Supermarket Price Setting on the Two Sides of the Atlantic - Evidence from Scanner Data

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- Food inflation matters
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  - Affects inflation expectations (D'Acunto et al., 2021)
- Volatility is affected by differences in nominal rigidity
  - How many prices adjust (frequency)
  - Which prices adjust (state dependence): are large price changes selected?

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  - Assess state-dependence through estimating generalized- and duration hazard functions

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- Interpret the evidence through the lens of a micro-founded price-setting model (Woodford, 2009)

What do we find?

- A state-dependent price-setting model (Woodford, 2009) captures facts
  - Price adjustment is infrequent (menu costs)
  - Price changes are large (product-level shocks)
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- Both frequency and size are larger in the US than in the euro area
  - Implies more volatile product-level environment (shocks) in the US
- State dependence also stronger in the US
  - Comes predominantly from more misaligned prices
  - In line with more volatile product-level shocks

Selected literature

- We contrast euro area and US price setting as Gautier et al. (2022a) (see also Dhyne et al., 2006)
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- Estimation of state-dependence in price setting
  - Increasing generalized hazard (Gagnon et al., 2012; Campbell and Eden, 2014; Eichenbaum et al., 2011; Gautier et al., 2022b)
  - Increasing duration hazard as Fougère et al. (2007) (differently from Nakamura and Steinsson, 2008; Klenow and Malin, 2010; Alvarez et al., 2021)

Selected literature, cont.

- Interpret evidence through the lens of a state-dependent price-setting model (Woodford, 2009)
  - Model matches evidence well
  - State-dependence plays limited role in flexibility of price level (Woodford, 2009; Costain and Nakov, 2011; Alvarez et al., 2020)
  - Higher idiosyncratic shock volatility in the US explains difference relative to euro area

Selected literature, cont.

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  - Higher idiosyncratic shock volatility in the US explains difference relative to euro area
- Role of sales as and adjustment margin
  - Conflicting evidence: Anderson et al. (2017): no; Kryvtsov and Vincent (2021): yes.
  - Supermarkets in Germany and Italy did adjust their sales during Covid-19 lockdowns

Supermarket scanner data

- Weekly (w) panel of
  - Revenues (TR_{psw}) and units sold (Q_{psw}) from
  - Products (p) identified at the barcode level in
  - Uniquely-identified stores (s).

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- Coverage
  - Germany, France, Italy, Netherlands, US
  - EA: 2013-2017; US: 2001-2012

Store coverage ▸ Table

- Representative sample of stores of participating supermarket chains (US: >3000; EA: 6000-15000 stores)

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  - Both: DE, IT (sample stores are ‘up-weighted’ using regional store-population)

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- EA: random 75% of IRi sample

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- US: All products within 31 broad categories (200.000 products)
- Covers most main categories reasonably well Expenditure share by category

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- EA: geographically representative
  - Stores from all 2-digit ZIP areas (around 100, e.g. Frankfurt area)
- US: covers the most populous areas
  - 50 markets (e.g. Chicago) out of 384 MSAs
  - 73% of US population
  - Store is dropped if too large in a market (to protect anonymity)

Cleaning

- Time aggregation (unit-value prices)
  - Weekly averages, include coupons, within-week changes (not membership cards)

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- Posted-price filter Table
  - Filter consecutive same-direction price changes (2-8% of changes)
  - Round upward remaining fractional prices (7-12%)

Cleaning, cont.

- Monthly aggregation

$$P_{pst} = \text{mode}_{w \in t} P_{psw}.$$

$$TR_{pst} = \frac{52}{12} \frac{\sum_{w \in t} \sum TR_{psw}}{\sum_{w \in t} 1},$$

Cleaning, cont.

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$$TR_{pst} = \frac{52}{12} \frac{\sum_{w \in t} \sum TR_{psw}}{\sum_{w \in t} 1},$$

- We work with a 5% representative sample by country
  - Baseline: 5% random sample of items (product-store)
  - For some analysis: 5% random sample of products

Frequency is higher in the US

- Frequency of price changes key moment of price rigidity
- Most price changes are caused by sales (2/3): fully undone within a quarter

Frequency (monthly, mean)	EA4	US
Posted	25.2	39.4
Reference	8.4	13.3

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Examples | Reference- and sales-inflation | Frequency time series

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▸ Examples ▸ Reference- and sales-inflation ▸ Frequency time series

- Reference (and posted) prices are stickier in EA4 (once in 12m) than in US (7.5m)

Distribution of price changes: size is larger in the US

- Absolute price change distribution
  - Price-change distribution is dispersed: small as well as large price changes

    Absolute price-change distribution
  - Size of reference price changes lower in EA (10%) than in the US (14%)

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    Absolute price-change distribution
  - Size of reference price changes lower in EA (10%) than in the US (14%)
- Standardized price change distribution
  - Standardize price changes at item level (at least 5 reference-price changes per item)
  - Kurtosis (EA: 2.5; US: 2.3) Standardized price-change distribution

State dependence

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- State dependence can affect price-rigidity as much as frequency: if *large* price changes are selected (Golosov and Lucas, 2007)
- Granularity of scanner data: moments revealing state dependence
  - Generalized (price gap) hazard: probability of adjustment as a function of misalignment; Constant in time-dependent Calvo (1983) model; 'upside-down top-hat' shape in state-dependent menu cost models (Golosov and Lucas, 2007); in-between in partially state-dependent models (e.g. Woodford, 2009)
  - Duration (price age) hazard: probability of adjustment as a function of time elapsed since the last change; constant in Calvo (1983), upward-sloping in state-dependent models

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$$x_{pst} = p_{pst}^{f} - \bar{p}_{pt}^{*f} - \hat{\alpha}_s,$$

where

  - $\bar{p}_{pt}^{*f}$ is the average (reference) reset price of competitors that changed their prices at t
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- Valid proxy Size
  - FE control for permanent differences across stores (amenities, geography)
  - $\bar{p}^{*f}_{pt}$ is 'optimal' as far as competitors reset to optimal prices

Estimating duration hazard

$$y_{pst,t+1} = \sum_{j=1}^{J} \beta_y^j I_{pst-1}^{[x_{j-1},x_j)} + \alpha_{ps} + \alpha_t + \varepsilon_{pst}$$

- An empirical challenge is to control for unobserved heterogeneity across products, stores, time
  - We run panel regressions with item (product-store) and time fixed effects
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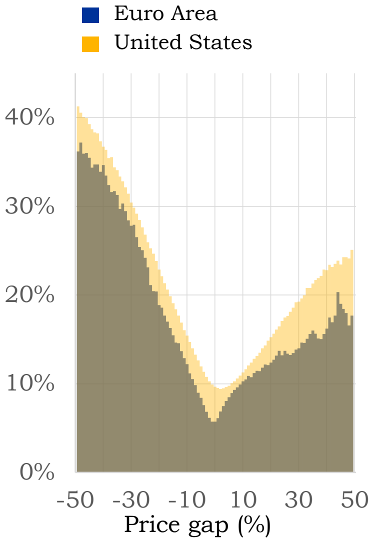
  - We run panel regressions with item (product-store) and time fixed effects
  - Fixed effects eliminate variation coming from permanent differences between items; variation coming from aggregate shocks with uniform impact
- Another challenge is to pick the right functional forms
  - We sidestep the issue by running non-parametric regressions by allocating products into J bins and estimating average effects within each bin

Estimated generalized hazard functions

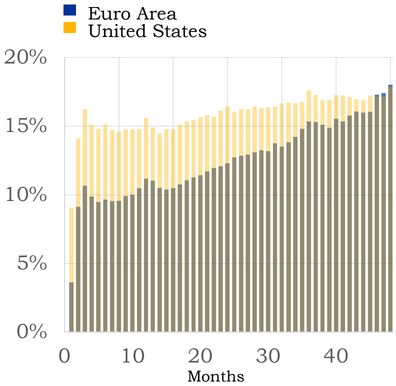
- State-dependence: Adjustment probability increasing with gap
- Flat: probability stays moderate even for large gaps
- Asymmetric: higher chance of adjustment at negative gaps
- Slope not too dissimilar across US and EA4



Estimated duration hazard

$$I_{pst,t+1} = \sum_{j=1}^{J} \beta^j I_{pst-1}^j + \alpha_{ps} + \alpha_t + \varepsilon_{pst},$$

- Not downward sloping (important to control for heterogeneity No FE and exclude sales Posted)
- Initially strongly upward sloping
- Mildly upward sloping in EA; close to constant in US



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- Impact effect of permanent shock m

$$\frac{\partial \pi}{\partial m} = \underbrace{\int \Lambda(x) f(x) dx}_{\text{intensive}} + \underbrace{\int x\Lambda'(x) f(x) dx}_{\text{extensive}},$$

Strength of state dependence, cont.

Margins	EA4	US
Overall impact effect	11.5%	17.2%
Intensive (relative)	74.6%	75.1%
Extensive (relative)	25.4%	25.0%

- State-dependence (extensive margin)
  - Matters
  - Affects price flexibility proportionally in US and euro area
  - Driven by more dispersed gap distribution in the US

Matching a state-of-the-art price-setting model (Woodford, 2009) ▸ Details

- Show how our moments can be used for model selection and calibration
- Take Woodford (2009) model off-the-shelf
  - Rational-inattention extension of Golosov and Lucas (2007) menu-cost model
  - Microfoundation of ‘random menu cost’ models (Dotsey et al., 1999; Alvarez et al., 2020, implies a particular functional form)

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- Calibrate (i) review cost (κ), (ii) standard deviation of idiosyncratic shocks (σ_A), (iii) information cost (θ) to match
  - Generalized hazard function, frequency, size of reference price changes
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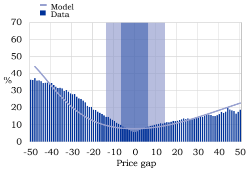
- Translate differences in moments into differences in parameters

Targeted moments

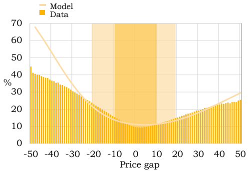
EA4

Generalized hazard

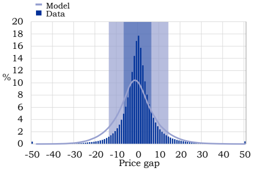


US

Generalized hazard



Price gap density



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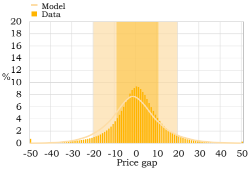
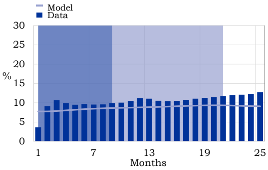


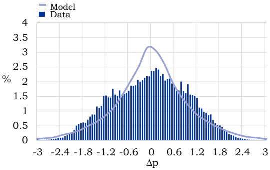
Untargeted moments

EA4

Duration hazard

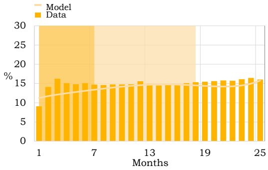


Standardized price-change distribution



US

Duration hazard



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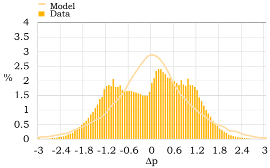

Implications for EA4 vs. US heterogeneity (Woodford, 2009)

- Calibrated parameters

Parameters	EA4	US
Review cost (κ)	9.0%	9.2%
Stdev. of idiosyncratic shocks (σ_A)	3.3%	5.5%
Information cost (θ)	0.72	0.46

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- Implications
  - State dependence is present but mild in both countries (information frictions are high)
  - Higher idiosyncratic-shock variation in US plays a prominent role in explaining higher frequency of price changes

Covid-19 shock in Germany and Italy

- What can the 2020 Covid shock in supermarkets can teach us about price setting?

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  ▸ Real Expenditure Growth
  - Restricted access to food-away-from-home
  - Limited cost shock: essential sector, sheltered from lockdown
- Sizable supermarket inflation in Germany and Italy: ▸ Inflation 2020
  - Have supermarket adjusted their temporary discounts?
  - What explains cross-country differences in inflation?

Result #1: Yes: significant adjustment through temporary discounts

- Fewer and smaller discounts in both Germany and Italy Change in sales frequency/size

Formulas

Result #1: Yes: significant adjustment through temporary discounts

- Fewer and smaller discounts in both Germany and Italy ▸ Change in sales frequency/size
  ▸ Formulas
- Can be justified by
  - Less competition for bargain hunters and product/store switching
  - Inventory management

Result #2: Heterogeneous response in Germany versus Italy

C-E (2007) decomposition	DE	IT
Overall impact effect	8.5%	12.4%
Intensive (relative)	58.9%	72.8%
Extensive (relative)	41.1%	27.2%

- Italian prices more flexible than German prices
  - Reference prices: DE: 44%; IT: 59% (annual, 2013-2017, EA weights)
  - Different market structure: DE: 16 chains; IT: 466 chains

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  - Different market structure: DE: 16 chains; IT: 466 chains
- Larger increase reference-price inflation in Italy (DE: +0.3%, IT: +1.2%) Reference

Conclusion

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  - Supermarket prices change more frequently and by larger amounts in the US than in the EA4
  - State-dependence raises price flexibility more in the US
  - Both factors are driven by higher product-level volatility in the US; confirmed by a structural model

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- Implications
  - State dependence means that higher trend inflation and large shocks will make prices endogenously more flexible
  - Further research is necessary to understand the source and the role of product-level shocks

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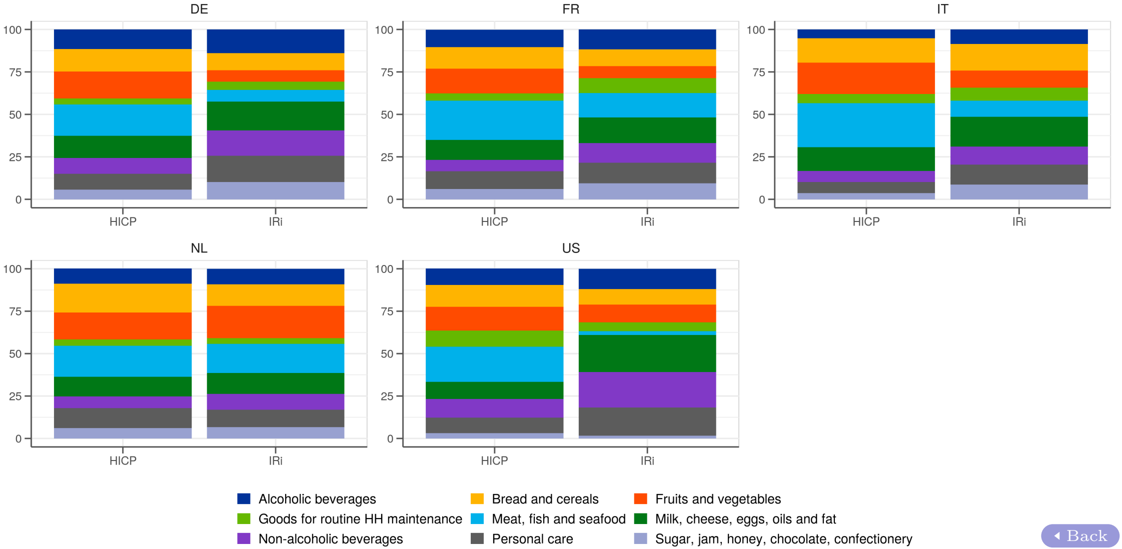
HICP vs IRi expenditure shares by category



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Overview table

	DE	FR	IT	NL	US
Time series			2013-2017		2001-2012
# 2-digit ZIPs	95	93	103	91	51
# stores	10412	5851	14700	6559	3280
# store types	4	4	6	2	3
# chains	16	43	466	29	147
% in HICP/CPI	18.5	23.3	23.4	20.7	19.6
# products	410276	426153	776521	391507	204519
# categories	216	311	459	140	31
# subcategories	496	1339	1662	891	109
av. ann. exp. (bn EUR/USD)	24.09	56.19	31.22	30.01	6.2
# observations (bn)	14.26	11.92	11.3	7.66	2.7

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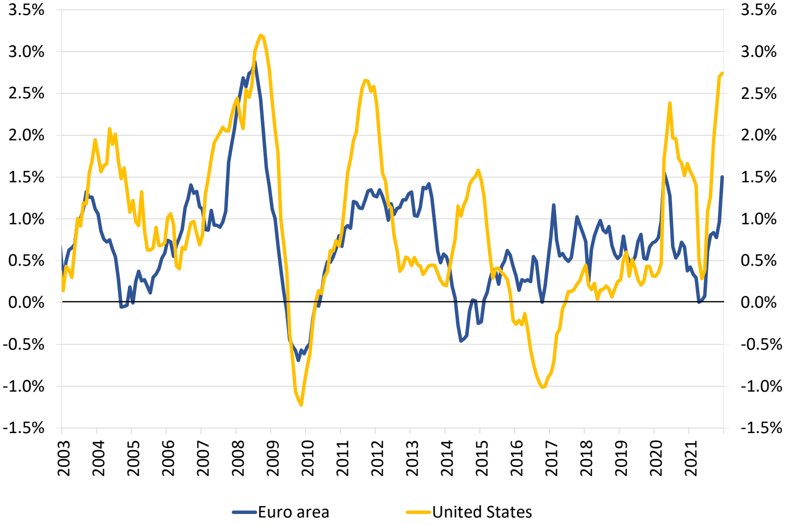
Food and non-alcoholic beverage inflation in the US and euro area



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Overview table, posted-price filter

	DE	FR	IT	NL	US
% same-direction changes	2.15	5.39	8.1	3.58	6.03
% also fractional	1.66	3.71	5.36	1.65	3.31
% fractional price	7.6	8.05	11.66	5.91	6.96
% below closest integer	68.93	53.83	59.48	62.33	58.95

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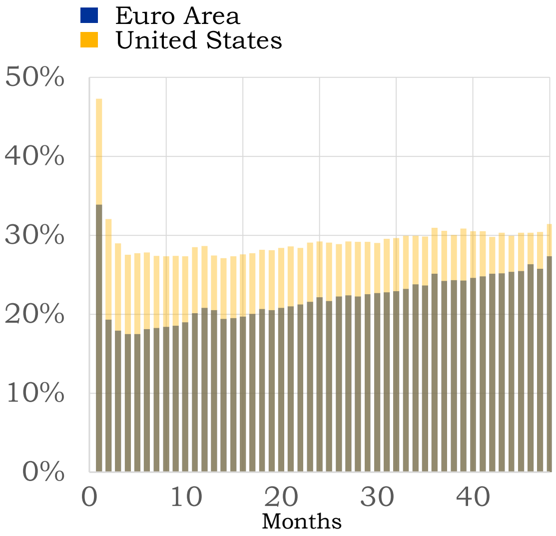
Duration hazard functions (posted prices)



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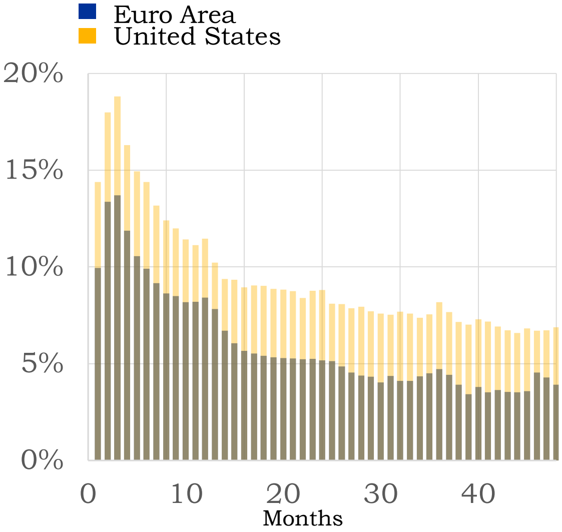
Duration hazard functions (with heterogeneity/no FE)



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Price setting with information frictions (Woodford, 2009)

- Starting point: a standard menu-cost model (Golosov and Lucas, 2007)
  - Monopolistic competition with differentiated goods (ε : elasticity of substitution)
  - Idiosyncratic cost shocks $A_t(i) = A_{t-1}(i) + \nu_t, \nu \sim N(0, \sigma_A^2)$
  - Price gap ($x_t(i) = p_t(i) - p^*(i)$) determines profit
  - Fixed (menu) cost of a price review κ

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- Timing of price review: rational inattention
  - Costly signal $f(x)$ about the state (cost ↑ w/ informativeness: $\theta I = -\theta E[\log f(x)]$)
  - Result #1: optimal policy described by a hazard function (adjustment (signal) probability as a function of current gap $\Lambda(x)$)
  - Result #2: Functional form of hazard function is well defined, depends on θ ($\theta = \infty$: constant hazard, calvo; $\theta = 0$: step function, (S,s)).

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Heterogeneity across EA4 countries

- Large cross-country heterogeneity across EA countries (particularly low in Germany - fewest chains, large in France - much more chains)

Frequency (monthly, mean)	DE	FR	IT	NL	US
Posted	12.41	42.23	27.56	24.77	39.35
Reference	4.53	12.78	9.04	10.06	13.34
Ratio	2.74	3.31	3.05	2.46	2.95

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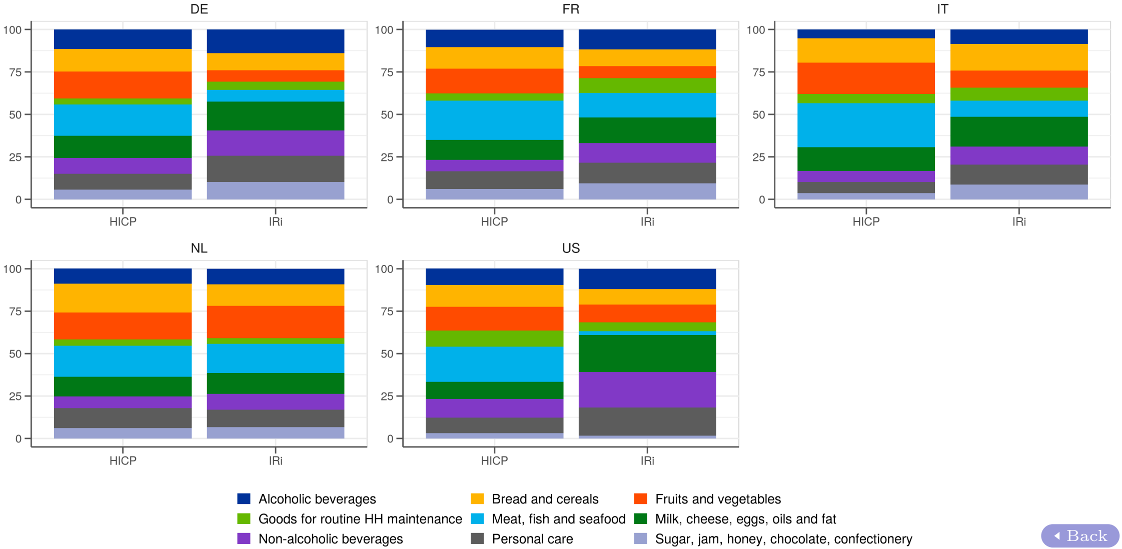
HICP vs IRi expenditure shares by category



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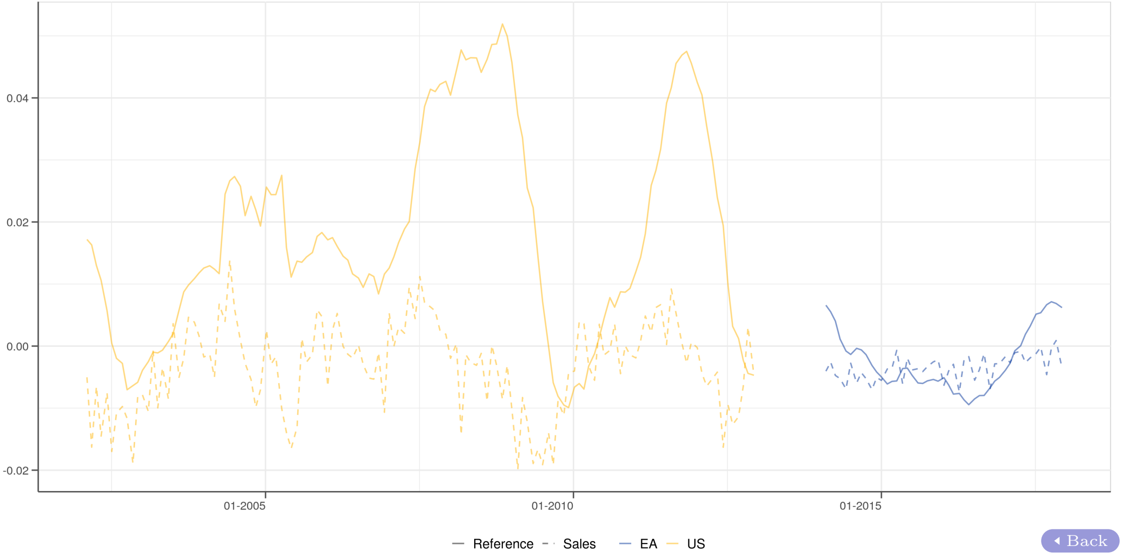
Reference-price vs sales inflation (year-on-year)



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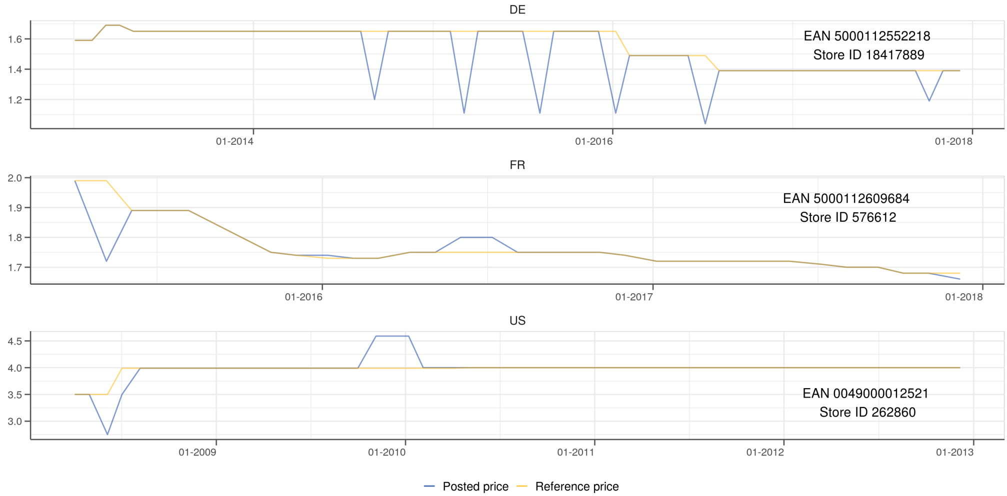
Examples of price spells



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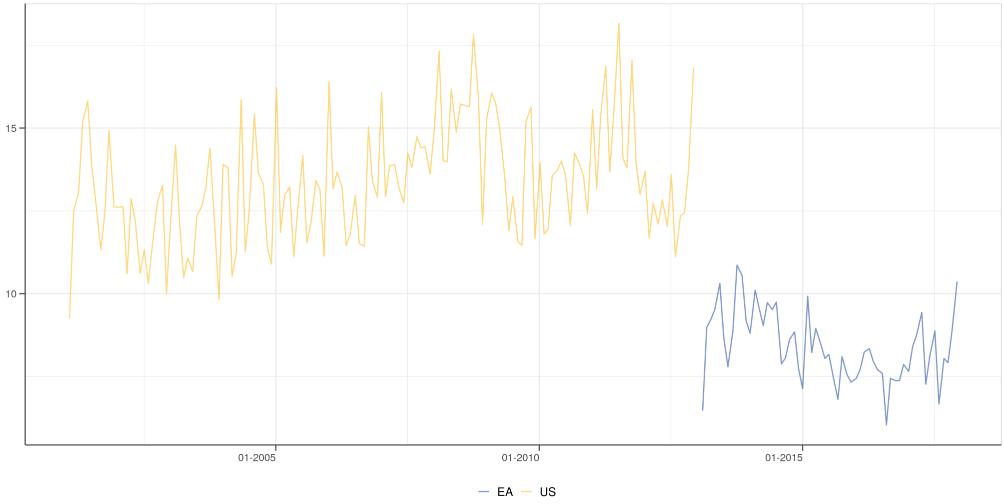
Frequency of reference-price changes, EA4 vs US



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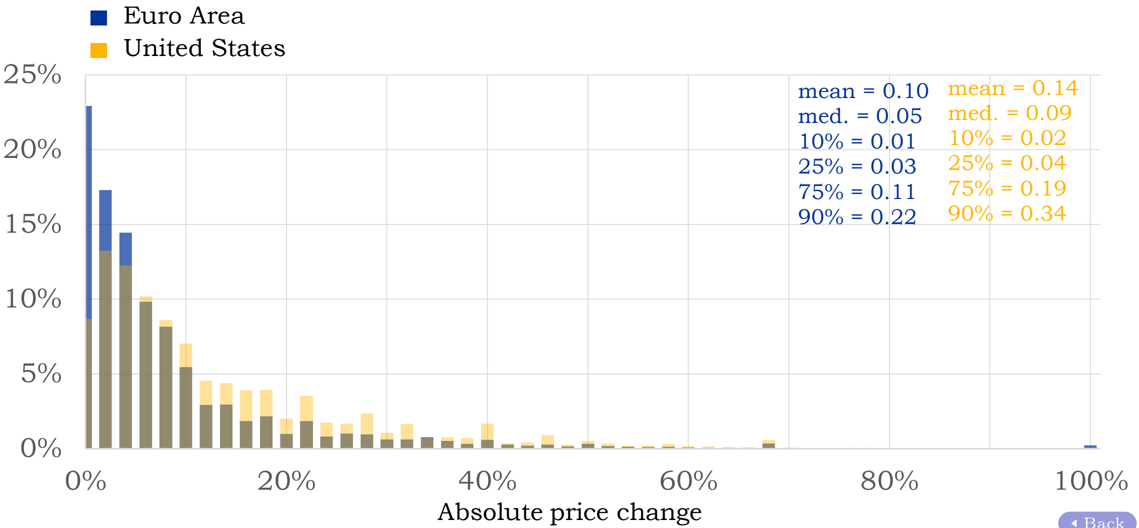
Absolute reference-price-change distribution



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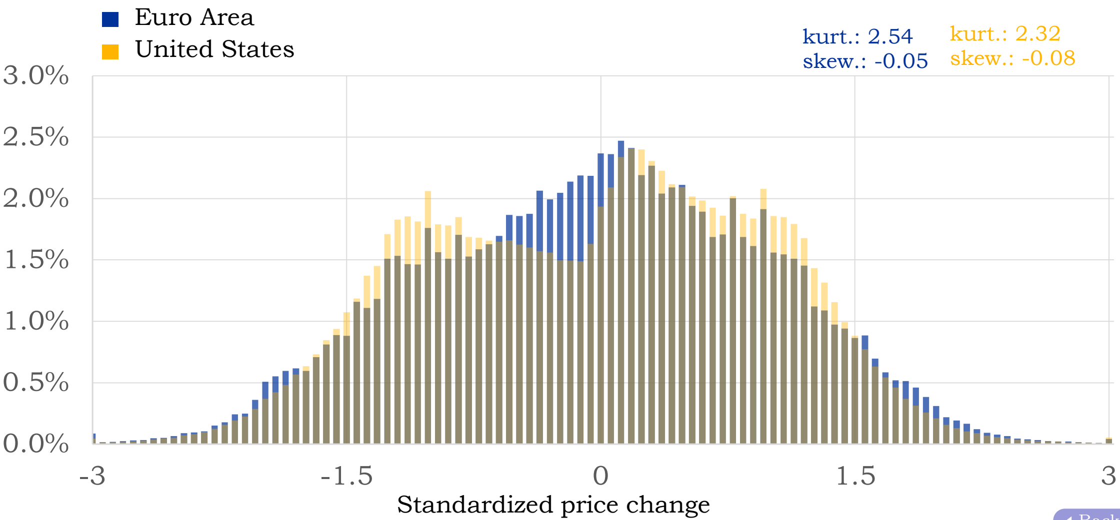
Standardized posted- and reference-price-change distribution



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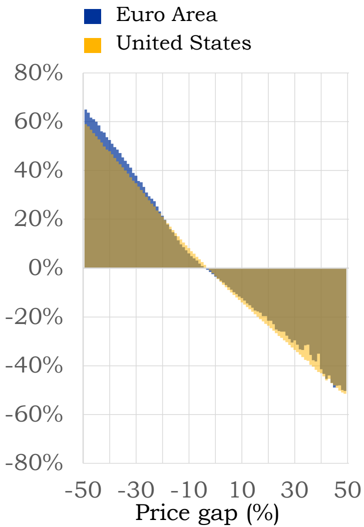
Size of price changes as a function of the price-gaps (reference prices)



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Store-level scanner data from IRi

- Germany and Italy; Large brick-and-mortar supermarkets; All products in these supermarkets
- From mid-February to mid-May in 2019 and 2020; 2013-2017
- 20 two-digit ZIP area in both countries (population share: DE: 16%, IT: 42%; expenditure share: DE: 8%, IT: 40%) Expenditure share by ZIP Population share by ZIP
- To minimize composition change
  - Stores that are available throughout 2013-2020 (DE: 668/815, IT: 1486/2387)
  - 'Established' products available throughout 2013-2020 (DE: 57.000/266.000, IT: 83.800/535.500)

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Price setting

- Cleaning weekly unit-value prices: posted-price (P^p_{psw}) filter
  - Mid-week price changes: consecutive same-direction weekly price change
  - Rounding upwards fractional prices
- Sales filtering:
  - Distinguish high-frequency vs persistent price adjustment
  - Approach: reference-price (P^f_{psw}) filter: 5-week modal price comp. 13-week
  - Iteratively updated to align its change with posted-price change as in Kehoe and Midrigan (2015)
- Decomposition: ‘Reference-price’ and ‘sales’ inflation

$$\pi^p_w = \pi^f_w + \pi^s_w.$$

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Change in sales

- Change in frequency and size of sales (current-weight)

$$\Delta\xi_w^s = \xi_w^s - \xi_{w-52}^s, \quad \xi_w^s = \sum_{psw} \gamma_{psw} I_{psw}^s, \quad \xi_{w-52}^s = \sum_{psw} \gamma_{psw} I_{psw-52}^s$$

$$\Delta\psi_w^s = \psi_w^s - \psi_{w-52}^s, \quad \psi_w^s = \frac{\sum_{ps} \gamma_{psw} I_{psw}^s \left(\log P_{psw}^s - \log P_{psw}^p\right)}{\sum_{ps} \gamma_{psw} I_{psw}^s},$$

$$\psi_{w-52}^s = \frac{\sum_{ps} \gamma_{psw} I_{psw-52}^s \left(\log P_{psw-52}^s - \log P_{psw-52}^p\right)}{\sum_{ps} \gamma_{psw} I_{psw-52}^s}$$

where I_{psw}^s is an indicator function that takes the value 1 if product p in store s is on sale.

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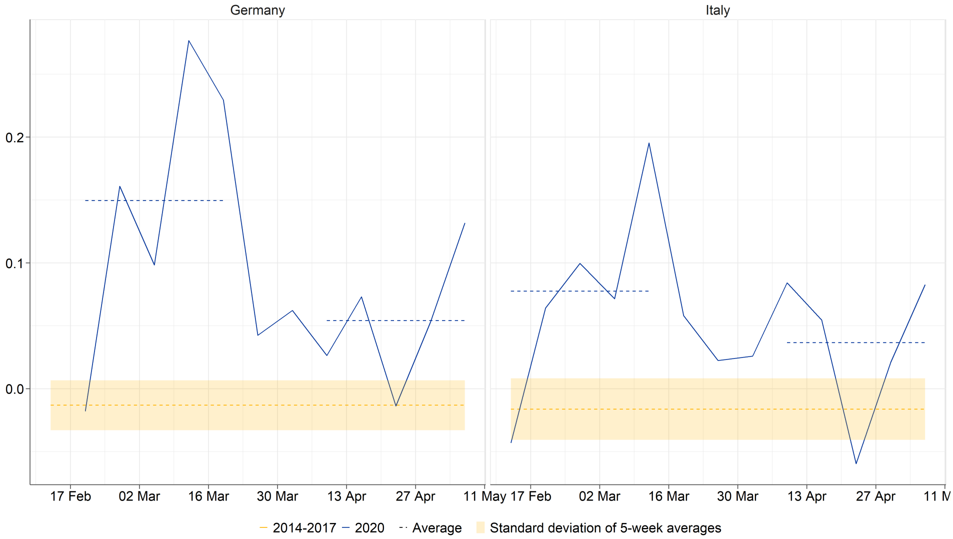
Real expenditure growth, y-o-y, 2020



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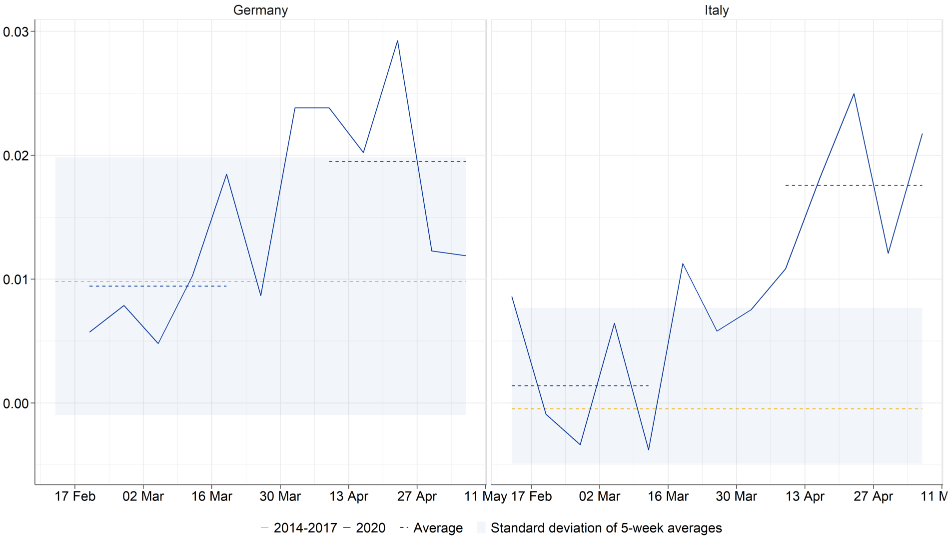
Inflation, y-o-y, 2020



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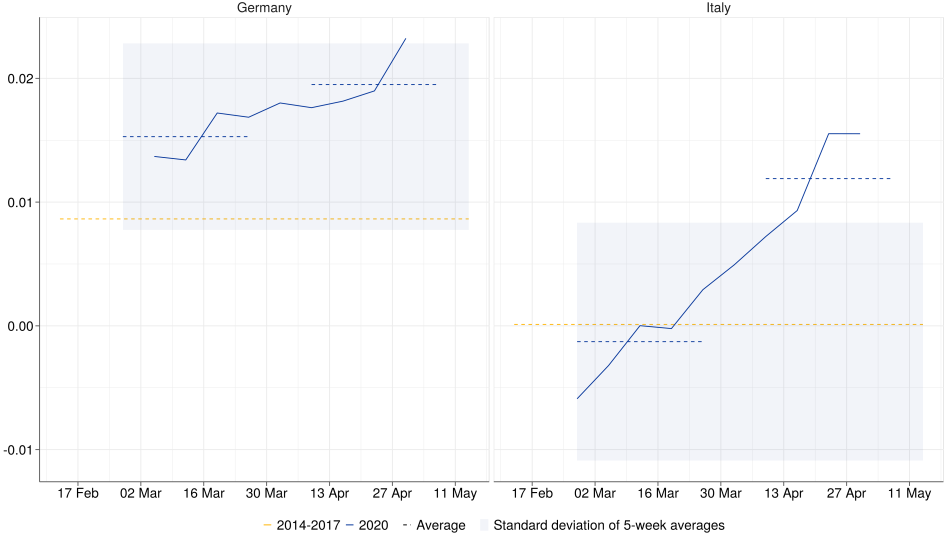
Reference-price inflation, y-o-y, 2020



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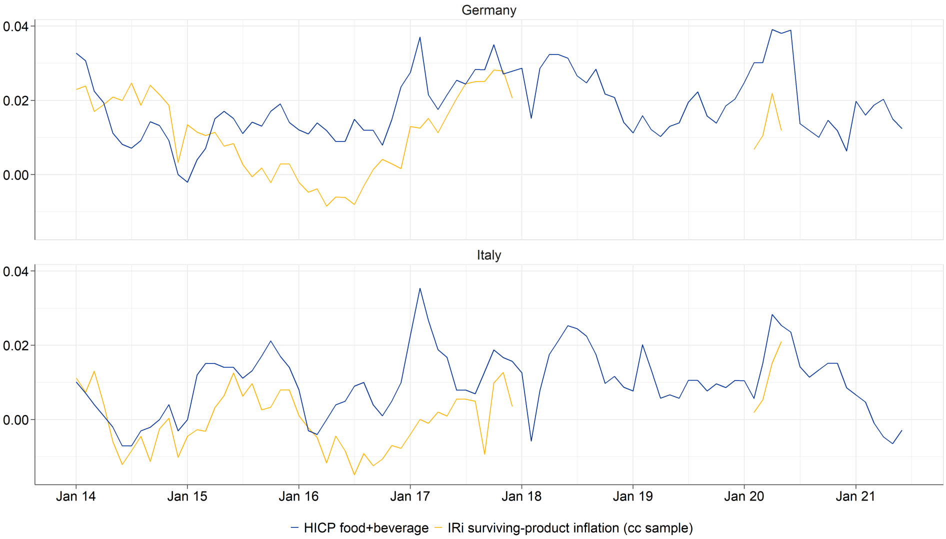
HICP (food and beverage) and IRi supermarket indexes



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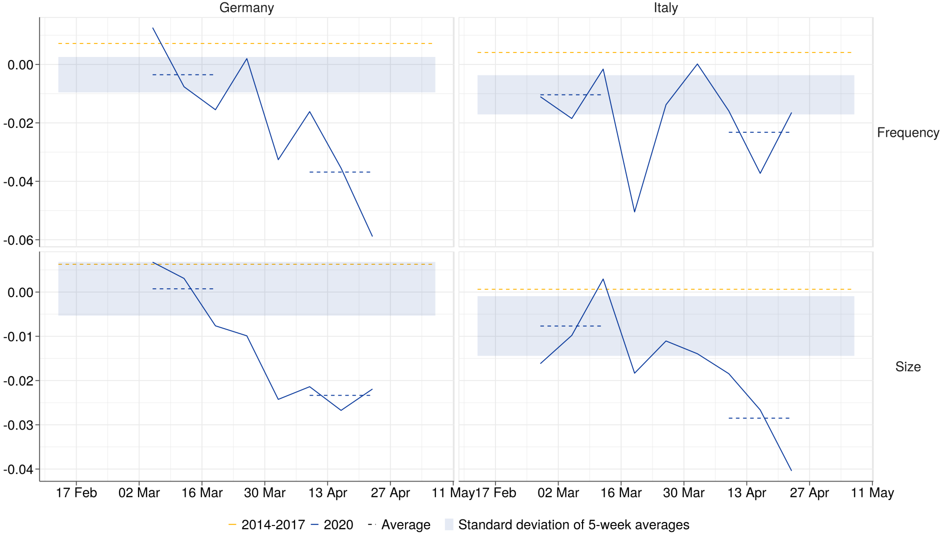
Change in the frequency and size of sales, y-o-y, 2020



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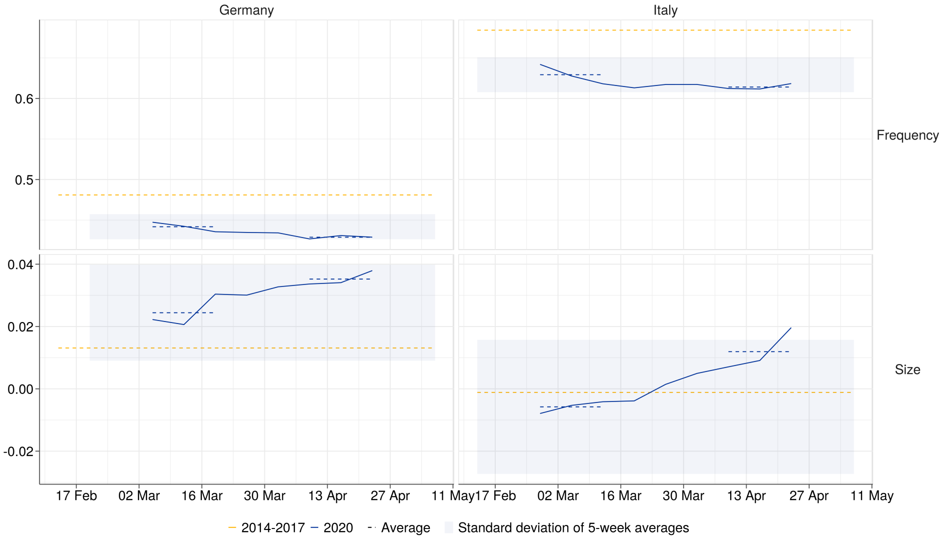
Frequency and size of reference-price changes, y-o-y, 2020



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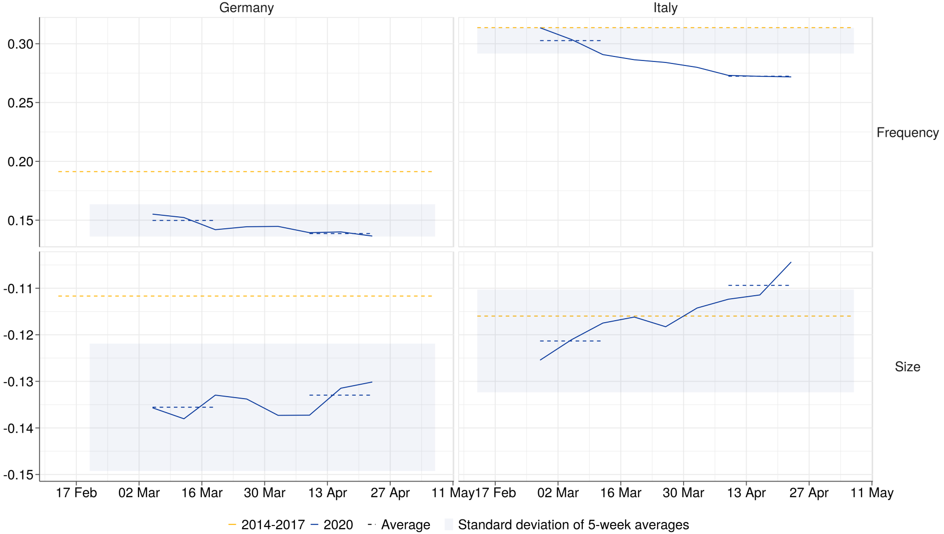
Frequency and size of reference-price decreases, y-o-y, 2020



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Frequency and size of reference-price increases, y-o-y, 2020