Input-output micro-macro twins

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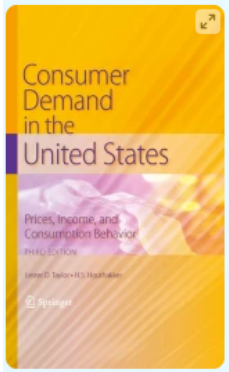
Outline

- Focus and contributions
- Taylor’s consumer expenditure model and its modification
  - Some details, price and income elasticities
  - Internal structure of EU consumption expenditures
- Integrating the micro-macro twins
  - Closed-form solutions of the IO micro-macro model
  - Novel multiplier matrices: price-to-income/consumption/production multipliers
  - Eliminating linearization errors
- Empirical results
- Concluding remarks



Consumer Demand in the United States

Prices, Income, and Consumption Behavior

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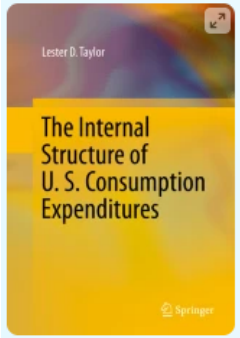
Overview

Authors: Lester D. Taylor , H.S. Houthakker

- Original editions sold 2500 copies and were among the most highly cited books in the field of demand theory
- Taylor and Houthakker are two of the most well-known scholars in the field of demand analysis and consumption behavior, and pioneered dynamic consumption models that have been workhorses of applied econometrics for over 40 years
- Most extensive coverage of price and income elasticities in relation to consumer demand to be found in any publication
- Introduces models that will help economists and industry specialists to forecast future price elasticities
- Stands at crossroads of economics and psychology, appealing to diverse audience



The Internal Structure of U. S. Consumption Expenditures

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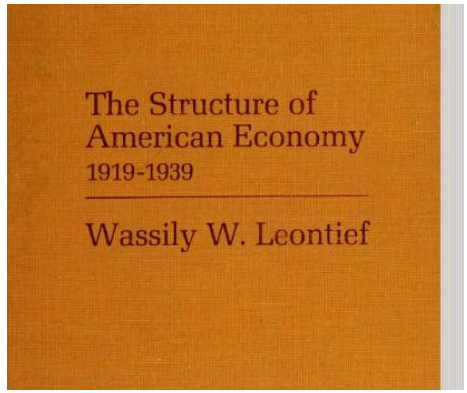
Overview

Authors: Lester D. Taylor

- Investigates consumer behavior beyond the conventional price and income elasticities
- Provides in-depth statistical analysis of consumer spending and behavior
- Examines the US allocation of expenditures amongst different categories of consumption



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Focus and contributions

- Taylor's non-traditional approach to the analysis of consumer behaviour
  - An "almost entirely statistical and mathematical" approach
  - May be consistent with a variety of preference structures: neoclassical, lexicographical, hierarchical, etc.
  - Direct and indirect interrelationships between all consumer expenditures
  - "Sufficient stability exists in expenditure interrelationships that *intra-budget coefficients* can be taken as *stable characteristics* of household consumption behaviour" (Taylor, 2014, p. 165)
- Estimate Taylor's model (its *extended* version) for the EU and individual EU countries
- Modify to properly incorporate household budget constraint
- Closed-form expressions for price and income elasticities

Focus and contributions

- Integrate the *modified* Taylor's micro-model with the Leontief's input-output quantity framework
  - Circular consumption-production-income propagation impacts
- Extension of Miyazawa and Masegi (1963, *Metroeconomica*) approach (see also Miyazawa (1960, QJE; 1968: HJE; 1976)
  - Integration of an IO macro-model with ***any*** micro-model of consumption demand
  - Analysis of consumer price impacts: *novel multiplier matrices* showing the impacts of consumer price changes on income, consumption, and production
- Illustrative distributional analysis of higher energy prices

Taylor's consumer expenditure model

Run OLS regressions:

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

Evaluate eq. (1) at the *observed* mean values of the variables:

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

B is the matrix of *intra-budget coefficients*

Structural form:

$$\mathbf{e} = \boldsymbol{\zeta} + \mathbf{B}\mathbf{e} + \boldsymbol{\gamma} y \tag{3}$$

Reduced-form:

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

Consumption expenditure multiplier matrix, or the *Taylor inverse*: $\mathbf{T} \equiv (\mathbf{I} - \mathbf{B})^{-1}$

Taylor's consumer expenditure model

Exogenous (or *autonomous*) *expenditures*, $\boldsymbol{\zeta}$'s:

- Consistent with *Maslovian hierarchy of needs* (physiological needs, security, love, self-esteem, and self-actualization)
- Largest (autonomy) for *basic needs and security*: housing, food, health, personal insurance
- Endogenous expenditures reflect *overlaps & interactions* across Maslowian hierarchy of needs
- Akin to *necessary/subsistent expenditures* within LES demand model (Klein & Rubin, 1947-48)
  - Independent of household income *and* endogenous expenditure interdependencies (**B**=**0**)
- Negative $\boldsymbol{\zeta}$: basic needs are "funded" by "selling" non-vital (more luxurious) goods

Internal structure of consumption:

- *Intra-budget coefficients* matrix, **B**
- Total expenditure multiplier matrix, or Taylor inverse: $\mathbf{T} = \mathbf{I} + \mathbf{B} + \mathbf{B^2} + \mathbf{B^3} + \cdots$
- Complex spillover and feedback spending effects among consumption categories
- Pressure or "*self-energy*" pushes consumption beyond available total expenditure (income)
  - Akin to *unbounded utility* in traditional demand theory

Internal structure of the EU consumption

- EU HBS 2010 and 2015 waves, plus Austrian microdata for 2009-2010 and 2014-2015
- Instead of single constant, we use country dummies

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

- The corresponding reduced form, with country relative size/weights **w**:

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

$\mathbf{Z} = [\boldsymbol{\zeta}^1 \; \boldsymbol{\zeta}^2 \; \cdots \; \boldsymbol{\zeta}^{n_r}]$ is the $g \times n_r$ matrix of exogenous expenditures

- All expenditures and net income are expressed *per adult equivalent*

Internal structure of the EU consumption expenditures

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

Consumption category	Intra-budget coefficients matrix B											Zw	Inc	R2
	c1	c2	c3	c4	c5	c6	c7	c8	c9	c10	c11			
	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	-258.6	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 *c3* and column *c1* indicate $\tilde{\beta}_{31}$. 'Inc' refers to $\tilde{\gamma}$.

- ⇒ Substitution and complementarities
- ⇒ OLS and WLS results exhibit similar general patterns
- ⇒ Exogenous expenditures: consistent with Maslowian hierarchy of needs
- ⇒ Contributions of total (mean) exogenous expenditures (30%-33%) and net income (27%-28%)
- ⇒ Thus, 40%-42% of total expenditures is *endogenously* generated through the complex feedback and spillover interactions

Internal structure of the EU consumption expenditures

Consumption category	Total expenditure multiplier matrix or Taylor inverse (T), 2015											Mean BdgSh (%)
	c1	c2	c3	c4	c5	c6	c7	c8	c9	c10	c11	
	Based on the intra-budget OLS regressions											
c1 FoodNalcBvg	1.0515	0.2191	0.1521	-0.0052	0.0544	0.0415	0.0075	0.2361	0.0373	0.0408	0.0807	24.0
c2 AlcBvgTbc	0.0715	1.0263	0.0170	0.0144	0.0093	0.0023	0.0033	0.1290	0.0067	0.0453	0.0076	3.2
c3 ClothFtwr	0.1140	0.0390	1.0765	0.0085	0.0479	0.0206	0.0143	0.3188	0.0501	0.1408	0.0875	4.9
c4 HousWtrElc	-0.0194	0.1662	0.0428	1.0168	0.0758	0.0247	-0.0015	0.6874	0.0118	0.0727	0.0357	20.5
c5 FurnshHeqp	0.1560	0.0813	0.1833	0.0577	1.0268	0.0425	0.0150	0.3038	0.0509	0.0900	0.0997	4.9
c6 Health	0.0817	0.0138	0.0542	0.0129	0.0292	1.0070	0.0026	0.0914	0.0270	0.0221	0.0455	4.8
c7 Transport	0.1101	0.1463	0.2789	-0.0058	0.0766	0.0196	1.0180	0.8540	0.0830	0.3529	0.1634	10.4
c8 Communicat	0.0185	0.0310	0.0334	0.0143	0.0083	0.0036	0.0046	1.0402	0.0090	0.0251	0.0204	4.6
c9 RecreatCult	0.1615	0.0891	0.2894	0.0136	0.0768	0.0592	0.0245	0.4977	1.0337	0.2068	0.1294	7.3
c10 RestrntHotl	0.0562	0.1910	0.2587	0.0266	0.0433	0.0155	0.0332	0.4394	0.0658	1.0706	0.0967	5.4
c11 MiscGSEduc	0.1742	0.0500	0.2520	0.0205	0.0750	0.0499	0.0241	0.5596	0.0645	0.1514	1.0537	9.9
Total multiplier	*1.9759*	*2.0531*	*2.6383*	*1.1744*	*1.5235*	*1.2864*	*1.1455*	*5.1575*	*1.4400*	*2.2185*	*1.8203*	
	Based on the intra-budget WLS regressions											
c1 FoodNalcBvg	1.0429	0.1888	0.1314	-0.0209	0.0684	0.0449	0.0074	0.2158	0.0411	0.0204	0.0810	20.9
c2 AlcBvgTbc	0.0561	1.0222	0.0178	0.0141	0.0085	0.0048	0.0043	0.1510	0.0075	0.0452	0.0046	3.0
c3 ClothFtwr	0.0721	0.0330	1.0676	0.0086	0.0459	0.0256	0.0158	0.3417	0.0489	0.1233	0.0654	4.9
c4 HousWtrElc	-0.0661	0.1504	0.0494	1.0188	0.0526	0.0319	-0.0042	0.8303	0.0161	0.0768	0.0052	22.1
c5 FurnshHeqp	0.1439	0.0603	0.1760	0.0350	1.0288	0.0502	0.0154	0.3133	0.0586	0.0671	0.1017	4.9
c6 Health	0.0597	0.0214	0.0620	0.0134	0.0317	1.0079	0.0012	0.0903	0.0282	0.0219	0.0416	4.0
c7 Transport	0.0847	0.1646	0.3286	-0.0150	0.0831	0.0099	1.0274	1.0082	0.0934	0.4433	0.1366	10.9
c8 Communicat	0.0121	0.0284	0.0348	0.0147	0.0083	0.0038	0.0050	1.0437	0.0108	0.0225	0.0151	4.2
c9 RecreatCult	0.1340	0.0825	0.2904	0.0166	0.0908	0.0692	0.0267	0.6279	1.0368	0.1931	0.1097	7.9
c10 RestrntHotl	0.0250	0.1866	0.2754	0.0298	0.0391	0.0202	0.0477	0.4929	0.0726	1.0732	0.0717	5.8
c11 MiscGSEduc	0.1720	0.0328	0.2535	0.0035	0.1027	0.0664	0.0255	0.5744	0.0716	0.1244	1.0475	11.4
Total multiplier	*1.7364*	*1.9710*	*2.6869*	*1.1185*	*1.5600*	*1.3347*	*1.1723*	*5.6895*	*1.4857*	*2.2113*	*1.6799*	

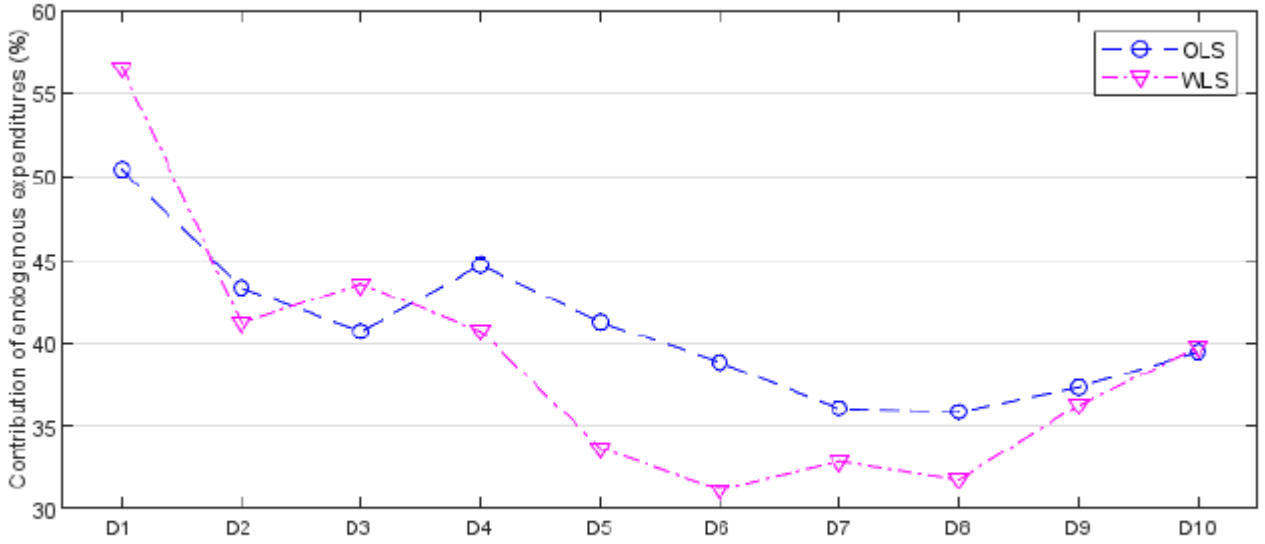
⇒ Changes in relative size and/or signs when moving from **B** to **T**

⇒ Relevance of exogenous expenditures and income multipliers

⇒ Applications using other IO techniques: SDA, SPA, etc.

Internal structure of the EU consumption expenditures

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.

The *capacity of endogenous generation of consumption* expenditures generally *decreases* with consumer's income level.

Mirrors the *decreasing MPC* as income rises (Keynes, 1936)

Price and income elasticities

- Modified Taylor (real) consumption demand:

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

where $\rho \equiv \iota' e_0 / y_0$ is the (average) propensity to consume of households in the base year

- Useful decomposition:

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

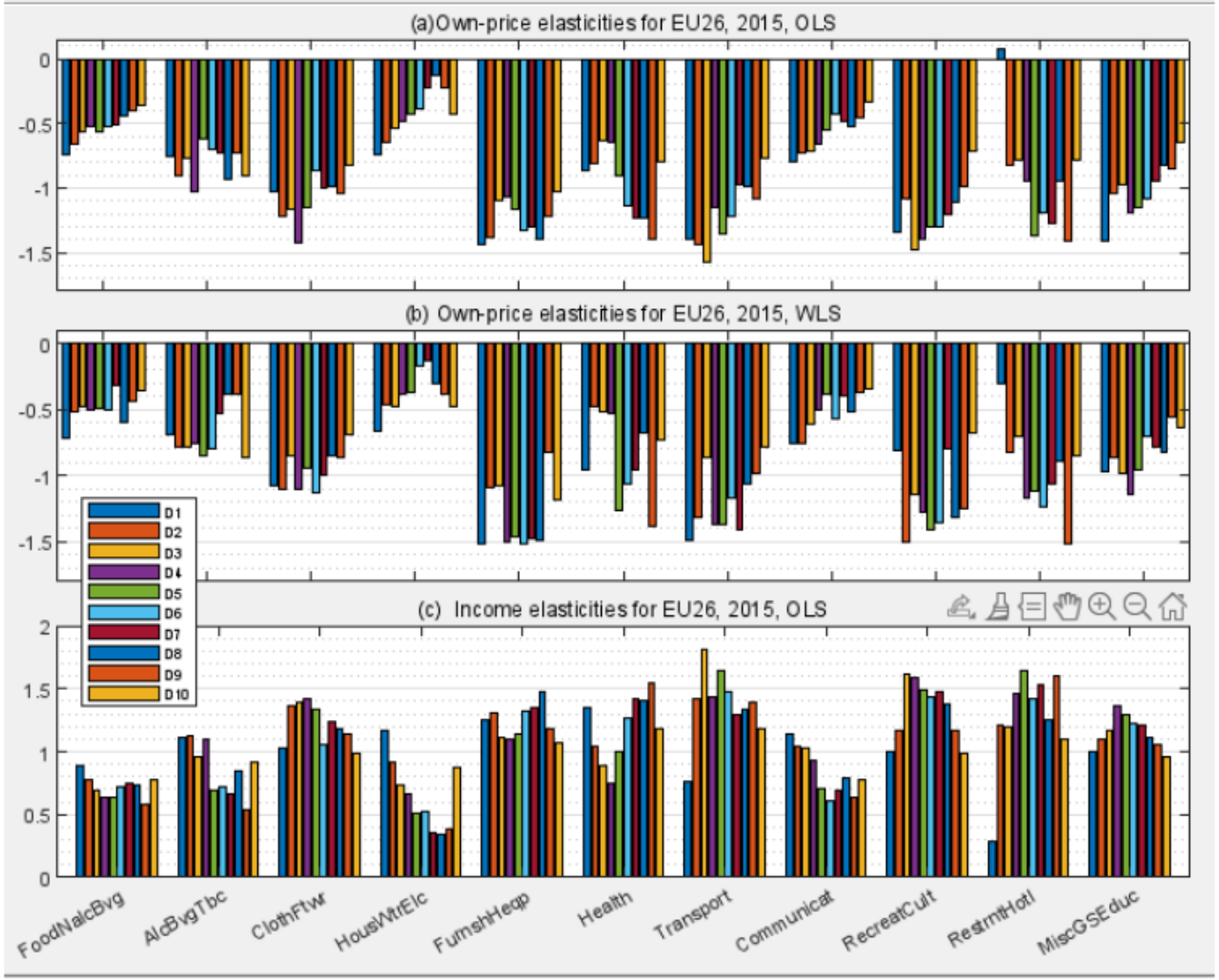
- Own/cross-price and income elasticities: Make quantity and price components of exogenous spending explicit, $\zeta_i = z_i p_i$, and denote budget share as $s_i \equiv \frac{e_i}{\sum_k e_k}$
- Elasticities satisfy demand homogeneity, Engel aggregation, and Cournot aggregation

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

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

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

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.

Integrating the micro-macro twins

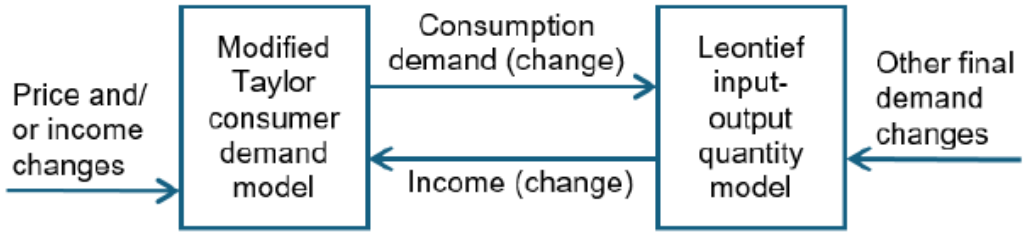
- A “partial equilibrium” analysis:

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

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

- To account for the demand-driven multiplier process, we interlink the micro-macro twins:

Figure 6: Linking the micro-macro twins



$$\mathbf{c}^r_{cpa} = \mathbf{P}^r\mathbf{c}^r, \tag{14}$$

$$\mathbf{h}^r = \mathbf{H}^r_c\hat{\mathbf{k}}^r_h\mathbf{c}^r_{cpa}, \tag{15}$$

$$\mathbf{x} = \mathbf{L}\left(\mathbf{f}^* + \textstyle\sum_{r\in EU}\mathbf{h}^r\right), \tag{16}$$

$$y^{io}_r = \left(\mathbf{w}^r_c\right)'\mathbf{x}^r, \tag{17}$$

$$y_r = k^r_y y^{io}_r + y^*_r. \tag{18}$$

Integrating the macro-micro twins

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

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

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

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

⇒ No closed-from solution, as the micro-model is *highly non-linear* in prices and income

⇒ One solution approach: *iterate back and forth* between (19) and (20) until convergence

⇒ *Linearize* to get a deeper understanding of the inner workings of this simple micro-macro model

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:*

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

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

for any given changes in prices, $\Delta \mathbf{p}$ *(relative to unitary benchmark 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 have the following general forms:*

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

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

Hence, we obtain the following multipliers:

$$\mathbf{M}_{yy} = (\mathbf{I} - \mathbf{V}_c \mathbf{D}_y)^{-1} = \mathbf{I} + \mathbf{V}_c \mathbf{M}_{cc} \mathbf{D}_y, \tag{25.a}$$

$$\mathbf{M}_{yc} = \mathbf{M}_{yy} \mathbf{V}_c = \mathbf{V}_c \mathbf{M}_{cc}, \tag{25.b}$$

$$\mathbf{M}_{yp} = \mathbf{M}_{yc} \mathbf{D}_p = \mathbf{V}_c \mathbf{M}_{cp}, \tag{25.c}$$

$$\mathbf{M}_{yf} = \mathbf{M}_{yy} \mathbf{V}_f = \mathbf{V}_f + \mathbf{V}_c \mathbf{M}_{cc} \mathbf{D}_y \mathbf{V}_f, \tag{25.d}$$

$$\mathbf{M}_{cc} = (\mathbf{I} - \mathbf{D}_y \mathbf{V}_c)^{-1} = \mathbf{I} + \mathbf{D}_y \mathbf{M}_{yy} \mathbf{V}_c, \tag{25.e}$$

$$\mathbf{M}_{cp} = \mathbf{M}_{cc} \mathbf{D}_p = \mathbf{D}_p + \mathbf{D}_y \mathbf{M}_{yy} \mathbf{V}_c \mathbf{D}_p, \tag{25.f}$$

$$\mathbf{M}_{cy} = \mathbf{M}_{cc} \mathbf{D}_y = \mathbf{D}_y \mathbf{M}_{yy}, \tag{25.g}$$

$$\mathbf{M}_{cf} = \mathbf{M}_{cy} \mathbf{V}_f = \mathbf{D}_y \mathbf{M}_{yy} \mathbf{V}_f. \tag{25.h}$$

$\mathbf{M}_{yy}$ is the exact counterpart of Miyazawa-Masegi's (1963) "*interrelational income multiplier*" in our framework

Income-to-income multiplier matrix, 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			

Budget share-weighted price-to-income multiplier matrix, 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			

Price-to-income multipliers for German price shocks

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

Category	Share	AT	DE	DK	IE	LU	MT	NL	REU	EU26	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 val ues 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.

Eliminating linearization errors

Table 2: Percentage errors (PEs) of linearized Δc and Δy

	PEs of linearized Δc				PEs of linearized Δy			
	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, $PE_{x_i} = (x_i/x_i^t - 1) \times 100$, where x_i^t denotes the true value of x_i. There are 286 and 26 data points in Δc and Δy, respectively.

⇒ *Partition* the shocks (here energy price increases)

⇒ *Reevaluate* the derivative matrices in a sequence of multi-step computations

⇒ *J-step computation*, *Richardson extrapolation*

Illustrative evaluation of impacts of higher energy prices

- Consider price changes from the MIX scenario in Weitzel et al. (2023)
- Reaching a 55% reduction in EU GHG emissions by 2030 compared to 1990 levels
- Effects of both regulatory measures and price-based policies:
  - implementation of standards for e.g. vehicles and buildings
  - Increased stringency in the EU ETS and carbon pricing for the buildings sector and transport under a second EU ETS
- We use the average EU prices, obtained from the JRC-GEM-E3 model
  - Use 11 COICOP consumption categories in the micro-model
  - Apply these prices identically to each EU country
- MRIO data from FIGARO (2015): 63 products, 28 regions (27 EU + RoW)

The micromodel-based impacts of (energy) price increases

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
FoodNaIcBvg	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.

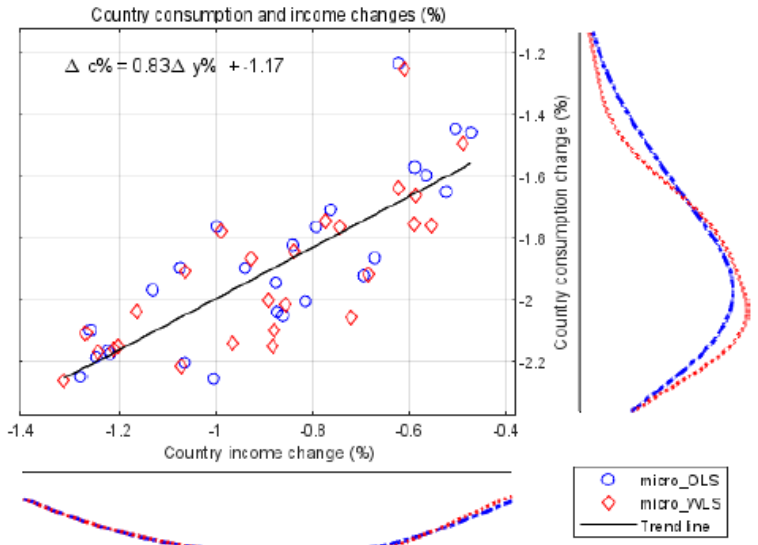
Relatively more basic or necessity nature of *HousWtrElc* compared to *Transport* (captured by **T** and **z**)

Accounting for income-induced impacts

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	-0.87	-1.94	55.3	-1.12	-0.88	-2.00	55.9
BE	-0.99	-0.58	-1.57	62.8	-1.02	-0.62	-1.64	62.3
BG	-0.95	-1.24	-2.19	43.4	-0.93	-1.23	-2.17	43.1
CY	-0.77	-0.99	-1.76	43.7	-0.79	-0.98	-1.78	44.7
CZ	-1.20	-0.85	-2.05	58.4	-1.23	-0.87	-2.10	58.5
DE	-1.20	-0.81	-2.00	59.6	-1.28	-0.88	-2.15	59.3
DK	-1.23	-0.69	-1.92	64.2	-1.35	-0.71	-2.06	65.4
EE	-0.95	-0.76	-1.71	55.7	-0.98	-0.77	-1.75	56.1
EL	-0.85	-1.25	-2.10	40.5	-0.85	-1.26	-2.11	40.3
ES	-0.85	-1.12	-1.97	43.0	-0.88	-1.16	-2.04	43.3
FI	-1.13	-0.52	-1.65	68.5	-1.21	-0.55	-1.76	68.7
FR	-0.98	-0.79	-1.76	55.4	-1.03	-0.74	-1.77	58.3
HR	-0.96	-1.21	-2.17	44.4	-0.96	-1.20	-2.16	44.3
HU	-1.17	-0.87	-2.04	57.6	-1.17	-0.85	-2.01	57.9
IE	-0.99	-0.47	-1.46	67.8	-1.01	-0.48	-1.50	67.6
LT	-0.83	-1.07	-1.90	43.8	-0.85	-1.06	-1.91	44.6
LU	-1.04	-0.56	-1.60	64.9	-1.08	-0.58	-1.66	65.0
LV	-0.96	-0.93	-1.90	50.8	-0.95	-0.92	-1.87	50.7
MT	-0.62	-0.62	-1.24	49.9	-0.65	-0.61	-1.26	51.7
NL	-0.95	-0.50	-1.45	65.4	-1.17	-0.59	-1.76	66.6
PL	-1.15	-1.05	-2.20	52.1	-1.15	-1.06	-2.21	52.0
PT	-0.95	-1.21	-2.16	43.9	-0.96	-1.19	-2.15	44.5
RO	-0.98	-1.27	-2.25	43.7	-0.96	-1.30	-2.26	42.6
SE	-1.20	-0.66	-1.87	64.4	-1.24	-0.68	-1.92	64.6
SI	-0.99	-0.83	-1.82	54.2	-1.01	-0.83	-1.85	54.9
SK	-1.26	-1.00	-2.26	55.8	-1.18	-0.96	-2.14	55.3
EU26	-1.02	-0.76	-1.79	57.2	-1.07	-0.78	-1.86	57.7

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



Generally, the greater portion of consumption losses comes from the *direct price-induced impacts*.

Country heterogeneity due to *different consumer responses* (micro-model), as well as *differing structure and size of production interdependencies and private consumption demand* (MRIO-model)

European Commission

Concluding remarks

- First application of the (modified) Taylor model for the EU case
  - Extensive comparisons of the estimated model's components over time for each MS
- Integrated input-output micro-macro twins
  - Closed-form solution, linearization, novel multiplier matrices
- Fit for distributional analysis
- Model uncertainties: LES, Rotterdam, Translog, AIDS, EASI, Taylor

- Lack of supply-side reactions, or further elaborate impact mechanisms
- Microdata surveys: data quality (e.g. income in HBS), zero expenditures

Thank you

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