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How does inflation propagate among consumer prices components? Evidence from the Euro area

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Abstract
This study employs a time-varying parameter vector autoregressive (TVP-VAR) model to investigate inflation propagation and spillovers among twelve major consumer prices components across eleven Euro area countries from 1999 to 2023. We uncover empirical regularities in the transmission channels of inflation, noting Transport and Clothing and Footwear as primary shock transmitters, whereas Communication, Alcohol and Tobacco consistently absorb shocks. These insights, consistent across various contexts and countries, contribute to understanding inflation persistence and households' inflation experiences in the Euro area and may contribute to more credible and effective policy design.

Keywords: inflation, HICP components, interconnectedness, spillovers, TVP-VAR, euro area
JEL Classification Codes: E31, F41, C32, E58

1. Introduction

Inflation, due to its effects and persistent nature, remains a challenging variable for policymakers. Rational expectations about future inflation, based on past and present indicators, can not only shape future inflation but instigate a self-reinforcing inflationary cycle. In the past 25 years inflation posed distinct challenges to policymakers trying to curb its inertia, especially in the Euro area (EA). Post-financial crisis, the persistent low inflation has raised questions on the effectiveness of standard monetary policy tools and the stability of relationships like the Phillips curve. Also, the persistence in recent inflationary period hasn't simplified the task for the ECB, still seen as playing catch-up as the rate-hike trajectory intensifies.

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In this letter we present a demand-side perspective on inflation propagation, focusing on spillover effects among EA Harmonised Index of Consumer Prices (HICP) components. The literature on inflation spillovers has concentrated on the supply-side or cross-country dynamics (Ciccarelli & García, 2021). Extensive research has explored inflation transmission between countries (Brož & Kočenda, 2018), between producer and consumer prices (Jia et al., 2022), and between commodity and consumer prices (Elsayed et al., 2021). By focusing mainly on aggregate inflation or supply-side elements, the complex demand-side dynamics contributing to inflationary pressures might be missed. Demand-side factors include shifts in consumer preferences, income distribution changes, or policy-induced aggregate demand adjustments, influencing final goods and services prices. This is particularly pertinent for the EA, where demand factors have increasingly impacted recent EA HICPX dynamics (Gonçalves & Koester, 2022). Understanding the demand-side spillover effects among HICP components is decisive for multiple stakeholders. For consumers, this knowledge aids in better anticipating and managing their expenditures. Businesses in sectors like retail, manufacturing, or services benefit from understanding these inflation dynamics for effective pricing strategies, inventory management, and overall financial planning. This understanding is also important for central banks, as monetary policy predominantly operates through the demand channel. Central banks strive to maintain price stability against demand-side shocks, making the comprehension of HICP components' interplay and their contribution to inflation inertia essential. With this insight, central banks can tailor monetary policies more effectively to address specific inflationary pressures. Additionally, other policymakers like governments can leverage this information to forecast inflationary trends and take preemptive actions in areas such as fiscal policy or public spending.

Addressing this need, our paper first examines the interconnectedness dynamics among HICP components. In a currency union like the EA, where one price law is expected to hold, deviations and convergences can illuminate inflation dynamics. Moreover, increasing similarity in economic structures might intensify price interconnectedness, both across components and countries. Next, we explore the transmission channels of inflation within the EA, examining how a shift in one HICP component influences other components, and verify the consistency of these spillovers across EA countries. We argue that such intra-country spillover effects, highlighting demand-side dynamics, can provide new perspectives on inflationary patterns.

We apply the econometric connectedness framework pioneered by Diebold & Yilmaz (2009) to analyze spillovers among HICP components, drawing on nearly 25 years of HICP inflation data from 11 EA countries. While many studies address inflation spillovers to various economic aggregates and between nations, ours is the first to concentrate on HICP components spillovers. Connectedness measures give a comprehensive insight into overall interconnectedness, the shifting dynamics influencing each HICP component, and highlight the evolving transmission channels between HICP component pairs. The paper is structured as follows: Section 2 covers methods, Section 3 describes the data, Section 4 discusses the results and Section 5 concludes.

2. Methods

In this study, we adopt the time-varying parameter vector autoregressions (TVP-VAR) methodology of Antonakakis et al. (2020), extending the dynamic connectedness approach introduced by Diebold & Yilmaz (2009). This method, rooted in a VAR framework, captures nonlinear transmission channels through Impulse Response Functions and Forecast Error Variance Decompositions, effectively highlighting feedback loops within the network. The TVP-VAR framework is particularly advantageous due to its capacity to accommodate time-varying coefficients and error covariance matrices, which are important for analyzing the evolving nature of economic relationships and inflation dynamics over various economic cycles. This flexibility is determining for our analysis that spans nearly 25 years, including various economic conditions. The Diebold and Yilmaz connectedness approach is known for its robustness to variable ordering in the VAR system and intuitive measures of interconnectedness and directional spillovers, complementing the TVP-VAR methodology. It provides a detailed quantification of dynamic spillovers among multiple variables, a key feature for our study's focus on the demand-side perspective of inflation propagation in the Euro area. Moreover, the TVP-VAR connectedness model's design eliminates the need to choose an optimal rolling window size and mitigates the loss of valuable observations, making it particularly suitable for studies with limited sample sizes like ours. This approach lets the variance adjust using a Kalman Filter estimation with forgetting factors ($\kappa_1 = 0.99$, $\kappa_2 = 0.96$) as introduced by Koop and Korobilis (2014). The TVP-VAR model is outlined as follows:

$$y_t = C_{1,t}y_{t-1} + \cdots + C_{p,t}y_{t-p} + \mu_t, \quad \mu_{t|\rho_{t-1}} \sim \mathcal{N}(0, \tau_t) \tag{1}$$

$$\text{vec}(C_t) = \text{vec}(C_{t-1}) + \gamma_t, \quad \gamma_{t|\rho_{t-1}} \sim \mathcal{N}(0, \varepsilon_t) \tag{2}$$

where y_t is an $n \times 1$ vector of endogenous variables, $C_{j,t}$ (for $j = 1,\ldots,p$) are $n \times n$ matrices of time varying coefficients and ρ_{t-1} depicts all the information available until $t - 1$. The error term μ_t is a $n \times 1$ vector of potentially heteroskedastic innovations, while γ_t is an $np\times1$ dimensional vector. The time-varying variance-covariance matrices, τ_t and ε_t, are $n \times n$ and $n^2p \times n^2p$ dimensional matrices respectively. The vectorization of C_t as depicted by vec(C_t) is an $n^2p \times 1$ dimensional vector.

To understand the effects of shocks across sectors, the TVP-VAR model is transformed into its moving average (VMA) representation using the Wold theorem:

$$y_t = \sum_{j=0}^{\infty} A_{j,t}\, \mu_{t-j} \tag{3}$$

Where $\mathbf{A}_{0,t}$ is an identity matrix of size $n \times n$. The matrix $\mathbf{A}_{j,t}$ represents the time-varying impact of a one-time shock to the innovations μ on future values of y_t. The coefficients in $\mathbf{A}_{j,t}$ are computed recursively using:

$$A_{j,t} = C_{1,t}A_{j-1,t} + C_{2,t}A_{j-2,t} + \cdots + C_{j,t} \tag{4}$$

After obtaining the VMA form, the generalized impulse response functions (GIRF) can be used to measure the system variable's response to shocks:

$$\omega_{ij,t}(H) = \sum_{j=0}^{H} \left(A_{j,t} \sum_t d_j\right) \Sigma_{jj,t}^{-\frac{1}{2}} \tag{5}$$

where $\omega_{ij,t}(H)$ represents the impact of a shock in variable j on variable i over horizon H at time t, $\mathbf{d}_j$ is a selection vector with one in the j-th position and zeros elsewhere and $\Sigma_{jj,t}$ is the variance of the j-th error term at time t. The GIRF clarify the dynamic propagation of sector-specific shocks throughout the system. The H-step ahead generalized forecast error variance decomposition measures the influence of variable j on variable i by its forecast variance share, computed as:

$$\theta_{ij,t}(H) = \frac{\sum_{t=1}^{H-1} \omega_{ij,t}^2}{\sum_{i=1}^{n} \sum_{t=1}^{H-1} \omega_{ij,t}^2} \tag{6}$$

Thereafter, we compute the total connectedness index (TCI), which the average degree of spillover from a shock in one variable to others:

$$TCI_t(H) = \frac{\sum_{i,j=1,i\neq j}^{n} \theta_{ij,t}(H)}{\sum_{i,j=1}^{n} \theta_{ij,t}(H)} \times 100 \tag{7}$$

To delve deeper into directional connectedness, we split the total directional connectedness into three components: total directional connectedness to others (TO), total directional connectedness from others (FROM), and net total directional connectedness (NET):

$$TO_{i,t}(H) = \frac{\sum_{j=1,i\neq j}^{n} \theta_{ji,t}(H)}{\sum_{i,j=1}^{n} \theta_{ji,t}(H)} \times 100 \tag{8}$$

$$FROM_{i,t}(H) = \frac{\sum_{j=1,i\neq j}^{n} \theta_{ij,t}(H)}{\sum_{i=1}^{n} \theta_{ij,t}(H)} \times 100 \tag{9}$$

$$NET_{i,t}(H) = \left(TO_{ji,t}(H) - FROM_{ij,t}(H)\right) \tag{10}$$

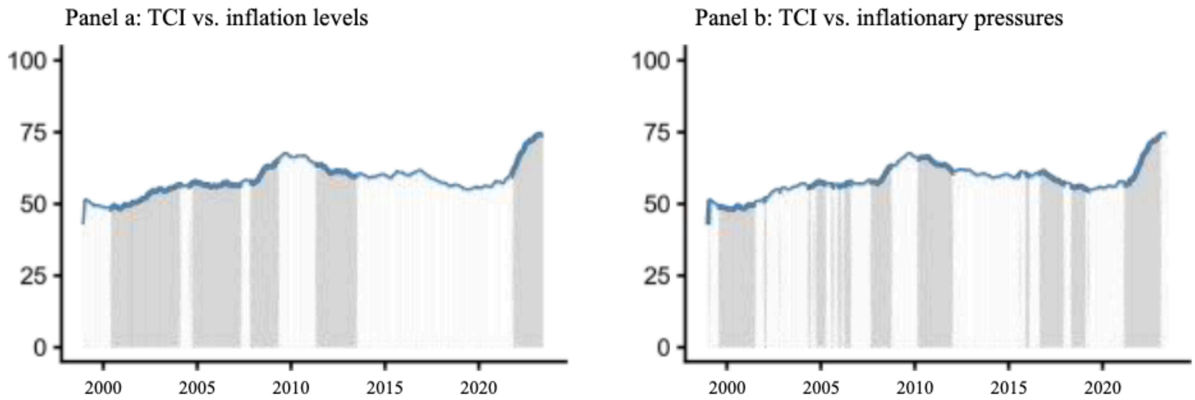
3. Data

The dataset, sourced from Eurostat, encompasses 12 principal consumer prices components from 11 selected EA countries. We use HICP monthly data (12-month average rate of change) from January 1999 to June 2023, capturing both inflationary and disinflationary periods. Countries selection was determined by data availability. This results in 132 (12*11) time-series, each with 294 temporal observations. For economy of space summary statistics and tests for all 132 time-series can be accessed in this link.

4. Results

Fig. 1 showcases the average time-varying TCI for EA countries, derived from a VAR(1) set by BIC with 10-month ahead forecasts. There's a clear uptick in the integration of HICP components, growing from approximately 48% in January 2000 to 75% in June 2023. This trend suggests that prices, on average, are moving closely in the EA, both across countries and final demand sectors. Such a pattern aligns with macro studies pointing to heightened inflation synchronization between countries, indicative of a 'globalization of inflation' (Auer et al., 2017). Recognizing this trend holds significance for policymakers, as the pronounced interconnectedness suggests that both shocks and policies have amplified effects, spreading faster in the system and significantly influencing consumers in final demand markets.

Figure 1. Average Total Connectedness Index across countries



Notes: Shaded areas denote above-average inflation (Panel a) and price acceleration (Panel b).

Linking interconnectedness directly to high inflation periods might seem intuitive, yet Fig. 1 reveals that TCI movements aren't closely tied to inflation levels or pressures. Thus, we turn to inflation microstructure to comprehend the transmission channels more accurately among HICP components, displaying their average connectedness in Table 1 and their dynamic net contribution to the system in Fig. 2.

Transport emerges as a primary shock transmitter, significantly influencing consumer behavior and household finances. Its impact on mobility costs indirectly affects demand in other sectors, largely due to energy market fluctuations. Notably, the pronounced spillovers from Transport coincide with energy market turbulence experienced in 2000, 2008-09, 2014-15, and 2022. A more detailed view of the net pairwise directional connectedness is available in Fig. A.1 (Online Appendix), showing how Transport propagates shocks to services and tradable goods, particularly housing utilities, food and non-alcoholic beverages, clothing, restaurants and hotels. Following Transport, Clothing and Footwear potential to significantly influence inflation dynamics is also consistently observed across countries. Conversely, Communication and Alcohol and Tobacco, accompanied to a lesser extent by housing related HICP components (HOUS and FURN), are robust net absorbers of shocks, which are passed on to their respective prices, reflecting the relatively inelastic demand for these goods and services.

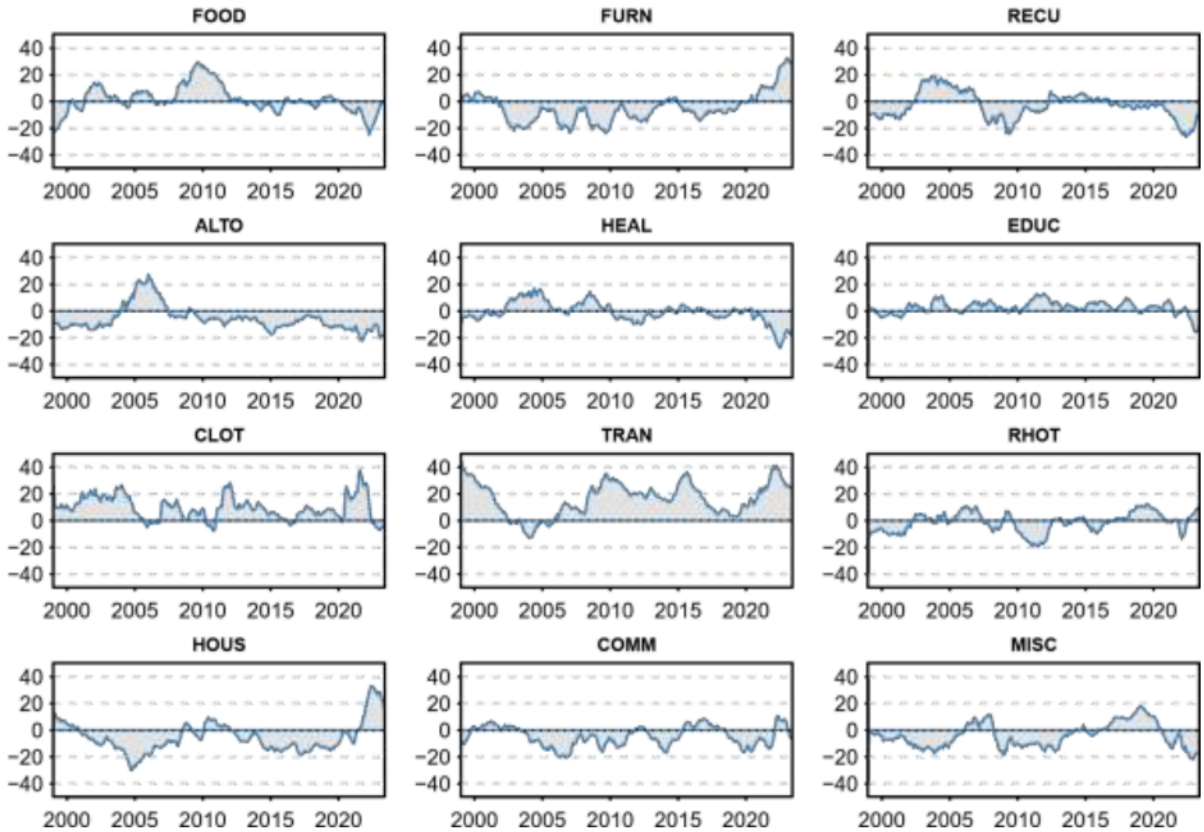
Our research underscores the important role of transport costs in driving inflation, highlighting the need for targeted policy interventions. Fluctuations in transport costs directly impact household budgets and influence business pricing strategies, emphasizing the sector's pervasive influence in the economy. Policymakers are advised to adopt a two-pronged approach: implementing immediate fiscal measures like subsidies or tax adjustments in the transport sector to mitigate external shocks and investing in long-term sustainable transportation solutions to reduce inherent volatility. Simultaneously, monetary policies should consider the inflationary impact of transport costs, with central banks taking its dynamics into consideration when adjusting monetary tools to maintain price stability. Additionally, the consistency of these findings across the Euro Area countries suggests the potential for harmonized regional policy actions. This uniformity across member states presents an opportunity for the European Central Bank and other EU institutions to implement region-wide strategies, potentially through coordinated fiscal policies targeting the transport sector and unified monetary policy adjustments. Such a harmonized approach could effectively address inflationary trends, enhance economic synchronization, and reinforce the Euro Area's resilience against external shocks. Moreover, recognizing common shock absorbers across the Euro Area could lead to policies that strengthen these sectors, contributing to the overall economic stability and resilience of the region.

Table 1. Average connectedness among HICP components

	ALTO	CLOT	COMM	EDUC	FOOD	FURN	HEAL	HOUS	MISC	RECU	RHOT	TRAN
ALTO	43.5***	4.8***	4.5***	5.2***	4.8***	4.4***	4.8***	5.2***	5.6***	5.4***	5.8***	5.9***
CLOT	3	53.8	4	3.1	4.5	6.4	5.1	4	4.2	3.6	4.5	3.8
COMM	5.5	5.5	42.8	5.5	5.5	3.7	4.8	4.8	5.6	5.3	5.1	5.9
EDUC	4.4	5	4.9	47.4	4.9	4.5	6.3***	4.7	5.7	3.7	3.7	4.7
FOOD	4.7	3.9***	4.6	4.7***	38.9	5.9	4.5	6.9	5.1	4.9	5.6	10.1
FURN	4.3	5.9	5***	4.8	6.4	39.4	5	6.6	6.1	5.2	5.7	5.7
HEAL	4.4	5.1***	4.2	6.9***	6.1	4.5	44	5.1	4.6	4.4	5.9	4.6
HOUS	4.7	4***	4.4	6.3***	6.1	4.4	4.7	30	5.5	5.7	5.2	19.1
MISC	5.2	4.5	5.1	5.4	5.2	6.5	5.7	6.2	39.8	5.8	4.8	5.9
RECU	4.8	5	4.7	5.3	5.4	5.7	4.7	5.6	5***	42.4	5.8	5.6
RHOT	4.5	6.2	5.2	4.1	5.8	5.1	5	6.4	4.1	4.9	40.8	7.7
TRAN	5.2	5.7***	5.9	4	7.7	4.3	4.8	9.3***	4.3	5.5***	5.9	37.3
TO	50.7	55.8	52.6	55.3	62.5	55.5	55.3	64.7	56	54.5	57.9	79.1
Inc.Own	94.2	109.6	95.4	102.7	101.5	94.9	99.3	94.7	95.8	96.9	98.7	116.4
NET	-5.8**	9.6**	-4.6***	2.7	1.5	-5.1	-0.7	-5.3	-4.2*	-3.1	-1.3	16.4***

Notes: This table displays connectedness values between HICP Components, averaged over time and then countries. Abbreviations: ALTO - alcoholic beverages and tobacco; CLOT - clothing and footwear; COMM - communication; EDUC education; FURN - furnishings and household equipment; HEAL - health; HOUS - housing and utilities; MISC - miscellaneous goods/services; RECU - recreation/culture; RHOT - restaurants/hotels; TRAN - transport. ***,**,* denote significance at 1%, 5% and 10% respectively.

Figure 2. Net spillovers for each HICP component, averaged across countries.



We structured this study emphasizing robustness. It follows a bottom-up approach, analyzing each EA country individually before aggregating results with confidence intervals. For detailed robustness checks, refer to our online appendix. Model specifications tested include adjusting the forgetting parameter κ_2 to 0.99 (table A.1) and extending the forecast horizon to 12 months (table A.2). The main findings remain consistent, with the Miscellaneous component's net absorber role becoming more pronounced at $\kappa_2 = 0.99$.

5. Concluding Remarks

This study reveals a rising integration of HICP components prices in the EA over the past 25 years leading to greater inflation synchronization across countries. This aligns with the Law of One Price expected dynamics but also poses challenges for policymakers due to how amplified shocks impact monetary policy, price-setting behavior, and economic stability. Hence, it makes understanding the transmission channels and tracing inflation spillovers of paramount importance. Transport is found to be a major transmitter of shocks, highlighting the importance of targeted fiscal and monetary strategies to mitigate its impact on overall inflation. Clothing and Footwear are also prominent shock transmitters, whereas Food prices show limited significance. In contrast, Communication, Alcohol and Tobacco consistently absorb shocks, suggesting differentiated policy approaches for these sectors. These findings enhance understanding of households' inflation experiences and may contribute to more credible and effective policy design, potentially harmonizing approaches across the EA to address shared economic dynamics.

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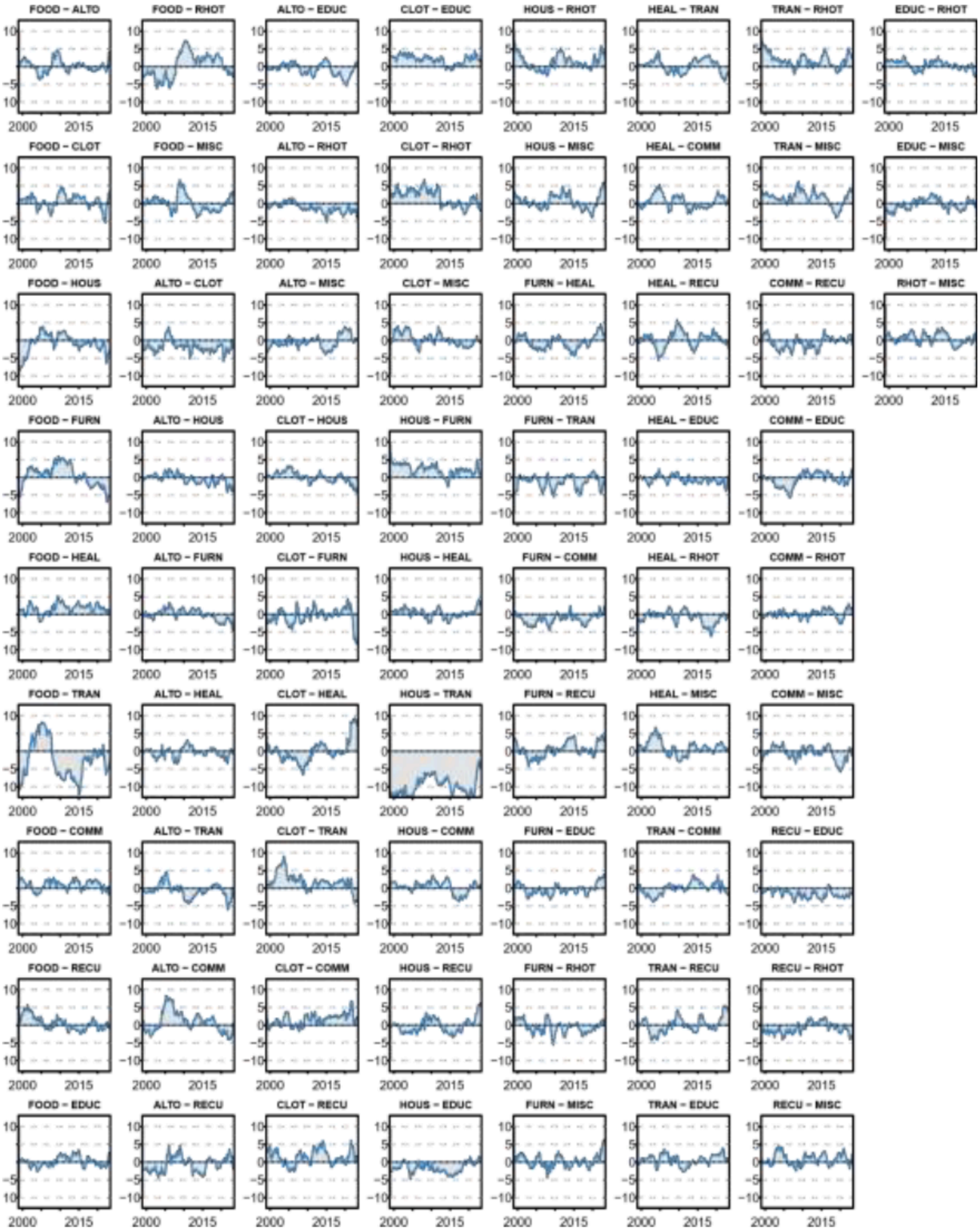
Supplementary materials

Figure A.1 Net pairwise directional connectedness



Notes: The net pairwise directional connectedness (NPDC) decompose the net total directional connectedness (NET), enabling the examination of the bidirectional relationships: $NPDC_{ij,t}(H) = (\theta_{ji,t}(H) - \theta_{ij,t}(H)) * 100$. When $NPDC_{ij}(H) > 0$ ($NPDC_{ij}(H) < 0$), variable *i* dominates (is dominated by) variable *j*.

Table A.1: Average connectedness among HICP components (forgettting parameters: k1 = 0.99, k2 = 0.99)

	ALTO	CLOT	COMM	EDUC	FOOD	FURN	HEAL	HOUS	MISC	RECU	RHOT	TRAN
ALTO	58.6***	5.9**	2.3***	3.3***	4.1***	2.9***	3.4***	2.3***	4.5***	4.5***	4.1***	4.2***
CLOT	1.4***	70.1	1.8***	2.2***	2.9***	6.2***	2.8	2.4**	2.2***	2.5	3.2***	2.3***
COMM	3.5***	5.7***	60.2	3.6***	3.4***	2.8	2.7	2.9	4.1	3.7***	3.7***	3.9***
EDUC	3.1**	4.7***	2.8	62.1	3.1***	3.8***	5.4**	2.4***	4***	3***	2.4***	3.3***
FOOD	3.1***	3.9***	2.3***	3.8***	46.5	6.3***	3	6.4	3.2***	4.3***	5.1***	12.1
FURN	1.9	5.9***	4.1***	3.7***	6.6***	49.7	3.1***	5.6***	4.9	4.4***	5.1***	5***
HEAL	2.8***	5.8**	2.5***	6.4**	4.3***	3.6***	56.8	3.1***	3.3***	3.2***	4.9***	3.3***
HOUS	2.2***	3.3***	2.2	4.7**	3.3	4.7***	2.7***	40.6	3.4***	4.2***	4.6	24
MISC	3.2	6***	3.4	4.8	3.7	7.3***	4.5***	4.8***	49.6	4.7***	3.7***	4.5***
RECU	2.8***	4.9***	2.9***	4.2***	4.3***	5.9***	2.5***	3.3	3.1***	55.9	5.3	4.9***
RHOT	3***	5.6	3.5***	3.2***	4.7***	6.1	3.1***	6.8	2.2	4.2***	49.8	8
TRAN	3.1	4.8***	4.2***	3***	5.6***	4.3***	3.2***	10.9***	1.9	4.9***	5.1	49
TO	30.1	56.4	32.1	42.7	46	53.9	36.3	50.7	36.9	43.6	47	75.4
Inc.Own	88.6	126.5	92.3	104.7	92.5	103.6	93.1	91.4	86.5	99.5	96.8	124.4
NET	-11.4***	26.5***	-7.7**	4.7	-7.5*	3.6	-6.9*	-8.6*	-13.5***	-0.5	-3.2	24.4***

Notes: This table shows connectedtness values between HICP Components, averaged firstly across time and then across countries. Components abbreviations: ALTO - alcoholic beverages and tobacco; CLOT - clothing and footwear; COMM - communication; EDUC - education; FURN - furnishings, household equipment and maintenance; HEAL - health; HOUS - housing, water, electricity, gas; MISC - miscellaneous goods and services; RECU - recreation and culture; RHOT - restaurants and hotels; TRAN - transport. ***,**,* denote significance at 1%, 5% and 10% respectively.

Table A.2: Average connectedness among HICP components (H=12 month forecast horizon)

	ALTO	CLOT	COMM	EDUC	FOOD	FURN	HEAL	HOUS	MISC	RECU	RHOT	TRAN
ALTO	40.1***	5.5***	4.6***	5.6***	5***	4.6***	5.1***	5.3***	5.9***	5.9***	6.2***	6.2***
CLOT	3.2	50.5	4.2	3.4	4.9	6.8	5.4	4.3	4.4	3.9	4.9	4.1
COMM	5.8	6.1	39.7	5.7	5.8***	3.9	5.1	5	6	5.8	5.3	6
EDUC	4.7	5.6	5	44.5	5.1	4.7	6.5***	5	6.1	3.9	3.8	5
FOOD	4.9	4.1	4.8	5	35.5	6.1	4.7	7.3	5.4	5	5.9	11.3
FURN	4.4	6.2	5.1***	5	6.6	36.4	5.4	6.9	6.3	5.5	6	6.1
HEAL	4.6	5.7***	4.3	7***	6.5	4.9	41	5.2	4.9	4.7	6.3	4.9
HOUS	5	4.5***	4.6	6.7***	6.5	4.5	5	27.1	5.8	6.1	5.3	19
MISC	5.4	4.8	5.3	5.6	5.4	6.8	5.9	6.7	36.6	6.2	5	6.3
RECU	5.1***	5.5	5.1	5.9	5.8	6	5	5.9	5.2	38.5	6.2	6
RHOT	4.8	6.6	5.3	4.3	6.2	5.5	5.2	6.7	4.3	5.2	37.9	8
TRAN	5.5	6.4***	6.1	4.3	8.1	4.6	5.2	9.1***	4.4	5.7***	6.1	34.5
TO	53.3	61	54.5	58.5	65.7	58.3	58.4	67.3	58.7	57.9	61.1	82.9
Inc.Own	93.4	111.5	94.2	103	101.2	94.7	99.4	94.4	95.3	96.4	99	117.4
NET	-6.6**	11.5**	-5.8***	3	1.2	-5.3	-0.6	-5.6	-4.7*	-3.6	-1	17.4***

Notes: This table shows connectedtness values between HICP Components, averaged firstly across time and then across countries. Components abbreviations: ALTO - alcoholic beverages and tobacco; CLOT - clothing and footwear; COMM communication; EDUC - education; FURN - furnishings, household equipment and maintenance; HEAL - health; HOUS housing, water, electricity, gas; MISC - miscellaneous goods and services; RECU - recreation and culture; RHOT - restaurants and hotels; TRAN - transport. ***,**,* denote significance at 1%, 5% and 10% respectively.