by the matrix $(\mathbf{I}-\mathbf{B})^{-1}$. In what follows, we refer to this matrix as the *consumption expenditure multiplier* matrix, or the *Taylor inverse*, akin to the Leontief inverse matrix in the IO literature. Hence, in what follows for mathematical brevity, we often use the notation $\mathbf{T} \equiv (\mathbf{I} - \mathbf{B})^{-1}$ for the Taylor expenditure multiplier matrix.

## 3 Internal structure of the EU consumption expenditures

In this section, we estimate the intra-budget regressions for EU households, which, to our knowledge, is the first application of the Taylor expenditure model for the case of the EU. We use the EU Household Budget Survey (HBS) data for the reference years of 2010 and 2015 (referred to as the EU HBS 2010 and 2015 waves), which are documented in, respectively, Eurostat (2015) and Eurostat (2020). Due to the voluntary nature of the HBS, both datasets do not include the survey data of Austrian households. The Austrian microdata of consumption survey for 2009-2010 and 2014-2015 were obtained from the national statistical office of Austria (Statistics Austria, 2013, 2018) and incorporated, respectively, into the EU HBS 2010 and 2015 waves. For brevity, we refer to these combined datasets as the EU-HBS-2010 and EU-HBS-2015.[11] Table A.1 in the Appendix gives the summary statistics of the EU-wide budget shares.

### 3.1 A multi-country intra-budget regression framework

We start with the EU-wide application of regression (1). However, instead of a single constant term $\zeta_i$, we use dummy variables $D_r$ for each EU country $r$ to capture country-specific factors, which allows for a more accurate estimation of the EU-wide relationships between the expenditures and income variables. Thus, we run the following intra-budget regressions[12]

$$e_{hi} = \sum_{r} \zeta_i^r D_r + \sum_{j \neq i} \beta_{ij} e_{hj} + \gamma_i y_h + u_{hi} \quad \text{for all } i = 1, \ldots, g, \tag{5}$$

where $\boldsymbol{\zeta}^r$ can be interpreted as the vector of "exogenous consumption expenditures" in country $r$. Also different from Taylor's approach, the expenditures $e_{hi}$ and net income $y_h$

[11] For details of processing these datasets, see Temursho et al. (2020) and Temursho and Weitzel (2024). The first report also provides a comprehensive overview of the HBS 2010 wave.

[12] For brevity, the country identifiers are suppressed in all the variables, except for the country indicators.

variables are all expressed in per adult equivalent terms in order to account, to the extent possible, for the differences in size and composition of households.[13]

To minimize the effect of zero-expenditure problem in survey data, we choose $g = 11$ exhaustive aggregate consumption categories, which correspond to the 2-digit divisions (i.e. level 1) of the European Classification of Individual Consumption according to Purpose (ECOICOP), with the only exception that "Education" (CP10) is added to "Miscellaneous goods and services" (CP12).[14]

Since the sum of $D_r$'s across all countries equals unity for each individual household, all the residuals from (5) sum to zero, which is the necessary condition for derivation of the reduced-form counterpart of (4). Hence, the reduced-form household expenditure model obtained from (5) is as follows:

$$\mathbf{e} = (\mathbf{I} - \mathbf{B})^{-1} \left( \mathbf{Z}\mathbf{w} + \boldsymbol{\gamma} y \right), \tag{6}$$

where $\mathbf{Z} = \left[ \boldsymbol{\zeta}^1 \; \boldsymbol{\zeta}^2 \; \cdots \; \boldsymbol{\zeta}^{n_r} \right]$ is the $g \times n_r$ matrix of exogenous expenditures of each of the $n_r$ EU countries, and $\mathbf{w}$ is the $n_r$-vector of countries' relative size, expressed in terms of the number of households in the sample. That is, the typical element of $\mathbf{w}$ is defined as $w_r = n_h^r / n_h^{EU}$, with $n_h^r$ being the number of sample households (observations) of country $r$ and $n_h^{EU} = \sum_r n_h^r$.[15]

By construction, the country weights sum to one, i.e. $\sum_r w_r = 1$. Therefore, the vector $\mathbf{Zw}$ in (6) can be interpreted as the (weighted) *average* exogenous expenditures on each considered consumption category of the whole EU, basically playing the same role as $\boldsymbol{\zeta}$ in a one-country Taylor framework (4).

An alternative estimation approach would be to use weighted least squares (WLS) instead of the standard OLS, where household survey weights are employed to account for the representativeness of different types (and locations) of households.[16] Within the WLS setting, country weights are no longer equal to simple averages of the corresponding number of observations, but instead are derived from the survey sample weights. If $\omega_h^r$ denotes the sample weight of household $h$ in country $r$, then $w_r = \left( \sum_h \omega_h^r \right) / \left( \sum_{r'} \sum_{h'} \omega_{h'}^{r'} \right)$. With the WLS applied to (5), it is now the weighted (and not the simple) sum of residuals that is zero. Thus, within the WLS framework, the mean expenditures and mean income variables should also be redefined as weighted averages, using the household sample weights, i.e. $\bar{e}_i = \left( \sum_h \omega_h e_{hi} \right) / \left( \sum_k \omega_k \right)$ for all $i = 1, \ldots, g$ and $\bar{y} = \left( \sum_h \omega_h y_h \right) / \left( \sum_k \omega_k \right)$,

[13]To obtain *equivalized* expenditures and net income variables, we use the modified OECD scale, which assigns a value of 1 to the first adult in the household, of 0.5 to the second and each subsequent person aged over 13, and of 0.3 to each child aged 13 or under.

[14]The reason is that the share of zero expenditures is by far the highest for Education compared to other categories, being 81% and 82% of households in our EU-HBS-2015 and EU-HBS-2010 data, respectively. The issue is more extreme for the poorest EU households. For example, the first and second income decile report, respectively, 97% and 93% zero Education expenditures in EU-HBS-2015 and EU-HBS-2010.

[15]We do not set the number of EU countries to $n_r = 27$, because a few countries do not report income variables, which varies between EU-HBS-2010 and EU-HBS-2015.

[16]For the pros and cons of using survey weights in WLS vs. unweighted OLS when analyzing survey data, see e.g. Deaton (2019).

where we suppressed the country superscripts for simplicity. With these redefinitions of country weights and mean variables, equation (6) based on the WLS estimates exactly replicates, as it should, the observed weighted average expenditures for the base year (or baseline scenario) that represents the survey data.

**Table 1:** Estimated coefficients of the intra-budget regressions for EU, 2015

| Consumption category | Intra-budget coefficients matrix B c1 | c2 | c3 | c4 | c5 | c6 | c7 | c8 | c9 | c10 | c11 | Zw | Inc | R2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Coefficients of intra-budget OLS regressions | | | | | | | | | | | | | |
| c1 FoodNalcBvg | -- | 0.2001 | 0.1075 | -0.0145 | 0.0395 | 0.0327 | 0.0022 | 0.1229 | 0.0224 | -0.0034 | 0.0564 | 1542.1 | 0.0125 | 0.33 |
| c2 AlcBvgTbc | 0.0653 | -- | -0.0058 | 0.0123 | 0.0028 | -0.0015 | 0.0012 | 0.0867 | 0.0012 | 0.0374 | -0.0034 | 74.0 | 0.0013 | 0.09 |
| c3 ClothFtwr | 0.0806 | -0.0134 | -- | 0.0003 | 0.0294 | 0.0089 | 0.0066 | 0.1851 | 0.0316 | 0.1058 | 0.0556 | 27.6 | 0.0097 | 0.24 |
| c4 HousWtrElc | -0.0547 | 0.1416 | 0.0016 | -- | 0.0674 | 0.0201 | -0.0071 | 0.6131 | 0.0001 | 0.0436 | 0.0149 | 1855.9 | 0.0064 | 0.30 |
| c5 FurnshHeqp | 0.1132 | 0.0242 | 0.1124 | 0.0513 | -- | 0.0279 | 0.0082 | 0.1210 | 0.0300 | 0.0397 | 0.0625 | -233.2 | 0.0188 | 0.12 |
| c6 Health | 0.0643 | -0.0093 | 0.0234 | 0.0105 | 0.0192 | -- | 0.0001 | 0.0269 | 0.0192 | 0.0045 | 0.0309 | -13.4 | 0.0199 | 0.08 |
| c7 Transport | 0.0327 | 0.0551 | 0.1300 | -0.0277 | 0.0419 | 0.0006 | -- | 0.5858 | 0.0423 | 0.2717 | 0.0969 | -17.9 | 0.0663 | 0.14 |
| c8 Communicat | 0.0097 | 0.0209 | 0.0194 | 0.0128 | 0.0033 | 0.0011 | 0.0031 | -- | 0.0050 | 0.0145 | 0.0136 | 284.6 | 0.0026 | 0.33 |
| c9 RecreatCult | 0.0969 | 0.0154 | 0.1826 | 0.0001 | 0.0454 | 0.0421 | 0.0125 | 0.2728 | -- | 0.1391 | 0.0740 | -11.2 | 0.0280 | 0.19 |
| c10 RestrntHotl | -0.0047 | 0.1576 | 0.1944 | 0.0159 | 0.0191 | 0.0031 | 0.0255 | 0.2546 | 0.0443 | -- | 0.0580 | -76.5 | 0.0268 | 0.29 |
| c11 MiscGSEduc | 0.1218 | -0.0224 | 0.1601 | 0.0085 | 0.0471 | 0.0339 | 0.0143 | 0.3739 | 0.0369 | 0.0909 | -- | 253.5 | 0.0303 | 0.37 |
| | Coefficients of intra-budget WLS regressions | | | | | | | | | | | | | |
| c1 FoodNalcBvg | -- | 0.1775 | 0.0889 | -0.0277 | 0.0526 | 0.0337 | 0.0022 | 0.1113 | 0.0263 | -0.0157 | 0.0611 | 1674.7 | 0.0149 | 0.24 |
| c2 AlcBvgTbc | 0.0527 | -- | -0.0039 | 0.0123 | 0.0022 | 0.0010 | 0.0017 | 0.1066 | 0.0014 | 0.0379 | -0.0043 | 117.9 | 0.0009 | 0.07 |
| c3 ClothFtwr | 0.0488 | -0.0072 | -- | 0.0020 | 0.0281 | 0.0141 | 0.0074 | 0.2139 | 0.0309 | 0.0941 | 0.0417 | 95.3 | 0.0087 | 0.18 |
| c4 HousWtrElc | -0.0877 | 0.1306 | 0.0115 | -- | 0.0478 | 0.0287 | -0.0109 | 0.7628 | 0.0041 | 0.0517 | -0.0089 | 2366.4 | 0.0093 | 0.26 |
| c5 FurnshHeqp | 0.1105 | 0.0153 | 0.1077 | 0.0318 | -- | 0.0327 | 0.0081 | 0.1311 | 0.0369 | 0.0234 | 0.0719 | -268.6 | 0.0200 | 0.10 |
| c6 Health | 0.0449 | 0.0045 | 0.0343 | 0.0121 | 0.0207 | -- | -0.0017 | 0.0199 | 0.0199 | 0.0066 | 0.0294 | 6.1 | 0.0153 | 0.06 |
| c7 Transport | 0.0249 | 0.0641 | 0.1540 | -0.0391 | 0.0436 | -0.0141 | -- | 0.6822 | 0.0422 | 0.3619 | 0.0761 | 6.5 | 0.0605 | 0.12 |
| c8 Communicat | 0.0062 | 0.0201 | 0.0218 | 0.0135 | 0.0035 | 0.0008 | 0.0034 | -- | 0.0067 | 0.0125 | 0.0101 | 315.7 | 0.0019 | 0.26 |
| c9 RecreatCult | 0.0855 | 0.0152 | 0.1836 | 0.0042 | 0.0572 | 0.0488 | 0.0121 | 0.3886 | -- | 0.1313 | 0.0629 | -0.7 | 0.0280 | 0.17 |
| c10 RestrntHotl | -0.0192 | 0.1562 | 0.2102 | 0.0200 | 0.0136 | 0.0061 | 0.0390 | 0.2747 | 0.0494 | -- | 0.0402 | -105.6 | 0.0267 | 0.23 |
| c11 MiscGSEduc | 0.1298 | -0.0305 | 0.1616 | -0.0060 | 0.0726 | 0.0469 | 0.0142 | 0.3825 | 0.0410 | 0.0698 | -- | 435.2 | 0.0312 | 0.29 |

*Note*: There are 261,271 observations for 26 EU countries, as Italy is excluded due to missing income data. A coefficient estimate corresponding to e.g. row *c*3 and column *c*1 indicate $\tilde{\beta}_{31}$. 'Inc' refers to $\tilde{\boldsymbol{\gamma}}$. The country weights and the estimates of $\boldsymbol{\zeta}^{c}$'s are reported in Table A.2 in the Appendix. All the *t*-ratios are given in the supplementary file.

The estimated coefficients of $\mathbf{B}$, $\mathbf{Zw}$ and $\boldsymbol{\gamma}$ from the OLS and WLS regressions of the intra-budget equations in (5) for the pooled data of all 26 EU countries in 2015 are presented in Table 1. The estimates of country-specific coefficients $\boldsymbol{\zeta}^{r}$ and country weights are reported in Table A.2 in the Appendix.[17] The *t*-ratios, based on the heteroskedastic-corrected standard errors, are given in the supplementary file. Given the large sample size of 261,271 observations, it is not surprising that the overwhelming majority of the coefficients are statistically significant.

Without delving into all the details, the following observations can be made from these results.

- The intra-budget coefficients matrix $\mathbf{B}$ contains both positive and negative elements, which is expected as these allow for substitution and complementarity between different categories of consumption expenditures of households. We note that unlike $\mathbf{B}$, the input-output coefficients matrix $\mathbf{A}$ in Leontief models (see next section) is a non-negative matrix.

[17] The estimates should be denoted as $\tilde{\mathbf{B}}$, $\tilde{\mathbf{Z}}\mathbf{w}$, $\tilde{\boldsymbol{\gamma}}$ and $\tilde{\boldsymbol{\zeta}}^{c}$. However, misusing the notation, for simplicity, we suppress the tilde sign (for estimate) throughout the text.

- The goodness of fit measures ($R^2$) of the WLS regressions are, on average, about 20% lower than those of the OLS regressions.
- From 110 direct expenditure interactions in $\mathbf{B}$, the following three pairs of reciprocal interactions (i.e. in six instances) show sign changes in the WLS as opposed to the OLS results: {AlcBvgTbc-Health}, {HousWtrElc-MiscGSEduc}, and {Health-Transport}. However, the coefficients of these interactions are found to be statistically (and size-wise) insignificant in both estimations.[18]
- Overall, the coefficients of the OLS and WLS results are rather different, yet exhibit similar general patterns. To quantify the closeness of two matrices, we use the weighted mean absolute percentage error (WAPE) indicator widely used in the IO literature (see e.g. Mínguez et al., 2009; Temurshoev et al., 2011). WAPE for any matrix $\mathbf{X}$ and its estimate $\tilde{\mathbf{X}}$ is defined as[19]

$$WAPE(\mathbf{X}, \tilde{\mathbf{X}}) = \sum_i \sum_j \left( \frac{|x_{ij}|}{\sum_k \sum_l |x_{kl}|} \right) \frac{|\tilde{x}_{ij} - x_{ij}|}{|x_{ij}|} \times 100, \tag{7.a}$$

which weights each percentage deviation of the estimate $\tilde{x}_{ij}$ from its "true" value $x_{ij}$ by the relative size of the true (or, better, benchmark) element $x_{ij}$ in their overall sum. Importantly, the deviations and benchmark entries $x_{ij}$'s are all taken in absolute values to properly account for both negative and positive deviations and the size of $x_{ij}$'s. In the current framework, as there is no way to know the "true" coefficients matrices/vectors (unless implemented in a simulation environment), we use the mean WAPE value instead, defined as

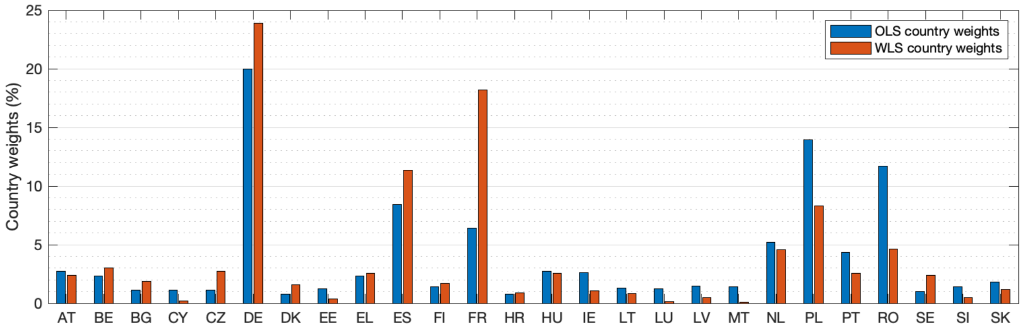
$$Mean\ WAPE = 0.5 \times \left( WAPE(\mathbf{X}, \tilde{\mathbf{X}}) + WAPE(\tilde{\mathbf{X}}, \mathbf{X}) \right). \tag{7.b}$$

The following results on comparing the OLS vs. WLS outcomes are obtained. The *mean WAPE* of 18.1% is found for $\mathbf{B}_{ols}$ and $\mathbf{B}_{wls}$, of 10.5% for $\mathbf{Z}_{ols}$ and $\mathbf{Z}_{wls}$ (i.e. the matrices of country intercepts or country-specific exogenous expenditures), and of 9.0% for $\boldsymbol{\gamma}_{ols}$ and $\boldsymbol{\gamma}_{wls}$. In terms of Taylor inverses, the mean WAPE between $\mathbf{T}_{ols}$ and $\mathbf{T}_{wls}$ further decreases to 7.7%. All these differences are obviously due to using or not using the household sample weights in the OLS and WLS regressions. As an illustration, Figure 1 shows the corresponding country weights. It can be seen that, compared to the OLS approach, in WLS the weights of e.g. France, Germany and Spain are much higher, while those of Romania, Poland and Portugal are substantially lower. The changes in the EU-wide intra-budget coefficients, thus, reflect how households in different EU countries are given more or less weights in the estimations, representing either the number of sample or population households in the micro-datasets.

[18] The only exception of statistically significant intra-budget coefficient in the mentioned interactions is found for {HousWtrElc-MiscGSEduc} in case of the OLS regression.

[19] We note that "WMAPE" would have been a better abbreviation, indicating it to be a weighted version of the simple (unweighted) mean absolute percentage error (MAPE) measure (Butterfield and Mules, 1980).

**Figure 1:** Country weights in the EU-wide OLS and WLS regressions, 2015



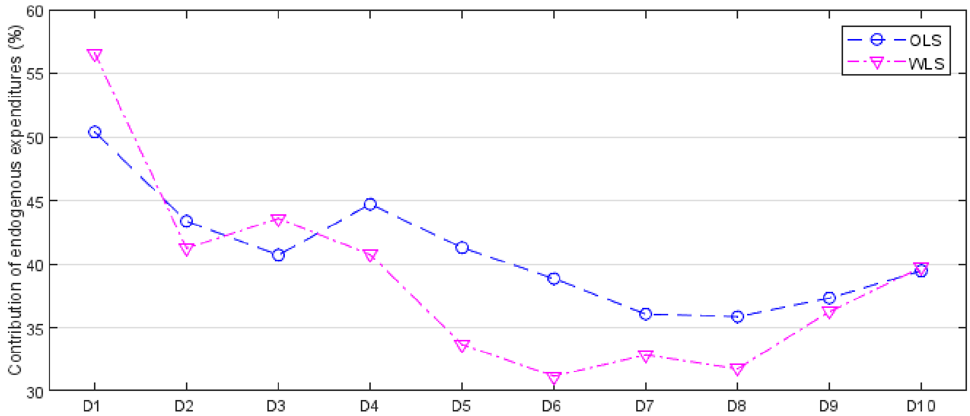

*Note*: Italy is excluded due to missing income data.

- In line with the interpretations of $\boldsymbol{\zeta}^r$'s given in the previous section, we find negative EU-wide average (equivalized) exogenous expenditures ($\boldsymbol{\zeta}^{EU} \equiv \mathbf{Zw}$, in EUR) for Furnishings and household equipment (FurnshHeqp), and Restaurants and hotels (RestrntHotl). The small negative average $\zeta_i^{EU}$ for Recreation and culture (RecreatCult) in both WLS and OLS, and for Health and Transportation in case of OLS are all found to be statistically insignificant.[20] By far the largest EU-wide average positive (equivalized) exogenous expenditures are found for Housing, water, electricity, gas and other fuels (HousWtrElc), and Food and non-alcoholic beverages (FoodNalcBvg), which is also consistent with the Maslovian hierarchy of needs interpretation. Analogous findings are obtained by Taylor from the US consumer surveys.
- The contributions of total EU-mean exogenous expenditures ($\boldsymbol{\imath}'\mathbf{Zw}$) and net income ($\boldsymbol{\imath}'\boldsymbol{\gamma}y$) to total expenditures ($\boldsymbol{\imath}'\mathbf{e}$) are found to be, respectively, 29.8% and 28.0% in case of OLS regressions. This implies that the remaining 42.3% of total expenditures is generated *endogenously* through the complex feedback and spillover interactions of the internal structure of EU consumption expenditures. The corresponding contributions of exogenous expenditures, income, and endogenous expenditures in the WLS case are found to be 32.9%, 27.4%, and 39.8%, respectively. The extent of average endogenous generation of expenditures in the EU is thus found to be *lower* than that in the US, which Taylor (2023*b*) estimates to be more than 50% (namely, 52.7%) of household total consumption expenditure. One potential explanation for this difference might be due to the fact that our estimations are based on equivalized variables, but those of Taylor are not. If we re-run the OLS and WLS regressions using non-equivalized expenditures and income variables, the relative size of total endogenous expenditures increases to 48.5% (from 42.3%) and 47.3% (from 39.8%), respectively. These non-negligible differences imply that one better account for the heterogeneity of households' size and composition in exploring the interdependencies between household spending on different consumption categories.

[20] The variance of of the $i$-th entry of $\mathbf{Zw}$ is readily obtained from $Var(\mathbf{Z}_{i\cdot}\mathbf{w}) = \mathbf{w}'Cov(\mathbf{Z}_{i\cdot})\mathbf{w}$, where $\mathbf{w}$ includes the country weights, $\mathbf{Z}_{i\cdot}$ is the $i$-th row of $\mathbf{Z}$ (i.e. country-specific estimates of "exogeneous expenditures" for good $i$), and $Cov(\mathbf{Z}_{i\cdot})$ is the corresponding heteroskedastic-consistent covariance matrix.

To gain a deeper understanding of the implications of the internal structure of EU consumption expenditures, we separately run the intra-budget regressions in (5) for 10 types of EU households, based on their equivalized net income.[21] All the coefficients and their (heteroskedasticity-robust) t-scores are reported in the supplementary file.

**Figure 2:** Contribution of total endogenous expenditures (%), 2015




*Note*: D1 and D10 refer, respectively, to the poorest and richest EU-wide deciles. This household categorization is based on equivalized net income.

Figure 2 shows the estimates of the shares of EU-wide total endogenous expenditures in total expenditures by household income decile. The results of both OLS and WLS estimations indicate that the capacity of endogenous generation of consumption expenditures generally decreases with consumer's income level. So, while the share of endogenous expenditures in total consumption spending is estimated to be between about 50% to 56% for the poorest households, it decreases to 39-40% for the richest households in the 10th decile. According to the WLS results, households in 5th to 8th deciles exhibit even lower expenditure-generating capacity, between about 31% to 34%. However, the overall downward trend of the extent of generation of endogenous expenditures in relation to income levels (or deciles) mirrors the well-established empirical observation of decreasing marginal propensity to consume as income rises (Keynes, 1936, Chapter 10).

### 3.2 Country-specific applications

We have also run the intra-budget regressions in (1) for each EU country separately using both EU-HBS-2010 and EU-HBS-2015 datasets. The corresponding OLS and WLS coefficients' estimates and t-ratios (for the year of 2015) are given in the supplementary file. It is of particular interest to compare the stability (or closeness) of matrices **B** and **T** for

[21]We note that the EU-wide deciles for OLS and WLS are different. To be consistent with the WLS approach, household sample weights are also explicitly accounted for in calculation of the EU deciles. This is not the case for deciles used in OLS regressions.

the two reference years.[22] Figure 3 shows the corresponding mean WAPE values and the number of sign changes of matrices $\mathbf{B}$ and $\mathbf{T}$ across the two reference years, from which the following conclusions can be made:

- Across all the 24 considered EU countries, the intra-budget coefficients between 2010 and 2015 differ, on average, by 55% in case of OLS regressions and by 60% for WLS results. However, there is a lot of heterogeneity in these differences at the individual country level. For example, Spain shows the smallest average WAPE of 26% for OLS results, while in Slovakia the corresponding WAPE is 93%.
- Compared to the $\mathbf{B}$ matrices, the expenditure multiplier matrices $\mathbf{T}$ are found to be more stable over time. On average, the country-specific mean WAPEs are 51% less than those for intra-budget coefficients matrices. This declining divergence outcome is not surprising as the elements in the Taylor inverse, $\mathbf{T} = (\mathbf{I} - \mathbf{B})^{-1}$, consider all direct and indirect links across expenditure categories, which in a way diminishes the extent of differences present in $\mathbf{B}$.
- The signs of the elements in $\mathbf{B}$ and $\mathbf{T}$ indicate complementary or substitutability nature of consumption expenditures. Hence, it is useful to see in how many cases these elements change over time out of possible 110 ($= g \times (g - 1)$) cases. On average, 15% of the elements of $\mathbf{B}$ have different signs for the reference years of 2010 and 2015. The corresponding value for the Taylor inverse matrix is 9%. Again, there are a lot of differences in the country-specific results. Surprisingly, in case of Romania and Slovakia the number of sign changes are higher in $\mathbf{T}$ than in $\mathbf{B}$.

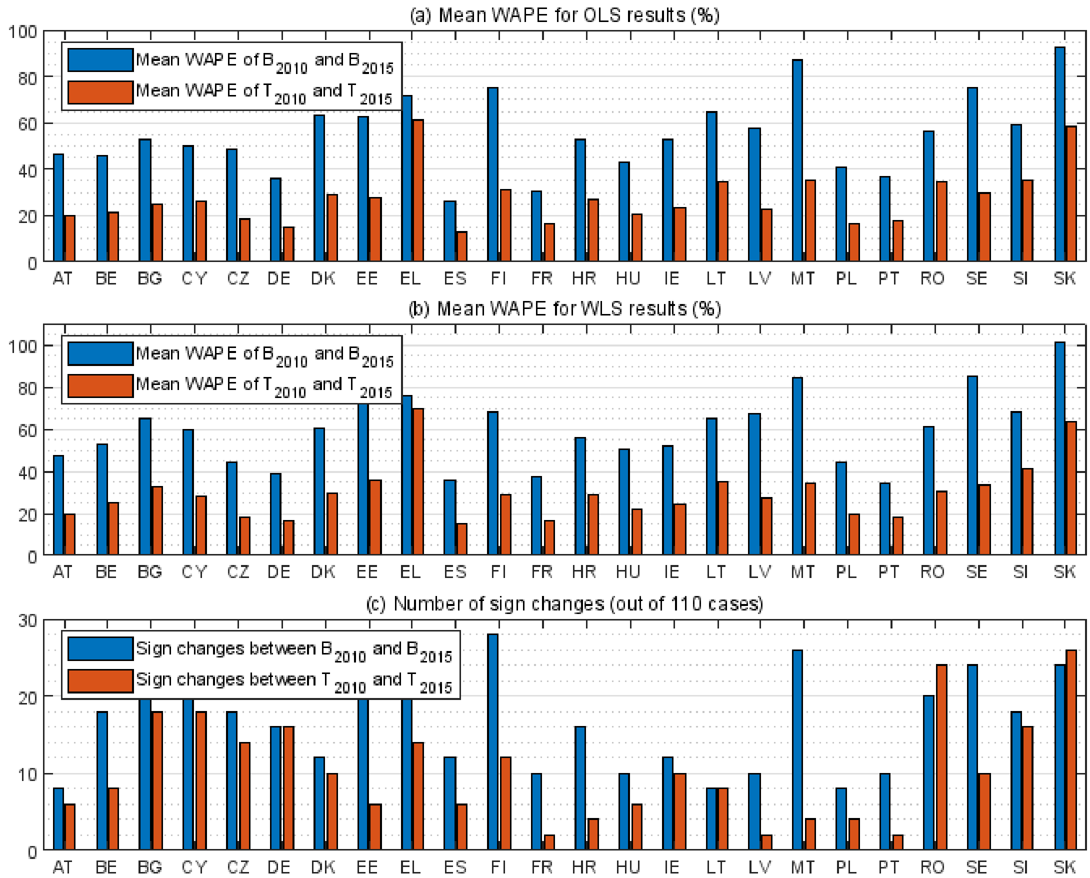
All in all, the higher stability of the expenditure multiplier elements is generally a favourable outcome, since it is the matrix $\mathbf{T}$ that is ultimately used in the modelling assessments. However, one should be cautious of this relative stability for certain countries. For example, Greece and Slovakia are found to be outliers with quite high mean WAPEs of the $\mathbf{T}$ matrices, ranging from 58% to 69% (depending on whether one looks at the OLS or WLS results). One practical way of dealing with such cases could be estimating the country-specific intra-budget regressions on a *pooled-across-time* data obtained from both EU-HBS-2010 and EU-HBS-2015. Indeed, this might increase the reliability of the estimated coefficients, and could even be preferable to carry out for all EU countries.[23]

Next, we show the estimates of the contributions of total exogenous and endogenous expenditures to total consumption spending by country. All the corresponding OLS and WLS results for both 2010 and 2015 reference years are illustrated in Figure 4. *On average, from 26% to 29% of total household spending is accounted for by exogenous expenditures, while the corresponding range of total endogenous expenditure contribution is 45%-49%.* There are, obviously, differences across countries, which we do not discuss here further.

[22] Because of missing data for Luxembourg and the Netherlands in EU-HBS-2010, these two countries are excluded from our 2010 vs. 2015 comparison exercises. As before, Italy is also excluded due to missing income data in both EU-HBS-2010 and EU-HBS-2015.

[23] However, as noted by one of the referees, a pooled regression with *panel* data surveys may not improve the reliability of the estimates as "the consumption structure of the same household might not significantly change in a span of 5 years".

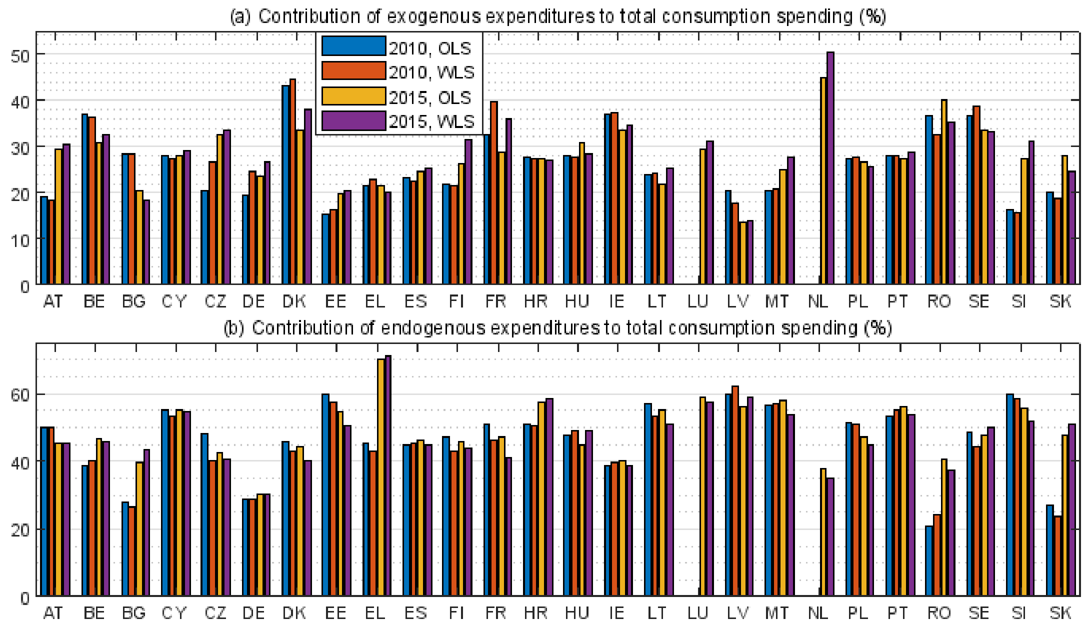
**Figure 3:** Comparison of country-specific matrices **B** and **T** for 2010 and 2015




*Note*: Here we consider 24 EU countries. Italy is excluded because of the missing income data in both EU-HBS-2010 and EU-HBS-2015. In addition, Luxembourg and the Netherlands are also excluded due to missing data in EU-HBS-2010.

We have noted earlier the rather close conceptual relation between exogenous expenditures in Taylor's expenditure framework and subsistence expenditures in the LES demand setting. From the empirical literature on the LES model (see e.g. Brown and Deaton, 1972; Clements et al., 2020; Temursho and Weitzel, 2024), it can be inferred that at the country level, on average, the total subsistence share in household budget ranges between 42% to 64%. Often an average value of 50% is chosen (Clements et al., 2022), which corresponds to a "compromise value of about -2 for the money flexibility" (Frisch, 1959, p. 189), also known as the Frisch parameter. While in the LES model, subsistence expenditures are (assumed to be) independent of money income, within the Taylor's framework, exogenous expenditures are additionally (assumed to be) independent of feedbacks from spending on all consumption categories. That is, Taylor's exogenous expenditures also exclude spending-generated endogenous expenditures. Therefore, the share of total exogenous expenditures has to be *lower* than the total subsistence share in the LES framework, which is indeed what we find. According to our findings, *if necessary, due to data lack/limitations, a rough counterpart to the 50% total subsistence share rule of thumb for exogenous expenditures is around 28%, or a "more convenient" figure of 30%*. However, as shown in

**Figure 4:** Contributions of total exogenous and endogenous expenditures




*Note*: For excluded countries, see the note to Figure 3. Direct income contribution is the residual that makes up for 100% of total consumption spending.

Figure 4, countries may differ considerably in terms of exogenous as well as endogenous expenditure shares.

## 3.3 Price and income elasticities

One of the useful applications of the Taylor expenditure model is the derivation of own- and cross-price elasticities based on expenditure data, without needing/using data for prices of individual consumption categories. The second appeal of such results lies in their "pure" empirical basis, rather than being grounded on a utility-maximization framework (for the proof, see Appendix C). Clearly, the usefulness of this approach assumes that the HBS data accurately capture the values and structure of actual household consumption expenditures for the survey period.

Unfortunately, the process of derivation and calculation of elasticities in Taylor's work is rather mechanical. A proper calculation of elasticities requires deriving their *closed-form* expressions. In addition, there is an issue of budget-constraint inconsistency when using only the basic household expenditure frameworks (4) or (6) for economic modelling purposes. Incorporating a budget constraint into the basic Taylor expenditure model needs to be linked to income in order to allow for a meaningful calculation of both price and income elasticities. For example, the consumer budget adding-up restriction implies that the budget-share-weighted own- and cross-price elasticities must always sum in a particular way (Cournot aggregation), or the budget-share-weighted income elasticities must always sum to one (Engel aggregation), see e.g. Jehly and Reny (2011, p.61).

Let us denote the (mean) quantity demanded and price of good $i$ by $q_i$ and $p_i$, respectively. We consider the following *modified* Taylor (real) consumption demand:

$$q_i = \frac{\rho y}{p_i} \frac{e_i}{\sum_k e_k}, \tag{8}$$

where $\rho \equiv \boldsymbol{\iota}'\mathbf{e}_0/y_0$ is the (average) propensity to consume of households in the base year, denoted by subscript 0, and $e_i$ is derived from the reduced form expenditure equations (4) or (6). We do not set $\rho = 1$ because, in the current setting, income includes household savings, which are not modelled similar to the consumption goods.

The term $\rho y$ in (8) ensures that the sum of total expenditures in nominal terms respects the overall budget constraint, which assumes that in simulations the share of total expenditures in income remains constant at its base-year proportion, $\rho$. With income (appearing in term $\rho y$) kept fixed, (8) boils down to Taylor's approach of keeping the base-year sum of total expenditures constant.[24] However, it is important to allow for changing income also in imposing the budget constraint for proper calculations of income elasticities. Furthermore, in our micro-macro modelling exercises in the next section, such consumption-income linking allows to capture the Keynesian multiplier effects that arise from interdependencies between consumption, production, and income.

Starting with the basic Taylor framework in (4), it becomes useful to decompose the total (mean) expenditure $e_i$ into its two constituent expenditure components, one driven by exogenous spending and the other by income, as follows:

$$e_i = \sum_j \underbrace{t_{ij}\zeta_j}_{e_{ij}^{xsp}} + \underbrace{\sum_j t_{ij}\gamma_j y}_{e_i^{inc}} = \sum_j e_{ij}^{xsp} + e_i^{inc}, \tag{9}$$

where $t_{ij}$ is the typical element of the Taylor inverse. Thus, $e_{ij}^{xsp}$ is the total expenditure on consumption good $i$ that is driven by exogenous spending on good $j$, and $e_i^{inc}$ is the total expenditure on good $i$ induced by income. Under the multi-country expenditure framework (6), exogenous spending $\zeta_j$ in (9) needs to be replaced by the $j$th element of $\mathbf{Zw}$, i.e. $\zeta_j = \sum_r \zeta_j^r w_r$.

To be able to use the expenditure model for policy evaluation purposes, following Taylor, the quantity and price components of the exogenous spending have to be made explicit by setting $\zeta_i = z_i p_i$. Finally, let $s_i \equiv \frac{e_i}{\sum_k e_k}$ denote the budget share of (or income share spent on) good $i$ in the Taylor expenditure framework.[25] With these new definitions at

[24]There are other options on how the budget constraint may be imposed. Taylor (2021) considers two alternative ways of imposing a total-expenditure budget constraint on levels and differences of expenditures, using budget shares as weights in the later case. The results show minor differences. Overall, in all other Taylor's work, preference is given to the proportional adjustment option of imposing the total-expenditure budget constraint.

[25]Thus, note that, alternatively, the modified Taylor demand function (8) can be written as $q_i = \frac{\rho s_i y}{p_i}$, which resembles the Cobb-Douglas utility-based Marshallian demand function (when $\rho = 1$). However, unlike the latter, where the income share is constant, in (8) it varies with prices, income, and the model

hand, it can be shown that the own/cross-price and income elasticities for the modified Taylor demand function (8) are readily obtained from the following expressions (for the proof, see Appendix B):

$$\epsilon_{ii} = \frac{e_{ii}^{xsp} - s_i e_{\bullet i}^{xsp}}{e_i} - 1, \tag{10.a}$$

$$\epsilon_{ij} = \frac{e_{ij}^{xsp} - s_i e_{\bullet j}^{xsp}}{e_i} \quad \text{with } i \neq j, \tag{10.b}$$

$$\eta_i = \frac{e_i^{inc} - s_i e_{\bullet}^{inc}}{e_i} + 1, \tag{11}$$

where the dot sign indicates summation taken over the corresponding dimension, i.e. $e_{\bullet j}^{xsp} = \sum_k e_{kj}^{xsp}$ and $e_{\bullet}^{inc} = \sum_k e_k^{inc}$. It is worth noting that the second terms in the numerators of the above expressions, which include income shares $s_i$, are due to the incorporation of a budget constraint into the basic Taylor expenditure framework.

It can also be shown that the elasticities in (10.a), (10.b) and (11) satisfy the properties of demand homogeneity, i.e. $\sum_j \epsilon_{ij} + \eta_i = 0$; Engel aggregation, i.e. $\sum_k s_k \eta_k = 1$; and Cournot aggregation, i.e. $\sum_k s_k \epsilon_{kj} = -s_j$ (for the interpretations of these properties, see e.g. Temursho and Weitzel, 2024).[26]

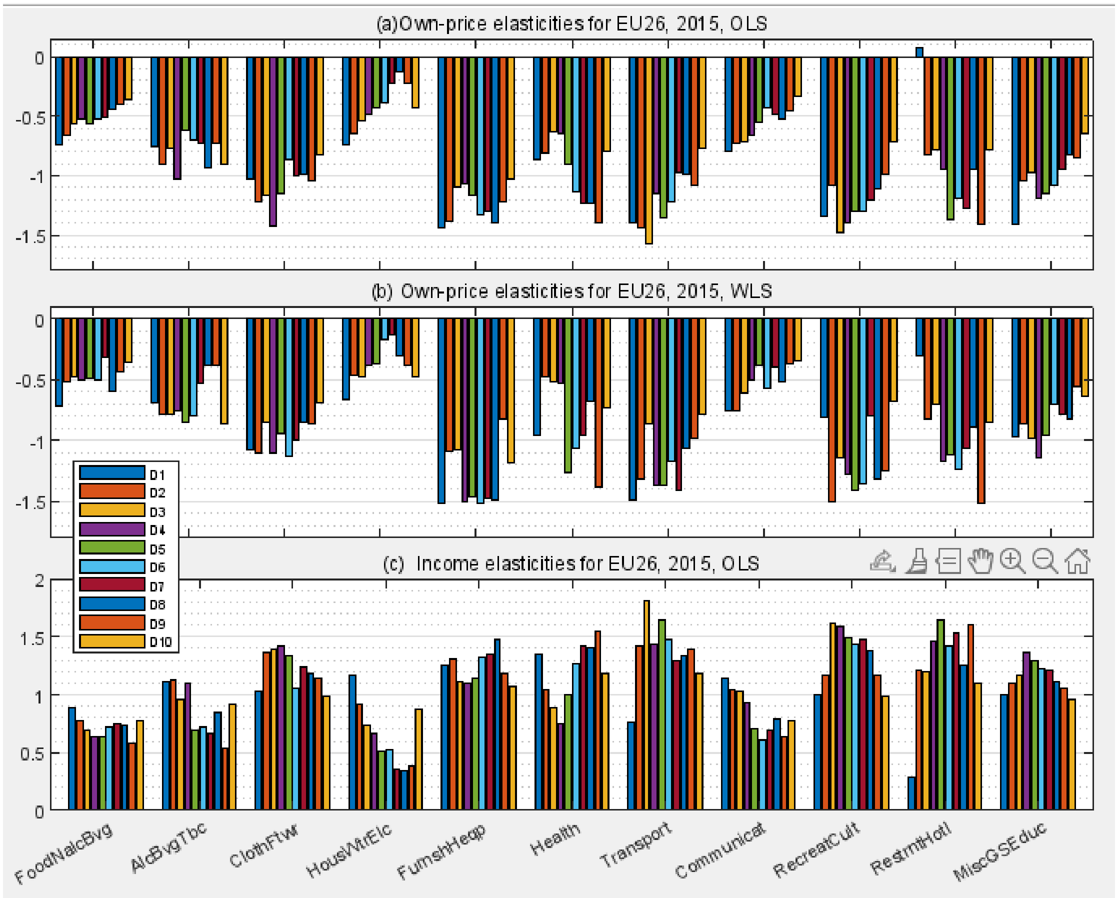
In Figure 5 we illustrate the estimates of the EU-wide own-price and income elasticities by income decile, with the corresponding own/cross-price and income elasticities given in the supplementary file. Note that the signs and/or evolution of own-price elasticities by household income level do not always match with what is expected as per traditional demand theory. For example, we find one case of (small) positive own-price elasticity for Restaurants and hotels demanded by the poorest households in case of OLS regressions. In traditional theory, positive own-price elasticity of demand can arise only for inferior goods with significant budget share. In the current setting, however, "a good that, in isolation, would respond inversely to movements in its own price can in fact move positively because of feedbacks from other goods" (Taylor, 2022, p. 245).[27] These complex web of interrelated expenditure effects can be traced through a thorough examination of the intra-budget coefficients matrix $\mathbf{B}$ and its round-by-round transformation into the expenditure multiplier matrix, as obtained from $\mathbf{T} = \mathbf{I} + \mathbf{B} + \mathbf{B}^2 + \mathbf{B}^3 + \cdots$. Here, one can

parameters, i.e. $s_i = s_i(\mathbf{p}, y; \mathbf{T}, \boldsymbol{\zeta}, \boldsymbol{\gamma})$, where one can set $\boldsymbol{\zeta} = \mathbf{z}$ in the base year with assumed unitary prices.

[26] If in (8), we instead impose a constant total expenditure constraint, as in Taylor's preferred expenditure proportional adjustment approach, i.e. set $\rho y = \alpha$, then the closed-form expressions for the corresponding own/cross-price elasticities can be shown to be identical to (10.a) and (10.b). However, the resulting income elasticity differs from (11) in that it omits the term +1. Consequently, the above-mentioned properties no longer hold, which is not surprising since the constant total expenditure constraint is independent of income.

[27] "Such can be the case in a three-good world if the first good has a strong negative relationship with the second good which in turn has a strong positive relationship with the third good which then feedbacks strongly positively on the first good. Such can also arise if the relationships amongst the goods are positive, negative, negative instead of negative, positive, positive" (Taylor, 2022, p. 245).

**Figure 5:** Own-price and income elasticities for EU26, 2015




*Note*: D1 and D10 refer, respectively, to the poorest and richest EU-wide deciles. This household categorization is based on equivalized net income.

start from observing the elements' sign-switches in the matrices **B** and **T**. Apart from such indirect expenditure interrelations and sign discrepancies, the signs and relative sizes of the exogenous expenditures and income effects are equally important in determining the nature of goods and their ultimate interdependencies, as can be inferred from equations (9)-(11). We do not further elaborate on all these details, given the different scope of the current study.

However, as a final note it is worth mentioning the possible adverse effects of the prevalence of reported zero expenditures on the results. Table A.3 in the Appendix presents the percentage of zeros in the EU-HBS-2015 by household income decile, as reported for net income and the 11 considered consumption categories. It is clear that the Restaurants and hotels category stands out at the bottom of income distribution: about 80% of the poorest households (with positive net income) in the sample report zero expenditures, which reduces to 64% once household weights are taken into account.[28] This at least raises doubt about the "necessity nature" of Restaurants and hotels for the poorest

[28] This may explain why the own-price elasticity for Restaurants and hotels changes from being positive in OLS to negative in the WLS regression (compare subplots (a) and (b) in Figure 5).

households, as indicated e.g. by the corresponding income elasticity in Figure 5. Thus, another approach to running the intra-budget regressions, which we do not take up here, is to delete the zero observations in the dependent variable and the corresponding households in all the explanatory variables. Note that in this case, the mean expenditures and mean income will be different for each intra-budget regression.

## 4 Integrating the micro-macro twins

In what follows, we focus on assessing the impact of changes in consumer prices. Evidently, any well-established consumer demand system can be utilized to evaluate demand responses to price changes. There is, however, no reason to preclude the use of the Taylor consumer expenditure framework for this purpose either. Given that the Taylor model, like other traditional demand frameworks, also considers income effects, we aim to extend our analysis by integrating this micro-model with the standard open input-output (IO) model. Owing to the similarities of the mathematical formalizations of the two models, we may refer to the Taylor micro- and the Leontief macro-economic models jointly as the "*micro-macro twins*." Combining the micro-macro twins allows us to account for the circular, roundabout impacts of consumption demand, production, and income.

In the empirical application, we use the coefficients' estimates of country-specific intra-budget equations (4) for 26 EU countries for the reference year of 2015. To implement IO modelling, we use FIGARO (Full International and Global Accounts for Research in input-Output analysis) inter-country product-by-product IO table for the year of 2015 (see e.g. Remond-Teidrez and Rueda-Cantuche, 2019). This choice is consistent with the reference year of the EU-HBS-2015 microdata that underlies the micro-model. For our purpose, we use a reduced version of the FIGARO multi-regional (MR) IO table, which covers 63 products and 28 regions, including 27 EU countries plus the rest of the world (RoW) region.

### 4.1 From partial equilibrium to micro-macro synthesis

Let $\mathbf{p}^r_{rel}$ be a $g$-dimensional vector of the new-to-old price ratios (i.e. relative prices), with $p^r_{i,rel} \equiv p^r_{i1}/p^r_{i0}$ for good $i = 1, \ldots g$, where the superscript $r$ indicates the EU country (region) of interest, and the subscripts 0 and 1 refer, respectively, to the pre- and post-shock environments. The effects of price changes on consumption expenditures expressed in current (new) and base-year (old) prices can be estimated, respectively, as follows:

$$\tilde{\mathbf{e}}^r = \rho_r y_r \times \frac{\mathbf{T}^r\left(\hat{\mathbf{p}}^r_{rel}\boldsymbol{\zeta}^r + \boldsymbol{\gamma}^r y_r\right)}{\boldsymbol{\iota}'\mathbf{T}^r\left(\hat{\mathbf{p}}^r_{rel}\boldsymbol{\zeta}^r + \boldsymbol{\gamma}^r y_r\right)}, \tag{12.a}$$

$$\mathbf{c}^r = \left(\hat{\mathbf{p}}^r_{rel}\right)^{-1}\tilde{\mathbf{e}}^r, \tag{12.b}$$

where $\mathbf{T}^r = \left(\mathbf{I} - \mathbf{B}^r\right)^{-1}$ is the Taylor inverse for country $r$, $\rho_r = \boldsymbol{\iota}'\mathbf{e}_0^r/y_0^r$ is the base-year average propensity to consume of households in country $r$, $y_r$ is the mean household net income in country $r$, and $\hat{\mathbf{p}}_{rel}^r$ is a $g \times g$ diagonal matrix with the elements of the vector of relative prices of consumption goods in country $r$ along its main diagonal (recall the notation introduced in fn. 5). Equation (12.a) is the matrix counterpart of equation (8) with new prices, written in nominal terms.[29] Equation (12.b) re-expresses the derived current expenditures in the base-year prices.

We note that we apply the new prices on *exogenous* expenditures, $\hat{\mathbf{p}}_{rel}^r \boldsymbol{\zeta}^r$, to model the effects of changes (here, increases) in consumer prices as in Cory and Taylor (2017), instead of adding $\hat{\mathbf{e}}^r(\mathbf{p}_{rel}^r - \boldsymbol{\iota})$ as a new "exogenous" cost term, wherein price changes are applied to total expenditures as in Taylor (2022). To ensure full consistency with the micro-modelling framework, particularly regarding the overall (direct and indirect) interrelationships among the *signs and relative sizes* of exogenous expenditures and the consumption expenditure multipliers, we believe that price changes should be applied to the *exogenous* expenditures component, rather than to the endogenous total expenditures, to avoid overestimation of the impacts.

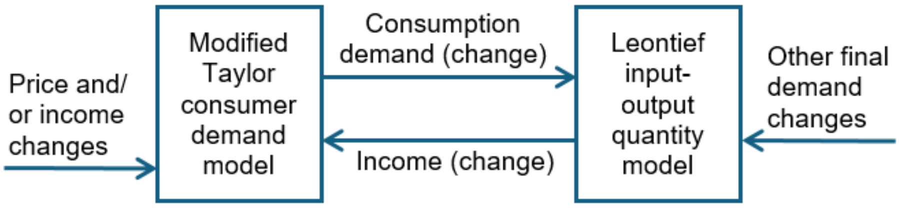
The "partial equilibrium" analysis of price changes would typically stop here. However, changes in consumption expenditures in base-year prices influence aggregate demand and, consequently, production and income levels. This chain of effects (theoretically) continues indefinitely, with each subsequent impacts diminishing in magnitude. At the aggregate level, of course, these interrelated demand (here, referring to consumption demand), production, and income changes reflect the well-known Keynesian autonomous expenditure multiplier process. In line with this approach, Figure 6 visualizes how the micro-macro twins are (inter)linked in this paper. Note that instead of the Taylor consumption model, one could alternatively use any other demand system, with prices and income modelled as inputs and consumption demands as outputs. In fact, our formalization in the next section allows for such generality. Thus, besides considering price shocks, external income shocks could also be assessed. Exogenous changes in other components of final demand could also be modelled with such a combined framework. In this case, the initial shock originates in the IO model, with consumption demand feedback loops from induced income effects incorporated by the model.

Consumption expenditure reactions to price (and income) changes in (12.a)-(12.b) are given in terms of ECOICOP categories. To establish a connection between these and the statistical classification of products by activity (abbreviated as CPA) in the MRIO table, we make use of the corresponding bridging matrices for all the EU countries, constructed and made public by Cai and Vandyck (2020). Coincidentally, these COICOP-CPA concordance matrices also pertain to the (reference) year of 2015.

According to the open Leontief model, gross outputs (here, by CPA products), $\mathbf{x}$, are

[29] We thus denote the ultimate nominal expenditure for good $i$ by $\tilde{e}_i$ (with a tilde) in order to distinguish it from its *non-normalized* counterpart $e_i$, used in the previous sections. We recall that the non-normalized expenditure, $e_i$, is obtained directly from the basic Taylor model (4) and is *not* adjusted for the household budget constraint with a link to income.

**Figure 6:** Linking the micro-macro twins




determined by the vector of final demand (including household and government consumption, investment and exports), $\mathbf{f}$, given the structure of inputs per unit of outputs, $\mathbf{A}$, as follows:

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{f} = \mathbf{L}\mathbf{f}, \tag{13}$$

where $\mathbf{L} \equiv (\mathbf{I} - \mathbf{A})^{-1}$ is the well-known *Leontief inverse*, also called as the *total (input) requirements matrix* (see e.g. Miller and Blair, 2022). The effects on e.g. employment and income could then readily be derived by multiplying $\mathbf{x}$ with the direct employment and value-added coefficients, respectively.

The mathematical similarity of the Leontief macro-model and the Taylor micro-model can be immediately observed by comparing equations (13) and (4). Despite this surface-level similarity, the two models are fundamentally different in many respects. Without going into details, one could note, for example, that the Leontief model is derived from an accounting identity of supply and demand, capturing the complex production interdependencies among all industries (or products) in an economy. In contrast, the Taylor model focuses on consumption expenditures, is estimated from consumer surveys, and captures complex expenditure interrelationships between household purchases of (or demands for) different consumption categories. While the IO coefficients matrix, $\mathbf{A}$, and the implied Leontief inverse, $\mathbf{L}$, are non-negative matrices, that is not the case for the intra-budget coefficients matrix, $\mathbf{B}$, and the implied Taylor inverse, $\mathbf{T}$. Nevertheless, both the Leontief and Taylor inverses fully capture the direct and indirect effects in their corresponding modelling frameworks in a similar way.

## 4.2 Input-output micro-macro model

There are inherent conceptual and data-collection differences between the macro and micro datasets, which can be substantial at the individual consumption category level (Temursho et al., 2025). In addition, the Taylor model-based consumption demands and income levels are given in mean values, rather than total values. Consequently, one can integrate the micro-macro twins through either consistent *relative changes* in consumption demands and income, or by harmonizing their *absolute levels*. The first option is employed in Temursho and Weitzel (2025), whereas here we elaborate on the second approach, which has the advantage of enabling a deeper exploration of the distinct impact mechanisms underlying the integrated model.

The following equations formalize how consumption demands from the Taylor model are incorporated into the Leontief macro-model, which are explained subsequently:

$$\mathbf{c}^r_{cpa} = \mathbf{P}^r\mathbf{c}^r, \tag{14}$$
$$\mathbf{h}^r = \mathbf{H}^r_c\hat{\mathbf{k}}^r_h\mathbf{c}^r_{cpa}, \tag{15}$$
$$\mathbf{x} = \mathbf{L}\left(\mathbf{f}^* + \textstyle\sum_{r\in EU}\mathbf{h}^r\right), \tag{16}$$
$$y^{io}_r = \left(\mathbf{w}^r_c\right)'\mathbf{x}^r, \tag{17}$$
$$y_r = k^r_y y^{io}_r + y^*_r. \tag{18}$$

Equation (14) translates consumption demands in COICOP categories to products use of both domestic and imported origin in CPA classification for each region $r$. The "product shares" matrix $\mathbf{P}^r$ is of $q \times g$ dimension, where $q$=63 (CPA products) and $g$=11 (COICOP commodities).[30] $\mathbf{P}^r$ is derived from the CPA-COICOP bridge matrices, normalized along the commodity dimension, i.e. $\boldsymbol{\iota}'\mathbf{P}^r = \boldsymbol{\iota}'$. Thus, each commodity is fully allocated to products according to the corresponding product shares in $\mathbf{P}^r$.[31]

In (15), we first scale up the demands for total products from the micro-model, $\mathbf{c}^r_{cpa}$, to total final household expenditures in an IO table, $\hat{\mathbf{k}}^r_h\mathbf{c}^r_{cpa}$, using the scaling factors in $\mathbf{k}^r_h$. These factors are derived as the ratios of base-year macro-level household final consumption to the base-year micro-level (mean) total expenditures for each product, and are held fixed in the simulation exercises. The source coefficients of expenditures of region $r$'s households are given in the $(n_r q) \times q$ matrix $\mathbf{H}^r_c \equiv \left[\hat{\mathbf{h}}^{1r}_c\ \hat{\mathbf{h}}^{2r}_c\ \cdots\ \hat{\mathbf{h}}^{n_r r}_c\right]'$, which are obtained from the base-year MRIO data and enable us to further redistribute the total final household consumption of each product to $n_r$=28 countries of origin.[32] Note that $\boldsymbol{\iota}'\mathbf{H}^r_c = \boldsymbol{\iota}'$. As a result, (15) gives the 1764 (=$n_r \times q$)-dimensional vector of household final consumption for region $r$, $\mathbf{h}^r \equiv \left[(\mathbf{h}^{1r})'\ (\mathbf{h}^{2r})'\ \cdots\ (\mathbf{h}^{n_r r})'\right]'$, where $\mathbf{h}^{sr}$ is a $q$-dimensional vector of final consumption by households in region $r$ of goods and services produced in region $s$.

Equation (16) calculates gross outputs, $\mathbf{x} = \left[(\mathbf{x}^1)'\ (\mathbf{x}^2)'\ \cdots\ (\mathbf{x}^{n_r})'\right]'$, using the Leontief IO quantity model in an MRIO setting, where $\mathbf{L}$ is the $(n_r p)$-square Leontief inverse matrix and $\mathbf{f}^*$ is the remaining final demand categories obtained from the base-year MRIO table, excluding final expenditures of the EU households, i.e. $\mathbf{f}^* = \mathbf{f}_0 - \sum_{r\in EU}\mathbf{h}^r_0$.

The direct income coefficients vector for region $r$, $\mathbf{w}^r_c$, indicates product-level gross value-added (GVA) per unit of product output of the region, using the relevant base-year data. Hence, (17) derives the impact of final demands, $\mathbf{f}^* + \sum_{r\in EU}\mathbf{h}^r$, on the income generated in country $r$, $y^{io}_r$. We note that equations (16) and (17) include *inter-country feedback*

[30]The number of products $q$ should *not* be confused with $q_i$ in (8), which denotes the quantity demanded for good $i$.

[31]Due to the presence of zero rows in these concordance matrices for some EU countries, in the empirical section we use the implied EU-wide normalized CPA-COICOP bridge matrix for all EU countries.

[32]In this section, we use $n_{eu}$ (=26) as the number of EU countries modelled within the micro-model, which is different from the total number of regions $n_r$ used in the MRIO modeling. Micro-modelling is not performed for Italy (due to missing income data) and the ROW region.

*and spillover effects* (including with the RoW region), whose details – both technical and empirical – are not discussed in this paper (for such specifics, see e.g. Miller and Blair, 2022; Temursho, 2018; Oosterhaven, 2022).

In (18), the IO- or macro-based income, $y_r^{io}$, is then downscaled to the mean equivalized (net) income of households in country $r$, $y_r$, using the scaling factor $k_y^r$. The latter is again obtained from the base-year macro and micro income data and is held fixed in the simulations. In addition, in (18) we consider exogenous (mean) income of households in country $r$, $y_r^*$, which includes such items as incomes from financial assets or from the rest of the world. Using the values of $y_r$ back in the modified Taylor model, (12.a)-(12.b), accounts for the income-induced impacts on household consumption spending.

Let the matrix of direct income coefficients be

$$\mathbf{W}_c = \left[\begin{array}{cccc|c} \mathbf{w}_c^1 & \mathbf{0}' & \cdots & \mathbf{0}' & \mathbf{0}' \\ \mathbf{0}' & \mathbf{w}_c^2 & \cdots & \mathbf{0}' & \mathbf{0}' \\ \vdots & \vdots & \ddots & \vdots & \mathbf{0}' \\ \mathbf{0}' & \mathbf{0}' & \cdots & \mathbf{w}_c^{n_{eu}} & \mathbf{0}' \end{array}\right],$$

where $\mathbf{0}$ is a $p$-dimensional vector of zeros. Note that the last $p$ columns of $\mathbf{W}_c$ are all zeros, which correspond to the position of the RoW region in the MRIO setting as its consumption is *not* modelled within the micro-model. Further, denote $\mathbf{k}_y \equiv \left[k_y^1 \; k_y^2 \cdots k_y^{n_{eu}}\right]'$, $\mathbf{y} \equiv \left[y_1 \; y_2 \cdots y_{n_{eu}}\right]'$ and $\mathbf{y}^* \equiv \left[y_1^* \; y_2^* \cdots y_{n_{eu}}^*\right]'$. Then, combining equations (14) to (18) gives the following result.[33]

***Proposition 1:*** *Within the integrated micro-macro model, the following system of equations determine the mean household consumption expenditures in base-year prices,* $\mathbf{c}^r$*, and the mean household incomes,* $\mathbf{y}$*, for all regions* $r \in EU$*:*

$$\mathbf{c}^r = \rho_r y_r \times \frac{(\mathbf{p}^r)^{-1}\mathbf{T}^r(\hat{\mathbf{p}}^r\boldsymbol{\zeta}^r + \boldsymbol{\gamma}^r y_r)}{\boldsymbol{\imath}'\mathbf{T}^r(\hat{\mathbf{p}}^r\boldsymbol{\zeta}^r + \boldsymbol{\gamma}^r y_r)} \quad \textit{and} \tag{19}$$

$$\mathbf{y} = \hat{\mathbf{k}}_y\mathbf{W}_c\mathbf{L}\left(\mathbf{f}^* + \textstyle\sum_{r\in EU}\mathbf{H}_c^r\hat{\mathbf{k}}_h^r\mathbf{P}^r\mathbf{c}^r\right) + \mathbf{y}^* \tag{20}$$

*for any given vectors of prices,* $\mathbf{p}$ *(relative to unitary base-year prices), exogenous incomes,* $\mathbf{y}^*$*, and other autonomous final demands,* $\mathbf{f}^*$*.*

Given that the modified Taylor demand (19) is highly nonlinear with respect to prices and income, it is complicated to derive the closed-form solution for (19) and (20). One approach to solving the integrated micro-macro twins for, say, a given price shock is to start with the "partial equilibrium" consumption impacts using (19), plug the results in (20), and then iterate back and forth between these equations until convergence of $\mathbf{c}^r$ (for all regions) and $\mathbf{y}$.

However, if we want to learn more about the inner workings of this simple integrated

[33] Equation (19) combines (12.a)-(12.b), and implicitly sets $\boldsymbol{\zeta}^r = \mathbf{z}^r$ as exogenous consumption quantities, assuming unitary prices in the base year.

micro-macro model, we may want to use a first-order Taylor approximation and write the system (19) and (20) in terms of (mean) consumption changes, $\Delta\mathbf{c}^r \equiv \mathbf{c}^r - \mathbf{c}_0^r$, and changes in mean household incomes, $\Delta\mathbf{y} \equiv \mathbf{y} - \mathbf{y}_0$, both relative to their corresponding base-year levels. For convenience, write the $(gn_{eu})$-dimensional vector of consumption changes as $\Delta\mathbf{c} \equiv \left[(\Delta\mathbf{c}^1)' \;\; (\Delta\mathbf{c}^2)' \;\; \cdots \;\; (\Delta\mathbf{c}^{n_{eu}})'\right]'$. An expanded vector of changes in prices, $\Delta\mathbf{p}$, is similarly defined. Next, let $\mathbf{H} \equiv \left[\mathbf{H}_c^1\hat{\mathbf{k}}_h^1\mathbf{P}^1 \;\; \mathbf{H}_c^2\hat{\mathbf{k}}_h^2\mathbf{P}^2 \;\; \cdots \;\; \mathbf{H}_c^{n_{eu}}\hat{\mathbf{k}}_h^{n_{eu}}\mathbf{P}^{n_{eu}}\right]$ be the $(qn_r) \times (gn_{eu})$ commodity-to-product by source conversion matrix, which maps $g$ COICOP consumption demands from $n_{eu}$ regions to $q$ CPA products across all $n_r$ regions. Let us further denote $\mathbf{V}_f \equiv \hat{\mathbf{k}}_y\mathbf{W}_c\mathbf{L}$ as the $(n_{eu} \times qn_r)$ matrix of region-specific mean household income generated per unit of other autonomous final demand, and $\mathbf{V}_c \equiv \mathbf{V}_f\mathbf{H}$ as the $(n_{eu} \times gn_{eu})$ matrix of region-specific mean household incomes generated per unit of region-specific total (i.e. domestic plus imported) consumption demands. For example, the typical element $\{\mathbf{V}_c\}_j^{rs} = \{\mathbf{V}_f\mathbf{H}_c^s\hat{\mathbf{k}}_h^s\mathbf{P}^s\}^{rj}$ indicates the total (mean) income in region $r$ that is generated due to a unitary increase in the (mean) total consumption of commodity $j$ by households resident in region $s$. We note that both $\mathbf{V}_f$ and $\mathbf{V}_c$ can be considered as the typical *simple income multipliers*, used in the IO literature (Miller and Blair, 2022, Ch. 6), with the only distinction that we scale down the effects to mean household income levels and, in the case of $\mathbf{V}_c$, additionally express the multipliers per mean household consumption of COICOP commodities.[34] Using these new notations, we obtain the following result.

***Proposition 2***: *The closed-form solutions of the linearized integrated micro-macro model, as derived from equations (19)-(20), are given in terms of the mean household consumption and income changes as follows:*

$$\Delta\mathbf{c} = \left(\mathbf{I} - \mathbf{D}_y\mathbf{V}_c\right)^{-1}\left(\mathbf{D}_p\Delta\mathbf{p} + \mathbf{D}_y\mathbf{V}_f\Delta\mathbf{f}^* + \mathbf{D}_y\Delta\mathbf{y}^*\right) \quad \textit{and} \tag{21}$$

$$\Delta\mathbf{y} = \left(\mathbf{I} - \mathbf{V}_c\mathbf{D}_y\right)^{-1}\left(\mathbf{V}_c\mathbf{D}_p\Delta\mathbf{p} + \mathbf{V}_f\Delta\mathbf{f}^* + \Delta\mathbf{y}^*\right), \tag{22}$$

*for any given changes in prices, $\Delta\mathbf{p}$ (relative to unitary base-year prices), exogenous incomes, $\Delta\mathbf{y}^*$, and other autonomous final demands, $\Delta\mathbf{f}^*$. In (21)-(22), $\mathbf{D}_p$ and $\mathbf{D}_y$ are defined as*

$$\underset{gn_{eu}\times gn_{eu}}{\mathbf{D}_p} \equiv \begin{bmatrix} \mathbf{D}_p^1 & \mathbf{O} & \cdots & \mathbf{O} \\ \mathbf{O} & \mathbf{D}_p^2 & \cdots & \mathbf{O} \\ \vdots & \vdots & \ddots & \vdots \\ \mathbf{O} & \mathbf{O} & \cdots & \mathbf{D}_p^{n_{eu}} \end{bmatrix} \quad \textit{and} \quad \underset{gn_{eu}\times n_{eu}}{\mathbf{D}_y} \equiv \begin{bmatrix} \mathbf{d}_y^1 & \mathbf{o} & \cdots & \mathbf{o} \\ \mathbf{o} & \mathbf{d}_y^2 & \cdots & \mathbf{o} \\ \vdots & \vdots & \ddots & \vdots \\ \mathbf{o} & \mathbf{o} & \cdots & \mathbf{d}_y^{n_{eu}} \end{bmatrix},$$

*with $\mathbf{D}_p^r$ and $\mathbf{d}_y^r$ being the matrices of first-order derivatives of the modified Taylor consumption demand for region $r$, (19), with respect to (local) consumer prices and incomes, respectively, and*

[34] Simple multipliers differ from *total multipliers* in that the latter additionally include induced effects due to households being endogenized in an IO model.

*have the following general forms:*

$$\mathbf{D}_p^r = \hat{\mathbf{c}}^r (\hat{\mathbf{e}}^r)^{-1} (\mathbf{T}^r \hat{\boldsymbol{\xi}}^r - \mathbf{s}^r \boldsymbol{\imath}' \mathbf{T}^r \hat{\boldsymbol{\xi}}^r) - \hat{\mathbf{c}}^r (\hat{\mathbf{p}}^r)^{-1} \quad \textit{and} \tag{23.a}$$

$$\mathbf{d}_y^r = \hat{\mathbf{c}}^r (\hat{\mathbf{e}}^r)^{-1} (\mathbf{T}^r \boldsymbol{\gamma}^r - \mathbf{s}^r \boldsymbol{\imath}' \mathbf{T}^r \boldsymbol{\gamma}^r) + \frac{1}{y_r} \mathbf{c}^r. \tag{23.b}$$

*Based on (21)-(22), obtaining the changes in macro-level endogenous variables is straightforward. For example, the (approximate) changes in gross outputs can be computed as*

$$\Delta \mathbf{x} = \mathbf{L} \Delta \mathbf{f}^* + \mathbf{L} \mathbf{H} \Delta \mathbf{c}. \tag{24.a}$$

*Proof:* The use of linearization to solve systems of nonlinear equations is a standard practice in economic modeling (see e.g. Dixon et al., 1992). Accordingly, we provide here a sketch of the proof of Proposition 2. Total differentiation of equations (19) and (20) yields $\Delta \mathbf{c}^r = \mathbf{D}_p^r \Delta \mathbf{p}^r + \mathbf{d}_y^r \Delta y_r$ for all $r$ and $\Delta \mathbf{y} = \mathbf{V}_f \Delta \mathbf{f}^* + \mathbf{V}_c \Delta \mathbf{c} + \Delta \mathbf{y}^*$. The expressions for the derivative matrices $\mathbf{D}_p^r$ and $\mathbf{d}_y^r$ in (23.a) and (23.b) can be readily derived from the formulas for price and income elasticities, as obtained in (B.3.a)-(B.4) in the Appendix. Finally, solving the compactly written linearized equations for changes in mean household consumption and income leads to (21) and (22). □

It is worthwhile to dig deeper into equations (21) and (22). Let us start with the *income-to-income multiplier matrix*, defined as $\mathbf{M}_{yy} \equiv (\mathbf{I} - \mathbf{V}_c \mathbf{D}_y)^{-1}$. From (22) it follows that the $rs$-th element $\mathbf{M}_{yy}$ indicates the total household (mean) income in region $r$ generated (or induced) by consumption expenditures from €1 of (mean) income initially (exogenously) earned by households in region $s$. Consequently, this matrix quantifies the inter-regional income-to-income (inter)dependencies of regions. In fact, $\mathbf{M}_{yy}$ is the exact counterpart of Miyazawa-Masegi "*interrelational income multiplier*" matrix (Miyazawa and Masegi, 1963) within our integrated IO micro-macro twins framework.[35] Formally, the main difference is that instead of the average consumption-per-income coefficients, we use the matrix of marginal propensities to consume, $\mathbf{D}_y$, in the underlying *direct* inter-regional income-to-income matrix, $\mathbf{V}_c \mathbf{D}_y$.[36] Importantly, $\mathbf{D}_y$ is generally *not* a constant matrix as it depends on (variable) prices and incomes, alongside the constant parameters of the modified Tay-

[35] Miyazawa's work on endogenizing households in an IO framework first appears in the English literature in Miyazawa (1960), where he acknowledges that "The author is indebted to Mr. Shingo Masegi ... for the mathematical formulation in Section V". The origin of the interrelational income multiplier matrix goes to eq. (19) derived in Section V in Miyazawa (1960). However, it is presented only for a scalar case (without household groupings or regional disaggregation), and the concept as a separate multiplier is neither mentioned nor elaborated upon. It is in Miyazawa and Masegi's (1963) paper where a detailed elaboration of "the interrelational multiplier in the income groups" (p. 94) is presented. Miyazawa's later work (Miyazawa, 1968, 1976) applies these findings also to regional disaggregation. For a comprehensive overview, elaborations, and further applications of Miyazawa-Masegi approach, see e.g. Hewings et al. (1999) and Temursho and Hewings (2021).

[36] Specifically, instead of the matrix of (average) consumption coefficients, denoted as $\mathbf{C}$ in Miyazawa and Masegi (1963), we use $\mathbf{H}\mathbf{D}_y$. Miyazawa and Masegi (1963) refers to the counterpart matrix of $\mathbf{V}_c \mathbf{D}_y$ in our framework as the "matrix of inter-income-group coefficients" (p. 94), which would be a valid designation if we focused on different household types instead of regions.

lor demand model. The matrix $\mathbf{V}_c\mathbf{D}_y$ quantifies a single cycle of income-to-income effects: €1 income earned by households in a given region increases consumption demand for both domestic and imported products, which in turn boosts production and subsequently generates income across all regions. Taking into account all such (infinite) rounds of impacts, one obtains the final multiplier matrix, $\mathbf{M}_{yy} = \mathbf{I}+\mathbf{V}_c\mathbf{D}_y+(\mathbf{V}_c\mathbf{D}_y)^2+\cdots$, where the identity matrix, $\mathbf{I}$, includes the initial €1 income injections in each region.

Similarly, following the causal impacts captured by (22), we may define the matrices $\mathbf{M}_{yc} \equiv \mathbf{M}_{yy}\mathbf{V}_c$, $\mathbf{M}_{yp} \equiv \mathbf{M}_{yc}\mathbf{D}_p$ and $\mathbf{M}_{yf} \equiv \mathbf{M}_{yy}\mathbf{V}_f$ as the *consumption-to-income*, *price-to-income*, and *other final demand-to-income multiplier matrices*, respectively. Since base-year prices are (assumed to be) unitary, dividing all elements of $\mathbf{M}_{yp}$ by 100 yields the mean income effects (in €) per 1% price increases. For example, the element $\{\mathbf{M}_{yp}\}_j^{rs}/100$ shows the increase in mean household income in region $r$ induced by a 1% increase in the price of commodity $j$ in region $s$.

Applying the same logic to equation (21), we define the *consumption-to-consumption*, *price-to-consumption*, *income-to-consumption*, and *other final demand-to-consumption multiplier matrices* as $\mathbf{M}_{cc} \equiv \left(\mathbf{I}-\mathbf{D}_y\mathbf{V}_c\right)^{-1}$, $\mathbf{M}_{cp} \equiv \mathbf{M}_{cc}\mathbf{D}_p$, $\mathbf{M}_{cy} \equiv \mathbf{M}_{cc}\mathbf{D}_y$, and $\mathbf{M}_{cf} \equiv \mathbf{M}_{cy}\mathbf{V}_f$, respectively.[37] In the empirical section, we will discuss the $\mathbf{M}_{yy}$, $\mathbf{M}_{yp}$ and $\mathbf{M}_{cp}$ multiplier matrices. In general, there is more than one way to define and calculate the exact same multipliers due to alternative formulations of the circular demand-production-income propagation process. For convenience, two alternative (and perhaps more intuitive) representations for each multiplier matrix are presented below:[38,39]

$$\mathbf{M}_{yy} = \left(\mathbf{I}-\mathbf{V}_c\mathbf{D}_y\right)^{-1} = \mathbf{I}+\mathbf{V}_c\mathbf{M}_{cc}\mathbf{D}_y, \tag{25.a}$$
$$\mathbf{M}_{yc} = \mathbf{M}_{yy}\mathbf{V}_c = \mathbf{V}_c\mathbf{M}_{cc}, \tag{25.b}$$
$$\mathbf{M}_{yp} = \mathbf{M}_{yc}\mathbf{D}_p = \mathbf{V}_c\mathbf{M}_{cp}, \tag{25.c}$$
$$\mathbf{M}_{yf} = \mathbf{M}_{yy}\mathbf{V}_f = \mathbf{V}_f+\mathbf{V}_c\mathbf{M}_{cc}\mathbf{D}_y\mathbf{V}_f, \tag{25.d}$$
$$\mathbf{M}_{cc} = \left(\mathbf{I}-\mathbf{D}_y\mathbf{V}_c\right)^{-1} = \mathbf{I}+\mathbf{D}_y\mathbf{M}_{yy}\mathbf{V}_c, \tag{25.e}$$
$$\mathbf{M}_{cp} = \mathbf{M}_{cc}\mathbf{D}_p = \mathbf{D}_p+\mathbf{D}_y\mathbf{M}_{yy}\mathbf{V}_c\mathbf{D}_p, \tag{25.f}$$
$$\mathbf{M}_{cy} = \mathbf{M}_{cc}\mathbf{D}_y = \mathbf{D}_y\mathbf{M}_{yy}, \tag{25.g}$$
$$\mathbf{M}_{cf} = \mathbf{M}_{cy}\mathbf{V}_f = \mathbf{D}_y\mathbf{M}_{yy}\mathbf{V}_f. \tag{25.h}$$

Reading such expressions becomes easier by tracing the causal effects, represented by each matrix term involved, in reverse order. For example, in the case of the price-to-

[37]The counterpart matrix of $\mathbf{M}_{cc}$ in Miyazawa (1960) is called the "*subjoined inverse matrix*" (p. 60). Incorporating it into the consumption equation, as in (21), rather than within the gross output equation, as in Miyazawa and Masegi writings, clarifies its exact economic meaning: it shows how initial changes in consumption affect consumption demands through the consumption-production-income multiplier propagation process. Hence, the term "consumption-to-consumption multiplier".

[38]The identity matrix $\mathbf{I}$ may be of dimension $n_{eu}\times n_{eu}$ or $(gn_{eu})\times(gn_{eu})$, which is not specified for simplicity.

[39]We do not provide proofs for all these expressions, but show the derivation for one case only. For example, the income-to-income multiplier matrix can be expanded as follows: $\mathbf{M}_{yy} = \mathbf{I}+\mathbf{V}_c\mathbf{D}_y+(\mathbf{V}_c\mathbf{D}_y)^2+(\mathbf{V}_c\mathbf{D}_y)^3+\cdots = \mathbf{I}+\mathbf{V}_c\left(\mathbf{I}+\mathbf{D}_y\mathbf{V}_c+(\mathbf{D}_y\mathbf{V}_c)^2+\cdots\right)\mathbf{D}_y = \mathbf{I}+\mathbf{V}_c\mathbf{M}_{cc}\mathbf{D}_y$, which proves (25.a).

consumption multiplier in (25.f), the direct consumption effect of unitary increases in consumer prices is captured by the corresponding first-order derivative matrix of the demand function, $\mathbf{D}_p$. Thus, premultiplying $\mathbf{D}_p$ by the consumption-to-consumption multiplier, $\mathbf{M}_{cc}$, which incorporates all the consumption-production-income-consumption feedback loop effects, readily yields the first expression of the price-to-consumption multiplier in (25.f). On the other hand, the second expression in (25.f) decomposes the direct and indirect price effects additively. The indirect effects are given by $\mathbf{D}_y\mathbf{M}_{yy}\mathbf{V}_c\mathbf{D}_p$, here formalized using the income-to-income multipliers in $\mathbf{M}_{yy}$. So, $\mathbf{V}_c\mathbf{D}_p$ indicates the income effects induced by the initial consumption responses to price shocks. Pre-multiplying these initial income effects by $\mathbf{M}_{yy}$, which fully accounts for the income-consumption-production-income feedback loops, yields the corresponding total income effects across all regions. Further pre-multiplication of $\mathbf{M}_{yy}\mathbf{V}_c\mathbf{D}_p$ by the matrix of marginal propensities to consume, $\mathbf{D}_y$, translates these income effects into total consumption effects of the initial price-induced income impacts, $\mathbf{V}_c\mathbf{D}_p$. Hence, $\mathbf{D}_y\mathbf{M}_{yy}\mathbf{V}_c\mathbf{D}_p$ quantifies the total indirect consumption impacts of price shocks.

In all the multipliers discussed so far, we have deliberately hidden the role of "production" for the sake of simplicity of exposition of the multiplier formulas. However, since "production" plays an equally important role in the propagation process as "consumption demand" and "income", one may seek to formalize the corresponding roundabout effects around "production", rather than around "consumption" or "income", as captured by the $\mathbf{M}_{cc}$ or $\mathbf{M}_{yy}$ matrices, respectively. This would imply making explicit the role of production, as captured by the Leontief inverse $\mathbf{L}$, within the simple income multiplier matrix, i.e. $\mathbf{V}_c = \hat{\mathbf{k}}_y\mathbf{W}_c\mathbf{L}\mathbf{H}$. Thus, we may define the *production-to-production multiplier matrix* as[40]

$$\mathbf{M}_{xx} \equiv \left(\mathbf{I} - \mathbf{L}\mathbf{H}\mathbf{D}_y\hat{\mathbf{k}}_y\mathbf{W}_c\right)^{-1}, \tag{25.i}$$

which captures the circular production-income-consumption propagation impacts, with gross outputs as the starting point. Using this alternative power series expansion of the propagation process in, for example, equation (24.a) yields the following closed-form solution for changes in gross outputs

$$\Delta\mathbf{x} = \mathbf{M}_{xx}\mathbf{L}\left(\mathbf{H}\mathbf{D}_p\Delta\mathbf{p} + \Delta\mathbf{f}^* + \mathbf{H}\mathbf{D}_y\Delta\mathbf{y}^*\right). \tag{24.b}$$

Note that in (24.b), the multiplier matrix $\mathbf{M}_{xx}$ is post-multiplied by the Leontief inverse matrix, $\mathbf{L}$, because exogenous shocks in prices, other final demand components, and/or exogenous incomes must first be converted into gross outputs to enable a meaningful application of the production-to-production multipliers.

As a final note, all the multipliers in equations (25.a)–(25.h) can alternatively be expressed using the production-to-production multiplier matrix, $\mathbf{M}_{xx}$. One could also for-

[40] We could equally have called it the *output-to-output multiplier* matrix. However, in the IO literature, the term "output-to-output multiplier" refers to a distinct multiplier concept used in mixed IO models (see e.g. Miller and Blair, 2022, Chapters 6.6 and 14.2).

malize their counterpart multiplier matrices centered on output impacts, such as price-to-production, income-to-production, consumption-to-production, and other final demand-to-production multipliers. However, we do not elaborate further on these details here, partly because income and consumption – rather than gross outputs – are the primary focus of policymaking concern.

### 4.3 Eliminating linearization errors

The simplest way to obtain the approximate solution of the (linearized) IO micro-macro twins model in (21)-(22) is to use the required derivative matrices that are evaluated at the base-year (mean) consumption and income values. In this case, the matrices $\mathbf{D}_p^r$ and $\mathbf{d}_y^r$ in (23.a) and (23.b) boil down to

$$\mathbf{D}_{p,0}^r = \mathbf{T}^r\hat{\boldsymbol{\zeta}}^r - \mathrm{s}_0^r\boldsymbol{\imath}'\mathbf{T}^r\hat{\boldsymbol{\zeta}}^r - \hat{\mathbf{c}}_0^r \quad \text{and} \tag{25.a}$$

$$\mathbf{d}_{y,0}^r = \mathbf{T}^r\boldsymbol{\gamma}^r - \mathrm{s}_0^r\boldsymbol{\imath}'\mathbf{T}^r\boldsymbol{\gamma}^r + \frac{1}{y_{r,0}}\mathbf{c}_0^r. \tag{25.b}$$

because $\mathbf{p}^r = \boldsymbol{\imath}$ and $\mathbf{c}_0^r = \mathbf{e}_0^r$ in the base (benchmark) state (0). Note that since the budget shares sum to one, i.e. $\boldsymbol{\imath}'\mathrm{s}_0^r = 1$ for all $r$, the column sums of the benchmark price and income derivatives in (25.a) and (25.b) equal the benchmark (negative) expenditure amounts and the average propensity to consume, respectively. That is, $\boldsymbol{\imath}'\mathbf{D}_{p,0}^r = -(\mathbf{c}_0^r)'$ and $\boldsymbol{\imath}'\mathbf{d}_{y,0}^r = \boldsymbol{\imath}'\mathbf{c}_0^r/y_{r,0} = \rho_r$.[41]

As an empirical illustration, the next section assesses the impact of consumer price increases for 26 EU countries. While the corresponding results will be discussed there, this subsection examines the extent of linearization errors when using the system of equations (21)-(22) instead of (19)-(20), and explores approaches from Dixon et al. (1992, Chap. 3, pp. 109-116) to eliminate these errors. In terms of the exogenous shocks, we thus have $\Delta\mathbf{p} \neq \mathbf{0}$ (which are presented in Table 4), with $\Delta\mathbf{f}^* = \mathbf{0}$ and $\Delta\mathbf{y}^* = \mathbf{0}$. Using the fixed derivative matrices in (25.a) and (25.b) in the linearized IO micro-macro twins model yields approximate solutions for $\Delta\mathbf{c}$ and $\Delta\mathbf{y}$, and the underlying procedure is referred to as the *1-step computation*.[42] The descriptive statistics of the percentage errors (PEs) of the linearized $\Delta\mathbf{c}$ and $\Delta\mathbf{y}$ obtained from this simplest procedure, compared to their true values, are shown in the "1-step computation" row of Table 2. We find that the PEs of $\Delta\mathbf{c}$ range between -5.7% to 5.5%, with the mean PE of 2.6%. The corresponding figures for PEs of linearized $\Delta\mathbf{y}$ are [1%,4.3%] and 3%. In the current exercise with an average

[41] The interpretations are straightforward. In the first case, a €1 increase in the price of good $j$ leads to a decrease in spending on *all* goods, equivalent to the base-year value of good $j$, $c_j^r$. That is because with unitary base-year prices, a €1 price increase corresponds to a 100% increase in price. Thus, with fixed income, the total change in the value of demand for all goods due to a €1 in $p_j^r$ should be equal to $-c_j^r$. In the second case, the sum of the benchmark marginal propensities to consume for all goods equals the average propensity to consume, which reflects our modification of the Taylor micro-model in (8).

[42] Here, the designations of the considered computation procedures are borrowed from Dixon et al. (1992), which examines the multi-step Johansen procedure due to Johansen (1960).

price shock of 1.1% and the maximum residential energy price increase of 4.4% (Table 4), these errors for *changes* in consumption and income levels may or may not be acceptable. Whatever the preference, one can do (much) better.

**Table 2:** Percentage errors (PEs) of linearized $\Delta\mathbf{c}$ and $\Delta\mathbf{y}$

| | PEs of linearized $\Delta\mathbf{c}$ | | | | PEs of linearized $\Delta\mathbf{y}$ | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | StDev | Min | Max | Mean | StDev | Min | Max |
| 1-step computation | 2.598 | 1.166 | -5.715 | 5.500 | 3.012 | 0.830 | 0.992 | 4.346 |
| 2-step computation | 1.272 | 0.567 | -2.810 | 2.682 | 1.473 | 0.402 | 0.495 | 2.113 |
| 4-step computation | 0.631 | 0.280 | -1.388 | 1.328 | 0.730 | 0.199 | 0.248 | 1.044 |
| 8-step computation | 0.315 | 0.140 | -0.684 | 0.665 | 0.365 | 0.100 | 0.125 | 0.520 |
| 16-step computation | 0.159 | 0.070 | -0.334 | 0.345 | 0.184 | 0.051 | 0.063 | 0.261 |
| 32-step computation | 0.081 | 0.036 | -0.161 | 0.186 | 0.094 | 0.027 | 0.032 | 0.132 |
| {1,2}-step extrapolation | -0.054 | 0.034 | -0.158 | 0.172 | -0.065 | 0.026 | -0.120 | -0.001 |
| {1,2,4}-step extrapolation | 0.004 | 0.004 | -0.001 | 0.030 | 0.005 | 0.005 | 0.001 | 0.021 |
| {1,2,4,8}-step extrapolation | 0.003 | 0.004 | 0.000 | 0.028 | 0.004 | 0.005 | 0.001 | 0.019 |

*Note*: Here, the modified Taylor micro-model, as used within the IO micro-macro twins system, is based on OLS intra-budget regressions. Results are similar when WLS-based estimations are used (see supplementary material). Percentage errors (PEs) are defined with respect to the true values of the variables of interest: for a linearized estimate $x_i$, $PE_{x_i} = \left(x_i/x_i^t - 1\right) \times 100$, where $x_i^t$ denotes the true value of $x_i$. There are 286 and 26 data points in $\Delta\mathbf{c}$ and $\Delta\mathbf{y}$, respectively.

In general, larger changes in exogenous variables result in greater linearization errors. Hence, to obtain a more accurate linearized solution, the total changes in exogenous shocks are often divided into smaller parts. Each such exogenous part is then used in a sequence of multi-step computations, where the derivative (or elasticity) matrices are *reevaluated* using the values of endogenous variables obtained from the previous step. Many possibilities exist for partitioning of shocks, such as braking a total change into $J$ ($>$ 1) equal parts, equal percentage parts, or equal logarithmic parts. It is generally believed that "the choice between schemes such as equal changes and equal percentage or log changes in *not* often an important one" (Dixon et al., 1992, p.117, emphasis added). For our IO micro-macro framework, we use the equal changes scheme. Let $\Delta\mathbf{p}^r$ be the percentage changes in commodity prices relative to their unitary benchmark prices in region $r$. Then, the following formalizes the main steps of the *J-step computation* of the linearized system (21)-(22) in a (readable) pseudocode style:

$\Delta\boldsymbol{\pi}^r = \Delta\mathbf{p}^r\ /\ J;$ `%J-equal partitioning of the total price shocks`

`Step` $j = 1, 2, \ldots, J$ :

  $\mathbf{s}_j^r = \hat{\mathbf{c}}_{j-1}^r\left(\boldsymbol{\imath} + (j-1)\Delta\boldsymbol{\pi}^r\right) / \left(\rho_r y_{r,j-1}\right);$ `%update budget shares, using` (19)

  $\mathbf{e}_j^r = \mathbf{s}_j^r \times \boldsymbol{\imath}'\mathbf{T}^r\left(\boldsymbol{\zeta}^r\left(\boldsymbol{\imath} + (j-1)\Delta\boldsymbol{\pi}^r\right) + \boldsymbol{\gamma}^r y_{r,j-1}\right);$ `%update non-normalized expenditures`

  $\mathbf{D}_{p,j}^r = \hat{\mathbf{c}}_{j-1}^r\left(\hat{\mathbf{e}}_j^r\right)^{-1}\left(\mathbf{T}^r\hat{\boldsymbol{\zeta}}^r - \mathbf{s}_j^r\boldsymbol{\imath}'\mathbf{T}^r\hat{\boldsymbol{\zeta}}^r\right) - \hat{\mathbf{c}}_{j-1}^r\left(\mathbf{I} + (j-1)\hat{\boldsymbol{\pi}}^r\right)^{-1};$ `%update the derivatives in` (23.a)

  $\mathbf{d}_{y,j}^r = \hat{\mathbf{c}}_{j-1}^r\left(\hat{\mathbf{e}}_j^r\right)^{-1}\left(\mathbf{T}^r\boldsymbol{\gamma}^r - \mathbf{s}_j^r\boldsymbol{\imath}'\mathbf{T}^r\boldsymbol{\gamma}^r\right) + \mathbf{c}_{j-1}^r / y_{r,j-1};$ `%update the derivatives in` (23.b)

  `Combine to get the expanded derivative matrices` $\mathbf{D}_{p,j}$ `and` $\mathbf{D}_{y,j}$ ;

$\Delta \mathbf{y}_j = (\mathbf{I} - \mathbf{V}_c\mathbf{D}_{y,j})^{-1}\mathbf{V}_c\mathbf{D}_{p,j}\Delta\boldsymbol{\pi}$; `%compute income changes, using` (22)
$\mathbf{y}_j = \mathbf{y}_{j-1} + \Delta\mathbf{y}_j$; `%update country income levels`
$\Delta \mathbf{c}_j = \mathbf{D}_{p,j}\Delta\boldsymbol{\pi} + \mathbf{D}_{y,j}\Delta\mathbf{y}_j$; `%compute consumption changes, exactly equivalent to` (21)
$\mathbf{c}_j = \mathbf{c}_{j-1} + \Delta\mathbf{c}_j$; `%update country- and commodity-specific consumption levels`
`Move to the next step` $j+1$ `until reaching step` $J$.

Table 2 presents the descriptive statistics of linearization errors of the $J$-step computations for $J = 1, 2, 4, 8, 16, 32$. We observe that the four statistics (mean, standard deviation, min and max of PEs) of the 2-step computation are 50% to 52% *lower* than those of the 1-step computation. Each subsequent reported $(2 \times J)$-step procedure yields PEs statistics that are 46%-52% lower than those of the $J$-step computation. We thus observe a dramatic improvement of the linearized estimates of consumption and income changes when comparing the linearization errors in the 1-step computation vs. those in the 32-step procedure.

With a big data, a $J$-step computation with a sufficiently large $J$ may require significant computation time, although ongoing advancements in computing power are mitigating this issue. Since approximation errors decrease with higher-step computations, one wonders whether other approximations based on *few* $J$-step computations exist. Let $F(h)$ denote the approximate value of a certain variable computed using step size $h$. Assume that: (a) $F(h)$ approaches the true value of the variable, $F_t$, as $h \to 0$, and (b) $F(h)$ is a higher-order polynomial. The latter assumption is based on the idea that any continuous function can be approximated arbitrarily closely by a sufficiently high-degree polynomial. When considering polynomials of degree 1, 2, and 3, for each case one can derive the following extrapolation formulas (for details, see Dixon et al., 1992, pp.112-115):

$$F_t = 2F\left(\frac{h}{2}\right) - F(h), \tag{26.a}$$

$$F_t = \frac{8}{3}F\left(\frac{h}{4}\right) - 2F\left(\frac{h}{2}\right) + \frac{1}{3}F(h), \text{ and} \tag{26.b}$$

$$F_t = \frac{64}{21}F\left(\frac{h}{8}\right) - \frac{56}{21}F\left(\frac{h}{4}\right) + \frac{14}{21}F\left(\frac{h}{2}\right) - \frac{1}{21}F(h). \tag{26.c}$$

Equations (26.a)-(26.c) are examples of *Richardson extrapolation*, the details of which can be found in the literature on numerical methods (see e.g. Dahlquist and Björn, 2008, Chapter 3.4.6). For our purposes, we set $h = 1$ and use our $J$-step computation outcomes (i.e. the estimates for changes in consumption and income) in these extrapolation expressions, which yield alternative estimates of the impacts. For example, $F(1/2)$ would be replaced by the 2-step computation results. Thus, *{1,2}-step extrapolation* is computed according to (26.a), using the outcomes of the 1- and 2-step procedures. Similarly, application of (26.b) and (26.c) results in the *{1,2,4}-* and *{1,2,4,8}-step extrapolations*. The PE statistics for these extrapolations are also reported in Table 2. Notably, already the {1,2}-step extrapolation method produces results with negligible PEs, fully comparable or more precise than the 32-step computation. The $\{1{,}2{,}4\}$-step extrapolation yields even more precise estimates of consumption and income changes, with errors so small which can be safely ignored for any practical purposes. We conclude that the linearized IO micro-macro twins system (21)-(22) yields solutions that can be brought arbitrary close to those of its nonlinear counterpart (19)-(20). Consequently, both frameworks are practically equivalent for empirical purposes, provided the linearized system is solved with computation techniques that minimize or eliminate linearization errors.[43]

Two implications follow. First, the linearized IO micro-macro system (21)-(22) extends the Miyazawa-Masegi framework in two important ways. It enables integration of the IO macro-model with *any* micro-model of consumption demand. For demand systems other than the modified Taylor model considered here, only the derivative matrices in (23.a) and (23.b) need redefinition to match the chosen demand system. In addition, the system (21)-(22) supports analysis of consumer price impacts within an IO demand-driven framework. These developments provide further rationale for the title of this work. To the best of our knowledge, the price-to-income matrix (25.c), price-to-consumption matrix (25.f), and the price-to-production matrix, defined as $\mathbf{M}_{xp} \equiv \mathbf{M}_{xx}\mathbf{L}\mathbf{H}\mathbf{D}_p$ as follows from (24.b), are *novel* multiplier matrices that have not been previously explored or studied in the IO literature.[44]

Second, the linearized system clearly shows that the IO micro-macro twins model has a solution whenever the multiplier matrices $\mathbf{M}_{yy}$, $\mathbf{M}_{cc}$ and $\mathbf{M}_{xx}$ are well-defined. All three are Leontief inverse-type matrices, hence the well-established conditions for the existence of $\mathbf{L}$ directly apply in the current setting (for details, see e.g. Takayama, 1985, Chap. 4). Take the income-to-income multiplier matrix, $\mathbf{M}_{yy} = (\mathbf{I} - \mathbf{V}_c\mathbf{D}_y)^{-1}$. Its power series converges if and only if every eigenvalue of $\mathbf{V}_c\mathbf{D}_y$ has a modulus strictly less than one, i.e., when the spectral radius of $\mathbf{V}_c\mathbf{D}_y$ is less than one (see e.g. Horn and Johnson, 2013, Theorem 3.2.5.2).[45] Importantly, if one of the multiplier matrices $\mathbf{M}_{yy}$, $\mathbf{M}_{cc}$, or $\mathbf{M}_{xx}$ is well-defined, the other two multiplier matrices are also well-defined.[46]

[43] In CGE modelling, while some modellers favor nonlinear systems, others, particularly at the Centre for Policy Studies in Melbourne, Australia, prefer working with the linearized models (see e.g. Dixon et al., 1982; Dixon and Jorgenson, 2013).

[44] Kim and Hewings (2019) integrate *age-group-specific* labor and consumer demand models into the Miyazawa-Masegi framework to assess the multiplier impacts of an ageing population in the Chicago region. The integration of consumer demand basically follows the Miyazawa-Masegi approach when estimating a consumption coefficients matrix, whose entries indicate the consumption shares of total income across different age groups.

[45] Assuming that $\mathbf{V}_c\mathbf{D}_y$ is non-negative and using the fact that the spectral radius of a matrix is bounded from above by the matrix norm (Horn and Johnson, 2013, Theorem 5.6.9), the stated convergence condition simplifies to all column sums of $\mathbf{V}_c\mathbf{D}_y$ being less than one. Note that the column sums of $\mathbf{D}_y$ should generally be less than one, as they indicate the marginal propensities to overall consumption for each region. However, this might not be the case for a certain types of consumers, such as low-income or young households, who rely on borrowing to finance part of their consumption.

[46] Consider any two matrices $\mathbf{X}$ and $\mathbf{Y}$ of dimensions $m \times n$ and $n \times m$, respectively, where $n \neq m$. Then, the non-zero eigenvalues of $\mathbf{XY}$ and $\mathbf{YX}$ are identical (Horn and Johnson, 2013, Theorem 1.3.22). This result can be readily applied to the matrices $\mathbf{M}_{yy}$, $\mathbf{M}_{cc}$, and $\mathbf{M}_{xx}$ by rewriting them as functions of three matrices: $\mathbf{M}_{yy} = (\mathbf{I} - \widetilde{\mathbf{W}}_c\widetilde{\mathbf{L}}\mathbf{D}_y)^{-1}$, $\mathbf{M}_{cc} = (\mathbf{I} - \mathbf{D}_y\widetilde{\mathbf{W}}_c\widetilde{\mathbf{L}})^{-1}$ and $\mathbf{M}_{xx} = (\mathbf{I} - \widetilde{\mathbf{L}}\mathbf{D}_y\widetilde{\mathbf{W}}_c)^{-1}$, where $\widetilde{\mathbf{W}}_c \equiv \hat{\mathbf{k}}_y\mathbf{W}_c$ and $\widetilde{\mathbf{L}} \equiv \mathbf{LH}$.

## 5 Empirical results

As mentioned in the previous section, in our empirical exercises the macro-model covers more countries than the micro-model. While the MRIO framework includes all 27 EU countries and the rest of the world (ROW) region, the micro-model excludes Italy (due to missing income data) and the ROW region. Thus, it should be kept in mind that the follow-up reported results do *not* account for the effects induced by Italian and the RoW households in quantifying the consumption-production-income propagation mechanism.

### 5.1 Income-to-income and price-to-income/consumption multipliers

In this section, we provide some quantitative details of the income-to-income, price-to-income, and price-to-consumption multipliers, evaluated at the 2015 benchmark data. Note that such benchmark multipliers are valid only for small changes in the corresponding exogenous variables. Due to space constraints, we do not discuss all other multipliers elaborated in Section 4.2.

Table A.4 in the Appendix presents the estimated income-to-income multiplier matrix, $\mathbf{M}_{yy}$, for 26 EU countries for the reference year of 2015 (excluding Italy). As an example, consider selected values along its 6th column, corresponding to Germany (DE). We thus find that €1 of income earned by German households generates €0.568 in DE itself (€1.568 includes the initial €1 of exogenous income injection), €0.208 in Luxembourg (LU), €0.082 in Austria (AT), €0.069 in the Netherlands (NL), €0.023 in France (FR), and €0.019 in Spain (ES).

The top five countries with the highest income-generating multipliers (i.e. the column sums of $\mathbf{M}_{yy}$, labelled as 'EU26' in Table A.4) are Romania (2.635, including the initial €1 injection), Spain (2.504), Germany (2.481), Greece (2.420), and Poland (2.417). However, these total multipliers hide large variations in the relative extent to which countries generate income within and across their borders. In terms of the capacity of generating income abroad per its total 'income-producing' multiplier, Germany stands out: about 37% of its total income-producing multiplier of 2.481 is generated in the other 25 EU countries (see the last row, labelled 'Outside (%)'). It is followed by Poland (32%), Romania (31%), France (28%), and Spain (21%).

On the other hand, the row sums of $\mathbf{M}_{yy}$ indicate income inducements *received* per €1 (increase in) earned income in all 26 EU countries simultaneously. The top five EU countries with the highest 'income-absorbing' multipliers (column 'EU26' in Table A.4) are Cyprus (2.358, including the initial €1), Greece (2.273), Croatia (2.222), Portugal (2.142), and Spain (2.124). Countries differ greatly according to their relative size of income absorption from within and outside their borders. In terms of cross-boarder income dependency, Luxembourg leads, with 42% of its total income-absorbing multiplier of 2.044 received from the other 25 EU countries (see column 'Outside (%)'). After Luxembourg, the countries most reliant on external EU income are Austria (21%), Ireland (20.4%), the Netherlands (20.3%), and Denmark (19%). Importantly, all above-mentioned interdependencies capture both direct and indirect (though complex supply/demand chains) production linkages among countries.

The definition of $\mathbf{M}_{yy}$ in (25.a) shows that all the above results stem from the structure and relative sizes of the elements of three matrices (an alternative decomposition is given fn. 46): the $26 \times 1764$ matrix of down-scaled direct value-added coefficients, $\hat{\mathbf{k}}_y\mathbf{W}_c$; the 1764-square matrix of the global Leontief inverse, $\mathbf{L}$; and the $1764 \times 26$ matrix of marginal propensities to consume for domestic and imported products, $\mathbf{HD}_y$. Note that the multipliers (through $\mathbf{L}$ and $\mathbf{H}$) also capture the differences in the inter-country and inter-product trade structure of intermediate and final goods across countries.

The $26 \times 286$ matrix of price-to-income multipliers, $\mathbf{M}_{yp}$, is too big to display here. We thus aggregated it along the columns (i.e. the commodity price dimension) by taking the weighted averages of the income effects across the 11 considered commodities for each country, using the corresponding benchmark expenditure shares. The results are presented in Table A.5 in the Appendix. The *rs*-th element of this weighted average price-to-income multiplier matrix indicates the *average household equivalized income loss* (in €) in country *r* due to a 1% (weighted) price increase for *all* commodities in country *s*. We thus find, for example, that a 1% price increase for all commodities in Germany leads to a €17.5 decrease in the mean equivalized income of German households, and a €28.6 average equivalized income loss for households in the other 25 EU countries. This implies an overall mean per-adult-equivalent income impact of -€46.1 for EU26 households due to 1% price increases in Germany. The next largest EU-wide average impacts are found from price increases in France (-€34.7), Spain (-€25.8), Denmark (-€24.8), and Austria (-€20.9).

One can again observe significant heterogeneity in the extent to which price changes in one country affect income generation in other countries. In absolute terms, the largest "price-spillover" effects are found for Germany (−€28.6), France (−€17.4), and Spain (−€9.1). In terms of the percentage of total price-to-income multipliers, the ranking of the average price-spillover effects differs (see the 'Outside (%)' row in Table A.5): Germany (62% of its total multiplier corresponds to income effects in other countries), Poland (51%), France (50%), Romania (46%), and Hungary (36%).

The row sums of the average price-to-income multiplier matrix in Table A.5 show the total mean equivalized income losses in each country when (weighted) consumer prices in *all* countries increase by 1%. For Germany, this average loss is −€21.7, with only 20% (−€4.3) attributed to price spillover effects from other EU countries. Comparing the average 'incoming' and 'outgoing' price-spillover income effects of, respectively, −€4.3 and −€28.6 (discussed above), we may conclude that price increases in Germany have significantly larger income impacts abroad than those due to the price shocks in the other EU countries.[47] This comparison is markedly different for LU, where the incoming and outgoing price-spillover income effects are estimated to be −€18.7 and −€0.3, respectively.

[47]When directly using $\mathbf{M}_{yp}$ without aggregation,the corresponding absolute 'incoming' and 'outgoing' price-spillover income effects are −€32.5 and −€223.6, respectively, while the DE own domestic price-induced income loss is −€139.1 (see Table 3).

As an illustration, Table 3 presents the commodity-specific details of (a part of) the price-to-income multipliers for German price shocks. The largest mean equivalized income loss of –€32.2 is due to a 1% price increase in Housing, water, electricity and other fuels category (HousWtrElc), which reflects its high expenditure share of 21% in German households' budget. When the parameters of the modified Taylor micro-model are based on WLS (instead of OLS) intra-budget regressions, the corresponding estimated loss is –€33.1 (see the supplementary file). For context, a 1% share of the benchmark mean household equivalized expenditure on HousWtrElc in Germany is €41.3 (see the last column in Table 3), while 1% of the average equivalized income of German households is €245, as follows from the EU-HBS-2015.

**Table 3:** Price-to-income multipliers for German price shocks, 2015

| Category | Share | AT | DE | DK | IE | LU | MT | NL | REU | EU26 | Outside € | Outside % | 1% of DE cons. (€) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FoodNalcBvg | 13.0 | -2.8 | -20.4 | -2.3 | -1.6 | -6.3 | -1.5 | -2.8 | -12.2 | -49.9 | -29.5 | 59.1 | 25.1 |
| AlcBvgTbc | 1.9 | -0.4 | -1.5 | -0.4 | -0.2 | -0.7 | -0.2 | -0.5 | -1.7 | -5.6 | -4.1 | 73.0 | 3.7 |
| ClothFtwr | 5.4 | -0.5 | -1.8 | -0.3 | -0.2 | -0.8 | -0.3 | -0.3 | -2.8 | -7.0 | -5.2 | 74.8 | 10.4 |
| HousWtrElc | 21.3 | -4.3 | -32.2 | -3.2 | -2.8 | -11.1 | -3.2 | -3.8 | -19.5 | -80.1 | -47.8 | 59.7 | 41.3 |
| FurnshHeqp | 5.7 | -1.1 | -3.8 | -0.6 | -0.4 | -1.1 | -1.0 | -0.5 | -5.3 | -13.7 | -9.9 | 72.5 | 11.1 |
| Health | 5.4 | -0.5 | -7.0 | -0.5 | -0.4 | -0.9 | -0.3 | -0.4 | -2.5 | -12.6 | -5.5 | 44.1 | 10.4 |
| Transport | 15.7 | -3.1 | -11.6 | -1.8 | -1.3 | -4.6 | -1.2 | -2.4 | -16.2 | -42.3 | -30.7 | 72.5 | 30.4 |
| Communicat | 2.9 | -0.5 | -2.9 | -0.4 | -0.3 | -1.2 | -0.3 | -0.4 | -2.0 | -7.9 | -5.0 | 63.7 | 5.7 |
| RecreatCult | 11.8 | -2.4 | -14.7 | -1.5 | -2.0 | -5.0 | -2.9 | -2.1 | -11.0 | -41.6 | -26.9 | 64.6 | 22.8 |
| RestrntHotl | 6.2 | -2.3 | -22.8 | -1.6 | -1.4 | -5.5 | -1.5 | -1.9 | -10.1 | -47.0 | -24.2 | 51.5 | 11.9 |
| MiscGSEduc | 10.7 | -2.2 | -20.4 | -1.4 | -2.3 | -13.9 | -2.9 | -1.7 | -10.4 | -55.2 | -34.8 | 63.0 | 20.6 |
| Total sum | | -20.0 | -139.1 | -13.9 | -13.0 | -51.0 | -15.1 | -16.8 | -93.8 | -362.8 | -223.6 | – | 193.4 |
| Weighted average | | -2.6 | -17.5 | -1.8 | -1.6 | -6.5 | -1.9 | -2.2 | -12.0 | -46.1 | -28.6 | 63.1 | 24.5 |

*Note*: The 'Share' column shows the 2015 expenditure shares of the 11 consumption categories (see Table 4) for German households. REU denotes the rest of EU countries (excluding Italy) not listed in the table. 'Outside' refers to income impacts outside Germany. The last '1% of DE cons. (€)' column shows the values of 1% of the average equivalized expenditures of German households in 2015. The parameters of the modified Taylor micro-model are based on the OLS intra-budget regressions.

The largest EU-wide average per-adult-equivalent income loss is also due to HousWtrElc price increase in Germany, which amounts to –€80.1. Thus, about 60% of this total impact represents the price-spillover effects on the other 25 EU countries. The countries most affected (in absolute terms) by a 1% HousWtrElc price increase in Germany are Luxembourg (–€11.1), Austria (–€4.3), and the Netherlands (–€3.8). Interestingly, all commodity price shocks in Germany have greater overall spillover effects on other EU countries than on its domestic market, except for the Health category (see the 'Outside (€)' and 'Outside (%)' columns in Table 3). The spillover effects are distributed unevenly across the 'destination' countries and extend beyond direct bilateral impacts. In general, all the multipliers represent the ultimate corresponding outcomes, capturing the complex direct and indirect production, income, and consumption interrelations among countries and products, and fully accounting for global supply/demand chains.

For completeness, the aggregated price-to-consumption multiplier matrix, with consumption impacts properly allocated to domestic and imported sources, is shown in Table A.6 (the supplementary file provides the details of all the price-related multipliers).

The table is more complete, covering price-to-demand impacts with the price-shocks' origins in 26 EU countries and the corresponding consumption impacts in *all* regions, including Italy and the RoW region. Without going into further details, we only note that the (negative) price impacts are always larger in terms of consumption rather than income: across the 26 EU countries, total price-to-consumption multipliers are, on average, 83% higher than the total price-to-income multipliers (compare the 'EU26' rows in Tables A.5 and A.6). This is driven by the fact that prices first impact consumption, followed by production effects which in turn influence income generation.

## 5.2 Evaluation of the impacts of consumer price increases

In this section, we examine the impacts of price changes resulting from one of the scenarios analysed in Weitzel et al. (2023) for reaching a 55% reduction in EU greenhouse gas emissions by 2030 compared to 1990 levels. Specifically, for illustrative purposes, we select the MIX scenario that incorporates the effects of both regulatory measures and price-based policies, which come closest to the policy package now in place. In particular, this scenario includes an intensification in transport and energy policies through e.g. tightening of standards for vehicles and building codes, as well as strengthening the European Emission Trading System (EU ETS) though a higher mitigation in industrial and energy sectors and extending the coverage to buildings and road transport. The corresponding average EU price changes, obtained from the JRC-GEM-E3 model (Capros et al., 2013; Weitzel et al., 2023) and translated to the 11 COICOP consumption categories considered in this paper, are presented in the third column of Table 4. These price changes are identically applied for each individual EU country.

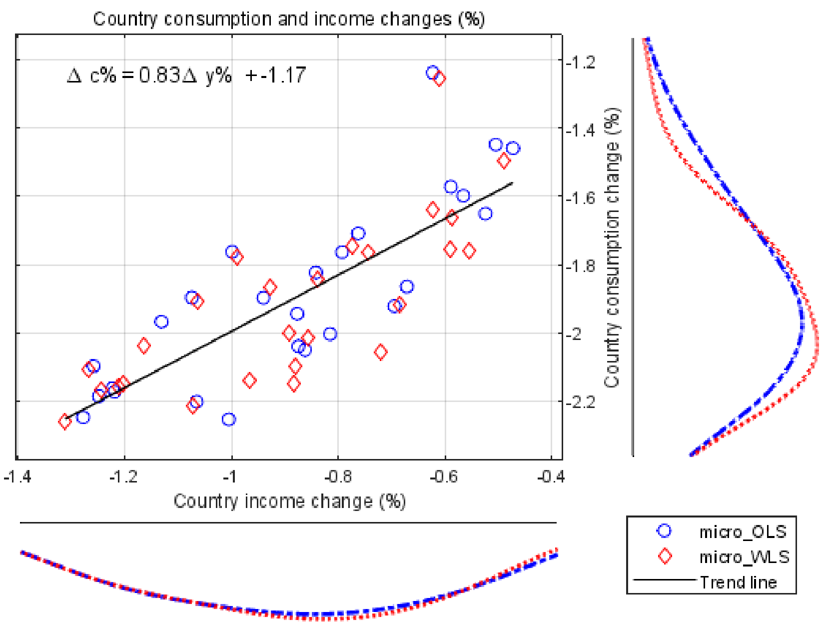
**Table 4:** Price shocks and the initial EU consumption impacts from the Taylor model

| Shortcut | Consumption category description | Price change (%) | Impact on EU consumption (%) | |
|---|---|---|---|---|
| | | | OLS | WLS |
| FoodNalcBvg | Food and non-alcoholic beverages | 0.12 | -0.76 | -0.84 |
| AlcBvgTbc | Alcoholic beverages, tobacco and narcotics | 0.12 | -0.40 | -0.45 |
| ClothFtwr | Clothing and footwear | 0.07 | -0.70 | -0.76 |
| HousWtrElc | Housing, water, electricity, gas and other fuels | 4.43 | -1.60 | -1.49 |
| FurnshHeqp | Furnishings, household equipment and routine maintenance of the house | 0.09 | -0.45 | -0.53 |
| Health | Health | 0.06 | -0.43 | -0.48 |
| Transport | Transport | 1.26 | -1.94 | -2.07 |
| Communicat | Communication | 0.02 | -0.47 | -0.52 |
| RecreatCult | Recreation and culture | 0.20 | -0.85 | -0.92 |
| RestrntHotl | Restaurants and hotels | 0.20 | -0.66 | -0.71 |
| MiscGSEduc | Miscellaneous goods and services, inc. education | 0.03 | -0.66 | -0.75 |
| *Average EU price change and total EU consumption impact (%)* | | 1.08 | -1.02 | -1.07 |

*Note*: EU results refer to total consumption of 26 EU countries, excluding Italy (EU26). Consumption impacts are based on equations (12.a) and (12.b). The average EU price change is a weighted average, where the mean EU consumption expenditure shares are used as weights.

Within a "partial equilibrium" analysis framework, equations (12.a) and (12.b) are used to estimate consumption reactions to the price increases in each individual EU country. The resulting EU-wide impacts, based on the estimates of OLS and WLS intra-budget equations, are presented along the last two columns of Table 4. The country-specific results are reported in the supplementary file. Thus, we find an overall decrease of just over 1% in EU consumption expenditures, with the greatest impact on Transport (of about -2%) and HousWtrElc (approximately -1.6%). Note that even the price increase in the latter category is 3.5 times larger than that in Transport (i.e. 4.43% vs. 1.26%), the relative impact on HousWtrElc is lower. Naturally, this is due to the more basic nature of the HousWtrElc consumption category, which – apart from the elements of the household expenditure multiplier matrix – is also captured by the estimates of exogenous expenditures. Demand for all other consumption categories also changes, whose relative sizes are the outcome of the complementarity and substitutability effects captured by the modified Talor micro-model.

**Figure 7:** Total consumption and income impacts for 26 EU countries




*Note*: The changes (in %) are given in relation to the corresponding benchmark values. 'micro_OLS' indicates that the results of the micro-model are based the OLS intra-budget regressions.

Next, we account for the income-induced consumption impacts, as detailed in Section 4.2. The country-level total impacts, including the effects of the demand-driven multiplier process, on income and consumption are shown in the scatter-plot (with marginal histograms) in Figure 7. Further, the decomposition of total consumption changes into the direct price-induced and indirect income-induced impacts are reported in Table 5. The total consumption losses range from -2.3% to -1.2%, with the EU-wide impacts of -1.7% and -1.9% when using the OLS- and WLS-based micro-models, respectively. The results also indicate that the losses estimated by the IO micro-macro twins model with the WLS-based Taylor micro-model outputs are generally higher (on average, by 2%) than

**Table 5:** Direct price-induced and indirect income-induced consumption impacts (%)

| | Micro-model based on OLS | | | | Micro-model based on WLS | | | |
|---|---|---|---|---|---|---|---|---|
| | Direct | Indirect | Total | Direct (%) | Direct | Indirect | Total | Direct (%) |
| AT | -1.08 | -0.79 | -1.87 | 57.7 | -1.12 | -0.82 | -1.93 | 57.8 |
| BE | -0.99 | -0.61 | -1.59 | 62.0 | -1.02 | -0.64 | -1.66 | 61.6 |
| BG | -0.95 | -0.81 | -1.76 | 53.8 | -0.93 | -0.82 | -1.76 | 53.2 |
| CY | -0.77 | -0.80 | -1.57 | 49.1 | -0.79 | -0.82 | -1.61 | 49.3 |
| CZ | -1.20 | -0.77 | -1.97 | 60.9 | -1.23 | -0.79 | -2.02 | 60.9 |
| DE | -1.14 | -0.78 | -1.92 | 59.3 | -1.22 | -0.84 | -2.06 | 59.3 |
| DK | -1.23 | -0.69 | -1.92 | 64.3 | -1.35 | -0.73 | -2.07 | 64.9 |
| EE | -0.95 | -0.64 | -1.59 | 59.8 | -0.98 | -0.66 | -1.64 | 59.8 |
| EL | -0.85 | -1.14 | -1.99 | 42.7 | -0.85 | -1.15 | -2.00 | 42.4 |
| ES | -0.85 | -0.87 | -1.72 | 49.3 | -0.88 | -0.91 | -1.79 | 49.2 |
| FI | -1.13 | -0.66 | -1.79 | 63.1 | -1.21 | -0.70 | -1.91 | 63.4 |
| FR | -0.98 | -0.70 | -1.68 | 58.2 | -1.03 | -0.72 | -1.75 | 58.9 |
| HR | -0.96 | -1.00 | -1.97 | 49.1 | -0.96 | -1.00 | -1.96 | 48.9 |
| HU | -1.17 | -0.74 | -1.91 | 61.5 | -1.17 | -0.74 | -1.91 | 61.0 |
| IE | -0.99 | -0.44 | -1.43 | 69.3 | -1.01 | -0.46 | -1.47 | 68.8 |
| LT | -0.83 | -0.75 | -1.58 | 52.6 | -0.85 | -0.76 | -1.61 | 52.7 |
| LU | -1.04 | -0.53 | -1.57 | 66.0 | -1.08 | -0.57 | -1.65 | 65.6 |
| LV | -0.96 | -0.77 | -1.74 | 55.6 | -0.95 | -0.78 | -1.73 | 54.8 |
| MT | -0.62 | -0.51 | -1.13 | 54.8 | -0.65 | -0.53 | -1.18 | 55.0 |
| NL | -0.95 | -0.56 | -1.50 | 63.0 | -1.17 | -0.65 | -1.82 | 64.4 |
| PL | -1.15 | -0.95 | -2.10 | 54.8 | -1.15 | -0.96 | -2.11 | 54.5 |
| PT | -0.95 | -1.08 | -2.03 | 46.9 | -0.96 | -1.09 | -2.05 | 46.7 |
| RO | -0.98 | -0.95 | -1.93 | 51.0 | -0.96 | -0.94 | -1.90 | 50.5 |
| SE | -1.20 | -0.66 | -1.86 | 64.4 | -1.24 | -0.69 | -1.92 | 64.4 |
| SI | -0.99 | -0.74 | -1.73 | 57.1 | -1.01 | -0.75 | -1.77 | 57.3 |
| SK | -1.26 | -0.90 | -2.16 | 58.3 | -1.18 | -0.89 | -2.07 | 57.2 |
| EU26 | -1.02 | -0.71 | -1.72 | 59.1 | -1.07 | -0.74 | -1.80 | 59.2 |

*Note*: The changes (in %) are given in relation to the corresponding benchmark values. 'Direct' and 'Indirect' refer, respectively, to direct price-induced and indirect income-induced consumption impacts. 'Direct %' shows the contribution of the direct effect to total impact in relative terms (in %).

those using the OLS-based micro-model.

Table 5 shows that the greater portion of total consumption losses generally comes from the direct price-induced impacts. For the EU26, this direct effect makes 57% of the total consumption impact, while the remaining 43% change is induced by income changes resulting from the demand-production-income propagation process. The overall trendline along the 52 (= 26 × 2) data-points in Figure 7 gives $\Delta c_r\% = -1.17 + 0.83\Delta y_r\%$, which also captures the extent of the direct price-induced impact on consumption in its negative intercept (with zero income change). There is a clear variation among countries in the relative sizes of the considered decomposition components. As an example, the direct price impact on consumption is found to be the largest in Finland (69%) and the smallest in Greece (40%). These differences and those of the other country-specific impacts reflect the country specificities of consumer responses to price and income changes, as captured by the Taylor model, as well as the structure and size of domestic and inter-country production interdependencies and private consumption expenditures, as captured by the Leontief macro-model.

We note that the integrated micro-macro model employed here does not account for other potentially significant impacts, such as e.g. the effects of the EU demand-driven decreased income in the rest of the world on the EU exports. Importantly, we do not adjust the production structure. This is the main change in JRC-GEM-E3, in that the composition within the consumption bundles changes, the production technology changes, wages and capital returns change, and that there are macro effects, e.g. on aggregate investment (which obviously also affects income). Nonetheless, it is interesting to observe that the the overall EU results derived from this rather simplified integrated micro-macro model closely align with those reported in Weitzel et al. (2023), which utilizes a much more complicated modelling framework (see the 'Before transfer' impact line in Figure 8, corresponding to the MIX scenario). All in all, we may conclude that our modelling exercises suggest that the modified Taylor household expenditure model can be used within an integrated micro-macro modelling framework, however simple or complex, in order to get a deeper understanding of the household-level consumption, income, and other distributional impacts of policies under consideration.

## 6 Concluding remarks

This paper adds to the broad literature on demand estimation from micro-data and integration of consumer demand model to an input-output (IO) macro-model. Regarding the first contribution, we have examined the performance of a (rather) new household expenditure model, proposed by Taylor (2014) and further elaborated in his subsequent work. The model has been applied for the first time to the EU household budget surveys for the reference years of 2010 and 2015 in order to gain deeper insights into the workings and implications of the internal structure and interdependencies of European households' consumption expenditures.

We have modified the Taylor framework to account for country-specific factors and relative size to more accurately estimate the parameters of the expenditure model in a multi-country (or multi-region) framework. We have also added the income effects in incorporating the household budget constraint into the basic Taylor expenditure model, which becomes relevant for its empirical applications in policy assessments. We derive the formulae for own/cross-price and income elasticities, and briefly discuss the estimated EU-wide elasticities by household income group.

To evaluate the impacts of consumer price changes, we have integrated the modified Taylor micro-model with the Leontief quantity IO framework. This integration enables us to account for the circular demand-production-income multiplier effects. To get a better understanding of the inner workings of the proposed IO micro-macro model, we linearize the system and show how in practice the linearization errors can be eliminated. We show that the linearized micro-macro model extends the Miyazawa-Masegi approach in that it enables the integration of the IO macro-model with *any* micro-model of consumption demand, and it supports analysis of consumer price impacts within the IO demand-driven framework. As such, we also discuss novel multiplier matrices that capture the impacts of price changes on income, consumption, and production.

In the empirical section, we discuss some quantitative results of income- and price-related multiplier matrices for 26 EU countries. Additionally, for illustrative purposes, we apply the model to examine the consumption and income impacts of increased consumer prices corresponding to a climate policy scenario for reaching a 55% reduction in EU greenhouse gas emissions by 2030 compared to 1990 levels. The empirical results of this minimal (or simple) IO micro-macro twins model are rather encouraging. Thus, we expect that the modified Taylor household expenditure model, or its further extensions, can be effectively used within an integrated micro-macro modelling framework of any complexity to account for consumer responses to price and income changes and assess the distributional impacts of policies.

We acknowledge the typical limitations of using consumer surveys that may affect the scope and precision of any estimated demand system outcomes, including those of the Taylor model. Estimation of the Taylor expenditure model for a detailed commodity classification is likely to be problematic due to issues such as data quality and the frequent occurrence of a large number of zero-expenditure records in expenditure surveys for certain consumption categories. The latter is concerning when the prevalence of zero expenditures is a consequence of the data collection process and/or non-reporting by respondents. Accuracy and quality concerns are also often raised with respect to the income variables in the EU Household Budget Survey data, particularly when compared to those in the EU Statistics on Income and Living Conditions (EU-SILC).[48]

[48] To tackle this last issue to a certain extent, statistical matching techniques are often used to combine two separate datasets (see e.g. D'Orazio et al., 2006; Lamarche et al., 2020; Tomás et al., 2021).

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# A Annex tables

**Table A.1:** Descriptive statistics of the EU-wide budget shares (%)

| | Mean | MeanW | Median | MedianW | StdDev | StdDevW | Min | Max |
|---|---|---|---|---|---|---|---|---|
| | | | | EU-HBS-2010 | | | | |
| FoodNalcBvg | 26.2 | 22.0 | 22.5 | 18.9 | 16.0 | 13.9 | 0.0 | 99.5 |
| AlcBvgTbc | 3.4 | 3.1 | 1.2 | 1.1 | 5.5 | 5.0 | 0.0 | 95.1 |
| ClothFtwr | 5.0 | 4.9 | 3.2 | 3.3 | 6.0 | 5.6 | 0.0 | 93.3 |
| HousWtrElc | 19.2 | 20.6 | 15.8 | 17.0 | 13.9 | 14.7 | 0.0 | 100.0 |
| FurnshHeqp | 4.9 | 4.9 | 2.8 | 2.8 | 6.7 | 6.7 | 0.0 | 90.7 |
| Health | 4.7 | 4.0 | 2.0 | 1.7 | 7.4 | 6.6 | 0.0 | 91.6 |
| Transport | 10.4 | 11.4 | 7.5 | 8.2 | 11.9 | 12.4 | 0.0 | 93.8 |
| Communicat | 4.4 | 4.3 | 3.7 | 3.6 | 3.4 | 3.2 | 0.0 | 82.5 |
| RecreatCult | 7.8 | 8.5 | 5.5 | 6.2 | 8.0 | 8.2 | 0.0 | 96.1 |
| RestrntHotl | 4.8 | 5.5 | 1.8 | 2.8 | 7.4 | 7.5 | 0.0 | 95.9 |
| MiscGSEduc | 9.2 | 10.9 | 6.8 | 8.6 | 8.7 | 9.2 | 0.0 | 98.8 |
| | | | | EU-HBS-2015 | | | | |
| FoodNalcBvg | 24.1 | 21.1 | 21.1 | 18.4 | 14.5 | 13.0 | 0.0 | 97.5 |
| AlcBvgTbc | 3.2 | 3.0 | 1.0 | 1.0 | 5.6 | 5.2 | 0.0 | 87.4 |
| ClothFtwr | 5.0 | 4.9 | 3.2 | 3.3 | 5.9 | 5.6 | 0.0 | 90.7 |
| HousWtrElc | 20.2 | 21.8 | 16.8 | 18.2 | 13.9 | 14.9 | 0.0 | 100.0 |
| FurnshHeqp | 5.0 | 4.9 | 2.9 | 2.8 | 6.7 | 6.7 | 0.0 | 93.8 |
| Health | 4.9 | 4.0 | 2.1 | 1.6 | 7.5 | 6.8 | 0.0 | 94.0 |
| Transport | 10.2 | 10.6 | 7.2 | 7.4 | 11.7 | 12.1 | 0.0 | 96.5 |
| Communicat | 4.6 | 4.3 | 3.9 | 3.6 | 3.4 | 3.1 | 0.0 | 95.3 |
| RecreatCult | 7.5 | 8.1 | 5.0 | 5.8 | 8.1 | 8.3 | 0.0 | 94.5 |
| RestrntHotl | 5.5 | 5.8 | 2.7 | 3.2 | 7.6 | 7.6 | 0.0 | 89.8 |
| MiscGSEduc | 9.9 | 11.4 | 7.8 | 9.3 | 8.6 | 9.3 | 0.0 | 92.0 |

*Note*: The reported summary statistics do not include expenditure data for Italy (both for EU-HBS-2010 and 2015) and the Netherlands (only for EU-HBS-2010). The suffix "W", indicates that the corresponding summary statistic (i.e. mean, median, or standard deviation) accounts for household sample weights.

**Table A.2:** Estimates of intercepts of the EU-wide intra-budget regressions (i.e. exogenous expenditures) and country weights, 2015

| | AT | BE | BG | CY | CZ | DE | DK | EE | EL | ES | FI | FR | HR | HU | IE | LT | LU | LV | MT | NL | PL | PT | RO | SE | SI | SK |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | Estimates of zeta's from OLS regressions | | | | | | | | | | | | | | |
| c1 FoodNalcBvg | 1919 | 2171 | 841 | 2237 | 1025 | 1761 | 2255 | 1309 | 1892 | 2059 | 2235 | 2041 | 1488 | 990 | 1815 | 1412 | 2010 | 1243 | 2056 | 1704 | 1008 | 1335 | 902 | 1862 | 1317 | 1122 |
| c2 AlcBvgTbc | 205 | 126 | 47 | -37 | 48 | 36 | 237 | 96 | 145 | 8 | 182 | 131 | 22 | 18 | 159 | 55 | -23 | 21 | 17 | 390 | 2 | -14 | 105 | 88 | 3 | 25 |
| c3 ClothFtwr | 198 | -21 | -52 | 125 | -4 | 126 | -128 | -22 | 3 | 118 | -345 | -121 | 27 | -92 | -112 | 60 | 521 | 4 | 287 | 75 | -7 | -145 | -16 | -24 | 74 | -47 |
| c4 HousWtrElc | 3625 | 2584 | 405 | 1194 | 1182 | 3547 | 4732 | 812 | 1116 | 1353 | 3467 | 2081 | 773 | 801 | 2269 | 594 | 4008 | 740 | 632 | 2522 | 871 | 1067 | 432 | 3385 | 1144 | 1200 |
| c5 FurnshHeqp | 163 | -134 | -122 | -179 | -136 | -343 | -350 | -92 | -287 | -274 | -494 | -354 | -233 | -203 | -628 | -152 | 204 | -188 | -88 | -226 | -167 | -227 | -132 | -194 | -330 | -192 |
| c6 Health | 5 | 155 | 53 | 325 | -149 | 177 | -551 | -18 | 409 | 53 | -44 | -511 | -104 | 54 | -351 | 146 | -477 | 156 | 176 | -654 | 40 | 297 | 13 | -471 | -219 | -80 |
| c7 Transport | 349 | 253 | -174 | -281 | -284 | 290 | 15 | -66 | -371 | -146 | 1062 | -42 | -86 | -253 | -232 | -142 | 521 | -56 | -349 | -43 | -283 | 75 | -209 | 305 | 414 | -280 |
| c8 Communicat | 64 | 460 | 107 | 504 | 197 | 330 | 380 | 215 | 301 | 311 | 394 | 306 | 238 | 257 | 672 | 149 | 556 | 166 | 395 | 496 | 185 | 277 | 93 | 483 | 435 | 235 |
| c9 RecreatCult | 1003 | 19 | -153 | -836 | -16 | 549 | 323 | 28 | -610 | -457 | 246 | -243 | -252 | -187 | -147 | -206 | -446 | -102 | -359 | 124 | -163 | -497 | -171 | 1384 | -215 | -203 |
| c10 RestrntHotl | 109 | -69 | -62 | 372 | -125 | -246 | -544 | -254 | 385 | 603 | -322 | -367 | -265 | -195 | -129 | -182 | 812 | -113 | 23 | -208 | -149 | 336 | -157 | -743 | -309 | -148 |
| c11 MiscGSEduc | 601 | 769 | -172 | 344 | -175 | 283 | 436 | -285 | -29 | 131 | 1001 | 1215 | -92 | -135 | 952 | -231 | 537 | -195 | 307 | 1689 | -205 | 45 | -191 | -472 | 223 | -161 |
| Weight (%) | 2.7 | 2.3 | 1.1 | 1.1 | 1.1 | 20.0 | 0.8 | 1.3 | 2.3 | 8.4 | 1.4 | 6.4 | 0.8 | 2.7 | 2.6 | 1.3 | 1.2 | 1.5 | 1.4 | 5.2 | 13.9 | 4.4 | 11.7 | 1.0 | 1.4 | 1.8 |
| | | | | | | | | | | | | Estimates of zeta's from WLS regressions | | | | | | | | | | | | | | |
| c1 FoodNalcBvg | 1896 | 2160 | 862 | 2102 | 1042 | 1714 | 2235 | 1276 | 1876 | 1990 | 2122 | 2098 | 1496 | 970 | 1796 | 1408 | 1998 | 1266 | 2000 | 1558 | 1000 | 1371 | 899 | 1865 | 1331 | 1110 |
| c2 AlcBvgTbc | 237 | 162 | 62 | 6 | 59 | 53 | 263 | 95 | 185 | 36 | 235 | 234 | 43 | 41 | 193 | 80 | 30 | 50 | 56 | 391 | 12 | -13 | 124 | 112 | 26 | 45 |
| c3 ClothFtwr | 281 | 103 | -22 | 273 | 30 | 205 | 37 | 22 | 107 | 208 | -174 | -13 | 92 | -48 | 24 | 109 | 583 | 71 | 348 | 122 | 35 | -54 | 24 | 98 | 153 | 23 |
| c4 HousWtrElc | 3751 | 2791 | 415 | 1238 | 1200 | 3686 | 5298 | 866 | 1116 | 1457 | 3772 | 2594 | 778 | 801 | 2333 | 634 | 4288 | 753 | 696 | 3458 | 869 | 1152 | 425 | 3658 | 1200 | 1079 |
| c5 FurnshHeqp | 158 | -140 | -121 | -200 | -115 | -330 | -323 | -95 | -268 | -243 | -459 | -407 | -228 | -202 | -618 | -151 | 181 | -185 | -62 | -325 | -157 | -215 | -130 | -130 | -306 | -173 |
| c6 Health | 154 | 367 | 81 | 408 | -76 | 189 | -299 | 53 | 456 | 139 | 139 | -391 | -46 | 71 | -199 | 165 | -219 | 187 | 255 | -449 | 86 | 359 | 26 | -241 | -121 | -47 |
| c7 Transport | 286 | 118 | -165 | -282 | -275 | 259 | 10 | -86 | -372 | -194 | 955 | -22 | -75 | -217 | -242 | -148 | 309 | -25 | -330 | -116 | -283 | 144 | -188 | 399 | 373 | -217 |
| c8 Communicat | 96 | 512 | 118 | 550 | 197 | 358 | 406 | 226 | 323 | 341 | 411 | 285 | 252 | 284 | 703 | 156 | 613 | 184 | 431 | 536 | 197 | 290 | 103 | 507 | 461 | 259 |
| c9 RecreatCult | 855 | -14 | -162 | -867 | -37 | 405 | 235 | 47 | -628 | -468 | 200 | -157 | -269 | -186 | -233 | -202 | -480 | -108 | -410 | -68 | -174 | -505 | -177 | 1421 | -231 | -229 |
| c10 RestrntHotl | 149 | 4 | -43 | 468 | -133 | -295 | -561 | -214 | 433 | 619 | -302 | -288 | -259 | -184 | -117 | -150 | 865 | -104 | 99 | -256 | -136 | 433 | -152 | -763 | -298 | -158 |
| c11 MiscGSEduc | 576 | 721 | -179 | 376 | -179 | 294 | 380 | -298 | -26 | 145 | 865 | 1409 | -103 | -144 | 926 | -238 | 549 | -203 | 256 | 1682 | -208 | 104 | -195 | -431 | 197 | -145 |
| Weight (%) | 2.4 | 3.0 | 1.8 | 0.2 | 2.7 | 24.0 | 1.6 | 0.4 | 2.6 | 11.3 | 1.7 | 18.2 | 0.9 | 2.6 | 1.1 | 0.8 | 0.1 | 0.5 | 0.1 | 4.5 | 8.3 | 2.6 | 4.6 | 2.4 | 0.5 | 1.2 |

*Note*: The reported intercepts can be interpreted as equivalized exogenous expenditures, expressed in EUR.

**Table A.3:** Percentage of zeros reported in EU-HBS-2015, by income decile (%)

| | D1 | D2 | D3 | D4 | D5 | D6 | D7 | D8 | D9 | D10 |
|---|---|---|---|---|---|---|---|---|---|---|
| | Percentage of zeros in the sample | | | | | | | | | |
| Net Income | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| FoodNalcBvg | 0.3 | 0.2 | 0.3 | 0.5 | 0.9 | 0.9 | 0.7 | 0.6 | 0.5 | 0.5 |
| AlcBvgTbc | 39.2 | 35.4 | 33.3 | 30.0 | 32.2 | 31.2 | 28.9 | 27.3 | 25.5 | 24.8 |
| ClothFtwr | 47.4 | 34.3 | 27.2 | 21.2 | 19.7 | 17.7 | 15.5 | 14.2 | 13.4 | 13.1 |
| HousWtrElc | 2.0 | 0.6 | 0.5 | 0.5 | 0.4 | 0.4 | 0.4 | 0.3 | 0.3 | 0.3 |
| FurnshHeqp | 14.6 | 9.6 | 6.8 | 6.0 | 8.3 | 8.1 | 6.9 | 6.4 | 5.1 | 4.0 |
| Health | 34.0 | 25.1 | 20.5 | 17.7 | 20.0 | 20.3 | 17.9 | 17.7 | 17.6 | 16.8 |
| Transport | 56.4 | 39.1 | 25.9 | 16.6 | 15.3 | 11.2 | 7.4 | 4.7 | 3.3 | 2.4 |
| Communicat | 16.0 | 4.2 | 2.9 | 1.9 | 2.5 | 2.6 | 2.5 | 2.6 | 2.5 | 2.6 |
| RecreatCult | 14.2 | 10.4 | 8.8 | 8.1 | 8.7 | 4.9 | 2.6 | 1.4 | 0.9 | 0.5 |
| RestrntHotl | 79.9 | 68.5 | 54.3 | 38.0 | 27.5 | 20.1 | 15.0 | 10.7 | 7.7 | 5.3 |
| MiscGSEduc | 17.4 | 7.4 | 4.4 | 2.5 | 1.6 | 0.8 | 0.3 | 0.2 | 0.1 | 0.1 |
| | Percentage of zeros, accounting for household weights | | | | | | | | | |
| Net Income | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| FoodNalcBvg | 0.4 | 0.5 | 0.8 | 1.6 | 1.5 | 1.3 | 1.4 | 1.3 | 0.9 | 1.1 |
| AlcBvgTbc | 34.9 | 31.9 | 29.2 | 33.1 | 33.4 | 33.0 | 31.2 | 30.5 | 29.4 | 27.8 |
| ClothFtwr | 35.8 | 23.2 | 18.3 | 19.1 | 19.3 | 18.5 | 16.4 | 15.5 | 15.2 | 13.2 |
| HousWtrElc | 1.3 | 0.7 | 0.7 | 0.6 | 0.5 | 0.5 | 0.4 | 0.3 | 0.5 | 0.4 |
| FurnshHeqp | 10.9 | 7.0 | 7.8 | 11.4 | 11.1 | 9.7 | 9.2 | 7.8 | 6.7 | 5.2 |
| Health | 28.6 | 19.9 | 19.2 | 21.2 | 20.9 | 19.7 | 18.6 | 17.2 | 16.8 | 14.6 |
| Transport | 41.4 | 24.2 | 16.3 | 17.2 | 14.4 | 12.2 | 9.2 | 6.9 | 5.6 | 4.1 |
| Communicat | 8.6 | 3.3 | 2.3 | 3.3 | 2.9 | 2.6 | 2.0 | 2.4 | 2.1 | 2.1 |
| RecreatCult | 13.3 | 9.2 | 8.3 | 8.1 | 5.4 | 3.3 | 1.8 | 1.1 | 1.0 | 0.4 |
| RestrntHotl | 64.3 | 46.0 | 29.8 | 25.5 | 23.2 | 21.5 | 17.9 | 14.6 | 11.8 | 8.0 |
| MiscGSEduc | 9.3 | 3.4 | 1.6 | 1.0 | 0.5 | 0.2 | 0.2 | 0.1 | 0.2 | 0.1 |

*Note*: Italy is excluded due to the missing income data. For the bottom part of the results, household weights are used consistently, both in calculating the percentage of zeros and in classifying households into income groups.

## Table A.4: Income-to-income multipliers, 2015

| | AT | BE | BG | CY | CZ | DE | DK | EE | EL | ES | FI | FR | HR | HU | IE | LT | LU | LV | MT | NL | PL | PT | RO | SE | SI | SK | EU26 | Outside | Outside (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AT | 1.550 | 0.006 | 0.024 | 0.001 | 0.018 | 0.082 | 0.001 | 0.001 | 0.009 | 0.018 | 0.002 | 0.023 | 0.027 | 0.036 | 0.001 | 0.004 | 0.000 | 0.003 | 0.000 | 0.004 | 0.048 | 0.005 | 0.079 | 0.003 | 0.006 | 0.012 | 1.964 | 0.413 | 21.1 |
| BE | 0.004 | 1.429 | 0.012 | 0.001 | 0.006 | 0.038 | 0.002 | 0.001 | 0.009 | 0.028 | 0.002 | 0.062 | 0.004 | 0.008 | 0.002 | 0.004 | 0.001 | 0.002 | 0.000 | 0.014 | 0.031 | 0.010 | 0.029 | 0.004 | 0.001 | 0.004 | 1.707 | 0.279 | 16.3 |
| BG | 0.002 | 0.001 | 1.759 | 0.001 | 0.002 | 0.009 | 0.000 | 0.000 | 0.017 | 0.005 | 0.000 | 0.005 | 0.002 | 0.003 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.001 | 0.009 | 0.001 | 0.050 | 0.001 | 0.002 | 0.001 | 1.873 | 0.114 | 6.1 |
| CY | 0.002 | 0.004 | 0.015 | 1.976 | 0.008 | 0.031 | 0.001 | 0.003 | 0.091 | 0.010 | 0.002 | 0.010 | 0.002 | 0.009 | 0.001 | 0.006 | 0.000 | 0.004 | 0.003 | 0.004 | 0.050 | 0.012 | 0.100 | 0.002 | 0.001 | 0.009 | 2.358 | 0.382 | 16.2 |
| CZ | 0.006 | 0.003 | 0.010 | 0.000 | 1.390 | 0.033 | 0.001 | 0.001 | 0.003 | 0.011 | 0.001 | 0.013 | 0.004 | 0.013 | 0.000 | 0.003 | 0.000 | 0.002 | 0.000 | 0.002 | 0.037 | 0.003 | 0.025 | 0.002 | 0.001 | 0.021 | 1.583 | 0.193 | 12.2 |
| DE | 0.011 | 0.008 | 0.015 | 0.001 | 0.014 | 1.568 | 0.002 | 0.001 | 0.008 | 0.029 | 0.002 | 0.036 | 0.007 | 0.014 | 0.002 | 0.005 | 0.001 | 0.003 | 0.000 | 0.007 | 0.058 | 0.008 | 0.038 | 0.004 | 0.002 | 0.006 | 1.850 | 0.282 | 15.2 |
| DK | 0.004 | 0.007 | 0.010 | 0.001 | 0.009 | 0.057 | 1.431 | 0.003 | 0.012 | 0.029 | 0.010 | 0.027 | 0.005 | 0.010 | 0.005 | 0.013 | 0.000 | 0.008 | 0.000 | 0.008 | 0.053 | 0.007 | 0.027 | 0.035 | 0.001 | 0.005 | 1.776 | 0.345 | 19.4 |
| EE | 0.001 | 0.002 | 0.004 | 0.000 | 0.002 | 0.011 | 0.002 | 1.466 | 0.002 | 0.006 | 0.013 | 0.007 | 0.001 | 0.002 | 0.000 | 0.036 | 0.000 | 0.052 | 0.000 | 0.002 | 0.024 | 0.002 | 0.007 | 0.008 | 0.000 | 0.001 | 1.653 | 0.186 | 11.3 |
| EL | 0.001 | 0.002 | 0.028 | 0.006 | 0.002 | 0.011 | 0.000 | 0.000 | 2.164 | 0.007 | 0.001 | 0.005 | 0.002 | 0.002 | 0.001 | 0.001 | 0.000 | 0.001 | 0.000 | 0.001 | 0.008 | 0.002 | 0.025 | 0.001 | 0.001 | 0.001 | 2.273 | 0.109 | 4.8 |
| ES | 0.002 | 0.004 | 0.007 | 0.000 | 0.003 | 0.019 | 0.001 | 0.000 | 0.005 | 1.971 | 0.001 | 0.030 | 0.002 | 0.003 | 0.001 | 0.002 | 0.000 | 0.001 | 0.000 | 0.003 | 0.015 | 0.035 | 0.014 | 0.002 | 0.001 | 0.002 | 2.124 | 0.153 | 7.2 |
| FI | 0.003 | 0.003 | 0.005 | 0.000 | 0.005 | 0.028 | 0.003 | 0.011 | 0.004 | 0.016 | 1.475 | 0.016 | 0.002 | 0.005 | 0.001 | 0.012 | 0.000 | 0.013 | 0.000 | 0.004 | 0.032 | 0.004 | 0.013 | 0.016 | 0.001 | 0.003 | 1.676 | 0.201 | 12.0 |
| FR | 0.002 | 0.010 | 0.005 | 0.000 | 0.003 | 0.023 | 0.001 | 0.000 | 0.005 | 0.026 | 0.001 | 1.615 | 0.002 | 0.005 | 0.001 | 0.002 | 0.000 | 0.001 | 0.000 | 0.004 | 0.017 | 0.007 | 0.016 | 0.002 | 0.001 | 0.002 | 1.751 | 0.136 | 7.7 |
| HR | 0.004 | 0.001 | 0.006 | 0.000 | 0.002 | 0.008 | 0.000 | 0.000 | 0.002 | 0.003 | 0.000 | 0.004 | 2.148 | 0.012 | 0.000 | 0.001 | 0.000 | 0.001 | 0.000 | 0.001 | 0.006 | 0.001 | 0.010 | 0.001 | 0.008 | 0.003 | 2.222 | 0.074 | 3.3 |
| HU | 0.004 | 0.002 | 0.011 | 0.000 | 0.005 | 0.016 | 0.000 | 0.000 | 0.002 | 0.006 | 0.001 | 0.007 | 0.010 | 1.455 | 0.000 | 0.001 | 0.000 | 0.001 | 0.000 | 0.001 | 0.015 | 0.002 | 0.056 | 0.001 | 0.001 | 0.006 | 1.605 | 0.150 | 9.4 |
| IE | 0.004 | 0.009 | 0.009 | 0.001 | 0.008 | 0.053 | 0.003 | 0.001 | 0.009 | 0.045 | 0.003 | 0.043 | 0.004 | 0.013 | 1.277 | 0.005 | 0.001 | 0.004 | 0.000 | 0.013 | 0.051 | 0.013 | 0.024 | 0.008 | 0.001 | 0.004 | 1.603 | 0.326 | 20.4 |
| LT | 0.002 | 0.002 | 0.006 | 0.000 | 0.003 | 0.013 | 0.002 | 0.008 | 0.002 | 0.006 | 0.002 | 0.008 | 0.001 | 0.003 | 0.000 | 1.880 | 0.000 | 0.039 | 0.000 | 0.002 | 0.027 | 0.002 | 0.008 | 0.004 | 0.001 | 0.002 | 2.023 | 0.143 | 7.1 |
| LU | 0.011 | 0.036 | 0.021 | 0.002 | 0.016 | 0.208 | 0.005 | 0.002 | 0.021 | 0.115 | 0.010 | 0.153 | 0.007 | 0.018 | 0.003 | 0.006 | 1.182 | 0.003 | 0.004 | 0.018 | 0.068 | 0.029 | 0.071 | 0.024 | 0.003 | 0.009 | 2.044 | 0.862 | 42.2 |
| LV | 0.001 | 0.001 | 0.004 | 0.001 | 0.002 | 0.008 | 0.002 | 0.010 | 0.001 | 0.004 | 0.002 | 0.005 | 0.001 | 0.002 | 0.000 | 0.045 | 0.000 | 1.617 | 0.000 | 0.001 | 0.016 | 0.001 | 0.004 | 0.003 | 0.000 | 0.001 | 1.734 | 0.117 | 6.7 |
| MT | 0.006 | 0.004 | 0.009 | 0.009 | 0.015 | 0.062 | 0.004 | 0.002 | 0.011 | 0.025 | 0.003 | 0.021 | 0.005 | 0.011 | 0.001 | 0.005 | 0.001 | 0.002 | 1.489 | 0.006 | 0.031 | 0.010 | 0.037 | 0.003 | 0.001 | 0.003 | 1.776 | 0.287 | 16.2 |
| NL | 0.005 | 0.026 | 0.013 | 0.001 | 0.009 | 0.069 | 0.003 | 0.001 | 0.012 | 0.031 | 0.003 | 0.045 | 0.006 | 0.011 | 0.004 | 0.007 | 0.001 | 0.003 | 0.000 | 1.378 | 0.044 | 0.011 | 0.035 | 0.006 | 0.001 | 0.004 | 1.728 | 0.350 | 20.3 |
| PL | 0.002 | 0.002 | 0.006 | 0.000 | 0.009 | 0.021 | 0.001 | 0.001 | 0.002 | 0.008 | 0.001 | 0.009 | 0.003 | 0.007 | 0.001 | 0.007 | 0.000 | 0.004 | 0.000 | 0.002 | 1.651 | 0.002 | 0.021 | 0.002 | 0.001 | 0.005 | 1.767 | 0.116 | 6.5 |
| PT | 0.001 | 0.003 | 0.003 | 0.000 | 0.002 | 0.014 | 0.001 | 0.000 | 0.003 | 0.066 | 0.001 | 0.024 | 0.001 | 0.002 | 0.000 | 0.001 | 0.000 | 0.001 | 0.000 | 0.003 | 0.010 | 1.987 | 0.015 | 0.001 | 0.000 | 0.002 | 2.142 | 0.155 | 7.2 |
| RO | 0.001 | 0.001 | 0.015 | 0.000 | 0.002 | 0.007 | 0.000 | 0.000 | 0.003 | 0.004 | 0.000 | 0.005 | 0.001 | 0.006 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.001 | 0.006 | 0.001 | 1.830 | 0.000 | 0.000 | 0.001 | 1.888 | 0.058 | 3.1 |
| SE | 0.003 | 0.007 | 0.008 | 0.000 | 0.005 | 0.034 | 0.009 | 0.003 | 0.005 | 0.016 | 0.013 | 0.023 | 0.003 | 0.007 | 0.002 | 0.009 | 0.000 | 0.006 | 0.000 | 0.005 | 0.041 | 0.006 | 0.016 | 1.437 | 0.001 | 0.003 | 1.665 | 0.228 | 13.7 |
| SI | 0.013 | 0.003 | 0.021 | 0.001 | 0.009 | 0.033 | 0.001 | 0.001 | 0.013 | 0.011 | 0.001 | 0.017 | 0.096 | 0.024 | 0.001 | 0.005 | 0.000 | 0.002 | 0.000 | 0.002 | 0.031 | 0.003 | 0.046 | 0.002 | 1.507 | 0.009 | 1.851 | 0.344 | 18.6 |
| SK | 0.006 | 0.002 | 0.012 | 0.001 | 0.024 | 0.024 | 0.001 | 0.000 | 0.003 | 0.010 | 0.001 | 0.013 | 0.006 | 0.029 | 0.000 | 0.003 | 0.000 | 0.001 | 0.000 | 0.002 | 0.038 | 0.003 | 0.037 | 0.001 | 0.001 | 1.475 | 1.695 | 0.220 | 13.0 |
| EU26 | 1.650 | 1.576 | 2.038 | 2.004 | 1.572 | 2.481 | 1.475 | 1.518 | 2.420 | 2.504 | 1.550 | 2.228 | 2.352 | 1.708 | 1.304 | 2.067 | 1.189 | 1.774 | 1.500 | 1.490 | 2.417 | 2.166 | 2.635 | 1.573 | 1.543 | 1.596 | | | |
| Outside | 0.100 | 0.147 | 0.279 | 0.028 | 0.182 | 0.913 | 0.044 | 0.052 | 0.255 | 0.533 | 0.074 | 0.613 | 0.204 | 0.253 | 0.027 | 0.187 | 0.007 | 0.157 | 0.011 | 0.112 | 0.766 | 0.179 | 0.805 | 0.136 | 0.035 | 0.121 | | | |
| Outside (%) | 6.1 | 9.3 | 13.7 | 1.4 | 11.6 | 36.8 | 3.0 | 3.4 | 10.6 | 21.3 | 4.8 | 27.5 | 8.7 | 14.8 | 2.1 | 9.1 | 0.6 | 8.9 | 0.7 | 7.5 | 31.7 | 8.3 | 30.6 | 8.6 | 2.3 | 7.6 | | | |

*Note*: The table presents the 2015 benchmark income-to-income multiplier matrix, $\mathbf{M}_{yy}$, for 26 EU countries, excluding Italy due to missing income data. The 'Outside' row (column) shows the row (column) sum of off-diagonal entries of $\mathbf{M}_{yy}$. The 'Outside %' row (column) expresses these off-diagonal sums as percentages of the corresponding row (column) totals, labelled as 'EU26'. The parameters of the modified Taylor micro-model are based on the OLS intra-budget regressions.

**Table A.5:** Weighted average price-to-income multipliers, 2015

| | AT | BE | BG | CY | CZ | DE | DK | EE | EL | ES | FI | FR | HR | HU | IE | LT | LU | LV | MT | NL | PL | PT | RO | SE | SI | SK | EU26 | Outside (€) | Outside (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **AT** | -17.7 | -0.2 | -0.1 | 0.0 | -0.2 | -2.6 | -0.1 | 0.0 | -0.1 | -0.3 | -0.1 | -0.6 | -0.2 | -0.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.1 | -0.4 | -0.1 | -0.4 | -0.1 | -0.1 | -0.1 | -23.9 | -6.2 | 25.8 |
| **BE** | -0.1 | -11.6 | 0.0 | 0.0 | -0.1 | -1.2 | -0.1 | 0.0 | -0.1 | -0.5 | -0.1 | -1.7 | 0.0 | -0.1 | -0.1 | 0.0 | -0.1 | 0.0 | 0.0 | -0.5 | -0.3 | -0.1 | -0.1 | -0.2 | 0.0 | 0.0 | -17.0 | -5.4 | 32.0 |
| **BG** | -0.1 | 0.0 | -3.3 | 0.0 | 0.0 | -0.3 | 0.0 | 0.0 | -0.2 | -0.1 | 0.0 | -0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.1 | 0.0 | -0.3 | 0.0 | 0.0 | 0.0 | -4.7 | -1.4 | 29.8 |
| **CY** | -0.1 | -0.1 | -0.1 | -18.7 | -0.1 | -1.0 | -0.1 | 0.0 | -1.1 | -0.2 | -0.1 | -0.3 | 0.0 | -0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.1 | -0.4 | -0.2 | -0.4 | -0.1 | 0.0 | -0.1 | -23.2 | -4.6 | 19.6 |
| **CZ** | -0.2 | -0.1 | 0.0 | 0.0 | -4.8 | -1.1 | 0.0 | 0.0 | 0.0 | -0.2 | 0.0 | -0.4 | 0.0 | -0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.1 | -0.3 | 0.0 | -0.1 | -0.1 | 0.0 | -0.2 | -7.9 | -3.1 | 39.4 |
| **DE** | -0.3 | -0.2 | -0.1 | 0.0 | -0.2 | -17.5 | -0.1 | 0.0 | -0.1 | -0.5 | -0.1 | -1.0 | -0.1 | -0.1 | -0.1 | 0.0 | 0.0 | 0.0 | 0.0 | -0.3 | -0.5 | -0.1 | -0.2 | -0.2 | 0.0 | -0.1 | -21.7 | -4.3 | 19.6 |
| **DK** | -0.1 | -0.2 | 0.0 | 0.0 | -0.1 | -1.8 | -22.6 | 0.0 | -0.2 | -0.5 | -0.3 | -0.7 | 0.0 | -0.1 | -0.2 | -0.1 | 0.0 | -0.1 | 0.0 | -0.3 | -0.5 | -0.1 | -0.1 | -1.2 | 0.0 | -0.1 | -29.3 | -6.7 | 22.9 |
| **EE** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.3 | -0.1 | -4.4 | 0.0 | -0.1 | -0.4 | -0.2 | 0.0 | 0.0 | 0.0 | -0.3 | 0.0 | -0.4 | 0.0 | -0.1 | -0.2 | 0.0 | 0.0 | -0.3 | 0.0 | 0.0 | -7.0 | -2.6 | 37.0 |
| **EL** | 0.0 | 0.0 | -0.1 | -0.1 | 0.0 | -0.3 | 0.0 | 0.0 | -15.6 | -0.1 | 0.0 | -0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.1 | 0.0 | -0.1 | 0.0 | 0.0 | 0.0 | -17.0 | -1.4 | 8.3 |
| **ES** | -0.1 | -0.1 | 0.0 | 0.0 | 0.0 | -0.6 | 0.0 | 0.0 | -0.1 | -16.7 | 0.0 | -0.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.1 | -0.1 | -0.5 | -0.1 | -0.1 | 0.0 | 0.0 | -19.5 | -2.8 | 14.3 |
| **FI** | -0.1 | -0.1 | 0.0 | 0.0 | -0.1 | -0.9 | -0.1 | -0.1 | -0.1 | -0.3 | -15.2 | -0.4 | 0.0 | 0.0 | 0.0 | -0.1 | 0.0 | -0.1 | 0.0 | -0.1 | -0.3 | 0.0 | -0.1 | -0.6 | 0.0 | 0.0 | -18.7 | -3.5 | 18.9 |
| **FR** | -0.1 | -0.3 | 0.0 | 0.0 | 0.0 | -0.7 | 0.0 | 0.0 | -0.1 | -0.5 | 0.0 | -17.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | 0.0 | 0.0 | -19.7 | -2.4 | 12.1 |
| **HR** | -0.1 | 0.0 | 0.0 | 0.0 | 0.0 | -0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.1 | -9.2 | -0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.1 | 0.0 | -0.1 | 0.0 | -0.1 | 0.0 | -10.3 | -1.1 | 10.6 |
| **HU** | -0.1 | 0.0 | 0.0 | 0.0 | -0.1 | -0.5 | 0.0 | 0.0 | 0.0 | -0.1 | 0.0 | -0.2 | -0.1 | -3.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.1 | 0.0 | -0.3 | 0.0 | 0.0 | -0.1 | -5.3 | -1.9 | 36.3 |
| **IE** | -0.1 | -0.2 | 0.0 | 0.0 | -0.1 | -1.6 | -0.1 | 0.0 | -0.1 | -0.8 | -0.1 | -1.2 | 0.0 | -0.1 | -9.3 | 0.0 | 0.0 | 0.0 | 0.0 | -0.4 | -0.4 | -0.2 | -0.1 | -0.3 | 0.0 | 0.0 | -15.5 | -6.2 | 39.9 |
| **LT** | -0.1 | -0.1 | 0.0 | 0.0 | 0.0 | -0.4 | -0.1 | -0.1 | 0.0 | -0.1 | -0.1 | -0.2 | 0.0 | 0.0 | 0.0 | -6.3 | 0.0 | -0.3 | 0.0 | -0.1 | -0.3 | 0.0 | 0.0 | -0.1 | 0.0 | 0.0 | -8.3 | -2.1 | 24.6 |
| **LU** | -0.4 | -1.0 | -0.1 | 0.0 | -0.2 | -6.5 | -0.2 | 0.0 | -0.3 | -2.0 | -0.3 | -4.5 | -0.1 | -0.1 | -0.1 | 0.0 | -9.2 | 0.0 | -0.1 | -0.7 | -0.6 | -0.4 | -0.3 | -0.7 | 0.0 | -0.1 | -27.9 | -18.7 | 67.1 |
| **LV** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.3 | -0.1 | -0.1 | 0.0 | -0.1 | -0.1 | -0.1 | 0.0 | 0.0 | 0.0 | -0.3 | 0.0 | -4.2 | 0.0 | 0.0 | -0.1 | 0.0 | 0.0 | -0.1 | 0.0 | 0.0 | -5.8 | -1.6 | 27.3 |
| **MT** | -0.2 | -0.1 | 0.0 | -0.1 | -0.2 | -1.9 | -0.2 | 0.0 | -0.1 | -0.4 | -0.1 | -0.6 | 0.0 | -0.1 | 0.0 | 0.0 | 0.0 | 0.0 | -8.1 | -0.2 | -0.2 | -0.1 | -0.2 | -0.1 | 0.0 | 0.0 | -13.1 | -5.0 | 38.2 |
| **NL** | -0.2 | -0.7 | -0.1 | 0.0 | -0.1 | -2.2 | -0.1 | 0.0 | -0.2 | -0.5 | -0.1 | -1.3 | 0.0 | -0.1 | -0.1 | -0.1 | 0.0 | 0.0 | 0.0 | -13.0 | -0.4 | -0.1 | -0.2 | -0.2 | 0.0 | 0.0 | -19.8 | -6.9 | 34.6 |
| **PL** | -0.1 | -0.1 | 0.0 | 0.0 | -0.1 | -0.7 | 0.0 | 0.0 | 0.0 | -0.1 | 0.0 | -0.3 | 0.0 | -0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.1 | -6.4 | 0.0 | -0.1 | -0.1 | 0.0 | -0.1 | -8.4 | -2.0 | 23.4 |
| **PT** | 0.0 | -0.1 | 0.0 | 0.0 | 0.0 | -0.4 | 0.0 | 0.0 | 0.0 | -1.1 | 0.0 | -0.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.1 | -0.1 | -13.1 | -0.1 | 0.0 | 0.0 | 0.0 | -15.9 | -2.8 | 17.7 |
| **RO** | 0.0 | 0.0 | -0.1 | 0.0 | 0.0 | -0.2 | 0.0 | 0.0 | 0.0 | -0.1 | 0.0 | -0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.1 | 0.0 | -4.6 | 0.0 | 0.0 | 0.0 | -5.5 | -0.9 | 15.6 |
| **SE** | -0.1 | -0.2 | 0.0 | 0.0 | -0.1 | -1.1 | -0.5 | 0.0 | -0.1 | -0.3 | -0.4 | -0.7 | 0.0 | 0.0 | -0.1 | -0.1 | 0.0 | 0.0 | 0.0 | -0.2 | -0.3 | -0.1 | -0.1 | -15.3 | 0.0 | 0.0 | -19.7 | -4.4 | 22.4 |
| **SI** | -0.4 | -0.1 | -0.1 | 0.0 | -0.1 | -1.0 | 0.0 | 0.0 | -0.2 | -0.2 | 0.0 | -0.5 | -0.8 | -0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.1 | -0.3 | 0.0 | -0.2 | -0.1 | -7.5 | -0.1 | -12.0 | -4.5 | 37.2 |
| **SK** | -0.2 | -0.1 | -0.1 | 0.0 | -0.3 | -0.8 | 0.0 | 0.0 | 0.0 | -0.2 | 0.0 | -0.4 | 0.0 | -0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.1 | -0.3 | 0.0 | -0.2 | -0.1 | 0.0 | -5.5 | -8.6 | -3.1 | 35.9 |
| **EU26** | -20.9 | -15.6 | -4.5 | -19.2 | -7.0 | -46.1 | -24.8 | -4.9 | -18.8 | -25.8 | -17.7 | -34.7 | -10.9 | -5.2 | -10.2 | -7.6 | -9.5 | -5.3 | -8.3 | -16.8 | -13.0 | -15.5 | -8.6 | -20.0 | -8.1 | -6.8 | | | |
| **Outside (€)** | -3.2 | -4.0 | -1.2 | -0.5 | -2.2 | -28.6 | -2.2 | -0.5 | -3.2 | -9.1 | -2.5 | -17.4 | -1.7 | -1.9 | -0.9 | -1.3 | -0.3 | -1.1 | -0.2 | -3.8 | -6.6 | -2.4 | -3.9 | -4.7 | -0.6 | -1.3 | | | |
| **Outside (%)** | 15.1 | 25.9 | 26.6 | 2.5 | 31.2 | 62.1 | 9.0 | 10.5 | 16.9 | 35.3 | 14.1 | 50.2 | 15.4 | 35.5 | 8.7 | 17.7 | 3.7 | 20.8 | 2.1 | 22.8 | 50.9 | 15.3 | 45.8 | 23.6 | 6.9 | 19.5 | | | |

*Note*: This table presents the 2015 benchmark *weighted average* price-to-income multiplier matrix, $(\mathbf{M}_{yp}\mathbf{S}_0)/100$, for 26 EU countries, excluding Italy due to missing income data. The weights in $\mathbf{S}_0$ (which is a 286 × 26 block-diagonal matrix) represent the benchmark mean expenditure shares for 11 commodities in the 26 countries. The matrix is divided by 100 because base-year prices are assumed to be unitary. Thus, its *rs*-th element, $\{\mathbf{M}_{yp}\mathbf{S}_0/100\}_{rs}$, indicates the *average household equivalized income loss* (in €) in country *r* due to a 1% price increase for all commodities in country *s*. The 'Outside €' row (column) shows the row (column) sum of off-diagonal entries of $(\mathbf{M}_{yp}\mathbf{S}_0)/100$. The 'Outside %' row (column) expresses these off-diagonal sums as percentages of the corresponding row (column) totals, labelled as 'EU26'. The parameters of the modified Taylor micro-model are based on the OLS intra-budget regressions.

**Table A.6:** Aggregated price-to-consumption multipliers, with consumption impacts allocated to the source countries, 2015

| | AT | BE | BG | CY | CZ | DE | DK | EE | EL | ES | FI | FR | HR | HU | IE | LT | LU | LV | MT | NL | PL | PT | RO | SE | SI | SK | EU26 | Outside (€) | Outside (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AT | -26.2 | -0.2 | -0.1 | -0.1 | -0.3 | -1.7 | -0.1 | -0.1 | -0.1 | -0.2 | -0.1 | -0.4 | -0.5 | -0.4 | 0.0 | -0.1 | -0.1 | -0.1 | -0.1 | -0.2 | -0.3 | -0.1 | -0.3 | -0.2 | -0.6 | -0.3 | -32.8 | -6.6 | 20.0 |
| BE | -0.2 | -22.3 | -0.1 | -0.2 | -0.1 | -1.2 | -0.4 | -0.1 | -0.3 | -0.5 | -0.3 | -1.6 | -0.1 | -0.1 | -0.1 | -0.1 | -2.4 | -0.1 | -0.1 | -1.2 | -0.3 | -0.2 | -0.1 | -0.5 | -0.1 | -0.1 | -32.6 | -10.3 | 31.5 |
| BG | -0.1 | 0.0 | -5.4 | -0.2 | 0.0 | -0.2 | 0.0 | 0.0 | -0.4 | -0.1 | 0.0 | -0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.1 | 0.0 | -0.3 | 0.0 | 0.0 | 0.0 | -7.2 | -1.8 | 24.9 |
| CY | 0.0 | -0.1 | 0.0 | -21.2 | -0.1 | -0.6 | 0.0 | 0.0 | -0.6 | -0.1 | 0.0 | -0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.1 | -0.2 | -0.1 | -0.2 | 0.0 | 0.0 | -0.1 | -23.9 | -2.7 | 11.2 |
| CZ | -0.8 | -0.2 | -0.1 | -0.1 | -8.5 | -1.0 | -0.3 | -0.1 | -0.1 | -0.3 | -0.4 | -0.4 | -0.1 | -0.2 | 0.0 | -0.1 | -0.1 | -0.1 | 0.0 | -0.2 | -0.3 | -0.1 | -0.1 | -0.2 | -0.2 | -1.0 | -15.1 | -6.6 | 43.5 |
| DE | -6.1 | -2.2 | -0.4 | -1.1 | -1.1 | -32.4 | -3.6 | -0.4 | -1.2 | -1.7 | -2.8 | -2.6 | -0.8 | -0.7 | -0.3 | -0.6 | -2.9 | -0.6 | -0.5 | -2.8 | -1.2 | -1.1 | -0.6 | -2.6 | -1.2 | -0.8 | -72.2 | -39.8 | 55.1 |
| DK | -0.1 | -0.2 | 0.0 | -0.1 | -0.1 | -0.9 | -31.7 | -0.1 | -0.2 | -0.3 | -0.5 | -0.4 | 0.0 | -0.1 | -0.1 | -0.1 | 0.0 | -0.1 | -0.1 | -0.3 | -0.3 | -0.1 | -0.1 | -1.8 | 0.0 | -0.1 | -37.7 | -6.0 | 15.8 |
| EE | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.2 | -0.1 | -7.2 | 0.0 | -0.1 | -0.6 | -0.1 | 0.0 | 0.0 | 0.0 | -0.3 | 0.0 | -0.6 | 0.0 | 0.0 | -0.1 | 0.0 | 0.0 | -0.3 | 0.0 | 0.0 | -9.8 | -2.6 | 26.8 |
| EL | -0.1 | -0.1 | -0.3 | -2.2 | 0.0 | -0.4 | -0.1 | 0.0 | -21.4 | -0.1 | -0.1 | -0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.1 | -0.1 | -0.1 | 0.0 | -0.2 | 0.0 | 0.0 | 0.0 | -25.5 | -4.1 | 16.1 |
| ES | -0.4 | -0.5 | -0.1 | -0.7 | -0.1 | -0.9 | -0.4 | -0.1 | -0.5 | -23.4 | -0.6 | -1.5 | -0.2 | -0.1 | -0.1 | -0.2 | -0.2 | -0.1 | -0.4 | -0.4 | -0.2 | -2.4 | -0.1 | -0.3 | -0.3 | -0.1 | -34.7 | -11.3 | 32.6 |
| FI | -0.1 | -0.1 | 0.0 | 0.0 | 0.0 | -0.5 | -0.3 | -0.6 | 0.0 | -0.2 | -26.5 | -0.3 | 0.0 | 0.0 | 0.0 | -0.2 | 0.0 | -0.3 | 0.0 | -0.1 | -0.2 | 0.0 | 0.0 | -1.1 | 0.0 | 0.0 | -30.7 | -4.3 | 13.8 |
| FR | -0.4 | -1.8 | -0.1 | -0.4 | -0.1 | -1.2 | -0.5 | -0.2 | -0.4 | -1.3 | -0.5 | -24.5 | -0.1 | -0.2 | -0.2 | -0.2 | -1.4 | -0.1 | -0.3 | -0.7 | -0.2 | -0.6 | -0.2 | -0.6 | -0.3 | -0.1 | -36.8 | -12.2 | 33.3 |
| HR | -0.1 | 0.0 | 0.0 | 0.0 | 0.0 | -0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.1 | -13.6 | -0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.3 | 0.0 | -14.8 | -1.2 | 8.3 |
| HU | -0.5 | -0.1 | -0.1 | -0.1 | -0.2 | -0.6 | -0.1 | -0.1 | -0.1 | -0.2 | -0.1 | -0.2 | -0.4 | -6.9 | 0.0 | -0.1 | 0.0 | 0.0 | 0.0 | -0.1 | -0.1 | -0.1 | -0.4 | -0.1 | -0.3 | -0.3 | -11.2 | -4.4 | 39.0 |
| IE | -0.1 | -0.3 | 0.0 | -0.1 | -0.1 | -1.2 | -0.3 | 0.0 | -0.1 | -0.6 | -0.2 | -0.9 | 0.0 | -0.1 | -25.5 | 0.0 | -0.1 | -0.1 | -0.1 | -0.5 | -0.3 | -0.2 | -0.1 | -0.4 | 0.0 | 0.0 | -31.3 | -5.8 | 18.5 |
| LT | -0.1 | -0.1 | 0.0 | 0.0 | 0.0 | -0.3 | -0.2 | -0.5 | 0.0 | -0.1 | -0.2 | -0.2 | 0.0 | 0.0 | 0.0 | -9.8 | 0.0 | -1.2 | 0.0 | -0.1 | -0.2 | 0.0 | 0.0 | -0.2 | 0.0 | 0.0 | -13.3 | -3.5 | 26.5 |
| LU | -0.2 | -0.7 | -0.1 | 0.0 | -0.1 | -3.6 | -0.2 | 0.0 | -0.2 | -1.1 | -0.3 | -2.6 | 0.0 | -0.1 | -0.1 | 0.0 | -30.8 | 0.0 | 0.0 | -0.4 | -0.3 | -0.2 | -0.2 | -0.5 | 0.0 | -0.1 | -41.8 | -11.0 | 26.4 |
| LV | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.2 | -0.1 | -0.3 | 0.0 | 0.0 | -0.1 | -0.1 | 0.0 | 0.0 | 0.0 | -0.5 | 0.0 | -6.9 | 0.0 | 0.0 | -0.1 | 0.0 | 0.0 | -0.1 | 0.0 | 0.0 | -8.7 | -1.8 | 20.4 |
| MT | -0.1 | -0.1 | 0.0 | -0.2 | -0.1 | -1.1 | -0.2 | 0.0 | -0.1 | -0.2 | -0.1 | -0.3 | 0.0 | 0.0 | 0.0 | 0.0 | -0.1 | 0.0 | -14.5 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | 0.0 | 0.0 | -17.7 | -3.3 | 18.5 |
| NL | -0.4 | -2.2 | -0.1 | -0.3 | -0.2 | -1.9 | -1.1 | -0.1 | -0.4 | -0.6 | -0.7 | -1.2 | -0.2 | -0.2 | -0.2 | -0.3 | -0.4 | -0.2 | -0.3 | -25.6 | -0.4 | -0.3 | -0.2 | -1.0 | -0.1 | -0.1 | -38.5 | -12.9 | 33.5 |
| PL | -0.4 | -0.3 | -0.2 | -0.1 | -0.5 | -1.0 | -0.6 | -0.3 | -0.1 | -0.3 | -0.4 | -0.4 | -0.2 | -0.3 | 0.0 | -0.6 | -0.2 | -0.6 | -0.1 | -0.4 | -9.2 | -0.1 | -0.2 | -0.7 | -0.2 | -0.5 | -17.9 | -8.7 | 48.4 |
| PT | -0.1 | -0.1 | 0.0 | 0.0 | 0.0 | -0.4 | -0.1 | 0.0 | 0.0 | -1.1 | -0.1 | -0.6 | 0.0 | 0.0 | 0.0 | 0.0 | -0.1 | 0.0 | 0.0 | -0.2 | -0.1 | -16.0 | -0.1 | -0.1 | 0.0 | 0.0 | -19.3 | -3.4 | 17.4 |
| RO | -0.2 | -0.1 | -0.3 | -0.1 | -0.1 | -0.3 | 0.0 | 0.0 | -0.1 | -0.1 | -0.1 | -0.2 | 0.0 | -0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.1 | -0.1 | 0.0 | -7.6 | -0.1 | -0.1 | -0.1 | -9.8 | -2.2 | 22.5 |
| SE | -0.2 | -0.4 | 0.0 | -0.1 | -0.1 | -0.7 | -2.2 | -0.3 | -0.1 | -0.2 | -2.0 | -0.5 | 0.0 | 0.0 | -0.1 | -0.2 | -0.1 | -0.2 | -0.1 | -0.4 | -0.2 | -0.1 | -0.1 | -23.1 | 0.0 | 0.0 | -31.3 | -8.2 | 26.2 |
| SI | -0.3 | -0.1 | -0.1 | 0.0 | -0.1 | -0.5 | 0.0 | 0.0 | -0.1 | -0.1 | 0.0 | -0.3 | -0.7 | -0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.1 | -0.1 | 0.0 | -0.1 | -0.1 | -11.1 | -0.1 | -14.2 | -3.1 | 21.6 |
| SK | -0.6 | -0.1 | -0.1 | -0.5 | -0.4 | -0.6 | -0.1 | 0.0 | -0.1 | -0.2 | -0.1 | -0.3 | -0.1 | -0.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.1 | -0.2 | -0.1 | -0.1 | -0.2 | -0.1 | -8.6 | -13.3 | -4.6 | 34.9 |
| IT | -1.2 | -0.7 | -0.2 | -1.1 | -0.2 | -0.9 | -0.6 | -0.2 | -0.8 | -0.7 | -0.4 | -1.1 | -0.7 | -0.2 | -0.1 | -0.3 | -0.4 | -0.2 | -1.6 | -0.5 | -0.3 | -0.3 | -0.3 | -0.6 | -1.7 | -0.2 | -15.6 | | |
| RoW | -4.6 | -3.4 | -0.9 | -5.1 | -1.1 | -6.0 | -5.6 | -1.9 | -3.4 | -4.5 | -5.1 | -5.6 | -1.1 | -0.8 | -3.0 | -1.7 | -3.2 | -1.1 | -3.4 | -4.8 | -1.7 | -1.8 | -1.0 | -4.9 | -2.4 | -1.2 | -79.3 | | |
| EU26 | -38.1 | -32.2 | -7.7 | -28.0 | -12.4 | -53.6 | -42.8 | -10.5 | -26.8 | -33.1 | -36.7 | -40.0 | -17.2 | -10.2 | -26.9 | -13.5 | -39.1 | -11.4 | -16.9 | -34.0 | -15.1 | -21.9 | -11.6 | -34.3 | -15.4 | -12.6 | | | |
| Global | -43.9 | -36.2 | -8.8 | -34.3 | -13.7 | -60.6 | -49.0 | -12.6 | -31.0 | -38.3 | -42.2 | -46.6 | -19.1 | -11.2 | -30.0 | -15.4 | -42.8 | -12.7 | -21.9 | -39.3 | -17.1 | -24.0 | -12.9 | -39.7 | -19.5 | -14.0 | | | |
| Outside (€) | -17.7 | -13.9 | -3.4 | -13.1 | -5.2 | -28.2 | -17.3 | -5.4 | -9.6 | -14.9 | -15.8 | -22.1 | -5.5 | -4.3 | -4.5 | -5.6 | -12.1 | -5.8 | -7.5 | -13.7 | -7.8 | -8.1 | -5.3 | -16.6 | -8.3 | -5.3 | | | |
| Outside (%) | 40.3 | 38.3 | 39.0 | 38.1 | 38.0 | 46.5 | 35.3 | 42.8 | 31.1 | 38.9 | 37.3 | 47.4 | 28.9 | 38.8 | 15.1 | 36.6 | 28.2 | 45.6 | 34.1 | 34.9 | 45.9 | 33.5 | 40.9 | 41.9 | 42.8 | 38.2 | | | |

*Note*: This table presents the benchmark *aggregated* price-to-consumption multiplier matrix, with total consumption impacts properly allocated to domestic and imported sources. Formally, it shows the matrix $(\mathbf{Q}\overline{\mathbf{H}}\mathbf{M}_{yp}\mathbf{S}_0)/100$, where $\mathbf{Q} = \mathbf{I}_{28} \otimes \boldsymbol{\iota}'_{63}$ is a $28 \times 1764$ aggregation matrix and $\overline{\mathbf{H}}$ is the counterpart of the commodity-to-product by source conversion matrix $\mathbf{H}$ without upscaling of the micro-impacts, i.e. $\overline{\mathbf{H}} \equiv \left[\mathbf{H}_c^1\mathbf{P}^1 \quad \mathbf{H}_c^2\mathbf{P}^2 \quad \cdots \quad \mathbf{H}_c^{n_{eu}}\mathbf{P}^{n_{eu}}\right]$. For $\mathbf{S}_0$, see the notes to Table A.5. The *rs*-th element, $\{(\mathbf{Q}\overline{\mathbf{H}}\mathbf{M}_{yp}\mathbf{S}_0)/100\}_{rs}$, indicates the *mean equivalized consumption impacts* (in benchmark €) in country *r* due to a 1% (weighted) price increase for all commodities in country *s*. The 'Outside €' row (column) shows the row (column) sum of $(\mathbf{Q}\overline{\mathbf{H}}\mathbf{M}_{yp}\mathbf{S}_0)/100$, excluding the within-country impacts for 26 EU countries. The 'Outside %' row (column) expresses these outside impacts as percentages of the corresponding row (column) totals, labelled as 'Global' and 'EU26', respectively. The parameters of the modified Taylor micro-model are based on the OLS intra-budget regressions.

## B Derivation of elasticities and their variances

Start with the modified Taylor consumption demand (8), which can be also written as:

$$q_i = \frac{\rho y}{p_i} s_i, \quad \text{where} \tag{B.1.a}$$

$$s_i = \frac{e_i}{\sum_h e_h} = \frac{\sum_k t_{ik}(z_k p_k + \gamma_k y)}{\sum_h \sum_k t_{hk}(z_k p_k + \gamma_k y)}. \tag{B.1.b}$$

The partial derivatives of the budget share of good $i$, $s_i$, in (B.1.b) with respect to price $p_j$ and income $y$ are easily derived to be equal to:

$$\frac{\partial s_i}{\partial p_j} = \frac{t_{ij} z_j - s_i \sum_h t_{hj} z_j}{e_\bullet}, \tag{B.2.a}$$

$$\frac{\partial s_i}{\partial y} = \frac{\sum_k t_{ik}\gamma_k - s_i \sum_h \sum_k t_{hk}\gamma_k}{e_\bullet}. \tag{B.2.b}$$

where, for simplicity, we denote $e_\bullet = \sum_h e_h$.

Using equations (B.1.a) and (B.2.a), one obtains the own- and cross-price elasticities of demand to have the following forms:

$$\epsilon_{ii} = \frac{\partial q_i}{\partial p_i}\frac{p_i}{q_i} = \frac{t_{ii} z_i p_i - s_i \sum_h t_{hi} z_i p_i}{e_i} - 1, \tag{B.3.a}$$

$$\epsilon_{ij} = \frac{\partial q_i}{\partial p_j}\frac{p_j}{q_i} = \frac{t_{ij} z_j p_j - s_i \sum_h t_{hj} z_j p_j}{e_i} \quad \text{whenever } i \neq j. \tag{B.3.b}$$

The expressions (B.3.a) and (B.3.b) are equivalent to the price elasticities formulas given in (10.a) and (10.b), respectively.

Similarly, using (B.1.a) and (B.2.b), the income elasticity of demand for good $i$ can be easily derived to be

$$\frac{\partial q_i}{\partial y}\frac{y}{q_i} = \frac{\sum_k t_{ik}\gamma_k y - s_i \sum_h \sum_k t_{hk}\gamma_k y}{e_i} + 1, \tag{B.4}$$

which proves the income elasticity formula given in (11).

With the multi-country (or multi-region) extension of the Taylor model in (6), one can also obtain the demand elasticities with respect to *region-specific prices*. Let $z_i^r$ and $p_i^r$ be, respectively, the exogenous real expenditure and price of good $i$ in region $r$. Using these in our definition of exogenous expenditures $\zeta_j = \sum_r \zeta_j^r w_r$ gives the overall EU (or national) price as a function of country-specific (or region-specific) prices as follows:

$$p_i = \sum_r \frac{z_i^r}{z_i} w_r p_i^r. \tag{B.5}$$

The non-normalized/adjusted total expenditure on good $i$ can now be written as $e_i = \sum_k t_{ik} \sum_r z_k^r p_k^r + \sum_k t_{ik}\gamma_k y$. Hence, it can be shown that the price elasticities of overall consumption demand with respect to region-specific prices have the following forms:

$$\epsilon_{ii}^{r} = \frac{\partial q_i}{\partial p_i^r}\frac{p_i^r}{q_i} = \left(\frac{t_{ii}z_i^r p_i^r - s_i \sum_h t_{hi} z_i^r p_i^r}{e_i} - \frac{z_i^r p_i^r}{z_i p_i}\right) \times w_r, \tag{B.6.a}$$

$$\epsilon_{ij}^{r} = \frac{\partial q_i}{\partial p_j}\frac{p_j}{q_i} = \frac{t_{ij}z_j^r p_j^r - s_i \sum_h t_{hj} z_j^r p_j^r}{e_i} \times w_r \quad \text{whenever } i \neq j. \tag{B.6.b}$$

The reason for appearing country weight $w_r$, in (B.6.a) and (B.6.b) is that in determining the overall (mean) consumption impact of the price change in a specific region one should account for the relative size of the region in question. Comparing expressions (B.3.a)-(B.3.b) to (B.6.a)-(B.6.b) reveals that

$$\epsilon_{ij} = \sum_r \epsilon_{ij}^r \frac{z_i p_i}{z_i^r p_i^r w_r}, \tag{B.7}$$

which reflects our definition of the total exogenous expenditures $\zeta_j = \sum_r \zeta_j^r w_r$, or, equivalently, the price relation in (B.5).

[To be added: closed-form expressions for the approximate variances of price and income elasticities.]

## C Taylor demand inconsistency with utility maximization

The *integrability theorem* in microeconomics states that a demand behavior is consistent with the theory of utility maximization if and only if it satisfies three independent conditions of budget balancedness, symmetry, and negative semidefiniteness (see e.g. Jehly and Reny, 2011, Theorem 2.6, p. 86). Substitution effects in demand are captured by the Slutsky matrix, whose typical element is, in general, given by

$$s_{ij} = \frac{\partial q_i}{\partial p_j} + q_j \frac{\partial q_i}{\partial y}. \tag{C.1}$$

The symmetry condition then implies that the Slutsky matrix must be symmetric, i.e. it should be the case that $s_{ij} = s_{ji}$ for all $i$ and $j$ ($\neq i$). The negative semidefiniteness condition also pertains to the Slutsky matrix, requiring it to be a negative semidefinite matrix.

We now set $\rho = 1$ in the modified Taylor demand (B.1.a), which ensures the budget balancedness condition, i.e.:

$$\sum_i p_i q_i = \sum_i p_i \frac{y}{p_i} s_i = y \sum_i s_i = y.$$

Using equations (B.1.a) to (B.2.b), it can be shown that the Slutksky matrix off-diagonal element (with $i \neq j$) for the (modified) Taylor demand system is given by

$$s_{ij} = \frac{y}{p_i}\frac{t_{ij}z_j - s_i \sum_h t_{hj} z_j}{e_\bullet} + \frac{y s_j}{p_j}\left(\frac{s_i}{p_i} + \frac{y}{p_i}\frac{\sum_k t_{ik}\gamma_k - s_i \sum_h \sum_k t_{hk}\gamma_k}{e_\bullet}\right)$$

$$= \frac{y}{p_i p_j}\left(\frac{t_{ij}z_j p_j - s_i \sum_h t_{hj}z_j p_j}{e_\bullet} + s_i s_j + y s_j \frac{\sum_k t_{ik}\gamma_k - s_i \sum_h \sum_k t_{hk}\gamma_k}{e_\bullet}\right) \tag{C.2.a}$$

$$= \frac{y s_i}{p_i p_j}\left(\epsilon_{ij} + \eta_i s_j\right). \tag{C.2.b}$$

Thus, from (C.2.a) it follows that for the symmetry condition $s_{ij} = s_{ji}$ to hold, the following identity (or constraint) must be valid for all $p_i$, $p_j$ and $y$:

$$t_{ij}z_j p_j - s_i \sum_h t_{hj}z_j p_j + y s_j \sum_k t_{ik}\gamma_k = t_{ji}z_i p_i - s_j \sum_h t_{hi}z_i p_i + y s_i \sum_k t_{jk}\gamma_k. \tag{C.3}$$

Only very restrictive configurations of the parameters may allow the condition (C.3) to be met. Even the assumption of symmetric Taylor matrix with $t_{ij} = t_{ji}$, which clearly is at odd with the results of our *unrestricted* regressions, does not imply the symmetry condition (C.3). Suppose we partition (C.3) into the price and income effects symmetry conditions of, respectively, $t_{ij}z_j p_j - s_i \sum_h t_{hj}z_j p_j = t_{ji}z_i p_i - s_j \sum_h t_{hi}z_i p_i$ and $s_j \sum_k t_{ik}\gamma_k = s_i \sum_k t_{jk}\gamma_k$. The last condition would then imply constant ratio of expenditure shares, $\frac{s_i}{s_j}$, leading to constant expenditure ratio, $\frac{p_i x_i}{p_j x_j}$. However, this only aligns with the full demand system (B.1.a)-(B.1.b) if $z_k = 0$ for all $k$, otherwise the price effects in $s_i$ disrupt the constancy. It is difficult to impose a sensible configuration of parameters that would guarantee (C.3) for all prices and incomes. Thus, we conclude that the symmetry condition does *not* hold for the modified Taylor demand model.

In fact, since the Taylor model is based on nominal expenditures (and income) and does *not* use price data separately, it is impossible to impose any kind of constraints on the parameters that would hold for all prices (and incomes). This is what distinguishes the Taylor approach from traditional demand estimation.

As a side-note, observe that multiplication of (C.2.b) by $p_j/q_i$ gives

$$\tilde{\epsilon}_{ij} \equiv s_{ij}\frac{p_j}{q_i} = \frac{y s_i}{p_i q_i}\left(\epsilon_{ij} + \eta_i s_j\right) = \frac{y}{e_\bullet}\left(\epsilon_{ij} + \eta_i s_j\right) = \epsilon_{ij} + \eta_i s_j,$$

which expresses the Slutsky equation (C.1) in elasticity form, revealing the "compensated" price elasticity $\tilde{\epsilon}_{ij}$.