New Facts on Consumer Price Rigidity in the Euro Area

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Abstract

Using CPI micro data for 11 euro-area countries over the period 2010-2019, we document new findings on consumer price rigidity in the euro area: (i) the average frequency of price changes is 12% (ii) the distribution of price changes is highly dispersed with frequent large and small changes (iii) price changes are more frequent in January (iv) the overall size of price changes rises with inflation but their frequency does not; these changes in the size are driven by movements in the fraction of price changes that are increases and not by the absolute size of price increases or decreases.

Keywords: price rigidity, inflation, consumer prices, micro data.

JEL codes: D40, E31.

How often and by how much prices adjust is of critical importance for the real effects of monetary policy. Since the early 2000s, several new findings on price adjustment have been documented for many countries in the world (see Klenow and Malin, 2010 for a survey). For the euro area, Dhyne et al. (2006) have provided empirical findings on consumer price rigidity for a limited set of 50 representative products covering a little more than 10% of the CPI basket. On the other hand, several papers have documented findings at the country level with a wider coverage of the CPI but with a much less harmonised empirical approach, making the results hard to compare across countries and difficult to aggregate at the euro area level.[1] In this paper, we document new evidence on consumer price rigidity for the euro area using about 135 million price quotes underlying the Harmonised Index of Consumer Prices (HICP) in 11 countries and covering about 60% of the euro area HICP over a period going from 2010 to 2019 for most countries.

To do this, we have conducted a similar empirical exercise in each of the 11 euro area countries for which we have access to granular consumer price data of the National Statistics Institutes (NSIs). First, we have defined a common sample of goods and services for which prices are available in at least three of the four largest euro area countries (i.e. 166 COICOP-5 level products excluding energy goods). Then, we have computed the same statistics on price changes (such as frequency, moments of the size distribution) at the disaggregate product level (COICOP-5 level) for each country (in both cross-section and time series dimensions), and we have built a euro area dataset gathering all these product-country statistics.[2] Using euro area product-level and country weights, we have aggregated these statistics to provide euro area wide empirical measures of price rigidity. The main facts yielded by this analysis are as follows.

First, consumer prices are sticky: we find that on average, in the euro area 12.3% of prices change in a given month. Country differences are relatively small, whereas sectoral heterogeneity is much more pronounced. Excluding price changes due to sales and temporary promotions lowers the average frequency to about 8.5%, which implies a typical price duration of about one year. Country heterogeneity remains quite limited whereas sectoral heterogeneity is smaller when we exclude sales. Moreover, at a very disaggregate level of products, we find that there is a strong positive correlation across products in the frequency of price changes for all pairs of countries. When we compare

[1] Early studies covering periods between the late 1990s and early 2000s include for instance Baudry et al. (2007) for France, Costa Dias, Dias and Duarte Neves (2008) for Portugal, Hoffmann and Kurz-Kim (2006) for Germany, Álvarez and Hernando (2006) for Spain, Aucremanne and Dhyne (2004) for Belgium, Rumler, Baumgartner and Stiglbauer (2011) for Austria, and Benkovskis, Fadejeva and Kalnberzina (2012) for Latvia, among others. More recently, see also Berardi, Gautier and Le Bihan (2015) for France or Blanas and Zimmer (2020) for Belgium.

[2] This dataset is publicly available in our online replication package: Gautier et al. (2023).

these results with US evidence, we find that for similar CPI products, prices are more rigid in the euro area than in the United States. However, once we exclude sales, the degree of price rigidity is similar in both economic areas. We also compare our results with those reported by Dhyne et al. (2006) using the same set of 50 products. We find that the frequency of price changes has increased in all available countries since the 1990s, but the extent of this increase is heterogeneous across countries and the limited number of products makes it hard to generalise this result to the whole consumption basket.

Regarding the size of price changes, we find that the typical price change is quite large: the median price increase is equal to 9.6% whereas the median price decrease is equal to 13%. This pattern is quite common to all euro area countries but we find greater heterogeneity across countries for the size of price changes than for the frequency. Moreover, the median price change is smaller for services than for other products. When we exclude price changes due to sales, the median price increase and median price decrease are lower: about 7% for price increases and, depending on the way we define sales, between 9% and 11% for price decreases. The effect of sales on the size of price changes is particularly strong for manufactured goods and processed food. Contrasting these results with existing US evidence, we find that on average price changes are somewhat smaller in the euro area, but again once price changes due to sales are excluded differences are much more limited. The large size of the median price increases and decreases suggests that idiosyncratic shocks might play a more important role in price change decisions than aggregate shocks. The relatively large size of price changes can also be linked to a large dispersion in the distribution of price changes. When we exclude sales, we find that 15% of price changes are below 2% in absolute value terms but that 10% of price changes are larger than 16% in absolute value terms. While the share of small price changes is quite homogeneous across sectors, the first and last deciles of the distribution of price changes show stronger differences across sectors. Finally, the distribution of price changes is rather asymmetric around 0, reflecting that price increases are more frequent than price decreases. In particular, small price increases are much more common than small price decreases. This is especially the case for services where the prevalence of smaller price increases might reflect that for this sector aggregate shocks (in particular labour costs) matter more than idiosyncratic shocks for price adjustment.

We then investigate how patterns of price rigidity have evolved between 2005 and 2019 and how they have contributed to inflation dynamics in the euro area. First, one robust finding is that the frequency of price adjustment is significantly higher in January, also when we control for sales and VAT changes. This seasonality in price adjustment is driven by a much larger number of price increases and is particularly strong in services. This seasonal pattern would be consistent with the predictions of a class of time-dependent models with a small degree of staggering (Taylor, 1980). Second, we find that the frequency and size of price changes do not show any strong time trend and do not differ much across years. Nevertheless, when inflation was quite low (between 2013 and 2019), the frequency of price increases was somewhat lower than during the Great Recession, and the size of price increases and decreases rises a bit over the years (partly because of sales). To investigate what is behind month-to-month variation in inflation, we assess the contribution of the variation in the frequency and size of price changes to inflation movements. We find that the overall size of (non-zero) price changes contributes substantially to changes in inflation over time, while the contribution of the overall frequency of price changes is much smaller. Looking in more detail, we show that changes in the overall size of price changes are mostly driven by variation over time of the share of price increases, whereas the contribution of the absolute size of price increases and the absolute size of price decreases is more limited.

Subsequently, we study how several types of aggregate shocks (i.e. monetary shocks, oil supply shocks, demand shocks and VAT shocks) are transmitted to prices. We confirm that firms respond to shocks by adjusting the overall size of price changes more than the overall frequency of price adjustments. When they adjust the overall size of price changes in response to a shock, they adjust the absolute size of price increases or decreases less than the share of price increases/decreases among price changes (which indirectly affects the overall size of price changes). We also find that price changes related to sales do not respond much to aggregate shocks. From a theoretical point of view, the fact that the overall frequency does not respond much to aggregate shocks is consistent with the predictions of a Calvo model or a menu cost model in a low inflation environment. In the latter model, idiosyncratic shocks are a more relevant motive for price changes than aggregate shocks and firms adjust their prices to the shock through adjustments in the size of price changes and not by adjusting the frequency of price changes. Moreover, since aggregate shocks are relatively small, the size of price changes does not vary due to variation in the sizes of price increases or decreases taken separately but through changes in the relative share of price increases (or decreases) among all price changes. All these predictions are in line with our findings on how consumer prices adjust to macroeconomic shocks.

Our paper adds to the existing literature on price rigidity in at least three respects.

First, we document new findings on the role of sales in price rigidity in the euro area and on how they shape the patterns of price adjustment in both the cross-sectional and time series dimensions. The existing literature has mainly focused on the determinants of sales in the United States or the United Kingdom and their aggregate implications (Kehoe and Midrigan, 2007, Guimaraes and Sheedy, 2011, Coibion, Gorodnichenko and Hong, 2015, Anderson et al., 2017 or Kryvtsov and Vincent, 2021). However, little evidence has been made available for the euro area as a whole whereas country-specific evidence has been documented recently by Berardi, Gautier and Le Bihan (2015) for instance. In Dhyne et al. (2006), price changes due to sales were very imperfectly observed in many national micro datasets including Belgium, Germany (see Hoffmann and Kurz-Kim, 2006 for discussion), Italy and Spain (Álvarez and Hernando, 2006) either because sales flags were not available or because the methodology of price collection failed to capture all prices on sales. This complicates cross-country comparisons as well as the assessment of the usual price rigidity measures (which often exclude price changes due to sales) for the euro area as a whole. For instance, in Dhyne et al. (2006), frequencies of price changes are reported with or without sales depending on the availability of a reliable sales flag in the country dataset. In this paper, we have reliable information on sales for more countries, which helps with the cross country comparison. Moreover, as some countries do not have exact information on sales, we have implemented a standard sales filter for all countries in order to provide a harmonised assessment on the importance of sales and promotions for price rigidity in the euro area.

Second, we contribute to the recent theoretical and empirical literature emphasising that frequency is not the only statistic to look at when assessing the transmission of monetary policy and that the dispersion of the price change distribution can be crucial for monetary policy transmission. This literature has documented in particular for the United States the importance of both small and large price changes (see for instance Eichenbaum et al., 2014 or Midrigan, 2011).[3] In a more recent contribution, Alvarez, Lippi and Oskolkov (2022) show theoretically that the cumulative real effects of monetary policy are not only related to the frequency of price changes but also to the kurtosis of price changes.[4] This implies that the whole distribution of price changes might be important for monetary policy transmission, and therefore we provide a description of the full distribution of price changes in the euro area.

Our third contribution is to document new findings for the euro area on how firms adjusted their prices over the period 2005-2019 when inflation was quite low, adding to an earlier literature (Gagnon, 2009, Wulfsberg, 2016, Nakamura et al., 2018, Al-

[3] Several theoretical models have recently been developed to rationalise these small price changes: multiproduct firms (Midrigan, 2011), errors in price revisions (Nakov and Costain, 2019) or information constraints (Woodford, 2009). Larger price changes are usually related to leptokurtic productivity shocks (Midrigan, 2011 or Karadi and Reiff, 2019).

[4] The empirical evidence supporting this prediction is mixed: on US PPI data, Hong et al. (2020) document that the kurtosis of price changes is not informative about the real effects of monetary policy while Alvarez et al. (2021) and Gautier, Marx and Vertier (2021) using French price data, report empirical evidence supporting the theoretical prediction.

varez et al., 2019). Moreover, a burgeoning literature investigates how firms adjust prices in response to observable aggregate shocks (see Balleer and Zorn, 2019, Dedola, Kristoffersen and Zullig, 2021 both on PPI data, Karadi, Schoenle and Wursten, 2019 on scanner data). We contribute to this literature here by looking at how different aggregate shocks are transmitted to all consumer prices via variation in the frequency and size of firms' price changes. All these empirical findings help us to understand better whether variation in the frequency or the size of price changes are behind aggregate variation in inflation. These facts are also linked to standard predictions of price rigidity models in order to document which price rigidity model fits best the main micro facts.

Our results are also relevant for a large literature investigating the implications of price stickiness for monetary policy. First, from a normative perspective, Aoki (2011), Mankiw and Reis (2003), Eusepi, Hobijn and Tambalotti (2011) or more recently Rubbo (2022) argue that it is crucial to account for the sectoral differences in unconditional price change frequencies when constructing the optimal price index that central banks should stabilize: the central bank should give more weight to stickier sectors, as in those sectors the distortions caused by nominal rigidities are larger.[5] Cross-country heterogeneity of price stickiness in a currency union leads to similar conclusions. Benigno (2004) and Benigno and Lopez-Salido (2006) have documented theoretical results on the optimal inflation target in a currency union with different degrees of price rigidity and an application for the euro area. Another literature has emphasized the role played by heterogeneity of price stickiness for the transmission of monetary policy shocks. Carvalho (2006), Nakamura and Steinsson (2010) or more recently Carvalho and Kryvtsov (2021) have emphasized the amplification effect resulting from sectoral heterogeneity in price stickiness using US data and Gautier and Le Bihan (2022) report similar results using price rigidity calibrations on French data. Recently, Pasten, Schoenle and Weber (2020) find that heterogeneity in price rigidity outweighs input-output linkages in amplifying the aggregate effects of monetary policy shocks while Bouakez, Rachedi and Santoro (2022) find that this result is reversed when it comes to amplifying the government spending multiplier.[6] New detailed results for price rigidity in the euro area should help to better understand the role of heterogeneity for monetary and fiscal policy. One recent example is Dedola et al. (2023) who use the statistics computed in this paper to calibrate state-of-the-art price-setting models to derive implications for the monetary policy transmission mechanism. In particular, they show that the implied Phillips curve has significant non-linearities that kick in when trend inflation

[5]See also Adam et al. (2022) for a recent contribution estimating the optimal inflation rate for the euro area in presence of sticky prices and trends in relative prices.

[6]Pasten, Schoenle and Weber (2022) show that sectoral heterogeneity in nominal price rigidity can also amplify the response of aggregate variables to idiosyncratic productivity shocks.

exceeds 5-6%, or when shocks to nominal costs are larger than 15%.

The structure of this paper is as follows. Section I describes the underlying micro price datasets and our harmonised approach to deriving comparable results across euro area countries. Section II presents cross-sectoral results on price rigidity in the euro area and relates them to previous findings for the euro area and the United States. It also analyses the role of sales in shaping price rigidity. Section III documents changes in the frequency and size of price changes over a relatively long time horizon and investigates how they contribute to the response of inflation to different shocks. Section IV concludes.

I Data and Methodology

We start with a description of the underlying country micro price datasets and our harmonisation approach (section A). Next, we present the definition of a common product sample across countries and aggregation procedures (section B), and discuss the treatment of sales and substitutions in computing price rigidity statistics (section C).

A Country-Specific Micro Price Data

At the heart of our analysis are individual country micro price datasets provided by the NSIs.[7] The datasets were released to research teams of the national central banks, which required a decentralised analysis at the country level whereas aggregation of the results was run in a centralised way (see Appendix A.1 for a full description of the national datasets). These datasets consist of sequences of individual prices collected at various outlets for individual specific products (sampled by the NSIs); these price series are then used to compile the national HICPs. Our sample consists of 11 countries (Austria, Belgium, France, Germany, Greece, Italy, Latvia, Lithuania, Luxembourg, Slovakia and Spain), which account for about 90% of the euro area aggregate (Table 1). Taken all together, our datasets consist of about 135 million monthly price observations. The available products and time periods differ across countries; the highest product coverage is found for Luxembourg, Slovakia and Latvia, and the longest time period for Austria, Greece and France with nearly two decades of micro price data. Most prices in the country-specific databases are collected on-site in stores, so they mainly reflect

[7] The datasets are the following: Statistik Austria (2017) for Austria, Statbel (2018) for Belgium, Destatis (2019) for Germany, INSEE (2019) for France, ΕΛΣΤΑΤ (2019) for Greece, ISTAT (2018) for Italy, Lietuvos Statistika (2018) for Lithuania, Statec (2017) for Luxembourg, CSP (2019) for Latvia, ŠÚSR (2020) for Slovakia, and INE (2018) for Spain.

"offline" prices.[8]

[Table 1 about here]

One key feature of the datasets is that the price collection process is framed in all euro area countries by the same general recommendations and regulations defined at the European level (see Eurostat, 2018). Since individual prices are collected to construct the official HICP, price information is highly reliable, and products are carefully sampled by NSIs to be representative of the consumption basket. In all datasets, we are able to track prices for the same product over time whereas the datasets mainly differ in terms of additional information provided by NSIs. This extra information includes flags on imputed prices, on product replacements and sales/promotions as well as information on quality adjustment.

Concerning data cleaning, outliers were removed beforehand in each country database on an individual basis (i.e. price changes below the 1^{st} or above the 99^{th} percentiles of (log) price changes). In addition, whenever possible, we exclude imputed prices from our samples. Generally, when a given product is temporarily unavailable in the store, NSIs impute the price of this product.

Moreover, the treatment of changes in product quality and quantity might also differ between euro area countries. Whenever possible, we use prices adjusted for quantity and quality changes in order to capture the "true" price change. For example, if the package size of a product is reduced while leaving its price unchanged, the consumer is actually facing a price increase. By contrast, if a product is sold at the same price but with higher quality, the consumer enjoys a price decrease. As such, in official price statistics, the monetary value of an observed quality improvement or deterioration over time is typically deducted from the reported product price. Our dataset contains quantity-adjusted prices in most countries[9] and quality-adjusted prices in Germany, France and Luxembourg. Nevertheless, the proportion of quality-adjusted prices in our sample is expected to be rather small.[10]

[8]One exception is the German database, which also contains micro prices for the outlet type "internet trade". Note that since the mid-2010s, some NSIs also switched for some products from traditional on-site price collection to higher-frequency data sources such as supermarket scanner data and web-scraping; due to data restrictions (including confidentiality agreements, different price collection processes), this kind of micro prices is generally not available for research purposes.

[9]Exceptions are Spain, Greece and Slovakia.

[10]For example, the share of quality-adjusted prices in the German CPI micro dataset is about 3.5% (Menz, Wieland and Mehrhoff, 2022). Moreover, our database does not include micro prices of ICT goods for most countries (e.g. smartphones and computers), which typically involve quality adjustment procedures.

B Common Product Sample and Aggregation

Throughout the paper, we compare price rigidity patterns of major product groups based on a common product sample to limit the possibility that our results are driven by different product compositions across countries. For this purpose, we define a common product sample that includes an item when it is available for at least three of the four largest euro area countries (Germany, France, Italy and Spain). Results are available at the most granular level of the HICP, which is the five-digit level of the *Classification of Individual Consumption by Purpose* (COICOP), e.g. "01.1.1.1 - Rice, incl. rice preparation".[11] Our common product sample includes 166 COICOP-5 products.[12] For most products of our common sample, we have price information for all or nearly all eleven countries: on average price data are available for 9.8 countries per COICOP-5 product and for 84% of the COICOP-5 products at least nine countries are available. The 166 COICOP-5 products cover 59% of the euro area HICP and 65% of the euro area HICP excluding energy. Table A1 in the Appendix provides details on the coverage of major product groups and corresponding subgroups ranging from services (40% of the common sample) through non-energy industrial goods (NEIG) (31%) to food (29%). Note that centrally collected prices or administered prices are regularly excluded from the national micro price datasets. In particular, the missing 41% of products in our common sample consists of all energy products (10%) and roughly half of the services sector (21%), where most of the missing share pertains to housing services (rents), communication services and some travel-related services such as package holidays. Moreover, our common sample does not include some centrally collected prices of NEIG (8% missing), such as new and used cars, pharmaceutical products and ICT products, as well as some food products (3%) whose prices are administered, such as tobacco and alcohol.[13]

To compute aggregate statistics for the euro area, we proceed in two steps: first, country-specific product results at the COICOP-5 level are aggregated at the country level by using euro area HICP weights obtained from Eurostat (2023), which we average over the period 2017-2020. This is done in order to avoid differences between countries being caused by differences in national consumption patterns. Second, we aggregate the country-specific results using country weights (also obtained from Eurostat (2023) and averaged over 2017-2020) to derive the euro area aggregate results. This aggregation

[11] For some national CPIs, information is also published at a more disaggregated level below COICOP-5, but these product categories are not harmonised across euro area countries.

[12] The complete list of COICOP-5 products used in this paper is provided in a dataset of the replication package Gautier et al. (2023) (`common_sample_def.dta`). Based on the above-mentioned rule, we observe two COICOP-5 products for energy, which represent only 3% of this product group, so we exclude them from our analysis.

[13] Eichenbaum et al. (2014) argue that for most of these products, there are serious measurement issues (unit values, quality adjustment issues...), which complicate the measure of individual price changes and could bias the measure of frequency and size of price changes.

method will be used to obtain euro area statistics for the total and by broad sectors (Appendix A.3 provides details on data methodology and aggregation). As a robustness check, we have also computed the statistics by first calculating product-level statistics at the euro area level (using country weights) and then aggregating over products.

C Treatment of Sales and Substitutions

In terms of measuring price rigidity, one major challenge arises from the treatment of sales and temporary promotions.[14] As argued by Nakamura and Steinsson (2008*a*), sales play an important role in typical measures of price rigidity like frequency or size of price changes since they usually come along with a large but temporary price change. The HICP regulation states that NSIs shall take into account discounts - e.g. temporary promotions or seasonal price reductions - in price collection at the time of purchase.[15] Without controlling for sales, differences in national sales periods could affect seasonal patterns of price change frequencies and sizes. For most countries in our sample, sales and promotions can be identified by a corresponding flag in the dataset (Table 1). Typically, the price collector assigns a sales flag in the NSI micro price database whenever a collected price is visibly flagged as a sale in the store or when a discount is given to all customers at the check-out desk. However, in some euro area countries in our sample, information on sales is missing in the corresponding micro price database.[16] Moreover, in countries where a sales flag is reported by the NSI, its definition might depend on national practices (see for instance Hoffmann and Kurz-Kim, 2006 for an earlier discussion on the potential limits of the flag in the German case). Hence, as a robustness exercise, we have implemented and extended a sales filter building on Nakamura and Steinsson (2008*a*) in order to identify sales in a consistent way across countries (see Appendix A.3 for a detailed explanation of the way we calculate price changes using NSI flags or the sales filter).

Finally, as discussed by Berardi, Gautier and Le Bihan (2015), another main concern in constructing measures of price rigidity relates to product replacements or substitutions. Typically, when a given product is (temporarily) unavailable or discontinued, the price of a close substitute is used for CPI compilation. Most countries in our sample have a

[14] In some countries, the main difference between sales and promotions is that sales correspond to end-of-season clearance sales when price decreases are very large and periods are often regulated, whereas temporary promotions/discounts correspond to smaller price decreases and promotion periods are less strictly regulated. For the sake of brevity, we will use the term "sales" to refer to both seasonal sales and temporary promotions. In Table A2, we provide more details on legislation regulating sales in the different countries.

[15] See Commission Implementing Regulation (EU) 2020/1148 of 31 July 2020 laying down the methodological and technical specifications in accordance with Regulation (EU) 2016/792 of the European Parliament and the Council as regards harmonised indices of consumer prices and the house price index, Article (6), `https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A32020R1148`.

[16] This is true of Spain, Greece, Lithuania (before 2013), Luxembourg (before 2015) and Slovakia. Moreover, the Belgian micro price database does not contain price changes due to seasonal sales, but only due to temporary promotions.

flag for product replacements in their database (exceptions are Belgium, Greece, Slovakia and to some extent Spain). Nevertheless, the definition of product replacement in our analysis strongly depends on the underlying national statistical practice and product identifier (e.g. link between old and new product identifiers, qualitative information on the type of replacement (fully new product, very similar product, different product), information on the price adjusted for quality, etc.). This is why we exclude replacements from our baseline statistics. However, for robustness, we still provide results on price rigidity measures based on price changes including price changes due to replacements (to the extent we can measure them) in section B.2 in the Appendix.

II Cross-Sectional Evidence on Euro Area Price Rigidity

In this section, we present cross-sectional results for the frequency of price changes in the euro area (section A). We also document our findings regarding the distribution of the (non-zero) price changes (section B). Moreover, we compare our results with previous evidence on consumer price rigidity for the euro area and the United States (section C).

A Frequency of Price Changes

Table 2 reports the average and median frequency of price changes for the euro area aggregate and the underlying 11 countries, both including and excluding price changes due to sales (see Appendix A.3 for details on frequency computations). We first discuss the results for the average frequency. When price changes due to sales are included, we find that the average frequency of price changes in the euro area is 12.3%. When we exclude price changes due to sales, which make up less than 5% of all price observations, the frequency drops to about 8.5% when we define sales by the NSI flag and 7.9% when we use the common sales filter. Moreover, we find that when we also take price changes due to product replacements into account, the frequency of price changes is 13.6% when price changes due to sales are included and 9.8% when price changes due to sales are omitted (Table A5 in the Appendix). In all of our exercises, we find that roughly two-thirds of price adjustments are price increases, with the share increasing slightly when excluding sales (Table A4).

As some macro models require quarterly instead of monthly frequency for calibration, we also express our findings on a quarterly basis.[17] From our monthly results, the

[17] We have approximated the quarterly frequency of a 5-digit COICOP/country pair by $1-(1-F_{j,c})^3$, where $F_{j,c}$ is the monthly frequency for 5-digit COICOP j in country c (Costa Dias, Dias and Duarte Neves, 2008). This approximation assumes among others that within a 5-digit COICOP/country pair, the monthly probability of a price change does not depend on whether the price has changed in the previous month. We have aggregated these quarterly frequencies to

quarterly frequency of price changes in the euro area is approximately 36.9% including sales, 25.4% excluding sales using the sales flag, and 23.6% excluding sales using the sales filter.

These findings are robust to several sensitivity checks. For example, instead of using country-specific time periods, we can restrict the underlying sample period to a shorter but common period of seven years (2011-2017), and we obtain a frequency of price changes equal to 12.4% (Table A6 in the Appendix). We also run robustness checks using different product samples (extending the analysis to the country-specific samples or restricting the analysis to products that are available in all 11 countries): frequencies of price changes are very close to our baseline case (Tables A7 and A9 in the Appendix). We also find that using country-specific weights instead of euro area weights has a small impact on the overall frequency of price changes (Table A11). Finally, we investigate the extent to which the aggregation method affects the results. To do this, we first calculate euro area statistics at the product level (i.e. averaging over countries) and then aggregate over the products. The frequency of price changes remains almost unchanged (12.5% for all price changes and 8.7% for price changes excluding sales) with respect to our baseline case (Table A13 in the Appendix).

Across countries, differences in the frequency of price changes are small: the frequency of price changes ranges from 10.3% in Italy (the lowest) to 18.6% in Latvia (the highest) whereas for most countries this frequency is between 11% and 14% (Table 2). When we exclude sales, cross-country heterogeneity remains fairly small. For most countries, the frequency of price changes is between 7% and 10%, being particularly low in Italy (4.8%) and relatively high in Belgium (13.3%).[18] When we use the sales filter instead of the flag, results are even more similar across countries. The share of sales is about the same in all countries, close to the average of about 5% (last two columns of Table 2). The only exception is Latvia, where the share of sales is 10.7% when we use the sales flag and 7.5% when using the sales filter; this higher rate is mainly due to a higher share of sales in processed and unprocessed food. Again, these conclusions are robust to the sales measure (NSI flag or sales filter).

[Table 2 about here]

Rather than cross-country heterogeneity, Table 2 reveals a significant amount of cross-sectoral heterogeneity in the euro area. Concerning our baseline case including price changes due to sales, we observe the highest frequency of price changes for unprocessed food (31%), whereas the average frequency of price changes is 15% for processed food

the euro area level in the same way as the monthly frequencies.

[18] For Belgium, the coverage in terms of products is lower than for other countries. This may contribute to its relatively high value.

and 13% for NEIG. The lowest frequency of price changes is found in services (6%). The share of price increases among price changes also differs substantially between sectors (Table A4). NEIG have, due to their large number of sales, slightly more price decreases than price increases, while unprocessed and processed food sectors have somewhat more price increases than decreases. Notably, in services price decreases are relatively rare as more than 80% of all price changes are price increases. Excluding price changes due to sales has a sizeable impact on the frequency of price changes in the unprocessed food, processed food and NEIG sectors, where the frequency is lowered by about 5 to 7 percentage points (pp), but has only a limited impact on services. Specifically, the share of sales and promotions make up 8.1% in NEIG and 5.7% in unprocessed food, about 3% in processed food but only 0.2% in services (using information from NSI flags where available, Table A4 column 7). Moreover, within main aggregate sectors, the share of sales is highly concentrated in individual product groups. In Table A3 in the Appendix, we have reported some percentiles of the distribution of the share of sales across products. For example, within NEIG, 10% of the products have 20% of their price quotes recorded as sales price (mainly in the "clothing and shoes" sector) whereas for 25% of the NEIG products, the share of price quotes which are sales prices is lower than 2%. Similarly, product replacements mainly affect the frequency of price changes in the NEIG sector, which goes from 6.4% to 9.4% when we include replacements (Table A5).

This cross-sectoral heterogeneity in the frequency of price changes is also pervasive within broad sectors. Figure A6 in the Appendix shows that the spread in the frequency is large in sectors like unprocessed food or NEIG, even once we control for sales. We also find that this cross-product heterogeneity is very similar across countries. In Table A16 in the Appendix, we report correlations in the 5-digit COICOP frequencies across countries and find that correlation coefficients are higher than 0.5 for most country pairs and that the average correlation coefficient across country pairs is 0.59.

Nakamura and Steinsson (2010) find that sectoral heterogeneity in price rigidity can amplify the real effects of monetary policy shocks and argue that a model calibrated using median frequency can generate monetary non-neutrality similar to that in a multisector model (Gautier and Le Bihan, 2022 find similar results for France). In Table 2, we therefore also report median frequencies. We find a median frequency of about 10% when we include price changes due to sales and 6% when we exclude them. These median frequencies are only a little lower than the average frequencies (about 2.5 pp) whereas in Nakamura and Steinsson (2010) and Gautier and Le Bihan (2022) the difference is larger than 6 pp. This is due to the fact that we exclude energy products, which, in other studies, contribute greatly to the difference between the median and the mean frequency (and more generally to sectoral heterogeneity). Moreover, we find that within aggregate sectors, the median and the mean can differ, in particular the median frequency in services is 3% versus 6% for the average.

To investigate further the sources of cross-sectoral heterogeneity, we run OLS regressions linking the frequency of price changes at the COICOP-5 level to some possible economic factors behind this heterogeneity. In particular, we estimate for each product its cost structure using the symmetric input-output table for the euro area from Eurostat (see also Cornille and Dossche, 2008 and Álvarez, Burriel and Hernando, 2010). By inverting the input-output table, we get the cumulated cost structure for each product group, which gives a more complete picture of the inputs potentially influencing price-setting behaviour (we look at the "inputs of the inputs" over the production chain).[19] Specifically, we estimate the following regression:

$$F_{j,c} = \alpha + \beta_1 Labour_j + \beta_2 Commodities_j + \beta_3 Import_j + \beta_4 Online_{j,c} + \beta_5 Reg_{j,c} + \gamma_c + \epsilon_{j,c} \quad (1)$$

where $F_{j,c}$ is the frequency of price changes (excluding price changes due to sales) for 5-digit COICOP j in country c, $Labour_j$ is the share of labour costs, $Commodities_j$ is the share of imported energy and raw material inputs, and $Import_j$ is the share of all imported inputs.[20] The regression also includes non-cost explanatory variables: $Online_{j,c}$ is the percentage of individuals that bought the type of product online according to a Eurostat survey and $Reg_{j,c}$ is a dummy for products with regulated prices in line with Eurostat's classification of administered prices. Finally, the γ_c's denote a full set of country dummies and $\epsilon_{j,c}$ is an error term. The sources and a detailed description of the variables are provided in Table A17 in the Appendix.

Table 3 reports the main results. We find that the cost structure matters in explaining cross-sectoral differences in the frequency of price changes. In our baseline regression, the share of labour costs has a negative effect on frequency: a 10 pp increase in the share of labour costs reduces the frequency of price adjustment by about 2 pp. This might reflect the fact that if the variance of labour costs is rather small, prices are less likely to change in sectors with a higher share of labour costs.[21] By contrast, the frequency of price changes is found to be higher when energy and raw material inputs have a larger share. Keeping the share of all imported inputs constant, a 10 pp increase in the share of imported energy and raw material inputs increases the

[19] We match product groups (classification of products by activity – CPA) to the 5-digit COICOP. See Table A17 in the Appendix for more details.

[20] National input-output tables describe domestic production. While this may be a reasonable approximation for large countries, this may not be the case for small countries where domestic production might be limited in some industries. The euro area cost data are a better description of the final consumption basket for these countries. In addition, in the aggregate euro area input-output tables, all imports relate to non-euro area imports and as a result these measure exchange rate costs better.

[21] Wage negotiations which alter the labour cost are less frequent than other cost adjustments as they typically happen only every one or two years (DuCaju et al., 2008).

frequency of price adjustment by about 8 pp.[22] The share of all imported inputs, the percentage of online consumers and whether prices are regulated are not important in explaining the frequency of price changes.

[Table 3 about here]

These results are quite robust to the inclusion of a concentration variable (col. 2) or considering price changes including sales (col. 3). When we include broad sector dummies (col. 4), the results are less significant but we still find a negative and significant effect of labour costs, which suggests that the cost structure matters not only for broad sectoral differences but also at a more disaggregated level.[23]

B Size of (Non-Zero) Price Changes

Recent studies highlight the importance of the patterns of the non-zero price change distribution for price rigidity models. In particular, higher moments of the price change distribution could shape monetary policy transmission because they affect which prices will adjust first to an aggregate shock (see Klenow and Malin, 2010 or more recently Karadi and Reiff, 2019 and Alvarez, Lippi and Oskolkov, 2022). In the following, we present some findings to fully characterise the distribution of (non-zero) price changes in the euro area.

B.1 Median Price Change

Table 4 reports the median price increase and decrease. When price changes due to sales are included, the median price increase amounts to 9.6%, while the median price decrease is larger (in absolute value terms), at 13%. When sales are excluded, the median price increase and the median price decrease are both smaller in absolute value terms: the median increase is about 7% whereas the median decrease is between 9% and 11% depending on the way we define sales (NSI flag or filter). In the Appendix, we report the results including price changes due to replacements and the results are only slightly modified (Table A5): the median price increase and the median price decrease (in absolute value terms) are higher by a little less than 1 pp. We also report sensitivity checks of the time period (Table A6), product sample definition (Tables A8 and A10), weighting structure (Table A12), and aggregation method (Table A14). Overall, in these robustness exercises, when we include sales, the median price increase at the

[22] The share of labour costs varies between 0.3 and 0.8 in our sample. The share of imported energy and raw material inputs varies between 0 and 0.1.

[23] We have also estimated the regression separately for the frequency of price increases and the frequency of price decreases. The share of labour costs has a somewhat more negative impact on the frequency of price decreases than on the frequency of price increases, but the qualitative conclusions do not change.

euro area level ranges between 8% and 11% whereas the median price decrease ranges between 11% and 15%. When we exclude sales, the results remain broadly unaltered with the median price increase at around 6.5% and the median price decrease at 8% to 9%. Overall, even when large price changes due to sales are excluded, the typical price increase or decrease is quite large compared with aggregate inflation over the period. This would suggest that idiosyncratic shocks play quite an important role in driving the size of price changes.

Table 4 also shows that cross-country heterogeneity is rather limited but more pronounced than the differences observed for frequencies. In France, Italy, Luxembourg and Spain, the median increase is between 7.5% and 9%, whereas in Austria and Germany as well as in Latvia, Lithuania and Slovakia the median price increase is above 10%. A similar difference is observed for price decreases: in the first group of countries, the median decrease is between 11% and 12% whereas in the second group, the median is closer to 15%.[24] When we exclude price changes due to sales, country differences are still observable and the ranking of countries remains similar.

With respect to the considerable sectoral differences we see that both NEIG and unprocessed food have relatively large median price increases in our baseline, at 13.8% and 12.6% respectively, while the median price decreases stand at 19.1% and 15.0% respectively. These magnitudes can be contrasted with the services sector where the median price increase is 5.6% and the median price decrease is 8.2%. Excluding price changes due to sales reduces the sectoral heterogeneity since this lowers the median increase and decrease for NEIG as well as for processed and unprocessed food where most sales are concentrated. When price changes due to product replacements are included, we find that the median size of price increases is higher for NEIG products (+2 pp), whereas for other products the effect of replacements is much more limited (about +0.5 pp).

This cross-sectoral heterogeneity in the size of price changes can also be observed within broad sectors (Figure A7 in the Appendix). We also find that this cross-product heterogeneity is less similar across countries than what we observe for product-level frequencies. In Table A16 in the Appendix, we report correlations of the 5-digit COICOP median price increases and decreases across countries and find correlation coefficients on average lower than 0.3. Some countries seem to share the same type of cross-product heterogeneity like France, Greece, Italy and Spain on the one hand and Austria, Germany and to some extent Latvia on the other. These country differences partly reflect different sales behaviour (in particular, in Germany and Austria sales in the food sector

[24] In Belgium, the median price change is much lower since price changes due to seasonal sales are not reported in the national micro price dataset.

are much more common than in France or Italy).

[Table 4 about here]

As shown for the frequency of price adjustment, we relate the median size of price changes to various cost and non-cost product-level factors. Results are reported in Appendix Table A18. Similarly to the frequency, we find that price changes are smaller when the share of labour costs is larger. This result is consistent with the lower variance of labour cost shocks that would lead to less frequent and smaller price adjustments. Furthermore, products with a large share of energy and raw material inputs have relatively many price adjustments and these are relatively small in size. We also find that the estimated broad sector dummies have a smaller contribution to size compared with frequency, which confirms the lower degree of heterogeneity for the size of price changes than for the frequency.

B.2 Dispersion of the Distribution of Price Changes

The recent literature has focused on the relevance of very small and very large price changes and not only on the average or median size of price changes. To characterise in more detail the distribution of price changes, Figure 1 plots the full distribution of price changes including price changes due to sales (in grey) and excluding price changes due to sales (solid line) whereas Table 5 provides different percentiles of these distributions. For all price changes, the main patterns of the distribution are as follows: it is asymmetric with more small positive price changes than negative ones, it shows a modal range of values between +1% and +3%, and it exhibits several peaks at large values corresponding to price changes due to sales.[25] When price changes due to sales are removed, the peaks at large values are smaller but still significant and the asymmetry around 0 is more pronounced. In both cases, large price increases and decreases are quite frequent. When we exclude sales, 10% of price changes are above 15.7% and 10% of price changes are below -13.1%. In the previous subsections, we have found that price increases are more common than price decreases, but that when they occur, price decreases are on average larger (even when sales are excluded). Figure 1 shows that an important driver of these findings is that small price increases are relatively common, while small price decreases are relatively rare.

When looking at country-level distributions, we find similar broad patterns in all countries with some differences (Figure A2 in the Appendix): in particular, in countries like Austria or Germany, once we remove price changes due to sales, we still find quite large

[25] Figure A3 in the Appendix plots the same distributions of price changes but calculated as percentage changes, which better identifies the peaks at rounded negative large values at -50%, -40%, -30% and -20%, especially for NEIG.

peaks at large values, which is less the case in France, Italy, Latvia or Luxembourg.[26] This suggests that in the first group of countries, large price changes are not rare and are not fully due to sales patterns. From this country comparison, we also see large differences in the size of typical sales: in France price decreases of -50% (-70% in log terms) are much more frequent than in other countries, whereas the range of peaks is much larger in Austria and Germany than in France, Italy or Luxembourg.[27]

Figure 1 also plots the distribution of price changes for three broad sectors (food, NEIG and services). Food and NEIG price change distributions share similar patterns: a small degree of asymmetry, large peaks corresponding to sales and a quite dispersed distribution of price changes. For services, the distribution is much more asymmetric (i.e. many more positive small price changes than negative small price changes) but also much less dispersed (more than 25% of price changes are between 0 and 3%). This finding for services might reflect the relatively higher relevance of aggregate nominal shocks (the aggregate wage component of the production cost for instance) compared with idiosyncratic shocks as a motive for price change. The aggregate wage component of the production cost tends to change with relatively small positive values, contributing to the apparent downward nominal price rigidity. Table 5 shows that the tails of the price change distributions are less fat for services than for food and NEIG irrespective of whether we include price changes due to sales or not.

Regarding the share of "small" price changes, we report in the last column of Table 5 the share of absolute non-zero price changes below 2%.[28] We find that 11.5% of price changes are smaller than 2% in absolute value terms and 15% when we exclude sales. This proportion is quite similar across sectors when we exclude sales. Differences are more pronounced across countries, with the share of small price changes being particularly high in France (especially in the food sector), Italy, Latvia, Luxembourg and Spain, but relatively low in, for example, Germany. For the United States, Eichenbaum et al. (2014) find that 10.5% of price changes including sales and 13.8% of price changes excluding sales are below 2.5% in absolute value terms.[29] They also find that 5.0% of price changes excluding sales are below 1% in absolute value terms, we find 5.1% for the euro area. Overall, the share of small price changes is the same in the euro area as what is found in the United States.

[26] In Greece, Lithuania and Spain, the remaining peaks might reflect the fact that the sales filter fails more frequently than the flag to capture price changes due to sales.

[27] Figure A4 in the Appendix plots the distributions of price changes calculated as percentage changes by country, peaks at rounded negative large values at -50%, -40%, -30% and -20% are easier to read.

[28] Table A15 in the Appendix reports the percentiles of the distribution of absolute price changes.

[29] Klenow and Kryvtsov (2008) report that for the United States 25% of price changes are below 2.5% in absolute value terms whereas Eichenbaum et al. (2014) challenge this result arguing that this high share of small price changes is driven by some "problematic" products such as cigarettes, gas services, electricity, telephone services or new cars where measurement issues are more frequent (because of unit values, taxes or bundling of goods). In our case, most of these "problematic" products are excluded from our sample of common products.

[Table 5 about here]

C Comparison with Previous Evidence on Consumer Price Rigidity

We now contrast our findings on euro area price rigidity with previous evidence obtained for the euro area for the late 1990s/early 2000s period based on a smaller sample of products, and with evidence from the US CPI.

C.1 Comparison with Previous Evidence for the Euro Area

Dhyne et al. (2006) presented the first harmonised cross-country study that characterises price rigidity in the euro area based on micro-level CPI data over the period 1996-2001. Their findings were derived from 10 countries and a harmonised sample of 50 product categories chosen to be broadly representative of the consumption basket.[30] The sample of 50 product categories represented altogether between 10% to 14% of the CPI baskets of member countries. Thus, the expenditure share covered at that time was much lower than what we cover in this paper.[31]

To guarantee a consistent comparison with the results of Dhyne et al. (2006), several adjustments to our methodology were necessary (see Appendix C for more details). First, we have calculated the frequency of price changes for the same product categories as in Dhyne et al. (2006) (i.e. below the COICOP-5 level); this was possible for five countries in our sample (Austria, Belgium, France, Germany and Italy), which make up for slightly more than 70% of total euro area GDP, and for 43 of the original 50 product categories (see Table A19 in the Appendix). Second, concerning the treatment of sales and substitutions, we followed the same country-specific approach as in Dhyne et al. (2006): price changes due to substitutions were included in all countries (except Belgium). For both periods, price changes due to sales were excluded in Belgium, Germany and Italy, and included in Austria and France. This implies that the resulting frequencies are less comparable across countries but rather across the two periods for a given country. In a similar vein, we restricted the underlying period to 2011-2017 (until 2015 for Belgium) to perform a comparison with Dhyne et al. (2006).

The upper panel of Table 6 presents the frequencies of price changes for 43 products aggregated to the three available sub-sectors processed food, NEIG and services.[32] We find that for all countries the overall frequency of price changes has increased since

[30] These product categories are well below the COICOP-5 level aggregate of products used in our main analysis. For instance, in Germany, the 50 products are taken from a total of more than 700 different products defined at a very detailed level in the micro price dataset; in Austria, they are taken from about 800 elementary products.

[31] For example, the German CPI dataset covers 83% of the CPI, but only 11% refer to the product categories included in Dhyne et al. (2006). In Austria, the coverage of these 50 products is about 13% of the CPI.

[32] Note that the reported numbers in Dhyne et al. (2006) diverge from those in Table 6 since we only include products that are available in both periods and use harmonised product and country weights in the aggregation.

Dhyne et al. (2006). The increase was most pronounced for Austria (+6 pp), followed by Germany (about +3.4 pp) and Belgium (+2.5 pp), and relatively small for France and Italy (about +1 pp). For the weighted average of these five countries (euro area-5), the frequency increased by 2.1 pp, from 7.8% to 9.9%. With regard to sectoral heterogeneity, the increase is observed in all 3 sectors but is larger for NEIG products.

[Table 6 about here]

At the product level, almost 70% of product-country combinations have a higher frequency in the more recent period (in particular for NEIG in Austria and Germany).[33]

In the middle and lower panels of Table 6, we compare the median size of price increases and decreases for the period 2011-2017 with those of Dhyne et al. (2006). At the euro area level, the median price increase is similar for both periods, while the median price decrease is somewhat higher in the more recent period. The latter is mainly due to a pronounced increase in the size of price decreases in France, in particular for NEIG (see also Figure A8 in the Appendix for a detailed comparison at the product level).

Overall, we find a higher frequency of price changes in the more recent period than in Dhyne et al. (2006), but no clear trend for the size of price changes. The increase in the frequency is dominated by NEIG items in Austria, Belgium and Germany. It should be borne in mind that in order to be comparable with Dhyne et al. (2006), our results are based on a small sample of 43 product categories and therefore differ somewhat from those presented in section A.

C.2 Comparison with US Evidence

In this section, we compare euro area price rigidity results at the product level with equivalent evidence provided by Nakamura and Steinsson (2008*a*) for the United States. We restrict our comparison to the equivalent products to control for possible differences in the composition of the consumption basket considered in both economies.[34] To do this, we build a mapping table between the Entry Level Items (ELIs) classification of the U.S. CPI as defined by the Bureau of Labor Statistics and the ECOICOP classification of euro area HICP as defined by Eurostat.[35] To control for possible differences in the

[33] Figure A8 in the Appendix shows the scatter plot of product level frequencies in both periods (recent period on the y-axis and Dhyne et al., 2006 period on the x-axis) for all five countries. Single products which contribute most to the overall increase are "TV set" (in Austria and Germany), "men's shirt" and "jeans" (in Austria), "hotel room", "toaster" and "car tyre" (in Germany).

[34] One important caveat regarding this comparison is that US moments were computed on the period 1998-2005 whereas most euro area results are obtained on a more recent period. However, to our knowledge, the US data moments provided by Nakamura and Steinsson (2008*a*) are the only information available for the United States at this disaggregate level of products.

[35] Almost all COICOP 5-digit products have a corresponding ELI product while some ELI products have no correspondence in our euro area dataset. Our replication materials Gautier et al. (2023) provide the mapping tables and both detailed classifications.

composition of the consumption baskets between the two economies, we apply euro area HICP weights as done in the previous sections to derive aggregate statistics for both economic areas.

Table 7 contrasts our price rigidity statistics for the euro area with those for the United States. When price changes due to sales are included, we find that prices are, on average, more frequently updated in the United States than in the euro area. The average frequency of price change is 19.3% in the United States for comparable products whereas it is only 12.3% in the euro area. However, when we exclude price changes due to sales, we find that the frequencies of price changes in both economies are much closer (10% in the United States versus 8.5% in the euro area). This would imply that the share of sales is higher in the United States than in the euro area. Indeed Nakamura and Steinsson (2008*a*) report that the share of sales is 7.4% whereas in the euro area we find that less than 5% of prices are sales prices.[36] Looking at sectoral differences, the picture is similar. Price changes due to sales and promotions explain a large share of the difference between price rigidity in the United States and the euro area. Regarding the share of price increases, the two economic areas are quite similar, both for the aggregate and across sectors.

[Table 7 about here]

On the size of price changes, Table 7 shows that the average price change is much larger in the United States than in the euro area (about 5 pp). As with the frequency results, when we exclude price changes due to sales the difference is much less pronounced: the average price increase is 10.6% in the United States versus 8.9% in the euro area and a similar difference is obtained for price decreases. Sectoral differences are once again large between the two regions, with the largest gap found in the food sector (both unprocessed and processed food products) and the smallest gap in services. Sales play an important role in this comparison: when we exclude them, we find that the difference in the size of price changes between the euro area and the United States decreases significantly for all goods except food products.

When looking at the tails of the price change distribution, we can compare the quartiles of the absolute price change distribution at the 5-digit COICOP level. We find that the first and third quartiles are lower in the euro area than in the United States even when excluding sales. We also find that the gap between the first quartile and the third quartile is larger in the United States than in the euro area. Using US scanner data and focusing on price changes excluding sales, Midrigan (2011) reports for the

[36] We cannot rule out that part of this gap can be due to differences in how sales flags are reported in the US and in the euro area.

United States that the 10th percentile of the price change distribution (in absolute value terms) is equal to 3% and the 25th percentile is equal to 5% whereas the 75th and 90th percentiles are respectively equal to 13% and 21%. These results are quite in line with the euro area results on the distribution of price changes (Table A15 in Appendix).

For a more disaggregated perspective, Figure 2 plots the comparison of frequency and size of price changes as well as the share of price increases for the common sample of products for the United States and the euro area. We find only a very few products for which frequencies and sizes are larger in the euro area than in the United States when we consider all price changes. Once we have removed price changes due to sales, the picture is more balanced, in particular for the frequency of price changes. When we compare US evidence with each of the euro area country results, we find for most euro countries that once price changes due to sales are excluded, the frequencies of price changes in the United States and the euro area countries are much more similar. With respect to size, we find more heterogeneity: compared with the US, price changes are often smaller in Belgium, France, Italy and Spain whereas in Austria, Germany, Lithuania, Latvia and Slovakia they look much more similar.[37]

[Figure 2 about here]

III Time Series Evidence on Euro Area Price Rigidity

In this section, we investigate how price adjustment patterns (frequency and size) evolve over time (section A). We analyse how variation in the frequency and size of price changes over time contributes to inflation variation and derive some possible implications for our understanding of aggregate price dynamics (section B). Finally, we explore how the various margins of price adjustment shape the response of inflation to aggregate shocks (section C).

A Frequency and Size of Price Changes over Time

Inflation results from the aggregation of millions of individual firms' price changes. In a given month, inflation can go up because more outlets increase prices or because the size of price changes is larger on average while the number of outlets adjusting prices remains the same. Using micro price data, we can decompose the monthly product-level inflation rate as follows (see for example Klenow and Kryvtsov, 2008):

$$\pi_{jt} = f_{jt} \times dp_{jt} \quad (2)$$

[37] See Appendix D for a detailed comparison between the United States and each euro area country.

where j is a COICOP-5 product-category in given country i (i.e. subscript j refers to a product (COICOP-5)-country pair), f_{jt} is the frequency of price changes and dp_{jt} is the average of non-zero price changes of group j at date t.

We can further decompose the monthly inflation rate by splitting price changes into price increases (+) and decreases (-).

$$\pi_{jt} = f_{jt}^{+} \times dp_{jt}^{+} - f_{jt}^{-} \times dp_{jt}^{-} \qquad (3)$$

where f_{jt}^{+} is the frequency of price increases, f_{jt}^{-} is the frequency of price decreases, dp_{jt}^{+} is the average absolute size of price increases and dp_{jt}^{-} is the average absolute size of price decreases of group j at date t. From these two expressions, we can see how changes in inflation can be related to changes in the frequency or size of price adjustment.

Using frequencies and sizes calculated over time at the product level for the different countries, we can investigate the time variation of the frequency and size of price changes in the euro area. To do this, we estimate simple panel OLS regressions relating the frequency and size of price changes at the product-country level to month and year fixed effects. In particular, we estimate the following set of regressions:

$$y_{j,t} = \mu_j + \mu_m + \mu_y + \beta\, VAT_{j,t} + \epsilon_{j,t} \qquad (4)$$

where μ_j is a COICOP-5 product-country fixed effect, μ_m is a calendar month fixed effect, μ_y is a year fixed effect and $VAT_{j,t}$ is a dummy variable that controls for VAT changes in our sample. The dependent variable $y_{j,t}$ differs according to specification: it can be the overall frequency of price adjustments, the frequency of price increases, the frequency of price decreases, the absolute size of price increases and the absolute size of price decreases.

Figure 3 plots the estimates and confidence intervals of μ_m and μ_y.

[Figure 3 about here]

Two main results emerge from these regressions.

First, both the frequency and size of price changes show large seasonal movements (bottom panel), which are also visible in the aggregate time series of the frequency and size of price changes for the euro area depicted in Figures 4 and 5.[38] Seasonality in the size of price decreases (left-hand bottom panel) is slightly more pronounced than that of price increases: in January and July (and to a lesser extent in February and August),

[38] We plot the aggregate euro area statistics from 2005 to 2019 controlling for composition effects due to countries entering or exiting the sample.

price decreases are larger in absolute value terms by about 2 pp, while price increases are smaller in these months. These movements are mostly explained by seasonal sales.[39] If we exclude price changes due to sales and promotions, the pattern for both price increases and decreases persists, yet is considerably less pronounced and closer to 0. Similarly for the frequency of price changes, we find that sales in January and July also play a key role in explaining seasonality. However, when we exclude sales, we still find that the frequency of price changes is much larger in January than in other months of the year. Table 8 reports more detailed results on such an estimated "January" effect. We find that this effect is significant for 77% of products in our sample and the average weighted effect is about 8 pp for the frequency of price changes including sales and 6 pp when sales are excluded. The January effect excluding sales is much larger for price increases (4.8 pp) than for price decreases (1.2 pp). While this effect is observed in almost all countries and in all sectors, it is stronger in Austria, Luxembourg, France, Germany and Spain. This type of seasonal effect which is unrelated to seasonal sales is in line with predictions of a class of time-dependent models with a small degree of price change staggering (see Taylor, 1980 where prices are kept constant for a fixed duration). Looking at these patterns across product groups (unprocessed and processed food, NEIG, and services), we find differences across sectors.[40] Seasonal movements in the size of price changes are much larger for NEIG but disappear once sales are excluded. For the frequency of price changes, the January effect is robust to the three broad sectors (food, NEIG and services) even when we exclude sales (see Table 8). In particular, the January effect is very strong in services (+11 pp), whereas the average frequency in this sector is 6%. A recent and expanding literature studies the role of sales for shocks' transmission and for the real effects of monetary policy, with different results depending on how they model the occurrence of sales.[41] Our results emphasize that, on top of sales, there can be other seasonal patterns, like the January effect, that might deserve further investigation to gauge their effect for the transmission of shocks.[42]

[Figure 4 about here]

Second, the frequency of price changes does not show any strong upward or downward trend over the time period from 2005 to 2019. Figure 4 plots the time trends of

[39] We do not fully capture price increases following sales periods since we disregard product replacements that often occur at the end of a sales period.

[40] Detailed results are reported in Appendix Figures A16 and A17 for unprocessed and processed food, Figure A18 for NEIG and Figure A19 for services.

[41] Alvarez and Lippi (2016) and Kryvtsov and Vincent (2021) argue that temporary sales substantially reduce the real effects of monetary policy shocks, while Guimaraes and Sheedy (2011) and Kehoe and Midrigan (2015) find that sales do not matter for macro analysis.

[42] See Tenreyro and Olivei (2007) for evidence on how seasonality of wage adjustment can matter for the response to monetary policy.

frequencies of price changes (estimated using a standard HP filter) and they are quite flat over time.[43] Since the link between prices and real output in a typical Phillips curve depends on the frequency of price changes, one important implication of the stability of the frequency over time is that any change in the slope of the Phillips curve cannot be attributed to a change in the frequency of price changes. Specifically, the frequency of price changes show some movements over the years of our sample period but they are rather limited (Figure 3 top right panel). Compared with the base year 2013, the frequency of price changes is significantly higher (+1 pp) during the Great Recession when euro area inflation reached a maximum at 4.1% in July 2008 and then fell to -0.6% in July 2009. It was also lower after 2013, when the average inflation rate was pretty low in the euro area.[44] These variations are mainly driven by changes in the frequency of price increases. By contrast, the frequency of price decreases has remained quite flat. Interestingly, the picture does not change if sales prices are excluded (right-hand side of the panel). Overall, we find that the lower inflation rates observed after 2013 are associated with less frequent price increases than before 2013 (as also shown in the bottom right-hand panel of Figure 4).

As regards the average sizes of price increases and decreases, we find a small trend increase when we include sales. However, when we remove price changes due to sales or promotions, we do not find large significant changes in the size of price decreases and the size of price increases over time (Figure 5).[45] More specifically, the average size of price increases and decreases is at most 1 pp larger after 2013 compared with before. Figure A5 plots the distribution of price changes (excluding sales) before and after 2013, the shift of the distribution to the left after 2013 is pretty small. This shift leads to a higher share of decreases in all price changes and a lower share of price increases but the average sizes of price increases and decreases are affected only a little.

Taking food, NEIG and services separately, we do not find any time trend in the size of price changes in any of the three sectors. Regarding the frequency, we find that the frequency of price increases is lower over the period 2014-2019 for food and to a lower extent for services.

[Figure 5 about here]

[Table 8 about here]

[43]In the Appendix, we have reported the same figures plotting frequencies of price changes by country (Figures A13 and A14): the main conclusions are broadly consistent across countries.

[44]Here we choose 2013 as a reference since before 2013 inflation was quite close to 2% (excluding energy, 1.7% on average) whereas after 2013, inflation was pretty low (1% on average).

[45]See also Appendix Figure A15 for country-level evidence.

B Contribution of Frequency and Size of Price Changes to Inflation Variation

To investigate how variation in the frequency and variation in the size of price changes over time contribute to inflation variation, we define counterfactual inflation rates. In particular, we calculate a counterfactual inflation rate assuming that the frequency of price adjustments is constant over time (equal to its product-specific average $f_{j.}$, j referring to a pair (country-product(COICOP-5)). That is, what inflation would be if the frequency was constant and the size of price changes varies over time. The counterfactual inflation with constant frequency $\pi_{jt}^{\bar{f}}$ is defined as:

$$\pi_{jt}^{\bar{f}} = f_{j.} \times dp_{jt} \tag{5}$$

Similarly, we can define a counterfactual inflation rate where outlets only vary their probability of price changes over time and where the size of price change is equal to its product-specific average ($dp_{j.}$):

$$\pi_{jt}^{\bar{dp}} = f_{jt} \times dp_{j.} \tag{6}$$

In this case, inflation variation is only the result of movements in the frequency of price changes over time.

For each product-country pair, we can calculate the correlation between our recomposed inflation (calculated following equation (3)) and these two counterfactual inflation rates.[46] In Table 9, we report average correlation coefficients, while Figure 6 plots the distribution of correlations between counterfactual inflation and recomposed inflation both calculated at the country-product level.

The main finding of this exercise is that recomposed inflation is highly correlated with counterfactual inflation assuming constant frequency (the average correlation coefficient is about 0.8 irrespective of the inclusion of price changes due to sales). The recomposed inflation has a lower correlation with the counterfactual inflation rate that assumes a constant size of price changes (correlation coefficient of 0.4 when sales are excluded). This finding is robust across sectors and across countries. Figure 6 shows that for almost all products the correlation coefficient associated with counterfactual inflation assuming constant frequency is higher than 0.6 (left-hand panel - grey bars), while the correlation associated with counterfactual inflation assuming constant size is very widespread.[47] Table A20 in the Appendix confirms the small impact of overall

[46] The correlation of HICP inflation at the COICOP 5-digit level and our recomposed inflation rate is about 0.7 and highly significant. Overall, the recomposed inflation rates are a good approximation of the actual inflation rates (see Figure A20 in the Appendix that compares recomposed and actual inflation rates at the product level).

[47] By definition the recomposed inflation and counterfactual inflation assuming constant overall frequency have the same sign. However, this does not drive the conclusion as the correlation of the absolute values is also high.

frequency as it shows that there is a weak relation between the recomposed inflation and overall frequency (the correlation equals 0.02 when we exclude sales). Thus, most of the short-term variation in inflation is due to variation in the overall size of price changes and not due to variation in the overall frequency. This pattern of the data is consistent with the standard predictions of a Calvo model (by construction of our counterfactual inflation), but also with a menu cost model in a low-inflation environment (see Alvarez et al., 2019 or Nakamura et al., 2018). In this latter model, aggregate shocks are relatively small compared with firm-specific shocks and are less a motive for firms to change their prices. It follows from this model that movements over time in the overall frequency are very small whereas inflation varies more with the average size of non-zero price changes, which is consistent with our empirical findings.

The average size of non-zero price changes can be further decomposed as follows:

$$dp_{jt} = \alpha_{jt} \times dp^{+}_{jt} - (1 - \alpha_{jt}) \times dp^{-}_{jt} \tag{7}$$

where α_{jt} is the share of price increases among all price changes $\frac{f^{+}_{jt}}{f_{jt}}$. As emphasized also in previous literature (e.g. Nakamura and Steinsson, 2008*a*), the average size of non-zero price changes can move either because the relative frequency of price increases and decreases moves (changes in α_{jt}), or because the absolute size of price increases and decreases move (changes in dp^{+}_{jt} and dp^{-}_{jt}).

Having this in mind, we investigate further the relationship between inflation and the average size of non-zero price changes considering two other counterfactual inflation rates. The first one $\pi^{\bar{f}^{+},\bar{f}^{-}}_{jt}$ assumes that not only the overall frequency is constant, but that also the frequencies of both price increases and price decreases are constant over time. In this case, movements in counterfactual inflation are due to changes in the average absolute size of price increases and in the average absolute size of price decreases (taken separately).

$$\pi^{\bar{f}^{+},\bar{f}^{-}}_{jt} = f^{+}_{j.} \times dp^{+}_{jt} - f^{-}_{j.} \times dp^{-}_{jt} \tag{8}$$

The second counterfactual inflation $\pi^{\bar{dp}^{+},\bar{dp}^{-}}_{jt}$ assumes that the average absolute sizes of both price increases and decreases are constant over time. The variation over time will come from movements in the frequency of price increases and the frequency of price decreases (translating into changes in the overall size of price changes).

$$\pi^{\bar{dp}^{+},\bar{dp}^{-}}_{jt} = f^{+}_{jt} \times dp^{+}_{j.} - f^{-}_{jt} \times dp^{-}_{j.} \tag{9}$$

Interestingly, we find that the recomposed inflation rates are much more correlated with the counterfactual inflation assuming constant size of price increases and decreases (correlation coefficient of about 0.85) than with the counterfactual inflation rate assuming constant frequencies of price increases and decreases (correlation coefficients of less than 0.5) (Table 9). This result is very robust across sectors and across countries. Figure 6 shows that for almost all products, the correlation with the counterfactual inflation assuming constant size of price increases and decreases is higher than 0.6 (right-hand panel - white bars). Consistently, we also find weak correlations between the recomposed inflation and the size of price increases or the size of price decreases (smaller than 0.2 when excluding sales) while the correlations between the recomposed inflation and the frequency of price increases or the frequency of price decreases are larger (about 0.3) (Table A20 in the Appendix). Thus, inflation varies over time much more because of time variation in the frequency of price increases and the frequency of price decreases than because of variation in the size of price increases and the size of price decreases (in absolute values). Combining this result with that documented previously on the limited contribution of overall frequency and the large contribution of the overall size of price changes, we find that inflation is mainly driven by movements in the proportion of price increases and decreases (translating to a change in overall size) and less by changes in the overall frequency, in the average size of price increases or in the average size of price decreases. To confirm this conclusion, we define one last counterfactual inflation in which only the share of price increases α_{jt} varies over time (that is, the overall frequency, the size of price increases and the size of price decreases are fixed):

$$\pi_{jt}^{\bar{f},\bar{dp}^{+},\bar{dp}^{-}} = \alpha_{jt} \times f_{j.} \times dp_{j.}^{+} - (1-\alpha_{jt}) \times f_{j.} \times dp_{j.}^{-} \tag{10}$$

The correlation is larger than 0.6 (and is much higher for goods than for services). Changes in inflation are indeed driven to a large extent by changes in the share of price increases.

Our results are broadly in line with the previous literature. For the US, Klenow and Kryvtsov (2008) document that aggregate inflation is mainly associated with movements in the average overall size of price changes rather than the overall frequency of price changes, because of offsetting movements in the frequency of price increases and decreases. The share of price increases is a key driving force behind inflation also for Nakamura and Steinsson (2008*a*) and Nakamura et al. (2018): they find a very weak correlation (if any) of the absolute size of price increases and price decreases with inflation, while the frequency of price increases covaries strongly with inflation. When inflation is low as in our case for the euro area, Nakamura et al. (2018) explain that "*the frequency and absolute size of price changes can be relatively constant as inflation rises if the fraction of price changes that are increases is rising with inflation. In this case, the behavior of the average size and the average absolute size can be quite different.*"

Our results are also consistent with what has been described in Gagnon (2009) for Mexico and Alvarez et al. (2019) for Argentina when inflation is low (generally below 5%).

[Table 9 about here]

[Figure 6 about here]

C Dissecting Inflation Adjustment in Response to Aggregate Shocks

In our last empirical exercise, we document how the counterfactual inflation rates respond to aggregate shocks. Our aim is to investigate what margin of price adjustment is key for the inflation response. We first focus on some exogenous shocks identified in the literature for the euro area, and on country-specific VAT changes; finally, we focus on the relation between inflation and unemployment.

C.1 Exogenous Shocks

We use local projection regressions à la Jordà (2005) and we estimate the dynamic response of prices to different aggregate shocks S_t.[48] We use different types of shocks. First, some exogenous shocks identified in the literature for the euro area: monetary policy shocks as identified by Jarociński and Karadi (2020), oil supply shocks and demand shocks (global demand shocks as identified by Baumeister and Hamilton, 2019). Second, country-specific VAT changes.[49] For each shock, the estimated model is as follows:

$$\pi^*_{j,t-1,t+h} = \alpha_{j,h} + \alpha_{m,h} + \beta_h S_t + \gamma_h X_{c,t} + \epsilon_{j,t_h} \tag{11}$$

where $\pi^*_{j,t-1,t+h}$ is the cumulated inflation rate for product j (product- and country-specific) between period $t-1$ and t+h[50], $\alpha_{j,h}$ are country-product fixed effects, $\alpha_{m,h}$ are country-month fixed effects (i.e. capturing seasonal country-specific variations), and $X_{c,t}$ are country specific controls (we use one lag of monthly changes in industrial production in all versions of this equation, regardless of the shocks).[51] ϵ_{j,t_h} are i.i.d.

[48] See also Balleer and Zorn (2019) or Dedola, Kristoffersen and Zullig (2021) for a similar empirical approach using producer price data for Germany and Denmark.

[49] In Appendix F.1 we provide more details on the shock variables we use in our regressions.

[50] We run the regressions on cumulative inflation calculated as the sum of monthly inflation rates over the period going from t to $t+h$. Alternatively, we could have run them directly on the level of inflation in each period (t+i-1, t+i) (i from 0 to h) and calculated the cumulative effects as the sum of the β coefficients over the $[t, t+h]$ horizon. These two methods give the same results when the product panel is balanced over time.

[51] For regressions with monetary policy shocks, we use as controls the central bank information shock as identified by Jarociński and Karadi (2020), and 6 lags of: HICP inflation, the one-month money market interest rate, and monthly changes in industrial production; for regressions with the VAT shock, we use as control unemployment, on top of one lag of monthly changes in industrial production.

error terms and β_h measures the effects of shock S_t at horizon h after the shock. Thus, in our exercise, specific parameters of interest are β_h from which we derive the impulse response function of prices to aggregate shocks. The size of the different shocks should be interpreted as follows: the monetary policy shock is equivalent to a positive surprise in the 3-month EONIA swap rate of 25 basis points; the oil supply and global demand shocks should be interpreted as a one standard deviation shock; for VAT, it is a 1 pp increase.

The cumulated inflation rate used as dependent variable will differ according to specifications. We will use first our cumulative recomposed inflation rate as a benchmark to document the typical response of inflation to a shock. Then, we will use the four counterfactual cumulative inflation rates corresponding to the different assumptions on frequencies and average sizes of price changes.[52] We plot impulse responses functions (IRF) corresponding to the different empirical exercises in Figures 7 and 8. The top panel of Figure 7 reports IRF of prices to a contractionary monetary policy shock, while the bottom panel reports IRF to a positive oil supply shock, both of which are expected to have a negative effect on inflation.[53] The top panel of Figure 8 reports IRF to a VAT increase, while the bottom panel reports IRF to a positive global demand shock, which are expected to have a positive effect on prices.

[Figure 7 about here]

[Figure 8 about here]

The impulse response functions in column 1 of each panel, which are associated with our recomposed inflation rates, are quite in line with theoretical predictions: a contractionary monetary policy shock and a positive oil supply shock have a long-term negative effect on prices whereas the VAT and the demand shocks have both a positive long-term effect on prices (even if this effect lasts less for VAT than for other shocks). The adjustment of prices to shocks is quite protracted for all shocks except VAT and takes about two years to converge towards a long-run effect. For VAT shocks, the reaction is much quicker and visible one month after the shock.[54] This exercise on recomposed inflation will be used as a benchmark to compare the IRFs obtained with counterfactual inflation rates.

Figures 7 to 8 also show the IRF when we assume constant size of price changes (col. (2)) and constant frequency of price changes (col. (3)). We find that the response of

[52] In Appendix F.2, we provide more details on how we construct the cumulative inflation rates in these exercises.

[53] In the Appendix, Figure A22 provides results using central bank information shocks as identified by Jarociński and Karadi (2020).

[54] In a robustness analysis, we have checked that VAT-related inflation effects are not observed before the shock (because of an anticipation effect).

counterfactual inflation when we assume constant size of price changes is not statistically different from 0 for all shocks and all horizons. By contrast, when we assume constant frequency, the IRF are close to the ones obtained in the benchmark case. Overall, in response to a shock, outlets adjust the size of their price changes but not the frequency at which they change their prices (which is consistent with the unconditional decompositions in the previous subsection). These results are also in line with predictions of a standard Calvo model or a menu-cost model in a low inflation environment. As shown by Alvarez et al. (2019), in this latter case, aggregate shocks are too small compared with firms' specific shocks to be the main motive for price adjustment. Idiosyncratic shocks matter more for pricing decisions than the aggregate shock. In that case, outlets adjust to the shock through variations in the size of price adjustment. To investigate these responses further, we have also reported the response of the cumulated frequency of price changes and cumulated size of price changes to the shocks (Appendix Figure A21). As expected, we do not see any reaction of the frequency of price changes to the shocks, except for VAT shocks whereas the reaction of the size is similar to that for inflation. VAT shocks are in general larger and trigger more frequent price changes. Karadi and Reiff (2019) show that this pattern could be consistent with predictions of a menu cost model.

Figures 7 to 8 also report the results associated with counterfactual inflation assuming constant sizes of price increases and decreases (col. (4)) and constant frequencies of price increases and decreases (col. (5)). Similar to the findings in the previous subsection, the main message from these results is that the overall response to all four shocks is mainly driven by the reaction of the frequencies of price increases and decreases and not by the average size of price increases and decreases. When we assume constant sizes of price increases and decreases, the IRFs are quite close to the ones obtained in our benchmark case (col. (1)). Overall, in response to an aggregate shock, firms adjust their relative frequency of price increases and decreases (which translates into changes in the overall size of price changes), but the size of price increases and the size of price decreases are not affected by the shock. This result is also in line with predictions of a standard menu cost model in a low-inflation environment. The average sizes of price increases and decreases mainly depend on idiosyncratic shocks, but the aggregate shock will still shift the price change distribution, mostly via its impact on the share of price increases and decreases.

Interestingly, the IRFs are quite similar whether or not sales are excluded (see Figures A23 and A24 in the Appendix). To investigate further how sales respond to shocks, we have also calculated a measure of sales inflation as the difference between the recomposed inflation rate when sales are included and the one when they are excluded.

We have run the same type of regressions linking sales inflation to our different shocks. Figure 9 plots the results. Monetary, oil supply and VAT shocks have no significant effect on sales inflation whereas the global demand shock has a small but significant effect.

[Figure 9 about here]

In order to explore the role of sectoral heterogeneity, we split the sample between COICOP-5 categories with a relatively high frequency of price changes and those with a relatively low frequency of price changes (using the average frequency of price adjustment over the sample period for each COICOP-5). The data point towards a somewhat stronger effect of shocks for the high-frequency sample (Figures 10 and 11).

A last exercise explores the role of country heterogeneity. We run the same regressions but restrict the sample to the three countries for which we have the longest time series: France (2003-2019), Austria (2000-2017) and Greece (2002-2019). Figures A25 and A26 in the Appendix plot the results which are very close to those obtained with all euro area countries.

C.2 Unemployment

We now focus on the reduced-form relation between inflation and unemployment, a crucial object for central banks, as the trade-off between unemployment and inflation is at the core of the monetary policy transmission mechanism.

First of all, we perform a similar exercise as for the exogenous shocks, estimating equation (11) with country-specific observed unemployment as shock S.[55] We obtain results in line with what we have documented in Figures 7 and 8 (see the top panel of Figure 12). However, unemployment cannot be reasonably considered exogenous; hence, to account for endogeneity and obtain causal effects of unemployment on inflation we resort to the method introduced by Barnichon and Mesters (2021). We estimate what they call Phillips multipliers, i.e. a non-parametric measure of the average change in inflation caused by a change in policy that increases the unemployment rate by 1 pp on average over the next h periods. Hence, following Barnichon and Mesters (2021), for each horizon h we estimate the equation:

$$\sum_{k=0}^{h} \pi^*_{j,t+k} = \alpha_{j,h} + \alpha_{M,h} + \beta_h \sum_{k=0}^{h} u_{c,t+h} + \gamma_h X_{c,t} + \epsilon_{j,t_h} \tag{12}$$

[55] In this specification we use as controls 4 lags of monthly changes in unemployment, on top of one lag of monthly changes in industrial production.

where the cumulative country unemployment $\sum_{k=0}^{h} u_{c,t+k}$ is instrumented by the same monetary policy shock adopted previously. $\alpha_{j,h}$ are country-product fixed effects, $\alpha_{M,h}$ are month fixed effects, $X_{c,t}$ are 12 lags of the country-specific unemployment level and π^* will differ depending on the specification: it can be either our recomposed inflation rate or one of the four counterfactual inflation rates. The Phillips multipliers are the β_h's parameters (one for each horizon h); we plot the Phillips multipliers for the five specifications in the bottom panel of Figure 12.

[Figure 12 about here]

The Phillips multipliers plotted in column 1 of the panel refer to recomposed inflation, and are in the same ballpark as the estimates obtained for euro area core inflation in Eser et al. (2020), where the authors use an analogous methodology with aggregate time series data. At horizons larger than or equal to 6 months the Phillips multiplier is estimated to be negative, in line with theory, with a coefficient around or slightly smaller (in absolute value) than -0.1.

The graphs in columns 2 to 4 confirm our previous findings. First of all, counterfactual inflation when we assume constant size of price changes does not significantly move with unemployment; instead, when we assume constant frequency, the Phillips multiplier is significantly negative. Second, the overall response of inflation to unemployment is mainly driven by the reaction of the frequencies of price increases and decreases and not by the sizes of price increases and decreases.

IV Conclusion

In this paper, we document several new stylised facts on consumer price rigidity in the euro area, following a harmonised approach in compiling price change statistics based on national CPI micro price spells in 11 euro area countries.

First, prices in the euro area are sticky: the average monthly frequency of consumer price changes is 12%, with limited heterogeneity across countries. In contrast, cross-sectoral heterogeneity is much more pronounced: each month, 6% of prices in services change whereas this number increases to about one third for unprocessed food. We also find that the cost structure matters for how often prices change: in particular, all other things being equal, the price of a product changes less often if the share of labour costs is larger. Comparing our results with previous literature, we find that prices in the US are updated more frequently than in the euro area, but the difference is mainly due to sales[56], and that the frequency of price changes for the euro area seems to be

[56] Once we exclude price changes due to sales, the degree of price rigidity is fairly similar in the two economies.

higher in the period 2011-2017 than in the period 1996-2001.[57]

Second, in our sample, idiosyncratic shocks play a larger role in pricing decisions than aggregate shocks: the median price increase is 9.6% in the euro area, whereas the median price decrease is 13.0%. Dispersion of the median price change is rather limited across euro area countries but larger than the differences observed for frequencies. Differences across sectors are large: the median price increase (resp. decrease) is about 6% (8%) for services and 14% (19%) for industrial goods; these differences are much smaller when we exclude sales. We also document that the distribution of price changes is highly dispersed and includes both very small and very large price changes. Furthermore we find that this distribution of price changes is rather asymmetric around 0: small price increases are more common than small price decreases. This is especially true in services, which might reflect the relatively higher relevance of aggregate nominal shocks (like aggregate wages) compared with idiosyncratic shocks as a motive for price change in that sector. In comparison with US evidence, we find that price changes are somewhat larger in the United States than in the euro area when all price changes are included but the difference is much smaller when price changes due to sales are excluded.

Third, over time, the degree of price rigidity in the euro area has remained quite stable from 2005 to 2019. The frequency of price changes in particular shows no clear trend over the years, and it has not contributed to steepening or flattening the Phillips curve over the last 15 years. Yet, the frequency of price changes shows some variation over time. First, price changes are more frequent in certain months of the year: in January, the frequency of price changes (when excluding sales) is 6 pp higher than in other months and this seasonality is mostly due to price increases. This can matter for monetary transmission if the seasonal synchronization of price changes makes them react more to aggregate shocks. Second, the repricing rate is also mildly cyclical: compared to 2013, it was around 1 pp higher in 2008-09 and 1 pp lower in 2014-17. If we decompose monthly inflation variation into variation in the frequency and variation in the size of price changes, we find that variation in the overall average size of price changes contributes more to movements in inflation than the variation in the overall frequency. When we look at price increases and price decreases separately, we find that changes in the overall size are mainly driven by the relative share of price increases among all price changes rather than by the average absolute sizes of price increases and price decreases. A similar picture emerges if we look at the response of inflation to different aggregate shocks (monetary policy, oil supply, VAT changes, real demand

[57]Compared with Dhyne et al. (2006), the only comprehensive study on moments of micro price adjustments in the euro area available so far, we find that the frequency of price changes for the same set of 50 products is about 2.4 pp higher in the period 2011-2017 than in the period 1996-2001 covered in Dhyne et al. (2006).

shocks): firms respond to shocks by adjusting the overall size of price changes rather than their overall frequency, generating more frequent price increases and less frequent price decreases in response to a positive shock, whereas the average absolute size of price increases and decreases are not affected by the shocks. Overall, aggregate shocks are transmitted via slow movements in the relative share of price increases and decreases. Taken together, these findings are consistent with the predictions of a standard Calvo model and a menu cost model in a low inflation regime where aggregate shocks play a limited role compared to idiosyncratic shocks.

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Tables and Figures

Table 1: CPI Micro Database with Country-Specific Periods

Country	Code	Data Source	Period	% of EA products[a]	% of EA HICP[b]	Sales flag	Number of obs.[c]
Austria	AT	Statistik Austria (2017)	2000M1-2017M12	89.2	3.4	Yes	8.3M
Belgium	BE	Statbel (2018)	2007M1-2015M12	42.5	3.8	Yes	8.5M
France	FR	INSEE (2019)	2003M4-2019M9	83.2	20.3	Yes	25.0M
Germany	DE	Destatis (2019)	2010M1-2019M12	86.9	27.9	Yes	46.8M
Greece	GR	ΕΛΣΤΑΤ (2019)	2002M1-2019M12	64.0	2.2	No	7.7M
Italy	IT	ISTAT (2018)	2011M1-2018M12	61.1	17.3	Yes	22.7M
Latvia	LV	CSP (2019)	2017M1-2019M12	92.5	0.3	Yes	0.7M
Lithuania	LT	Lietuvos Statistika (2018)	2010M1-2018M12	82.3	0.5	Yes	5.4M
Luxembourg	LU	Statec (2017)	2005M1-2017M12	97.0	0.3	No	1.2M
Slovakia	SK	ŠÚSR (2020)	2011M1-2019M12	94.1	0.8	No	8.3M
Spain	SP	INE (2018)	2008M1-2018M2	52.4	11.5	No	1.4M
Total			2000M1-2019M12	58.9	88.3		135.8M

Notes: ***(a):*** *% of EA products covered by the country-specific national price data set, expressed in terms of euro area product weights at the COICOP-5 level (2017-2020 average). For the euro area, we report the coverage of the common sample (see Table A1).* ***(b):*** *Country weights in euro area HICP (2017-2020 average).* ***(c):*** *OBS denotes the total number of monthly observations (in millions) (see Appendix A.1 for details).*

Table 2: Frequency of Price Changes (in %)

	Average frequency			**Median frequency**			**% of sales**	
	Including sales	**Excluding sales**		**Including sales**	**Excluding sales**			
		NSI flag	Sales filter		NSI flag	Sales filter	NSI flag	Sales filter
EURO AREA	**12.3**	**8.5**	**7.9**	**9.6**	**5.7**	**5.6**	**3.8**	**4.7**
by Sector								
Unprocessed Food	31.4	23.9	19.8	29.3	20.2	18.2	5.7	8.7
Processed Food	15.4	10.4	9.1	14.4	8.5	7.8	3.3	5.5
NEIG	12.9	6.4	6.7	11.9	5.1	5.6	8.1	7.9
Services	6.0	5.7	5.5	3.2	3.0	3.0	0.2	0.9
COUNTRY								
Austria	11.1	7.2	7.0	8.1	5.3	5.3	5.1	4.2
Belgium	14.5	13.3	11.0	6.6	6.6	4.9	1.1	3.8
France	12.6	9.8	8.0	11.3	7.9	5.7	3.2	5.0
Germany	12.7	9.2	8.1	8.9	4.5	5.4	4.1	4.2
Greece	11.3	7.3	7.3	9.2	6.4	6.4	.	3.8
Italy	10.3	4.8	6.1	7.9	4.1	5.5	4.3	5.4
Latvia	18.6	7.9	11.1	10.4	3.8	5.2	10.7	7.5
Lithuania	12.8	9.7	9.3	9.3	6.7	7.9	2.3	5.3
Luxembourg	14.1	8.8	8.8	10.9	6.0	6.0	.	4.6
Slovakia	14.3	9.3	9.3	9.9	7.9	7.9	.	4.9
Spain	13.5	9.0	9.0	11.2	7.0	7.0	.	5.1

Notes: Statistics are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries. Price changes due to replacement are excluded beforehand (except Greece and Slovakia). Seasonal sales are excluded in the Belgian dataset but temporary promotions are included. Results excluding sales are based on ***(a)*** *NSI sales flag (if available, and sales filter otherwise) or* ***(b)*** *common sales filter for all countries.*

Table 3: Some Determinants of the Frequency of Price Changes in the Euro Area

	I	II	III	IV
Share of labour costs	-0.221***	-0.510***	-0.302***	-0.121**
Share of imported energy and raw material inputs	0.786***	0.881***	1.611***	-0.296
Share of all imported inputs	-0.149	-0.172	-0.066	-0.195
% of online consumers	0.0001	0.0007*	0.0010**	0.0001
Regulated price dummy	-0.002		-0.011	0.007
Retail market concentration (HHI)		0.0032***		
Unprocessed food dummy				0.131***
Processed food dummy				0.033***
Services dummy				-0.046**
Constant	0.186***	0.281***	0.187***	0.190***
Country dummies	✓	✓	✓	✓
Number of observations	1,620	1,293	1,620	1,620
R^2	0.211	0.346	0.268	0.358

*Notes: All regressions are estimated using OLS and are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries. Standard errors are clustered at the product level. *, **, and *** denote significance at respectively 10%, 5%, and 1%. The dependent variable in Column I is the frequency of price changes excluding sales and excluding product replacements (for Greece, Luxembourg, Slovakia, and Spain sales are excluded via the sales filter, Greece and Slovakia include product replacements). Column II adds the Herfindahl–Hirschman Index (HHI) of the retail sector as explanatory variable. This regression uses fewer observations as the HHI is not available for all products (e.g., non-retail products). The regulated price dummy is not included in this regression as there is only one observation available for estimation. In Column III the dependent variable is the frequency of price changes including sales and excluding product replacements (instead of excluding sales and excluding product replacements). Column IV adds sector dummies to the regression in Column I. The reference sector is NEIG.*

Table 4: Size of Price Changes (in %)

	Including sales		**Excluding sales** (NSI sales flag if available)		**Excluding sales** (Sales filter)	
	Median		Median		Median	
	Increase	Decrease	Increase	Decrease	Increase	Decrease
EURO AREA	**9.6**	**13.0**	**6.7**	**8.7**	**7.2**	**10.8**
by Sector						
Unprocessed Food	12.6	15.0	10.0	10.9	10.7	11.9
Processed Food	9.2	12.0	5.8	6.5	5.9	7.1
NEIG	13.8	19.1	7.8	10.7	8.9	14.2
Services	5.6	8.2	5.5	7.8	5.7	9.8
COUNTRY						
Austria	10.4	14.6	6.9	8.7	7.3	10.8
Belgium	7.0	8.2	6.6	7.5	6.6	7.3
France	7.7	11.9	5.0	7.2	5.6	9.6
Germany	11.6	16.1	8.4	11.0	8.9	12.9
Greece	9.6	12.8	8.0	11.4	8.0	11.4
Italy	9.1	11.4	4.4	5.5	5.4	10.0
Latvia	15.9	14.8	7.9	6.2	11.5	11.8
Lithuania	13.5	17.2	11.8	12.8	10.6	12.1
Luxembourg	7.5	10.7	5.5	7.8	5.5	7.8
Slovakia	10.5	11.1	9.2	8.5	9.2	8.5
Spain	8.9	11.1	8.1	10.4	8.1	10.4

Notes: Statistics are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries. Price changes due to replacement are excluded beforehand (except Greece and Slovakia). Seasonal sales are excluded in the Belgian dataset but temporary promotions are included. Results excluding sales are based on ***(a)*** *NSI sales flag (if available, and sales filter otherwise) or* ***(b)*** *common sales filter for all countries.*

Table 5: Distribution of (Non-Zero) Price Changes

	Percentiles (in %)						% of
	5th	10th	25th	75th	90th	95th	$\lvert dp\rvert < 2\%$
				Including sales			
EURO AREA	**-29.1**	**-20.9**	**-9.5**	**9.6**	**20.8**	**28.3**	**11.5**
by Sector							
Food	-32.7	-24.3	-10.7	11.7	24.3	32.4	10.8
NEIG	-43.5	-34.5	-20.5	9.0	25.2	34.8	8.2
Services	-14.6	-7.4	0.3	8.4	14.6	20.1	14.3
COUNTRY							
Austria	-28.4	-21.4	-10.6	9.4	20.5	28.0	10.3
Belgium	-20.2	-12.9	-3.9	9.1	17.7	24.7	11.5
France	-27.8	-20.2	-9.2	5.8	16.2	23.2	16.6
Germany	-30.8	-23.4	-11.7	9.9	21.7	29.3	8.9
Greece	-23.6	-18.9	-8.6	13.4	22.3	26.9	8.1
Italy	-34.0	-22.7	-9.0	12.6	26.5	35.3	10.8
Latvia	-26.2	-19.8	-11.3	16.0	31.2	41.6	8.2
Lithuania	-32.4	-23.8	-10.6	17.1	30.0	37.9	5.1
Luxembourg	-17.7	-11.4	-3.4	9.4	17.4	25.4	10.8
Slovakia	-29.9	-20.5	-7.4	14.3	26.0	37.1	7.3
Spain	-24.2	-16.6	-7.5	9.5	18.2	24.9	11.3
				Excluding sales			
EURO AREA	**-20.7**	**-13.1**	**-4.3**	**8.4**	**15.7**	**22.0**	**14.8**
by Sector							
Food	-20.9	-14.0	-5.6	8.3	15.4	21.8	14.9
NEIG	-29.8	-20.5	-8.9	8.8	17.9	25.6	14.4
Services	-12.9	-6.2	0.5	8.2	14.1	19.1	14.8
COUNTRY							
Austria	-19.8	-12.7	-4.1	9.0	16.7	23.1	12.4
Belgium	-17.3	-10.6	-3.2	8.6	15.7	22.1	12.5
France	-16.4	-10.5	-3.0	6.2	11.9	16.6	20.8
Germany	-22.7	-15.0	-5.5	9.8	17.8	24.2	12.1
Greece	-21.7	-17.0	-6.6	11.9	20.7	25.1	9.6
Italy	-22.0	-11.9	-2.4	7.6	14.9	22.6	15.4
Latvia	-12.2	-6.8	-1.2	10.8	18.9	25.5	15.7
Lithuania	-27.6	-18.8	-5.4	13.6	25.6	34.7	8.3
Luxembourg	-11.5	-6.8	-0.0	7.4	14.2	21.5	15.3
Slovakia	-24.5	-14.8	-1.9	16.6	28.2	39.0	7.3
Spain	-22.6	-15.1	-6.4	8.6	16.2	22.8	13.1

Notes: Statistics are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries. Price changes due to replacement are excluded beforehand (except Greece and Slovakia). Seasonal sales are excluded in the Belgian dataset but temporary promotions are included. Results excluding sales are based on NSI sales flag (if available, and sales filter otherwise).

Table 6: Frequency and Size of Price Changes in % – Comparison with Dhyne et al. (2006) Based on 43 Products

	Dhyne et al. (2006) (1996-2001): core items (43 products)				2011-2017: core items of available products			
Average frequency of price changes								
	Proc. Food	NEIG	Services	Total Core	Proc. Food	NEIG	Services	Total Core
Euro area-5	13.6	9.4	5.0	7.8	15.6	13.1	6.2	9.9
Austria[a]	17.0	8.5	8.8	9.7	21.1	19.7	11.8	15.7
Belgium[b]	18.3	3.5	2.6	5.5	22.1	6.6	4.1	8.0
France[a]	20.2	16.8	6.4	12.0	24.6	18.6	5.3	12.7
Germany[b]	9.7	7.1	4.8	6.2	11.0	13.4	7.0	9.6
Italy[b]	10.6	5.9	3.6	5.4	9.9	6.4	5.5	6.5
Median size of price increases								
	Proc. Food	NEIG	Services	Total Core	Proc. Food	NEIG	Services	Total Core
Euro area-5	6.6	8.5	6.3	7.1	8.1	9.5	5.9	7.4
Austria[a]	12.1	10.2	5.9	8.2	17.3	11.8	5.2	9.0
Belgium[b]	6.7	6.4	7.0	6.8	4.6	11.3	4.6	6.9
France[a]	3.9	8.7	4.3	5.7	2.8	15.4	4.4	7.8
Germany[b]	7.7	9.4	5.1	6.8	14.1	7.8	6.5	7.9
Italy**	6.8	7.1	10.5	8.8	4.3	4.7	7.1	5.9
Median size of price decreases								
	Proc. Food	NEIG	Services	Total Core	Proc. Food	NEIG	Services	Total Core
Euro area-5	7.4	11.7	10.4	10.4	9.6	13.2	8.1	9.9
Austria[a]	12.7	13.2	9.0	10.9	20.6	15.8	7.2	11.8
Belgium[b]	7.0	8.0	6.7	7.2	3.9	14.3	4.7	7.8
France[a]	4.5	14.3	6.3	8.7	2.7	21.0	7.5	11.2
Germany[b]	9.4	12.7	13.5	12.7	17.1	10.3	8.8	10.4
Italy[b]	6.6	7.6	11.3	9.4	5.1	7.7	8.7	7.8

Notes: (a): Price changes including sales; (b): Price changes excluding sales (except for Processed Food in Germany). Price changes include substitutions (except for Belgium). Euro area-5 refers to Austria, Belgium, Germany, France and Italy. Only products available in both sample periods are included in the comparison and results are aggregated using country-specific product weights to product groups and then product-group weights (average of 2011-17) to the "Total core".

Table 7: Price Rigidity Statistics: Euro Area vs United States

	Frequency		Share of increases		Average size price changes: Increases		Average size price changes: Decreases	
	Incl. sales	Excl. sales[a]	Incl. sales	Excl. sales[a]	Incl. sales	Excl. sales[a]	Incl. sales	Excl. sales[1]
Aggregate								
United States	19.3	10.0	62.0	71.1	17.8	10.6	21.6	13.4
Euro Area	12.3	8.5	64.0	68.8	12.3	8.9	16.2	11.6
by Sector								
Unprocessed Food								
United States	42.8	29.3	53.1	58.4	27.5	18.9	30.0	20.6
Euro Area	31.4	24.0	54.5	57.6	16.7	12.7	18.9	13.7
Processed Food								
United States	26.3	12.0	55.3	66.3	24.4	11.5	28.1	15.8
Euro Area	15.4	10.4	57.0	61.8	12.3	7.8	14.5	8.8
NEIG								
United States	22.0	5.7	46.9	66.0	21.6	9.8	26.4	12.1
Euro Area	12.9	6.4	48.2	59.8	17.1	10.5	22.0	13.9
Services								
United States	8.9	8.6	78.9	80.1	9.5	9.1	12.8	11.7
Euro Area	6.0	5.7	82.5	82.4	7.5	7.4	11.8	10.7

	Distribution of size of price changes: 25th		50th		75th	
	Incl. sales	Excl. sales[a]	Incl. sales	Excl. sales[a]	Incl. sales	Excl. sales[a]
Aggregate						
United States	7.2	5.2	14.2	10.7	25.4	20.1
Euro Area	6.0	3.9	10.9	7.0	18.8	12.5
by Sector						
Unprocessed Food						
United States	11.7	9.9	22.4	17.6	38.5	30.9
Euro Area	6.9	5.8	13.4	10.5	25.4	18.2
Processed Food						
United States	8.2	5.1	17.7	10.4	35.6	23.9
Euro Area	4.7	3.3	10.2	5.9	19.4	10.5
NEIG						
United States	10.2	6.5	19.5	14.4	31.8	25.7
Euro Area	9.8	4.6	17.2	8.7	27.6	15.7
Services						
United States	3.4	3.4	6.7	6.6	12.5	11.8
Euro Area	3.3	3.2	5.7	5.6	10.1	9.7

Notes: U.S. product results are taken from Nakamura and Steinsson (2008a). Euro area statistics are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries. Price changes due to replacement are excluded beforehand (except Greece and Slovakia). (a) Results excluding sales are based on NSI sales flag, if available, or common sales filter.

Table 8: "January Effect" on the Frequency of Price Changes

	Including sales			Excluding sales		
	Average effect	Products with a significant Jan effect		Average effect	Products with a significant Jan effect	
		N	% HICP		N	% HICP
EURO AREA						
Price changes	0.082	109	77.2	0.060	120	85.3
Price decreases	0.036	92	68.0	0.012	72	55.5
Price increases	0.046	100	70.5	0.048	104	70.7
By Sector (price changes)						
Food	0.014	21	41.5	0.019	36	66.3
NEIG	0.106	49	85.0	0.028	44	84.6
Services	0.113	39	96.4	0.114	40	99.3
COUNTRY (price changes)						
Austria	0.121	77	72.4	0.096	74	64.7
Belgium	0.012	34	62.2	0.013	34	61.6
France	0.094	109	80.9	0.061	91	66.0
Germany	0.072	69	54.1	0.065	62	45.2
Greece	0.008	56	42.1	0.007	60	42.9
Italy	0.079	77	57.8	0.010	58	54.9
Lithuania	0.035	28	24.8	0.041	29	21.6
Luxembourg	0.146	71	52.0	0.137	69	51.7
Latvia	0.014	38	32.0	0.010	28	23.0
Slovakia	0.042	65	61.1	0.036	65	62.3
Spain	0.063	59	52.9	0.066	65	58.1

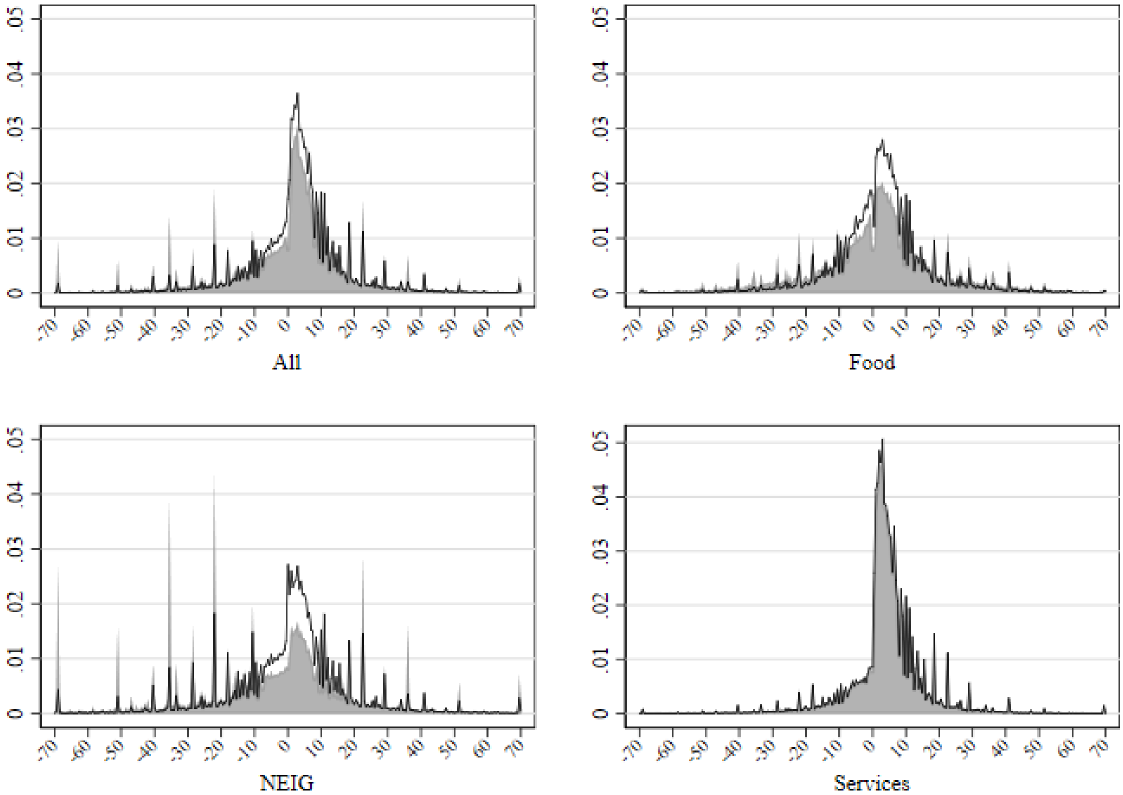
Notes: The table shows, the (weighted) average size of significant January-dummy coefficients of the COICOP-specific month-year regressions on the frequency of price changes (cols 1 and 4), the absolute number (cols 2 and 5) and weighted share of COICOP-5 groups for which the coefficient is positive and significant (cols 3 and 6). Statistics are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries and calculated using euro area product weights at the COICOP-5 level (2017-2020 average) and country weights in euro area HICP (2017-2020 average). Total COICOP-5 categories: 166. Price changes due to replacement are excluded beforehand (except Greece and Slovakia). Seasonal sales are excluded in the Belgian data set but temporary promotions are included. Results excluding sales are based on NSI sales flag if available and common sales filter otherwise. Outliers adjusted beforehand.

Table 9: Cross-Correlation between Recomposed Inflation and Counterfactual Inflation Rates

	$\pi_{jt}^{\bar{f}}$	$\pi_{jt}^{\bar{dp}}$	$\pi_{jt}^{\bar{f}^+,\bar{f}^-}$	$\pi_{jt}^{\bar{dp}^+,\bar{dp}^-}$	$\pi_{jt}^{\bar{f},\bar{dp}^+,\bar{dp}^-}$
EURO AREA					
π_{jt} (incl. sales)	0.813	0.340	0.444	0.850	0.672
π_{jt} (excl. sales)	0.773	0.411	0.427	0.846	0.618
By Sector					
Unprocessed food	0.968	0.113	0.460	0.889	0.865
Processed food	0.933	0.207	0.312	0.820	0.786
NEIG	0.883	0.203	0.590	0.859	0.752
Services	0.658	0.569	0.396	0.853	0.505
COUNTRY					
Austria	0.728	0.400	0.402	0.809	0.585
Belgium	0.716	0.537	0.341	0.862	0.598
France	0.824	0.361	0.349	0.848	0.724
Germany	0.802	0.388	0.352	0.870	0.699
Greece	0.746	0.227	0.266	0.848	0.667
Italy	0.866	0.281	0.682	0.828	0.595
Lithuania	0.830	0.262	0.432	0.880	0.720
Luxembourg	0.745	0.338	0.589	0.843	0.566
Latvia	0.894	0.313	0.619	0.817	0.661
Slovakia	0.827	0.286	0.451	0.865	0.687
Spain	0.796	0.224	0.557	0.847	0.668

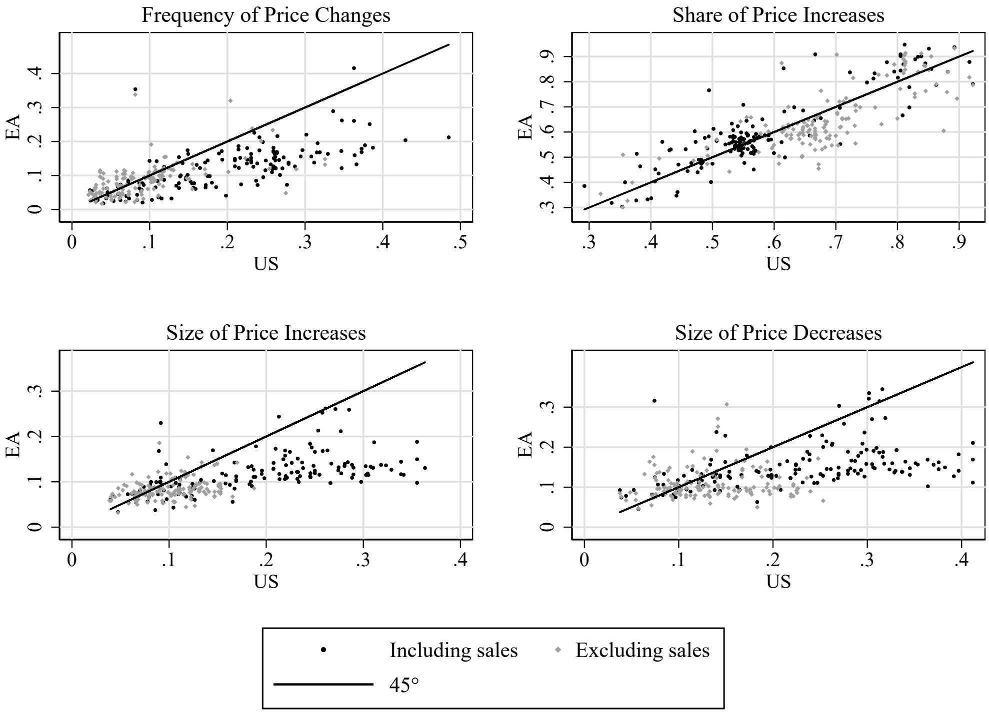
Notes: The table shows weighted average correlation coefficients between recomposed inflation (π_{jt}), as in Equation 3, and counterfactual inflation, as in Equation 5 to 10, calculated at the product(COICOP-5)-country level (more than 1,500 product-country pairs). For statistics at sectoral and country levels, calculations have been made for the case "including sales". Statistics are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries. Price changes due to replacement are excluded beforehand (except Greece and Slovakia). Seasonal sales are excluded in the Belgian dataset but temporary promotions are included. Results excluding sales are based on the NSI sales flag if available, and the common sales filter otherwise.

Figure 1: Distribution of (Log-)Price Changes (Euro Area - in %)



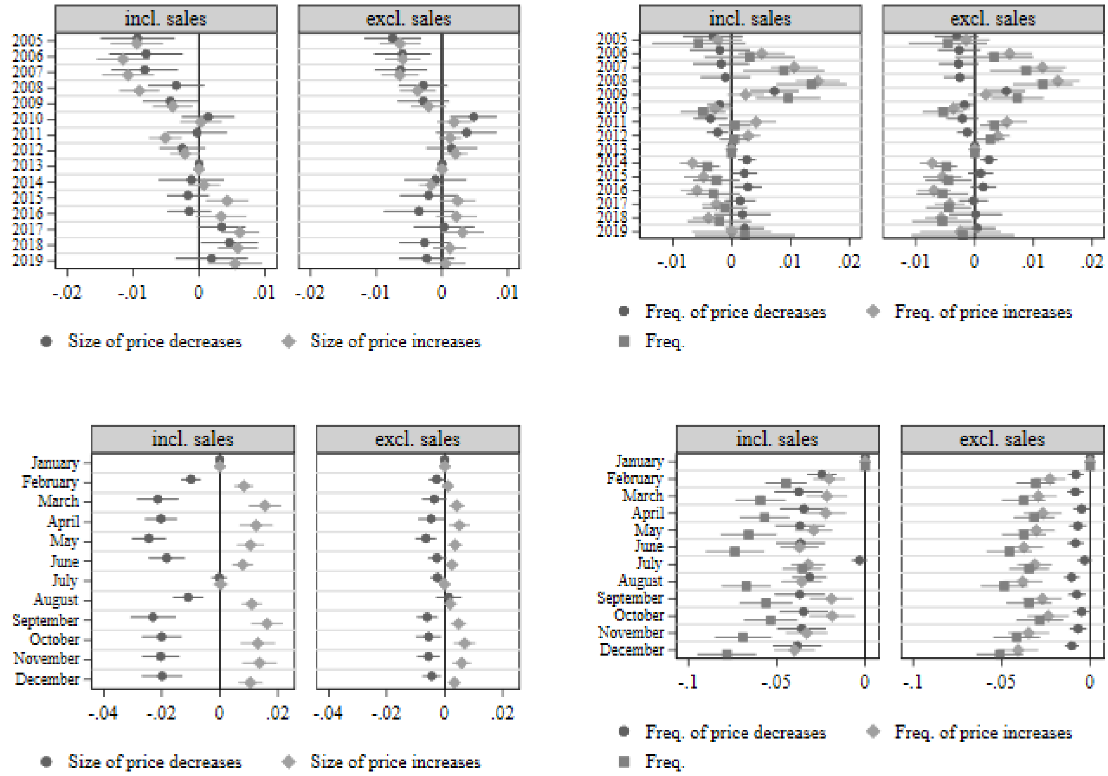
Notes: The histograms plot the distribution of price changes (dlog in %) calculated first at the country level by product for the common sample of products (bins of 0.5 pp), then aggregated at the country level using euro area product weights and then aggregated at the euro area level using HICP country weights. Grey shaded histogram corresponds to the distribution of price changes including price changes due to sales whereas the black line corresponds to the distribution of price changes excluding price changes due to sales. Results excluding sales are based on NSI sales flag if available, common sales filter otherwise.

Figure 2: Price Rigidity Statistics at the Product Level: Euro Area vs United States



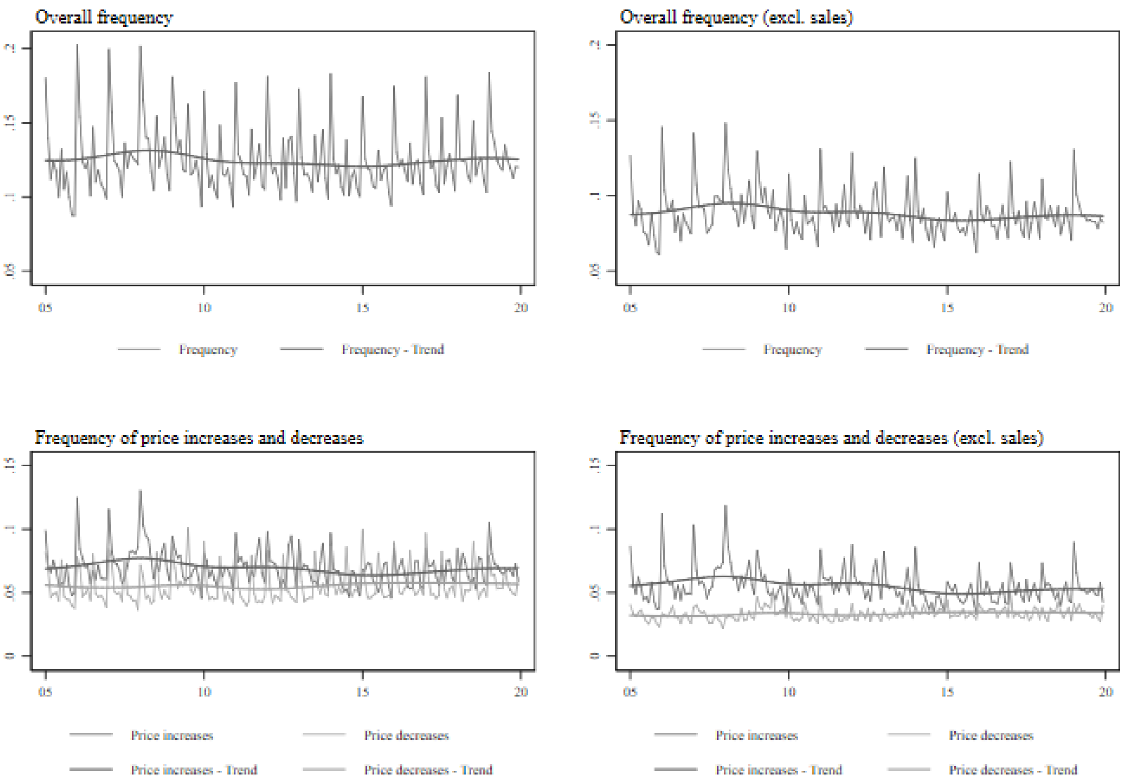
Notes: US product results are taken from Nakamura and Steinsson (2008a). Euro area statistics are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries and calculated using euro area product weights at the COICOP-5 level (2017-2020 average) and country weights in euro area HICP (2017-2020 average). Total COICOP-5 categories: 164. Price changes due to replacement are excluded beforehand (except Greece and Slovakia). Results excluding sales are based on 1) NSI sales flag if available or 2) common sales filter.

Figure 3: Frequency and Size of Price Changes over Time: Estimations of Year- and Month-Effects



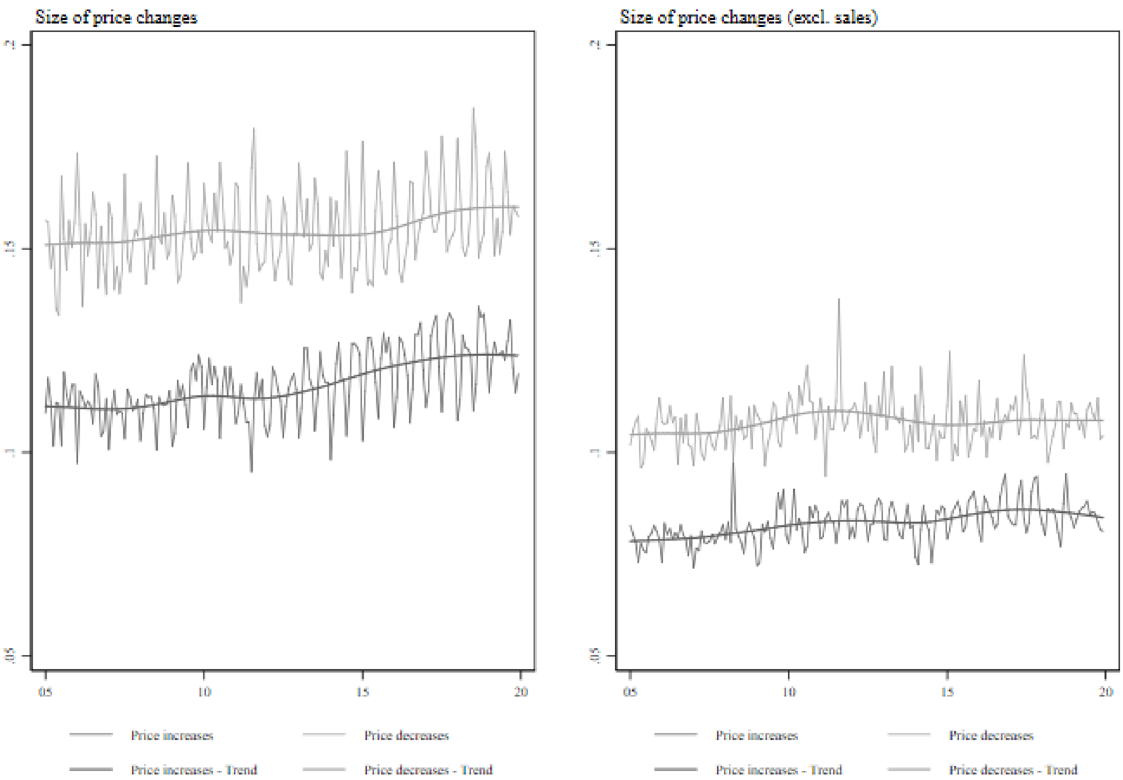
Notes: Coefficient plots from weighted panel regressions with COICOP, country, and time fixed effects and dummy for VAT changes in France (04/00, 01/12, 01/14), Italy (09/11), Slovakia (01/11), and Spain (09/12, 07-09/10), with country weights in euro area HICP (2017-2020 average) and robust standard errors. Dependent variables are frequency and size of price adjustment. Regressions are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries. Displayed are only the years 2005-2019, with the base year 2013, and base month January. Price changes due to replacement are excluded beforehand (except Greece and Slovakia). Results excluding sales are based on 1) NSI sales flag if available or 2) common sales filter. Outliers adjusted beforehand.

Figure 4: Frequency of Price Change in the Euro Area over Time



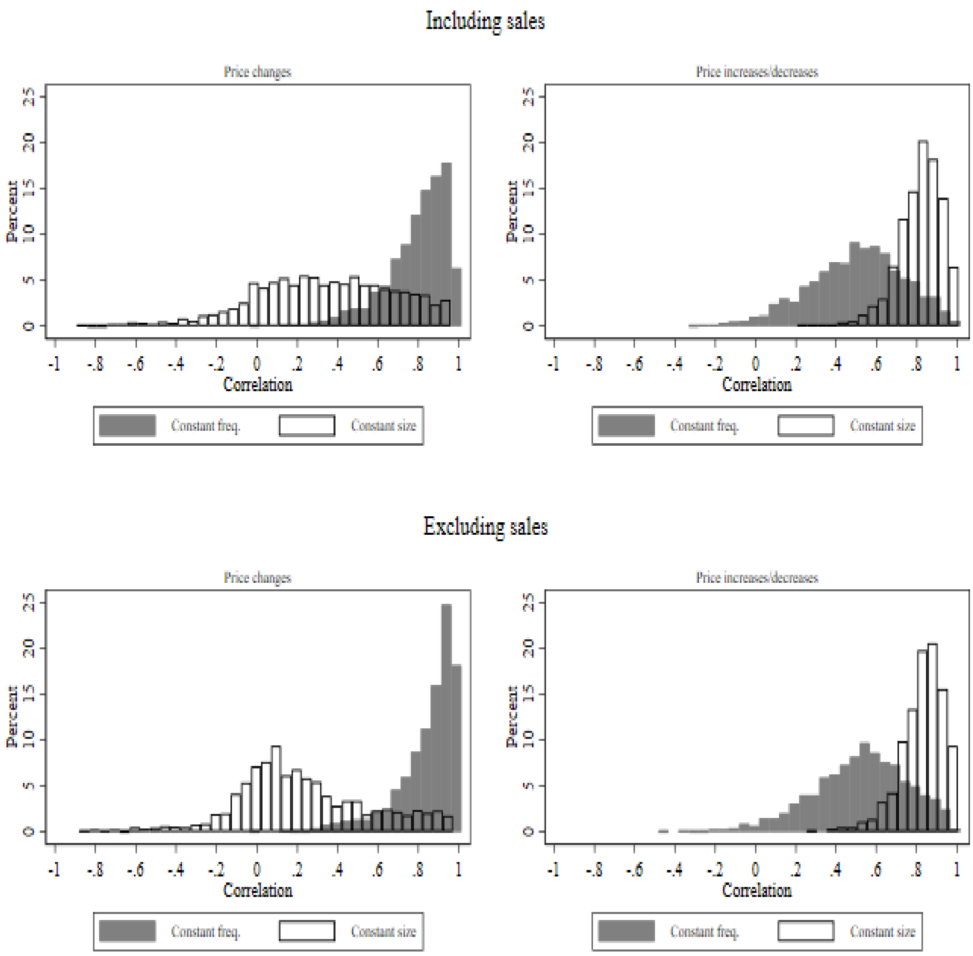
Notes: Time series are composition adjusted (using a countries' long-term weighted average) and based on products that are common to at least 3 of the 4 largest countries and calculated using euro area product weights at the COICOP-5 level (2017-2020 average) and country weights in euro area HICP (2017-2020 average). For the trend a HP filter is applied. Price changes due to replacements are excluded beforehand (except Greece and Slovakia). Results excluding sales are based on 1) NSI sales flag if available or 2) common sales filter. Outliers adjusted beforehand.

Figure 5: Size of Price Changes in the Euro Area over Time



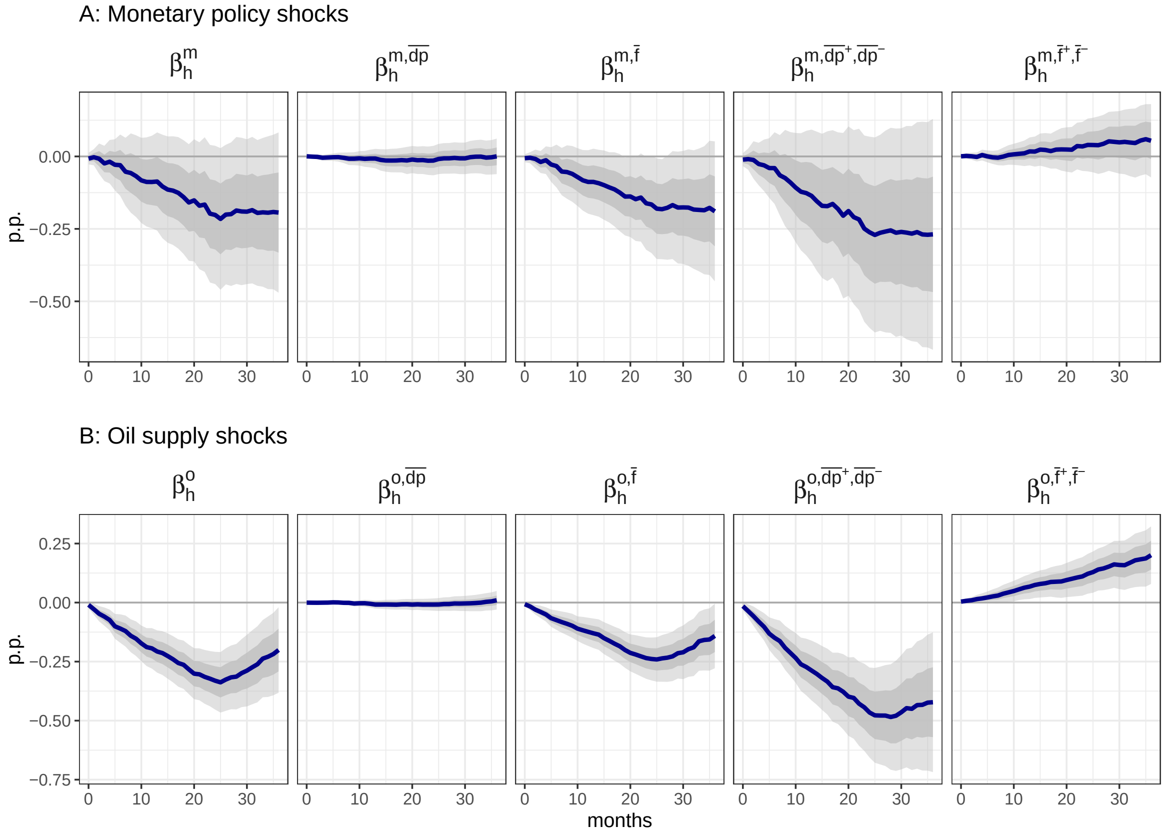
Notes: Time series are composition adjusted (using a countries' long-term weighted average) and based on products that are common to at least 3 of the 4 largest countries and calculated using euro area product weights at the COICOP-5 level (2017-2020 average) and country weights in euro area HICP (2017-2020 average). For the trend, a HP filter is applied. Price changes due to replacement are excluded beforehand (except Greece and Slovakia). Results excluding sales are based on 1) NSI sales flag if available or 2) common sales filter. Outliers adjusted beforehand.

Figure 6: Cross-Product Distribution of the Correlations between Recomposed and Counterfactual Inflation Rates



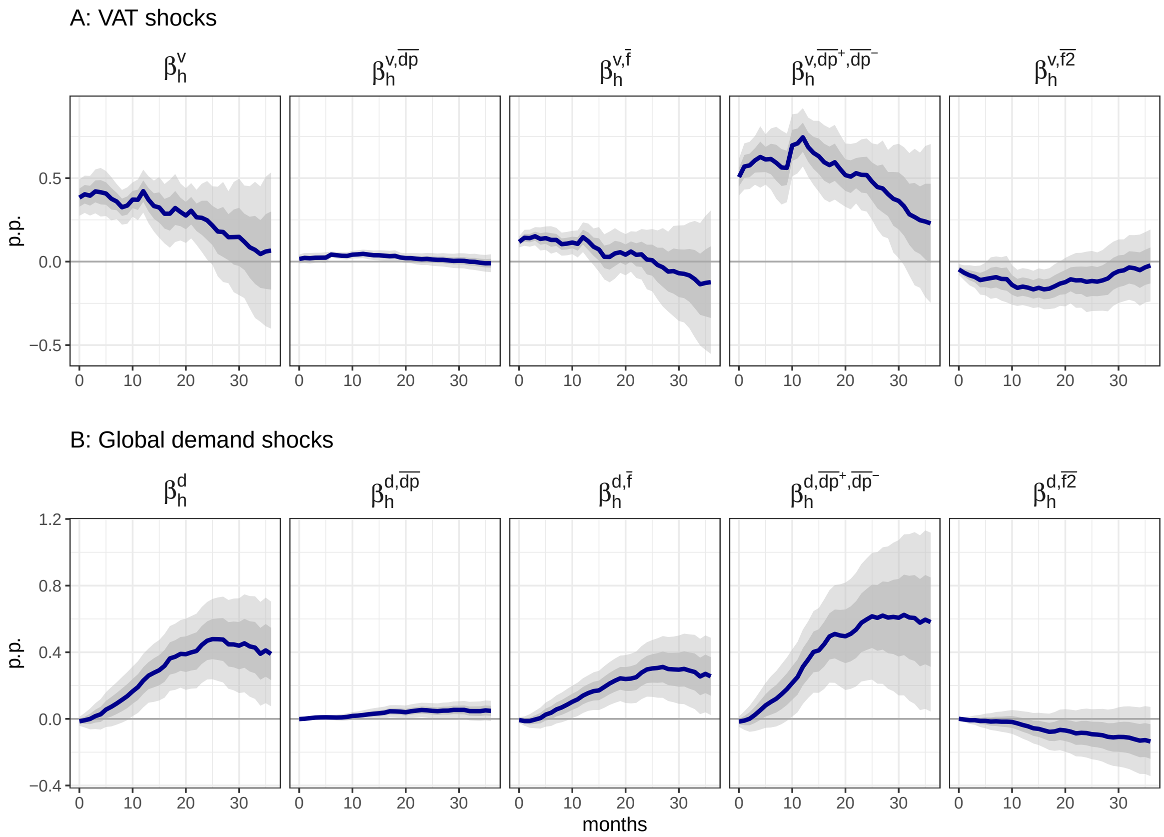
Notes: The figure plots the distribution of correlation coefficients between recomposed inflation, as in Equation 3, and counterfactual inflation, as in Equation 5 to 9. These correlation coefficients are calculated at the product(COICOP-5)-country level (more than 1,500 product-country pairs). Statistics are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries. Price changes due to replacement are excluded beforehand (except Greece and Slovakia). Outliers adjusted beforehand.

Figure 7: Conditional Responses to Positive Aggregate Shocks - Monetary Policy and Oil Supply Shocks



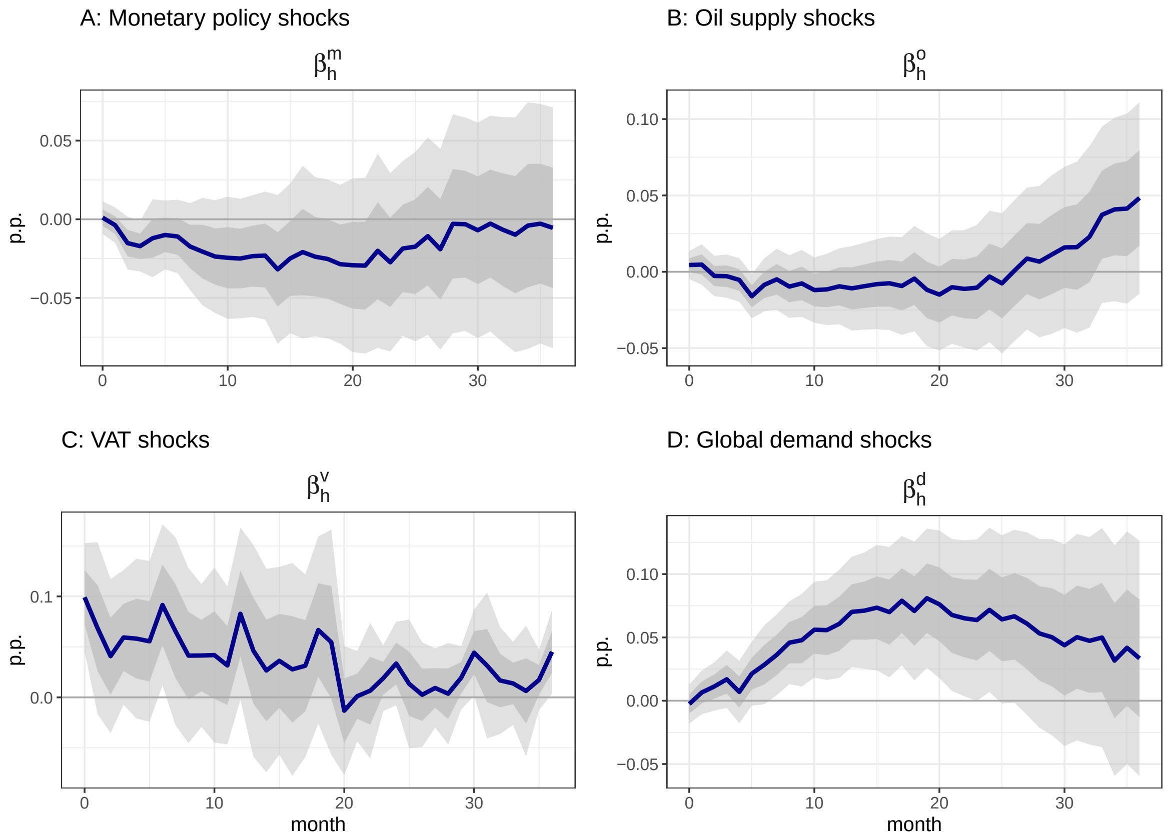
Notes: Local projections are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries. Price changes due to replacement are excluded beforehand (except Greece and Slovakia). Superscripts $x \in \{m, o\}$ *represent the monetary and oil shocks respectively. The models are specified in equation (11). In the order of the panels, the coefficients correspond to: The recomposed inflation* β_h^x*, counterfactual inflation assuming constant sizes of price changes* $\beta_h^{x,\bar{dp}}$*, counterfactual inflation assuming constant frequency of price changes* $\beta_h^{x,\bar{f}}$*, counterfactual inflation assuming constant sizes of price increases and decreases* $\beta_h^{x,\bar{dp}^+,\bar{dp}^-}$ *and counterfactual inflation assuming constant frequencies of price increases and decreases* $\beta_h^{x,\bar{f}^+,\bar{f}^-}$*. The light and dark gray areas correspond to one and two standard error bands, assuming calendar-based clusters.*

Figure 8: Conditional Responses to Positive Aggregate Shocks - VAT and Global Demand Shocks



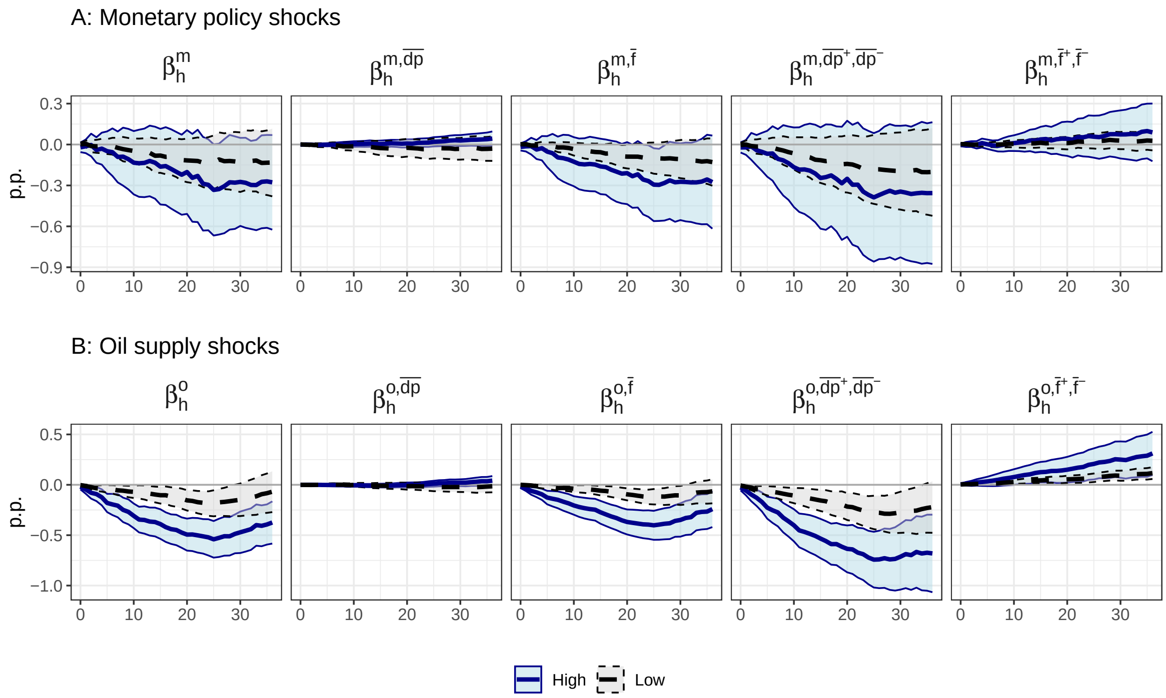
Notes: Local projections are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries. Price changes due to replacement are excluded beforehand (except Greece and Slovakia). Superscripts $x \in \{v, d\}$ represent the VAT and global demand shocks respectively. The models are specified in equation (11). In the order of the panels, the coefficients correspond to: The recomposed inflation β_h^x, counterfactual inflation assuming constant sizes of price changes $\beta_h^{x,\bar{d}p}$, counterfactual inflation assuming constant frequency of price changes $\beta_h^{x,\bar{f}}$, counterfactual inflation assuming constant sizes of price increases and decreases $\beta_h^{x,\bar{d}p^+,\bar{d}p^-}$ and counterfactual inflation assuming constant frequencies of price increases and decreases $\beta_h^{x,\bar{f}^+,\bar{f}^-}$. The light and dark gray areas correspond to one and two standard error bands, assuming calendar-based clusters

Figure 9: Conditional Responses of Sales Inflation to Aggregate Shocks



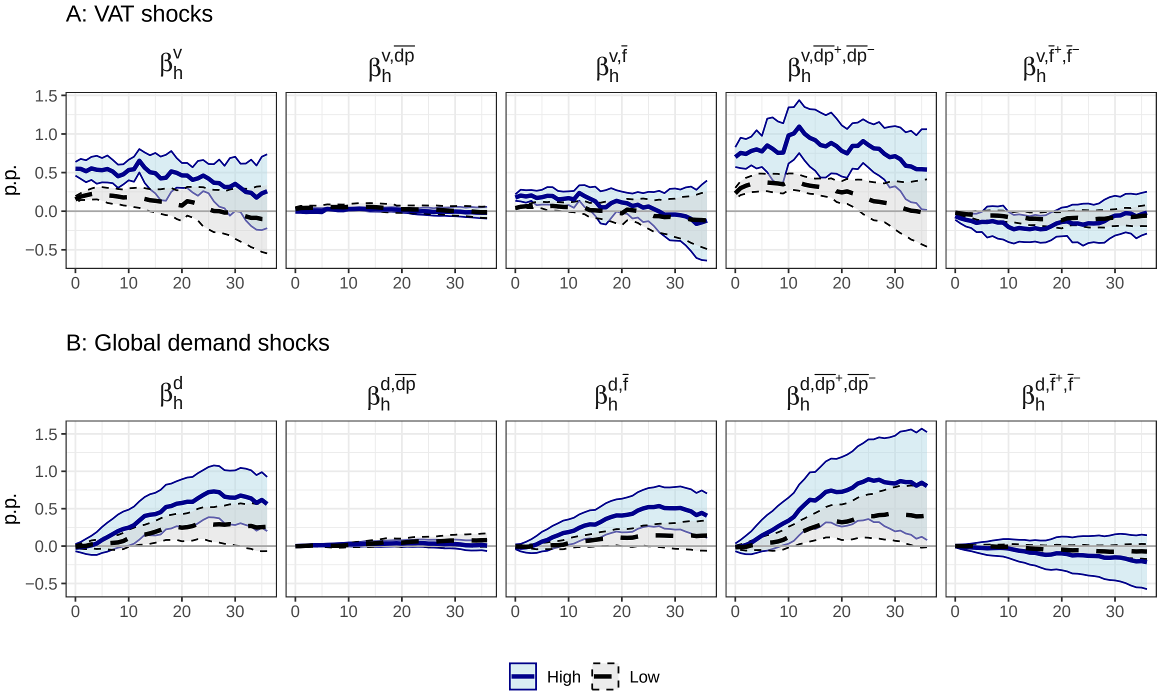
Notes: Local projections are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries. Price changes due to replacement are excluded beforehand (except Greece and Slovakia). Superscripts $x \in \{m, o, v, d\}$ *represent the monetary, oil. VAT and demand shocks respectively. The models are specified in equation* (11)*. The left-hand side variable is here a recomposed sales inflation calculated as the difference between the recomposed inflation included price changes due to sales and the recomposed inflation excluded the price changes due to sales. The figure plots coefficients* β_h^x *corresponding to the reaction of this sales inflation (cumulated between date* t *and* $t + h$*) to the different shocks. The light and dark gray areas correspond to one and two standard error bands, assuming calendar-based clusters.*

Figure 10: Conditional Responses to Positive Aggregate Shocks, Dividing the Sample between Categories with High and Low Frequency of Adjustment - Monetary Policy and Oil Supply Shocks



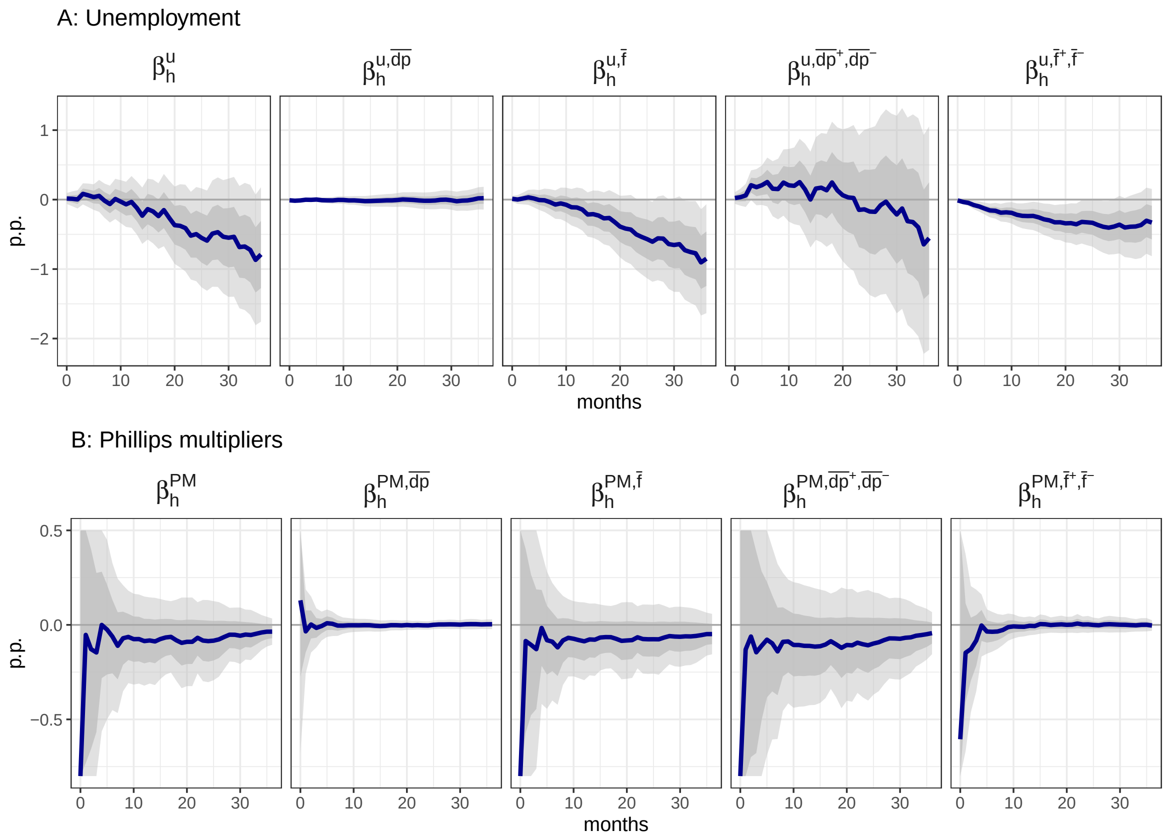
Notes: Local projections are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries. Price changes due to replacement are excluded beforehand (except Greece and Slovakia). In all panels, "High" and "Low" refer to the impulse response function of categories whose frequency of price adjustment over the considered time sample is above or below the mean value of that statistic for all categories in a country. Superscripts $x \in \{m, o\}$ represent the monetary and oil shocks respectively. The models are specified in equation (11). In the order of the panels, the coefficients correspond to: The recomposed inflation β_h^x, counterfactual inflation assuming constant sizes of price changes $\beta_h^{x,\bar{dp}}$, counterfactual inflation assuming constant frequency of price changes $\beta_h^{x,\bar{f}}$, counterfactual inflation assuming constant sizes of price increases and decreases $\beta_h^{x,\bar{dp}^+,\bar{dp}^-}$ and counterfactual inflation assuming constant frequencies of price increases and decreases $\beta_h^{x,\bar{f}^+,\bar{f}^-}$. The light and dark gray areas correspond to one and two standard error bands, assuming calendar-based clusters.

Figure 11: Conditional Responses to Positive Aggregate Shocks, Dividing the Sample between Categories with High and Low Frequency of Adjustment - VAT and Global Demand Shocks



Notes: Local projections are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries. Price changes due to replacement are excluded beforehand (except Greece and Slovakia). In all panels, "High" and "Low" refer to the impulse response function of categories whose frequency of price adjustment over the considered time sample is above or below the mean value of that statistic for all categories in a country. Superscripts $x \in \{v, d\}$ represent the VAT and global demand shocks respectively. The models are specified in equation (11). In the order of the panels, the coefficients correspond to: The recomposed inflation β_h^x, counterfactual inflation assuming constant sizes of price changes $\beta_h^{x,\bar{dp}}$, counterfactual inflation assuming constant frequency of price changes $\beta_h^{x,\bar{f}}$, counterfactual inflation assuming constant sizes of price increases and decreases $\beta_h^{x,\bar{dp}^+,\bar{dp}^-}$ and counterfactual inflation assuming constant frequencies of price increases and decreases $\beta_h^{x,\bar{f}^+,\bar{f}^-}$. The light and dark gray areas correspond to one and two standard error bands, assuming calendar-based clusters.

Figure 12: Conditional Responses to Unemployment - Local Projections and Phillips Multipliers



Notes: Estimates are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries. Price changes due to replacement are excluded beforehand (except Greece and Slovakia). Superscripts $x \in \{u, PM\}$ *are for "Unemployment" and "Phillips multiplier" respectively. Top panel corresponds to the price response to unemployment obtained from the model in equation (11) while the bottom panel corresponds to the Phillips multiplier (i.e. the measure of the average change in inflation caused by a change in policy increasing on average the unemployment rate by 1 pp). In the order of the panels, the coefficients correspond to: The recomposed inflation* β_h^x*, counterfactual inflation assuming constant sizes of price changes* $\beta_h^{x,\bar{dp}}$*, counterfactual inflation assuming constant frequency of price changes* $\beta_h^{x,\bar{f}}$*, counterfactual inflation assuming constant sizes of price increases and decreases* $\beta_h^{x,\bar{dp}^+,\bar{dp}^-}$ *and counterfactual inflation assuming constant frequencies of price increases and decreases* $\beta_h^{x,\bar{f}^+,\bar{f}^-}$*. The light and dark gray areas correspond to one and two standard error bands, assuming calendar-based clusters. Note that in panel B the y-axis is restricted from -0.8 to 0.5 pp to make the results more visible, the coefficients are estimated very poorly in the first months.*

Online Appendix for "New Facts on Consumer Price Rigidity in the Euro Area"

Erwan Gautier, Cristina Conflitti, Riemer P. Faber, Brian Fabo, Ludmila Fadejeva, Valentin Jouvanceau, Jan-Oliver Menz, Teresa Messner, Pavlos Petroulas, Pau Roldan-Blanco, Fabio Rumler, Sergio Santoro, Elisabeth Wieland, Hélène Zimmer

Date: 13th September 2023

A Data and Methods

A.1 National CPI Micro Datasets

In this section we provide basic information about each one of the country micro datasets underlying the analysis in our study. Further information can be found in the country-specific read-me files included in the replication materials: Gautier et al. (2023).

Austria. Data source: Statistik Austria (2017).

The dataset has been released by Statistics Austria to the Oesterreichische Nationalbank (OeNB) on the grounds of a confidentiality agreement and can thus not be shared with researches outside of the OeNB. Prices have been collected in 20 major cities of Austria, over the time period from 1996M1 to 2017M12. Overall, the dataset contains about 11 million price observations for 1,051 product categories (e.g. milk or men's t-shirt, no brand information), representing 96% of the Austrian CPI. Over the period 1996-2000, individual products could not be assigned to the ECOICOP5 classification used in the paper and overall, the total number of observations used to produce the results is 8.3 million price observations. The dataset also includes products with centrally collected prices, but some of them had to be removed as they already contain aggregate information from other data sources (e.g. rents taken from the Austrian rent price index). Furthermore, the dataset contains flags indicating price reductions due to temporary promotions and sales as well as for different quality adjustments and product replacement. The price quotes have been transformed to prices per unit in order to account for changes in quantity. The sample period covers the Euro cash changeover.

Belgium. Data source: Statbel (2018).

The dataset has been made available to the National Bank of Belgium (NBB) by the Belgian Statistical Office (Statbel), on the grounds that it also produces statistics within the National Accounts Institute (NAI), which is a member of the European

Statistical System (ESS). The confidentiality of the dataset must be guaranteed, namely only aggregated and anonymous results can be published. The dataset covers the period from 2007M1 to 2017M12 at a monthly frequency. Data collection over the period 2007-2015 was mostly made by regular visits of pollsters to retail shops, except in the case of cars where prices were collected from catalogues. By contrast, as of 2016, the Statistical Office has relied primarily on scanner data for a wide range of products sold at supermarkets in Belgium. As these data could not be released to the NBB for confidentiality reasons, the dataset has a limited product coverage from 2016 onwards. The Belgian HICP coverage falls from 46% (average 2007-2015) to 23% (average 2016-2017). For this reason, we drop the last two years and consider only the period between January 2007 and December 2015 in our analysis. Flags in the dataset indicate a price promotion, unavailability of the product for at least a month, and imputed price.

Individual products are grouped in 363 COICOP categories at the 6-digit level and 95 ECOICOP categories at the 5-digit level.

The Belgian micro price database does not contain seasonal sales (which are allowed twice a year in January and July), only temporary promotions (throughout the year), which are flagged. However, the NSI does apply a percentage reduction in prices in the January and July HICP releases, based on a sub-sample of items on sale. In other words, the sales percentages are measured on a sub-sample of products and then extrapolated to all products concerned when the HICP is calculated.

France. Data source: INSEE (2019).

We rely on the longitudinal CPI dataset of monthly price quotes collected by the Institut National de la Statistique et des Études Économiques (INSEE) for the period 2003M3 to 2019M9. Micro data have been made available to Banque de France researchers after a formal approval from the INSEE for this specific project. After INSEE's formal approval of this Banque de France project, BdF researchers got access to the data via a data procedure (see `https://www.comite-du-secret.fr/home/`) and via a restricted access to a secure data hub (Secure Data Access Center – CASD, `https://www.casd.eu/en/`) (for more details, see the readme file associated with French data in the replication package Gautier et al. (2023)). Centrally collected prices, such as car prices, administered prices (e.g. tobacco), public utility prices (e.g. electricity), and rents, are not part of the dataset. Since 2017, gasoline prices are collected through a dedicated website and are no longer available in the research dataset. Prices collected on internet are not part of this dataset. Individual products are classified in about 4,000 product categories at the most disaggregate (elementary) level of product classification. These categories are grouped in 334 COICOP categories at the 6-digit level and 230 ECOICOP categories at the 5-digit level. The dataset also contains information to recover the collected individual price (i.e. before quality/quantity adjustments) and various flags indicating changes in quantities or packaging, imputed prices or sales and temporary promotions.

Germany. Data source: Destatis (2019).

The German CPI micro dataset contains more than 70 million of observations for the period 2010M1-2019M12. The dataset is provided by the Research Data Centres (RDC) of the Federal Statistical Office and Statistical Offices of the Federal States and publicly available for research purposes (for more details, see the readme file associated with German data in the replication package Gautier et al. (2023)).[58] Most prices in the data base are decentrally collected by the Federal States. For prices of goods, the sample comprises up to eight different outlet types (e.g. department stores, discounters, supermarkets, internet trade). Concerning individual price information, the database contains flag indicators on sales, replacements and imputation as well as information on quality and quantity adjustment of the individual price. We use the quality and quantity-adjusted price of a product, which enters the official CPI. The lowest level of product category with weight information is the COICOP-10 level (e.g. "01.1.1.1.01100 - Rice"); After dropping those product categories based on less than 3 (offline) stores and products, our underlying research dataset contains more than 700 product categories at the COICOP-10 level. We have also excluded price spells flagged in the data set as aggregate numbers (and not micro price data) such as the package holiday index), which we need to drop beforehand. Overall, after excluding these observations, we use 46.8 million price observations to calculate price rigidity statistics used in the paper. Price rigidity statistics are computed stepwise: i) as a product-weighted average at the COICOP-5 level (e.g. "01.1.1.1 - Rice incl. rice preparations" using COICOP-10 weights) for 16 Federal States in Germany plus some centrally collected prices at the Federal level, and ii) as a German average (using state weights). The product id is constructed based on a combination of five variables (region, store id, COICOP-10 number, survey id and product variant). Due to the regular revision of the survey id with every new base year, the dataset contains a statistical break in 2015M1; thus, all price rigidity statistics are computed on each subsample separately (base year 2010: 2010M1-2014M12 and base year 2015: 2015M1-2019M12) and then weighted together.

[58] See "Verbraucherpreisindex für Deutschland", EVAS 61111, 2010 - 2019, DOI: https://doi.org/10.21242/61111.2010.00.00.3.1.0 to https://doi.org/10.21242/61111.2019.00.00.3.1.0.

Greece. Data source: ΕΛΣΤΑΤ (2019).

The Greek micro CPI dataset contains about 8 million observations for the period 2002M1 to 2020M3. It consists of price quotes on 744 products, across unique outlets at the regional level (NUTS 2 of the geographical classification), which translates into 46,729 unique product identifiers. It covers more than 75 percent of the Greek HICP. Centrally collected prices are not part of the dataset. Moreover, the data do not contain information/flags on sales, product substitution or product metric. The data were originally by 'product names' which have been matched to COICOP 8 level digits using a list on "products researched for the HICP index" for the years 2015 and 2010. Products that have not been included in these two lists have been approximated with a COICOP 8 digit by the Bank of Greece researchers. The data has been provided to the Bank of Greece by the Hellenic Statistical Authority based on a confidentiality agreement and cannot be shared.

Italy. Data source: ISTAT (2018).

The Italian CPI micro prices includes about 22 million of observations for the period 2011M1-2018M12, collected by the Istituto Nazionale di Statistica (ISTAT) and made available to Banca d'Italia within the agreement between ISTAT and Banca d'Italia in the PRISMA framework. The data are confidential and cannot be shared with researchers outside of the Banca d'Italia. Prices have been locally collected in 77 Italian province. Centrally collected prices, such as air fares, electricity and gas, gasoline etc. are not part of the data set. The database contains flag indicators on sales, replacements and imputation as well as information on quantity adjustment of the individual price. The elementary level of product category is at 10-digit (e.g 03.1.2.1.3.00.01-Men shirt) level but for the computation of statistics reported in this work we use the 5-digit COICOP level aggregation. The price quotes have been transformed to prices per unit in order to account for changes in quantity. Our data contains a structural break in 2016 as the COICOP classification changed and therefore we have proceeded to connect the products using our own methodology.

Latvia. Data source: CSP (2019).

The Latvian CPI micro prices are available to Latvijas Banka on the basis of a contract with Centrālā Statistikas Pārvalde (CSP), the Central Statistical Bureau of the Republic of Latvia. The micro data is confidential and cannot be shared with researchers outside the bank. The database includes about 670,000 observations for the period

2017M1-2019M12 and covers the full set of products and services. There are around 516 goods and services for which prices are regularly collected in 2,000 different outlets located in 11 Latvian cities. Each month almost 25,000 prices are reported. Prices are available at 5-digit COICOP level. Price quotes are reported as observed in the store and re-estimated per unit of measurement. The database includes flag indicators on replacements, imputations and price reductions due to temporary promotions and sales. Quality adjustment for prices is not available.

Lithuania. Data source: Lietuvos Statistika (2018).

The database is provided to the Lithuanian central bank (Lietuvos Bankas) by the statistical institute (Lietuvos Statistikos Departamentas). The use of the data is for research purposes and cannot be shared. Prices are a sample from the CPI database between 2010M1 and 2018M12. The price quotes are identifiable between the "elementary product group" (EPG) and "target sample" levels (according to the HICP manual). An example of an item is a 1 kg pack of "rice" characterized by a 12-digit identifier (01.1.1.1.00.00.00.01), a unique outlet number and type and the geographical location where it is sold (among 6 Lithuanian cities). In addition, the database contains "flags" that can indicate a reason for a price change in a given month. There are 25 different flags reporting sales, replacements, seasonality, etc. In total, the dataset covers 231 (out of 303) ECOICOP4 categories after cleaning. The changeover to the euro in Lithuania is included in the sample (January 2015). Statistics are adjusted to avoid capturing rounding effects at the changeover and are calculated using unit prices to account for changes in quantity.

Luxembourg. Data source: Statec (2017).

The dataset is provided by the Institut national de la statistique et des études économiques (Le Statec) via a confidentiality agreement with the Banque Centrale du Luxembourg. The dataset covers a period going from 2005M1 to 2017M12. It contains about 1 million individual prices. Sales flags have been included in the dataset only from 2015 onwards. A product replacement flag is available.

Slovakia. Data source: ŠÚSR (2020).

The Slovak CPI micro dataset is available to Národná banka Slovenska (NBS) on the basis of a contract with the Statistický úrad Slovenskej republiky (ŠÚ SR), which is the national statistical agency of Slovakia. The data are collected on the level of 720 individual "representatives" which can be connected to ECOICOP-5 categories though a matching file developed by Branislav Karmažin at the NBS. No sales or replacement flags are present in the dataset. The dataset covers the period 2011M1 – 2020M12 and contains about 9 million observations, we have excluded observations associated with year 2020 to exclude Covid-related observation and we use 8.3 million observations for the computation of the price rigidity statistics. About 65% of the entire consumption basket is covered until 2017. Excluded are prices of items such as administrative fees and utilities. Starting in 2017, all prices are included. The dataset is not freely available to researchers.

Spain. Data source: INE (2018).

The dataset has been made available to the Banco de España (BdE) by the Instituto Nacional de Estadística (INE), the Spanish national statistical agency. The confidentiality of the dataset must be guaranteed, namely only aggregated and anonymous results can be published. This is written in an official agreement signed between INE and BdE, following multiple meetings with representatives of INE, during which BdE explained the goal of the project and the microdata that would be needed. No researcher external to the BdE can make use of these data. The data is also not available for external researchers on the BdE's publicly accessible data labs. The sample used covers the period from January 2008 to December 2018 at a monthly frequency. Data collection over this period was made by regular visits of pollsters to retail shops, but also through emails and phone calls.[59] To produce its official CPI numbers, INE samples prices from 177 Spanish municipalities, 12 product groups, and 479 distinct articles corresponding to 6-digit COICOP categories.[60] To arrive at a final official figure for the Spanish consumption price index, INE uses about 220,000 price observations per month. Our sample, in contrast, includes municipalities from 17 provinces, 188 of the 479 articles used by INE to compute the CPI, and about 10,300 price observations per month of the 220,000 monthly observations used by INE on average.[61] Overall, our sample includes about 1.36 million price observations. All groups are represented with the least represented being Education (with 14.3% of the products that are used by INE to compute the CPI being included in our sample) and the most represented one being Health (63.3%).

[59] Since 2020, INE also includes scanner data in its CPI calculations, but these are not covered in the dataset used for this project.

[60] The 12 product groups are: food and non-alcoholic beverages, alcoholic beverages and tobacco products, clothing and footwear, housing, household products, health products, transportation, communication, leisure products, education, hotels and restaurants, and other goods and services. The most represented group is food an non-alcoholic beverages (with 170 articles), followed by clothing and footwear (with 66 articles), and household products (with 57 articles).

[61] The 17 provinces included in our sample are: A Coruña, Álava, Asturias, Badajoz, Barcelona, Cantabria, Comunidad de Madrid, Illes Balears, La Rioja, Las Palmas, Murcia, Navarra, Sevilla, Toledo, Valencia, Valladolid, and Zaragoza. These include some of the largest municipalities in Spain. For reference, Spain is composed of 50 provinces and two autonomous cities (Ceuta and Melilla).

A.2 Common Product Sample

Table A1: HICP Coverage of the Common Product Sample

Special aggregate (SA)	HICP total share in % (EA 2017-2020)	Share not covered in %	Share covered in %	No. of COICOP-5s covered
Food	19.3	2.5	16.8	59
Processed food	4.5	0.0	4.5	49
Unprocessed food	14.8	2.5	12.3	10
NEIG	26.4	8.0	18.4	66
Durables	9.2	5.1	4.1	23
Semi-durables	10.4	0.7	9.7	30
Non-durables	6.8	2.1	4.6	13
Energy	9.8	9.8	0.0	0
Services	44.6	20.8	23.7	41
Housing services	10.8	9.7	1.1	5
Transport services	7.3	1.5	5.8	9
Communication services	2.7	2.7	0.0	0
Recreational services rel. to accommodation	3.6	2.0	1.6	2
Recreational services (others)	11.7	0.6	11.1	14
Miscellaneous services	8.4	4.3	4.2	11
Total	**100.0**	**41.1**	**58.9**	**166**

Notes: The micro dataset covers the country-specific periods as indicated in Table 1 and is set up such that 166 COICOP-5 products are available at least in 3 out of the 4 largest countries (Germany, France, Italy and Spain). 'HICP total share' corresponds to euro area HICP weights calculated on average over the period 2017-2020. 'Share not covered' corresponds to the share (HICP euro area weights) of products missing in our common sample of COICOP-5 products. 'Share covered' corresponds to the share (HICP euro area weights) of products included in our common sample of COICOP-5 products.

A.3 Data Methodology

In this Appendix, we define the main price variables we use, how we deal with sales and promotions, how we calculate frequencies of price changes and how we aggregate the statistics at the euro area level.

A.3.1 Price Changes including Sales

First, we denote $P_{i,j,t}$ as the price of an individual store-specific product item i belonging to the (COICOP-5) product group j in month t.

We can then define the log-price change as:

$$dp_{i,j,t} = \ln(P_{i,j,t}) - \ln(P_{i,j,t-1}) \tag{A1}$$

We can then define a dummy variable equal to one if $dp_{i,j,t}$ is different from 0:

$$y_{i,j,t} = \begin{cases} 1, & \text{if } dp_{i,j,t} \neq 0 \\ 0, & \text{otherwise} \end{cases}$$

The frequency of price changes for a given product, F_j, is computed as the (weighted) share of non-zero price changes relative to the total number of observations, N_j:

$$F_j = \frac{\sum_{i=1}^{n_j} \sum_{t=2}^{\tau} y_{i,j,t}}{\sum_{t=2}^{\tau} N_{j,t}} \tag{A2}$$

where n_j represents the number of individual items of a given product j. The item-specific price changes i are aggregated to the product level j either unweighted or, if available, by using weights below the COICOP-5 level.[62]

For size statistics, we use only non zero price changes and for instance, the average size of price increases for the product j $\bar{dp}_j^+$ is computed as:

$$\bar{dp}_j^+ = \frac{\sum_{i=1}^{n_j} \sum_{t=2}^{\tau} dp_{i,j,t} y_{i,j,t}^+}{n_j^+} \tag{A3}$$

where n_j^+ is the total number of price increases for product j (i.e. $\sum_{i=1}^{n_j} \sum_{t=2}^{\tau} y_{i,j,t}^+$) and $y_{i,j,t}^+$ a dummy variable for price increases. The item-specific price changes i are aggregated to the product level j either unweighted or, if available, by using weights below the COICOP-5 level.

A.3.2 Price Changes excluding Sales

To calculate statistics excluding price changes due to sales and promotions, we use two different approaches: using NSI flag and an ad-hoc sales filter. For both methods, we

[62] This is the case for Germany and Slovakia.

define a new price variable (regular price) filtered for periods of sales and promotions identified either by the flag or the filter.

NSI flag When an NSI flag is available in the dataset, we define the regular price as follows:

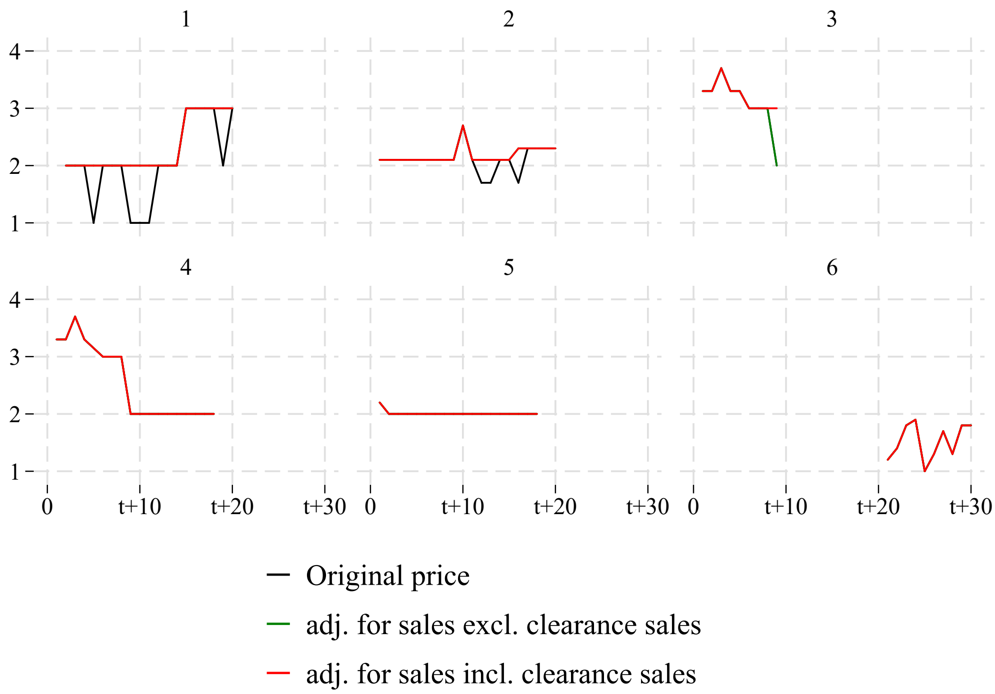
$$P_{i,j,t}^{reg} = \begin{cases} P_{i,j,t} & \text{if flag} = 0 \\ P_{i,j,t-1}^{reg} & \text{if flag} = 1 \end{cases}$$

Then, the frequency and size statistics are computed the same way as for actual prices $P_{i,j,t}$. In the previous expressions, we replace $P_{i,j,t}$ by $P_{i,j,t}^{reg}$.

Sales filter In order to rule out that our results are driven by methodological differences in defining and flagging sales across euro area member states, we implement an algorithm that defines sales periods in our dataset in a harmonised manner. Basically, we use the filter proposed by Nakamura and Steinsson (2008*a*) which is described in detail in the supplement to the original paper (Nakamura and Steinsson, 2008*b*). This method consists of identifying prices for products on sales from the price patterns. In a nutshell, the functioning of the filter is illustrated in Figure (A1) with the help of simulated data.

As shown in the figure, this method consists of creating a new variable $P_{i,j,t}^{regf}$ which is equal to $P_{i,j,t-1}^{regf}$ when the filter identifies a sales period by specific price patterns (as illustrated for good '1' and good '2'). Good '3' illustrates an additional feature that we added to the baseline filter developed by Nakamura and Steinsson (2008*a*). Many seasonal goods such as clothing are marked by clearance sales meaning that shops lower prices at the end of the season to clear their shelves. We take this on board by defining a sales period if the last price of a product is lower than the previous price over a given period. Hence, good '3' is affected by a clearance sale as shown by the red solid line highlighting the new regular price at the end of the product life-cycle, which is not found by the original sales filter of Nakamura and Steinsson (2008*a*) (green solid line). Good '4' has also a price drop at the end of its lifetime, however, the period over which this low price prevails is too long to be considered as a sale. By this restriction, we want to avoid that a long time span of constant prices is classified as a (clearance) sales period, as it was the case for product '5'. Finally, prices of good '6' are too volatile to be identified as sales.

Figure A1: Functioning of the Sales Filter including Clearance Sales



Notes: The graph shows the price trajectories of 6 hypothetical products. The black solid line gives the original price, the green solid line the price adjusted for sales using the filter developed by Nakamura and Steinsson (2008a) and the red solid line shows the price adjusted for sales and clearance sales.

The sales filter depends on four parameters:[63]

l : maximum length of the sales period followed by a new regular price.

k : maximum number of new regular prices to be considered.

j : maximum length of the sales period where the price returns exactly to the same price as before the sales period.

c : maximum number of periods used to identify a clearance sale at the end of a product's life-cycle.

In a preliminary analysis (available upon request), we have investigated the behaviour of the sales filter with respect to different parameter values for a subset of countries including Austria, Germany, France and Italy. Based on this, we use the parameters: $l = 3$, $k = 3$, $j = 5$ (like in Nakamura and Steinsson, 2008*a*) and $c = 3$.

This method delivers a new price variable $P^{reg}_{i,j,t}$ and all statistics at the product level are produced by replacing $P_{i,j,t}$ by $P^{regf}_{i,j,t}$ in the previous formulas.

[63]The filter is written as an ado-file in Stata and is available upon request.

A.3.3 Replacements

For country datasets in which we have information on product substitutions, we can define a new price variable $P^{subs}_{i,j,t}$. When a product i is replaced by a close substitute i' at date t, we can define a new product $i*$ and $P^{subs}_{i*,j,\tau} = P^{subs}_{i,j,\tau}$ when $\tau < t$ and $P^{subs}_{i*,j,\tau} = P^{subs}_{i',j,\tau}$ when $\tau \geq t$. Again, statistics can then be calculated using $P^{subs}_{i*,j,t}$ instead of $P_{i,j,t}$, they will include price changes at the product replacements.

A.3.4 Aggregation

For each product j in country c, we calculate product-level statistics. We then aggregate these statistics to produce country statistics, EA statistics and broad-sector statistics.

In our baseline exercises, we first calculate country-level statistics using euro area HICP weights averaged over the period 2017-2020. For instance, for frequencies, $F_{j,c}$ is the frequency of price changes in product j for country c and w_j is the euro area HICP weight of this product, then:

$$F_c = \sum_{j=1}^{N_{jc}} w_j F_{j,c} \tag{A4}$$

where N_{jc} is the number of COICOP 5-digit products available for each country c in the common sample of COICOP products.

Second, we apply HICP country weights W_c (averaged over 2017-2020) to derive the euro area aggregate.

$$F = \sum_{c=1}^{N_c} W_c F_c \tag{A5}$$

where N_c is the number of euro area countries (here 11).

Another option we use in a robustness analysis and in the EA vs US comparison, is to first calculate product-level EA statistics and then to average over the products. The EA frequency at the product level would be defined as:

$$F_j = \sum_{c=1}^{N_c} W_c F_{j,c} \tag{A6}$$

and then we could calculate:

$$\tilde{F} = \sum_{j=1}^{N_j} w_j F_j \tag{A7}$$

where N_j is the number of COICOP 5-digit products in the common sample of products.

$\tilde{F}$ and F differ because product coverage can differ between countries (see Table 1).

A.4 Additional Evidence on Sales

Table A2: Sale Periods

Country	Set periods for sales	Winter sales	Summer sales	Comments
Austria	No	Usually shortly after Christmas until February.	Usually from July until August.	
Belgium	Yes	3-31 January (if January 3rd is a Sunday, the winter sales start on Saturday, January 2nd).	1-31 July (if July 1st is a Sunday, the summer sales start on Saturday, June 30th).	Promotions are allowed throughout the year but, contrary to the seasonal sales period, shops cannot sell at a loss. In both cases, unfair trade practices are forbidden vis-à-vis the consumer.
France	Yes	Winter sales usually start the 2nd Wednesday of January (or the 1st Wednesday after the 12th of January).	Summer sales usually start the last Wednesday of June (or the Wednesday before, if the last Wednesday is after the 28th of June).	There are two main sales periods of a maximum duration of four weeks in winter and summer. The sale dates are decided by each French department by order of the Prefect. Beginning and ending dates are fixed compulsory for all sellers.
Germany	No	The winter sales usually begin at the end of January / beginning of February.	The summer sales usually start at the end of July / beginning of August.	
Greece	Yes	Winter sales: from the second Monday of January until end of February. Spring sales: 1-10 May.	Summer sales: from the second Monday of July until end of August. Autumn sales: 1-10 November.	
Italy	Yes	Winter sales usually start between the first and the second week of January and last approximately 60 days.	Summer sales usually from the first week of July until end of August.	Sales are regulated by regions.
Latvia	No			Usually in the middle or at the end of the season.
Lithuania	No	1-31 January, but allowed to prolong until the end of winter.	1-31 July, but limits are not strict, can be prolonged until end of summer.	Mid-season sales also allowed.
Luxembourg	Yes	Winter sales are usually organised at the beginning of January.	Summer sales are usually organised in the middle or the end of July.	The law foresees two sales periods per year which are annually fixed.
Slovakia	No	Usually after Christmas.	Usually after summer season.	
Spain	Yes	The starting date is usually 7 January, although it is possible that in certain cities, such as Madrid, winter sales may begin on 1 January. Depending on the region of Spain, the length varies and can even last until the end of March.	Usually from 1 July until the end of September. Depending on the region, the summer sales may be extended by a few days.	According to current legislation (article 25 of Law 7/1996, on the organization of retail trade), each establishment is free to choose the period and duration of the sales throughout the year.

Source: European Consumer Center Germany, `https://www.evz.de/en/shopping-internet/retail-store/sales-periods-in-europe.html` *(as of January 29, 2021); own research.*

Table A3: Cross-Product Distribution of the Share of Sales

	% of sales prices											
	NSI flag if available (filter otherwise)						**Sales filter**					
	Average	25th	50th	75th	90th	95th	Average	25th	50th	75th	90th	95th
EURO AREA	**3.8**	**0.1**	**1.7**	**4.5**	**12.7**	**18.8**	**4.7**	**0.7**	**3.4**	**6.6**	**12.3**	**17.2**
by Sector												
Unprocessed Food	5.7	4.6	5.2	5.7	8.9	9.7	8.7	6.5	9.2	9.8	12.4	13.1
Processed Food	3.3	2.2	3.0	4.0	6.0	6.3	5.5	4.2	5.4	6.6	8.2	8.6
NEIG	8.1	2.1	4.7	15.7	19.3	21.5	7.9	3.1	5.7	13.8	16.3	18.5
Services	0.2	0.0	0.0	0.3	0.6	0.8	0.9	0.3	0.5	0.9	2.2	3.7
COUNTRY												
Austria	5.1	0.2	3.3	7.5	16.8	18.8	4.2	0.8	2.9	6.2	11.1	11.3
Belgium	1.1	0.0	0.1	2.0	3.6	3.8	3.8	0.7	2.3	6.6	8.7	10.0
France	3.2	0.2	1.6	3.8	11.0	13.4	5.0	1.2	5.1	7.5	10.9	12.2
Germany	4.1	0.1	1.9	5.3	13.0	21.6	4.2	0.1	1.9	5.4	13.2	21.8
Greece	3.8	0.8	2.9	5.7	8.9	10.6	3.8	0.8	3.0	5.7	8.9	10.6
Italy	4.3	0.0	1.5	3.8	15.2	23.8	5.4	1.0	3.3	6.4	14.7	22.4
Latvia	10.7	0.2	5.5	20.7	28.8	32.7	7.5	0.5	3.8	15.0	21.6	22.7
Lithuania	2.3	0.0	1.8	3.6	5.4	7.6	5.3	0.8	5.4	8.3	12.0	12.9
Luxembourg	4.6	0.7	3.5	7.8	12.3	12.8	4.6	0.7	3.5	7.8	12.3	12.8
Slovakia	4.9	0.5	2.7	8.9	12.8	15.2	4.9	0.5	2.7	8.9	12.8	15.2
Spain	5.1	1.0	4.8	7.7	11.1	12.6	5.1	1.0	4.8	7.7	11.1	12.6

Notes: Statistics are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries. Price changes due to replacement are excluded beforehand (except Greece and Slovakia). Seasonal sales are excluded in the Belgian dataset but temporary promotions are included. Results excluding sales are based on 1) NSI sales flag if available or 2) common sales filter.

B Additional Results on Cross-Sectional Statistics

B.1 Percentage of Price Increases

Table A4: Fraction of Price Increases Among of Price Changes

	Including sales	**Excluding sales**	
		NSI flag	Sales filter
EURO AREA	**64.0**	**68.8**	**66.7**
by Sector			
Unprocessed Food	54.5	57.6	58.5
Processed Food	57.0	61.8	62.3
NEIG	48.2	59.8	55.2
Services	82.5	82.4	80.4
COUNTRY			
Austria	64.5	72.0	70.6
Belgium	69.0	69.7	70.9
France	60.8	67.0	65.4
Germany	61.9	67.2	67.1
Greece	61.3	63.9	63.9
Italy	69.9	75.6	67.0
Latvia	60.0	71.1	62.7
Lithuania	62.3	68.4	65.5
Luxembourg	73.4	78.4	78.4
Slovakia	64.8	66.6	66.6
Spain	64.0	65.3	65.3

Notes: Statistics are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries. Price changes due to replacement are excluded beforehand (except Greece and Slovakia). Seasonal sales are excluded in the Belgian dataset but temporary promotions are included. Results excluding sales are based on 1) NSI sales flag if available or 2) common sales filter.

B.2 Robustness: Product Replacements

Table A5: Frequency and Size of Price Changes – including Replacements

	Including sales		**Excluding sales** (Flag when available)		**Including sales**		**Excluding sales** (Flag when available)	
	Freq. price changes	% price increases	Freq. price changes	% price increases	Median Increase	Median Decrease	Median Increase	Median Decrease
EURO AREA	**13.6**	**63.8**	**9.8**	**67.3**	**10.4**	**13.4**	**7.5**	**9.5**
by Sector								
Unprocessed Food	32.0	54.5	24.7	57.2	13.0	15.2	10.4	11.3
Processed Food	16.1	56.6	11.0	60.7	9.6	12.5	6.1	7.1
NEIG	15.9	51.6	9.4	58.4	15.8	19.3	9.8	11.9
Services	6.8	79.3	6.6	80.0	5.9	8.8	5.8	8.5
COUNTRY								
Austria	13.9	62.7	10.1	64.3	11.8	16.4	8.3	11.8
France	14.9	61.9	12.1	64.5	8.8	12.0	6.5	8.6
Germany	13.5	62.5	10.2	66.6	12.4	16.0	9.1	11.2
Greece	11.3	61.3	7.3	63.9	9.6	12.8	8.0	11.4
Italy	11.5	68.9	6.3	74.6	9.6	12.0	5.0	6.5
Latvia	21.2	61.6	10.5	70.3	16.6	14.6	12.1	8.3
Lithuania	15.1	63.4	12.0	68.4	14.1	16.8	12.8	13.2
Luxembourg	14.3	72.8	9.0	77.7	7.5	11.5	5.6	8.5
Slovakia	14.3	64.8	14.3	66.6	10.5	11.1	10.5	11.1
Spain	14.9	63.4	10.4	64.3	9.2	11.2	8.5	10.4

Notes: Statistics are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries. Price changes due to replacement are included. Belgium does not have information on product replacements. Results excluding sales are based on 1) NSI sales flag if available or 2) common sales filter.

B.3 Robustness: Common Time Period

Table A6: Frequency and Size of Price Changes Based on Harmonised Sample Period 2011-2017

	Including sales		**Excluding sales** (Flag when available)		**Including sales**		**Excluding sales** (Flag when available)	
	Freq. price changes	% price increases	Freq. price changes	% price increases	Median Increase	Median Decrease	Median Increase	Median Decrease
EURO AREA	**12.4**	**63.4**	**8.7**	**68.5**	**9.7**	**13.2**	**6.8**	**9.0**
by Sector								
Unprocessed Food	31.2	54.3	24.0	57.3	12.6	14.9	10.1	10.9
Processed Food	15.3	56.5	10.4	61.3	9.1	11.8	5.8	6.6
NEIG	12.9	47.8	6.5	59.0	14.3	19.4	8.2	11.0
Services	6.3	81.6	6.2	82.6	5.8	8.6	5.7	8.2
COUNTRY								
Austria	12.3	64.8	7.4	73.9	11.8	16.2	7.0	9.9
Belgium	14.4	68.8	13.2	69.5	6.8	8.1	6.4	7.4
France	12.5	60.5	9.7	66.4	7.9	12.0	5.2	7.5
Germany	12.9	61.9	9.6	67.2	11.6	16.0	8.6	11.1
Greece	11.6	50.6	6.7	50.9	12.7	14.7	10.8	13.1
Italy	10.5	70.0	5.5	77.4	9.1	11.8	4.5	5.8
Latvia	18.6	60.0	11.1	62.7	15.9	14.8	11.5	11.8
Lithuania	13.1	62.9	9.9	69.4	13.3	16.7	11.6	12.3
Luxembourg	14.1	73.4	9.5	78.0	7.5	10.7	5.4	7.6
Slovakia	14.7	62.3	9.5	63.8	10.3	11.0	9.1	8.5
Spain	13.1	62.3	8.9	63.8	9.0	11.4	8.2	10.5

Notes: Statistics are based on the common sample period of 2011-2017 (Belgium: 2011-2015; Latvia: 2017) and on products that are common to at least 3 of the 4 largest countries. Price changes due to replacement are excluded beforehand (except Greece and Slovakia). Seasonal sales are excluded in the Belgian dataset but temporary promotions are included.

B.4 Robustness: Sample of Products

Table A7: Frequency of Price Changes Based on the Country-Specific Product Sample

	Including sales		**Excluding sales** (NSI sales flag if available)		**Excluding sales** (Sales filter)		**% of sales**	
	Freq. price changes	% price increases	Freq. price changes	% price increases	Freq. price changes	% price increases	NSI flag	Sales filter
EURO AREA	**11.8**	**66.9**	**8.5**	**71.0**	**8.0**	**68.9**	**3.2**	**4.2**
by Sector								
Unprocessed food	31.3	54.5	23.9	57.6	19.7	58.5	5.7	8.7
Processed food	14.7	60.6	10.1	64.9	8.9	65.4	2.9	5.1
NEIG	12.4	52.5	6.7	62.7	6.9	58.5	7.1	7.1
Services	6.8	82.3	6.5	82.0	6.3	79.9	0.2	1.0
COUNTRY								
Austria	12.7	66.9	9.4	72.7	9.1	71.9	4.7	3.9
Belgium	13.6	71.7	12.6	72.3	10.4	73.5	1.0	3.6
France	13.8	64.5	11.3	69.4	9.8	68.3	2.7	4.7
Germany	10.7	67.5	8.0	71.6	7.0	71.4	3.1	3.2
Greece	10.6	62.2	7.1	64.3	7.1	64.3	.	3.5
Italy	9.8	70.4	4.5	76.1	5.9	67.0	4.0	5.1
Latvia	22.7	60.0	14.9	68.6	16.8	62.7	7.8	5.9
Lithuania	12.7	62.9	10.1	68.0	9.4	66.1	1.9	5.1
Luxembourg	12.5	75.1	8.6	78.7	8.6	78.7	.	3.6
Slovakia	13.5	66.7	9.7	68.2	9.7	68.2	.	3.8
Spain	13.2	64.2	8.8	65.4	8.8	65.4	.	5.0

Notes: Statistics are based on the country-specific period and on all products that are available for an individual country. Price changes due to replacement are excluded beforehand (except for Greece and Slovakia). Seasonal sales are excluded in the Belgian dataset but temporary promotions are included. Results excluding sales are based on 1) NSI sales flag if available or 2) common sales filter.

Table A8: Size of Price Changes Based on the Country-Specific Product Sample

	Including sales		**Excluding sales** (NSI sales flag if available)		**Excluding sales** (Sales filter)	
	Median		Median		Median	
	Increase	Decrease	Increase	Decrease	Increase	Decrease
EURO AREA	**8.6**	**11.6**	**6.3**	**8.0**	**6.7**	**10.0**
by Sector						
Unprocessed food	12.6	15.0	10.0	10.9	10.6	11.9
Processed food	8.6	11.0	5.6	6.1	5.7	6.6
NEIG	12.3	16.8	7.2	9.8	8.1	12.6
Services	5.5	7.6	5.3	7.2	5.5	9.2
COUNTRY						
Austria	8.6	11.9	6.0	7.5	6.4	9.0
Belgium	6.4	7.5	6.1	6.9	6.0	6.7
France	6.5	10.0	4.5	6.3	4.9	8.1
Germany	10.2	13.7	7.7	9.8	8.1	11.6
Greece	9.6	12.9	8.3	11.8	8.3	11.8
Italy	8.8	11.1	4.4	5.5	5.2	9.9
Latvia	13.5	12.3	7.9	6.0	10.4	10.1
Lithuania	12.7	15.4	11.4	12.0	10.5	11.4
Luxembourg	7.8	9.5	6.4	7.4	6.4	7.4
Slovakia	9.3	10.3	8.5	8.5	8.5	8.5
Spain	8.8	11.0	8.0	10.3	8.0	10.3

Notes: Statistics are based on the country-specific period and on all products that are available for an individual country. Price changes due to replacement are excluded beforehand (except for Greece and Slovakia). Seasonal sales are excluded in the Belgian dataset but temporary promotions are included. Results excluding sales are based on 1) NSI sales flag if available or 2) common sales filter.

Table A9: Frequency of Price Changes Based on the Sample of Products Common to All Countries

	Including sales		**Excluding sales** (NSI sales flag if available)		**Excluding sales** (Sales filter)		**% of sales**	
	Freq. price changes	% price increases	Freq. price changes	% price increases	Freq. price changes	% price increases	NSI flag	Sales filter
EURO AREA	**11.6**	**62.3**	**6.8**	**68.9**	**6.6**	**66.2**	**5.2**	**5.7**
by Sector								
Unprocessed food	19.6	56.4	11.9	61.3	10.0	62.3	6.3	7.6
Processed food	15.4	57.0	10.4	61.8	9.1	62.3	3.4	5.5
NEIG	14.9	38.8	4.8	58.6	6.2	49.6	14.2	12.1
Services	3.7	86.4	3.7	85.3	3.8	83.4	0.2	0.8
COUNTRY								
Austria	9.8	61.9	5.0	73.1	5.3	69.8	6.6	4.6
Belgium	11.0	70.3	10.0	71.0	8.2	72.3	0.9	3.1
France	12.4	58.8	8.6	67.7	7.4	64.3	4.2	5.4
Germany	9.8	59.8	5.1	68.1	4.9	67.3	5.6	5.7
Greece	12.5	60.3	7.7	63.5	7.7	63.5	.	4.5
Italy	12.6	68.5	5.6	73.9	6.9	66.0	6.3	7.4
Latvia	15.8	60.8	4.0	75.1	7.4	63.6	11.8	8.4
Lithuania	11.6	62.1	8.3	68.7	7.8	66.9	2.3	5.3
Luxembourg	14.1	72.6	7.7	78.5	7.7	78.5	.	5.4
Slovakia	15.7	62.6	9.1	65.3	9.1	65.3	.	6.3
Spain	13.1	63.1	8.6	64.7	8.6	64.7	.	4.9

Notes: Statistics are based on the country-specific period and on products that are common to all countries (56 products, of which 4 for unprocessed food, 35 for processed food, 11 for NEIG and 6 for services). Price changes due to replacement are excluded beforehand (except for Greece and Slovakia). Seasonal sales are excluded in the Belgian dataset but temporary promotions are included. Results excluding sales are based on 1) NSI sales flag if available or 2) common sales filter.

Table A10: Size of Price Changes Based on the Sample of Products Common to All Countries

	Including sales		**Excluding sales** (NSI sales flag if available)		**Excluding sales** (Sales filter)	
	Median		Median		Median	
	Increase	Decrease	Increase	Decrease	Increase	Decrease
EURO AREA	**10.6**	**14.5**	**6.5**	**8.6**	**7.2**	**11.1**
by Sector						
Unprocessed food	10.1	13.3	6.2	7.2	6.5	8.3
Processed food	9.2	12.1	5.8	6.5	5.9	7.1
NEIG	19.5	27.3	9.2	13.6	11.4	20.0
Services	5.6	7.8	5.4	7.2	5.4	9.2
COUNTRY						
Austria	11.9	17.6	6.7	9.1	7.4	12.4
Belgium	6.3	7.6	6.0	6.9	5.8	6.6
France	8.2	12.6	4.4	6.6	5.2	10.2
Germany	12.9	18.8	8.3	11.3	9.1	13.6
Greece	9.2	11.8	7.2	10.3	7.2	10.3
Italy	11.1	13.1	4.2	4.7	5.0	9.2
Latvia	16.0	14.9	7.0	5.2	11.0	11.5
Lithuania	13.1	17.1	11.1	12.0	9.7	11.8
Luxembourg	7.4	10.4	4.5	6.2	4.5	6.2
Slovakia	10.5	11.3	8.7	8.1	8.7	8.1
Spain	9.8	11.6	9.3	11.2	9.3	11.2

Notes: Statistics are based on the country-specific period and on products that are common to all countries (56 products, of which 4 for unprocessed food, 35 for processed food, 11 for NEIG and 6 for services). Price changes due to replacement are excluded beforehand (except for Greece and Slovakia). Seasonal sales are excluded in the Belgian dataset but temporary promotions are included. Results excluding sales are based on 1) NSI sales flag if available or 2) common sales filter.

B.5 Robustness: Country Weights

Table A11: Frequency of Price Changes Using Country-Specific Product Weights for Aggregation

	Including sales		**Excluding sales** (NSI sales flag if available)		**Excluding sales** (Sales filter)		**% of sales**	
	Freq. price changes	% price increases	Freq. price changes	% price increases	Freq. price changes	% price increases	NSI flag	Sales filter
EURO AREA	**12.5**	**64.3**	**8.6**	**69.0**	**8.0**	**67.1**	**3.8**	**4.7**
by Sector								
Unprocessed food	32.8	54.4	25.4	57.4	20.9	58.2	5.6	8.6
Processed food	15.4	56.9	10.3	61.7	9.0	62.2	3.4	5.5
NEIG	13.2	48.9	6.8	60.0	6.9	55.8	8.0	7.8
Services	6.3	82.9	5.9	82.8	5.6	81.2	0.2	0.8
COUNTRY								
Austria	10.1	65.7	6.9	73.0	6.6	71.8	4.6	3.9
Belgium	14.5	68.6	13.3	69.3	10.9	70.7	1.1	3.9
France	12.5	61.8	9.9	67.2	8.1	66.1	2.9	4.9
Germany	12.8	61.5	9.4	66.9	8.3	66.7	4.1	4.1
Greece	12.4	61.6	8.4	64.2	8.4	64.2	.	3.9
Italy	10.7	69.9	4.8	75.6	5.9	67.7	4.7	5.7
Latvia	22.4	56.3	7.1	67.9	11.9	59.2	15.3	10.5
Lithuania	15.0	57.7	11.0	65.1	10.3	62.4	2.9	6.7
Luxembourg	13.1	74.2	7.8	79.2	7.8	79.2	.	4.6
Slovakia	17.0	62.7	10.2	65.0	10.2	65.0	.	6.5
Spain	13.6	66.1	9.2	67.3	9.2	67.3	.	4.9

Notes: Statistics are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries. Price changes due to replacement are excluded beforehand (except for Greece and Slovakia). Seasonal sales are excluded in the Belgian dataset but temporary promotions are included. Results excluding sales are based on 1) NSI sales flag if available or 2) common sales filter.

Table A12: Size of Price Changes Using Country-Specific Product Weights for Aggregation

	Including sales		**Excluding sales** (NSI sales flag if available)		**Excluding sales** (Sales filter)	
	Median		Median		Median	
	Increase	Decrease	Increase	Decrease	Increase	Decrease
EURO AREA	**9.4**	**12.8**	**6.6**	**8.6**	**7.0**	**10.6**
by Sector						
Unprocessed food	12.8	15.1	10.4	11.3	11.1	12.2
Processed food	9.2	12.0	5.8	6.5	5.9	7.0
NEIG	13.8	18.9	7.9	10.6	8.8	13.9
Services	5.5	8.1	5.4	7.8	5.4	9.6
COUNTRY						
Austria	9.5	13.6	6.5	8.4	6.9	10.3
Belgium	6.9	8.2	6.5	7.4	6.5	7.1
France	7.2	11.2	4.9	6.8	5.4	8.8
Germany	11.3	15.8	8.1	10.8	8.6	13.0
Greece	8.6	11.4	7.3	10.1	7.3	10.1
Italy	9.7	12.0	4.5	6.1	5.3	9.9
Latvia	16.8	15.3	7.7	5.7	11.9	12.0
Lithuania	13.9	17.8	12.0	12.7	10.1	12.1
Luxembourg	7.0	10.7	5.0	7.7	5.0	7.7
Slovakia	11.0	11.8	9.1	8.4	9.1	8.4
Spain	8.9	11.0	8.2	10.4	8.2	10.4

Notes: Statistics are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries. Price changes due to replacement are excluded beforehand (except for Greece and Slovakia). Seasonal sales are excluded in the Belgian dataset but temporary promotions are included. Results excluding sales are based on 1) NSI sales flag if available or 2) common sales filter.

B.6 Robustness: EA Aggregation

Table A13: Frequency of Price Changes Using Alternative Aggregation

	Including sales		Excluding sales (NSI sales flag if available)		Excluding sales (Sales filter)		% of sales	
	Freq. price changes	% price increases	Freq. price changes	% price increases	Freq. price changes	% price increases	NSI flag	Sales filter
EURO AREA	**12.5**	**64.1**	**8.7**	**68.9**	**8.1**	**66.7**	**3.8**	**4.7**
by Sector								
Unprocessed food	35.0	53.8	27.5	56.3	22.5	57.3	5.9	9.1
Processed food	15.3	57.0	10.4	61.8	9.0	62.3	3.3	5.4
NEIG	13.0	48.2	6.5	59.9	6.8	55.2	8.2	7.9
Services	6.4	82.1	6.0	82.0	5.8	79.7	0.2	0.9

Notes: We first aggregate at the product level and then calculate the average over the products. Statistics are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries. Price changes due to replacement are excluded beforehand (except for Greece and Slovakia). Seasonal sales are excluded in the Belgian dataset but temporary promotions are included. Results excluding sales are based on 1) NSI sales flag if available or 2) common sales filter.

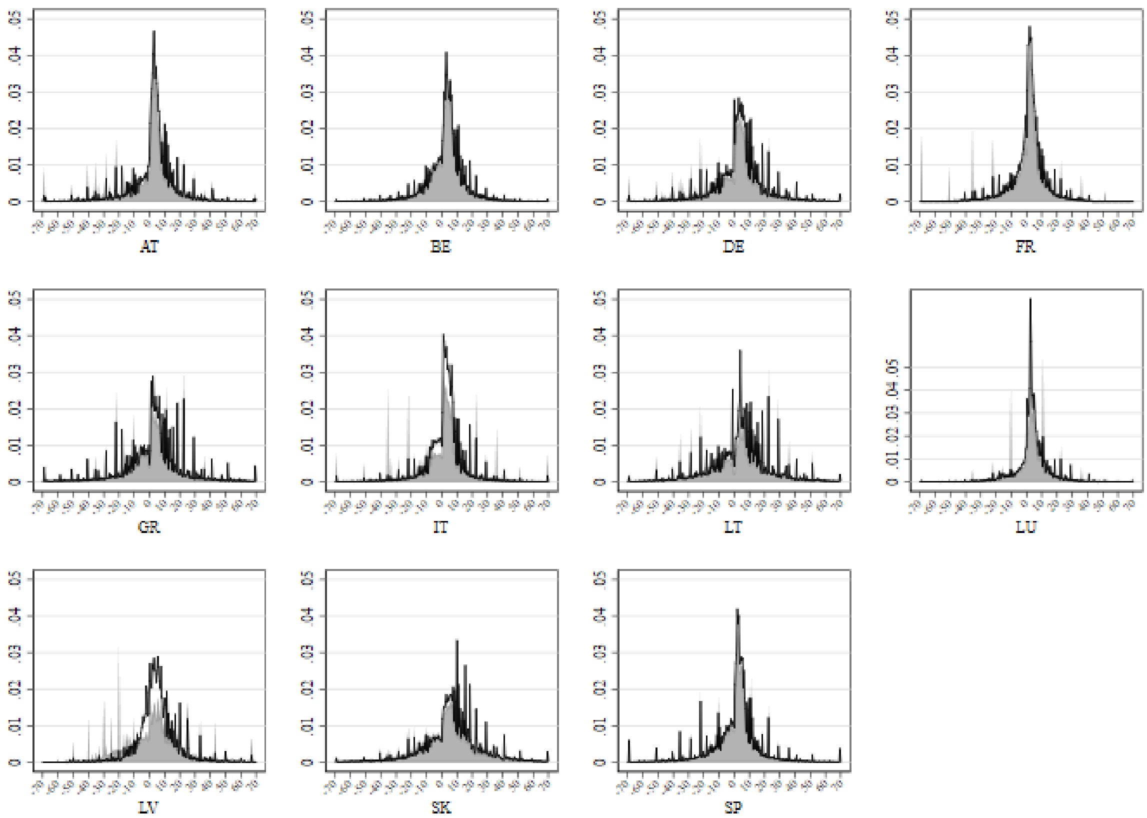
Table A14: Size of Price Changes Using Alternative Aggregation

	Including sales		Excluding sales (NSI sales flag if available)		Excluding sales (Sales filter)	
	Median		Median		Median	
	Increase	Decrease	Increase	Decrease	Increase	Decrease
EURO AREA	**9.6**	**13.0**	**6.7**	**8.7**	**7.2**	**10.9**
by Sector						
Unprocessed food	13.8	16.0	11.5	12.5	12.1	13.4
Processed food	9.2	12.0	5.8	6.5	5.9	7.1
NEIG	13.8	19.1	7.7	10.6	8.8	14.1
Services	5.6	8.1	5.5	7.7	5.7	10.0

Notes: We first aggregate at the product level and then calculate the average over the products. Statistics are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries. Price changes due to replacement are excluded beforehand (except for Greece and Slovakia). Seasonal sales are excluded in the Belgian dataset but temporary promotions are included. Results excluding sales are based on 1) NSI sales flag if available or 2) common sales filter.

B.7 Distribution of Price Changes

Figure A2: Distribution of (Log-)Price Changes by Country (in %)



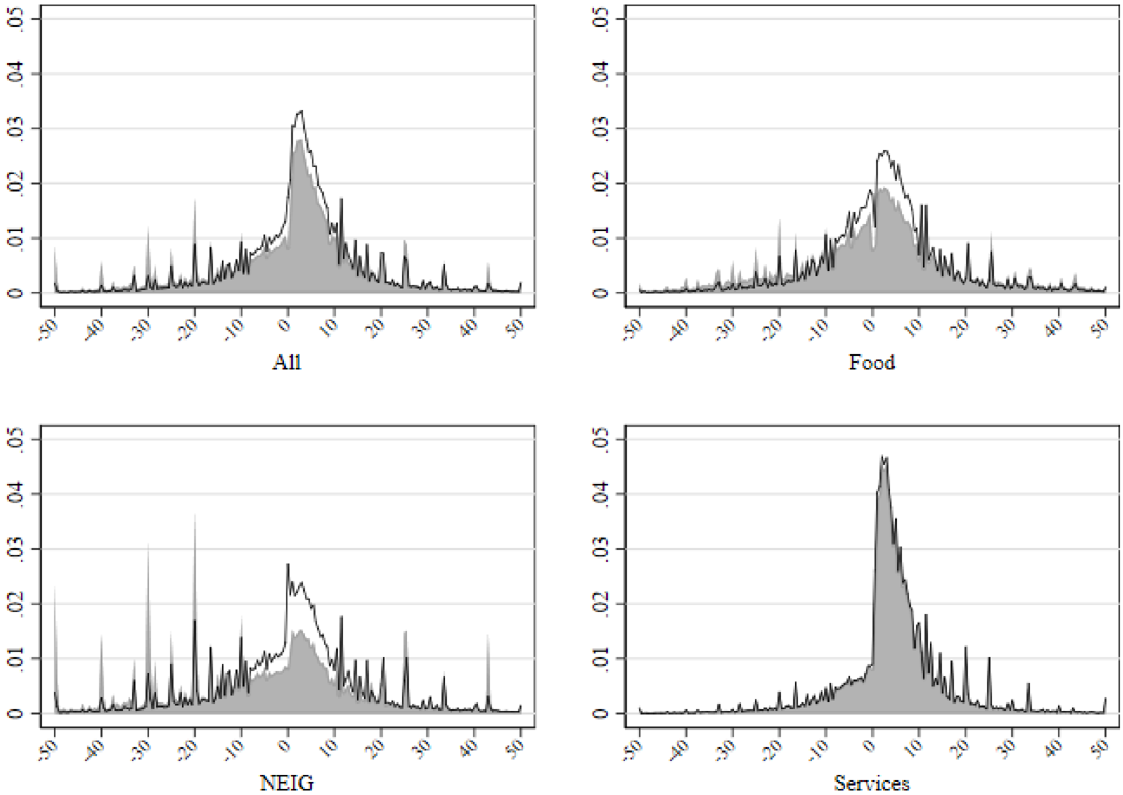
Notes: The histograms plot the distribution of price changes calculated first at the country level for the common sample of products and weighted using the EA product weights. Grey shaded histogram corresponds to the distribution of price changes including price changes due to sales whereas the black line corresponds to the distribution of price changes excluding price changes due to sales. Results excluding sales are based on 1) NSI sales flag if available or 2) common sales filter.

Table A15: Distribution of (Non-Zero) Absolute Price Changes

	Absolute size of price changes (in %)							
	Including sales				**Excluding sales[1]**			
	10th	25th	75th	90th	10th	25th	75th	90th
EURO AREA	**3.0**	**6.0**	**18.8**	**28.9**	**2.0**	**3.9**	**12.5**	**20.5**
by Sector								
Unprocessed Food	3.6	6.9	25.4	38.3	3.1	5.8	18.2	28.0
Processed Food	2.5	4.7	19.4	29.1	1.9	3.3	10.5	17.8
NEIG	4.7	9.8	27.6	41.2	2.1	4.6	15.7	25.8
Services	1.9	3.3	10.1	17.0	1.9	3.2	9.7	16.0
COUNTRY								
Austria	3.3	6.7	21.1	31.4	1.8	4.0	13.4	22.5
Belgium	2.1	4.0	13.7	23.3	2.0	3.8	12.2	20.8
France	2.4	5.3	16.9	27.5	1.3	2.7	9.9	16.8
Germany	3.9	7.3	22.9	34.1	2.8	5.0	15.6	25.9
Greece	3.0	5.6	19.4	31.6	2.4	4.6	17.0	30.6
Italy	2.6	5.3	16.7	25.0	1.3	2.4	7.9	12.2
Latvia	4.2	8.4	24.1	34.7	2.1	3.9	13.1	21.1
Lithuania	3.5	7.3	25.2	35.0	3.0	5.9	22.0	32.5
Luxembourg	2.2	3.9	12.8	21.7	1.8	3.1	10.7	17.9
Slovakia	2.9	5.6	18.0	25.1	2.7	5.0	16.0	23.5
Spain	2.9	5.4	16.0	25.0	2.6	5.0	14.5	23.1

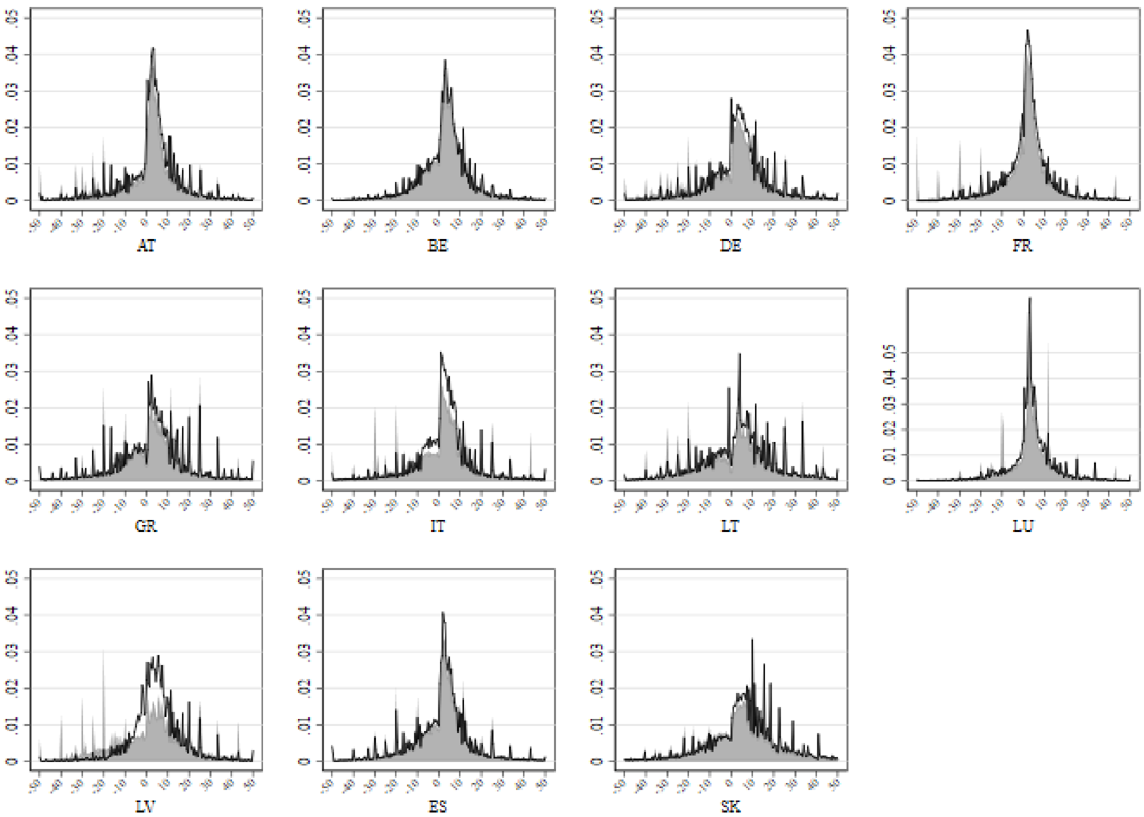
Notes: Statistics are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries. Price changes due to replacement are excluded beforehand (except Greece and Slovakia). Seasonal sales are excluded in the Belgian dataset but temporary promotions are included. 1) Results excluding sales are based on NSI sales flag, if available, or common sales filter.

Figure A3: Distribution of Price Changes (Euro Area - in %)



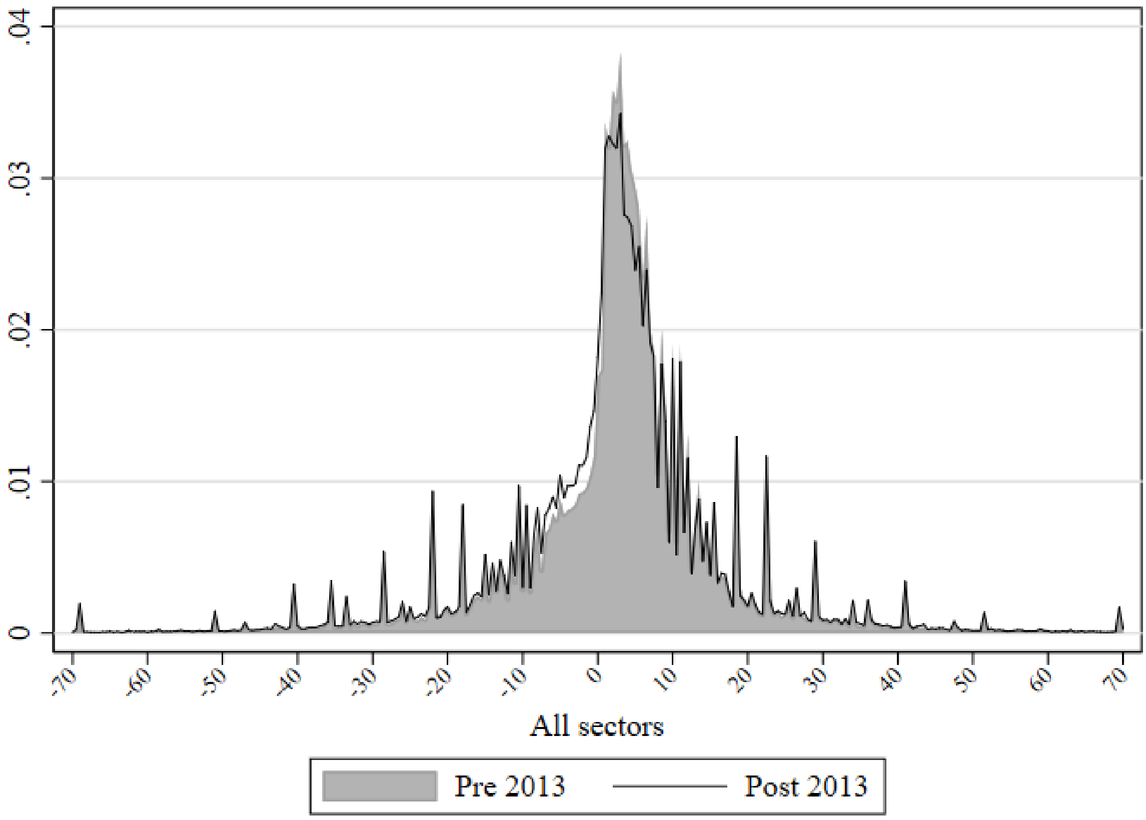
Notes: The histograms plot the distribution of price changes (in %) calculated first at the country level by product for the common sample of products (bins of 0.5 pp), then aggregated at the country level using euro area product weights and then aggregated at the euro area level using HICP country weights. Grey shaded histogram corresponds to the distribution of price changes including price changes due to sales whereas the black line corresponds to the distribution of price changes excluding price changes due to sales. Results excluding sales are based on NSI sales flag if available, common sales filter otherwise.

Figure A4: Distribution of Price Changes by Country (in %)



Notes: The histograms plot the distribution of price changes calculated first at the country level for the common sample of products and weighted using the EA product weights. Grey shaded histogram corresponds to the distribution of price changes including price changes due to sales whereas the black line corresponds to the distribution of price changes excluding price changes due to sales. Results excluding sales are based on 1) NSI sales flag if available or 2) common sales filter.

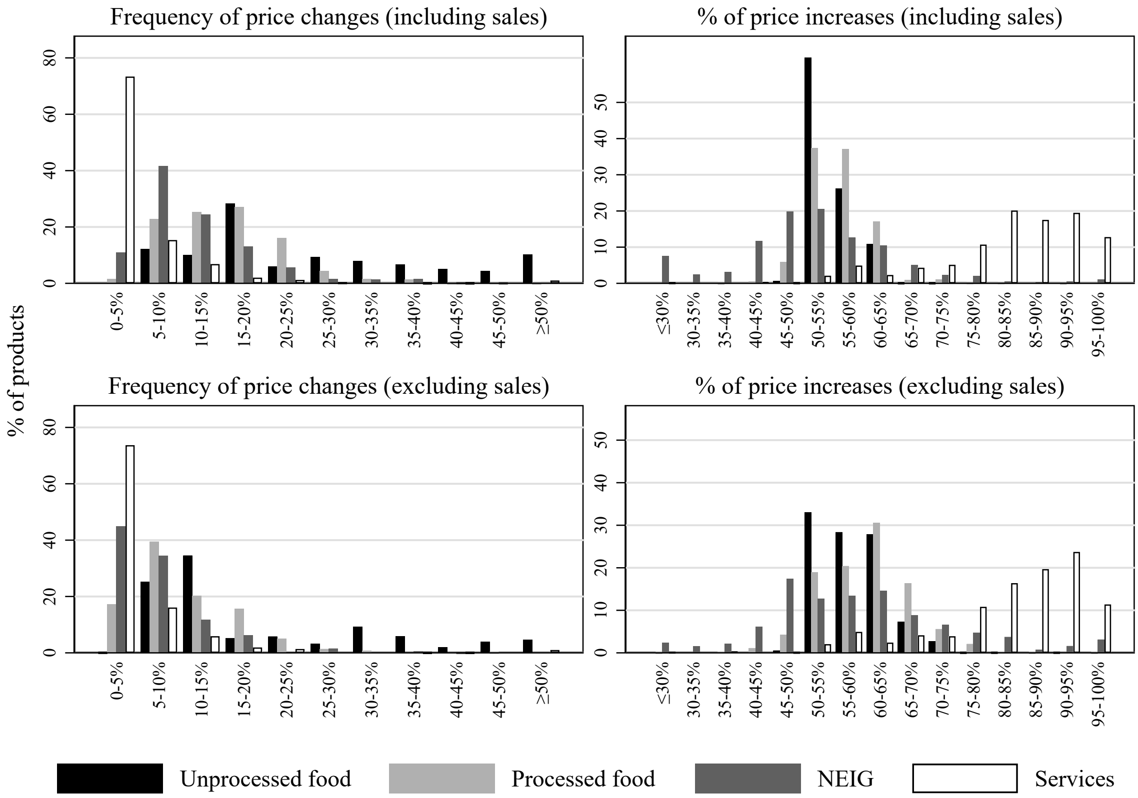
Figure A5: Distribution of (Log-)Price Changes before/after 2013 (in %)



Notes: The histograms plot the distribution of price changes calculated first at the country level for the common sample of products and weighted by the EA product weights and then weighted at the EA level using HICP country weights. Grey shaded histogram corresponds to the distribution of price changes excluding sales before 2013 and the solid black line corresponds to the distribution of price changes excluding sales after 2013. Results excluding sales are based on 1) NSI sales flag if available or 2) common sales filter.

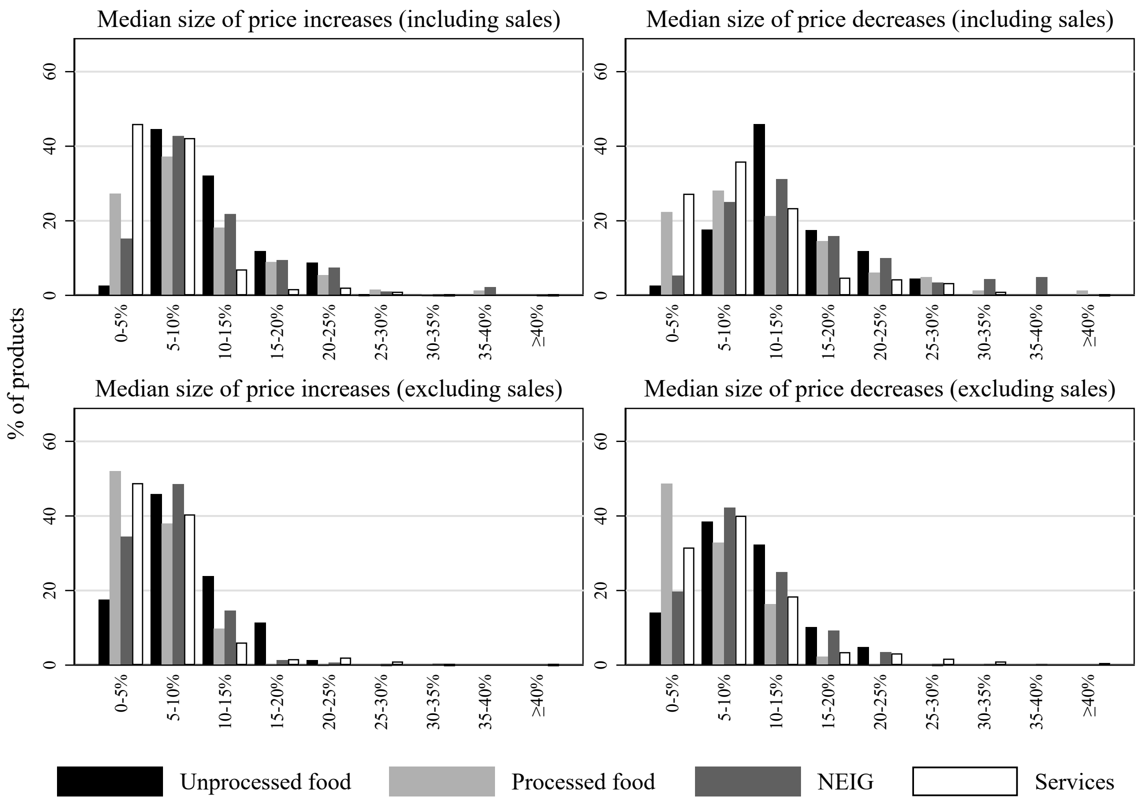
B.8 Sectoral Heterogeneity

Figure A6: Euro Area - Frequency of Price Changes: Distribution of COICOP-5 Products by Sector



*Notes: The histograms use country/product observations with country weights, and are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries. Price changes due to replacement are excluded beforehand (except for Greece and Slovakia). Results excluding sales are based on **1)** NSI sales flag (if available) or **2)** common sales filter.*

Figure A7: Euro Area - Size of Price Changes: Distribution of COICOP-5 Products by Sector



*Notes: The histograms use country/product observations with country weights, and are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries. Price changes due to replacement are excluded beforehand (except for Greece and Slovakia). Results excluding sales are based on **1)** NSI sales flag (if available) or **2)** common sales filter.*

B.9 Cross-Country Similarities

Table A16: Correlations between Countries

Frequency of price changes (average correlation: 0.59)											
	Austria	Belgium	France	Germany	Greece	Italy	Latvia	Lithuania	Luxembourg	Slovakia	Spain
Austria	1										
Belgium	0.86	1									
France	0.73	0.87	1								
Germany	0.55	0.67	0.46	1							
Greece	0.38	0.60	0.78	0.39	1						
Italy	0.30	0.21	0.57	0.32	0.70	1					
Latvia	0.45	0.80	0.65	0.41	0.46	0.33	1				
Lithuania	0.61	0.78	0.74	0.46	0.52	0.43	0.73	1			
Luxembourg	0.50	0.60	0.61	0.46	0.54	0.60	0.34	0.51	1		
Slovakia	0.57	0.81	0.82	0.49	0.68	0.56	0.65	0.83	0.53	1	
Spain	0.58	0.80	0.82	0.50	0.82	0.58	0.59	0.62	0.63	0.78	1
Median size of price increases (average correlation: 0.28)											
	Austria	Belgium	France	Germany	Greece	Italy	Latvia	Lithuania	Luxembourg	Slovakia	Spain
Austria	1										
Belgium	0.08	1									
France	0.20	0.44	1								
Germany	0.67	-0.02	0.17	1							
Greece	-0.13	0.42	0.60	-0.15	1						
Italy	0.46	0.16	0.72	0.38	0.45	1					
Latvia	0.44	0.38	0.23	0.48	0.21	0.36	1				
Lithuania	0.31	-0.05	-0.07	0.30	-0.15	0.04	0.52	1			
Luxembourg	0.23	0.47	0.39	0.20	0.42	0.40	0.26	-0.00	1		
Slovakia	0.36	-0.01	-0.20	0.43	-0.26	0.01	0.23	0.32	0.08	1	
Spain	0.49	0.45	0.82	0.38	0.57	0.87	0.47	0.10	0.50	-0.14	1
Median size of price decreases (average correlation: 0.27)											
	Austria	Belgium	France	Germany	Greece	Italy	Latvia	Lithuania	Luxembourg	Slovakia	Spain
Austria	1										
Belgium	0.27	1									
France	0.27	0.49	1								
Germany	0.71	0.03	0.36	1							
Greece	-0.01	0.27	0.51	0.06	1						
Italy	0.58	0.37	0.70	0.55	0.45	1					
Latvia	0.53	0.12	0.25	0.57	0.22	0.38	1				
Lithuania	0.48	-0.12	0.04	0.44	-0.02	0.32	0.53	1			
Luxembourg	0.10	0.46	0.20	0.19	0.16	0.18	0.06	-0.03	1		
Slovakia	0.35	-0.28	-0.34	0.34	-0.29	-0.04	0.26	0.43	-0.12	1	
Spain	0.39	0.45	0.71	0.38	0.54	0.68	0.35	0.19	0.16	-0.24	1

Notes: The correlations are calculated using statistics at the product level. Products that are common to at least 3 of the 4 largest countries are included. The reported averages are the mean correlations over all country pairs. Statistics are based on the country-specific period. Price changes due to sales are included, but price changes due to replacements are excluded beforehand (except Greece and Slovakia). Seasonal sales are excluded in the Belgian dataset but temporary promotions are included. Individual products can have a substantial impact on the correlation of a country pair.

B.10 Explanatory Variables of the Frequency and Size of Price Changes

Table A17: Description and Source of the Explanatory Variables Used in the Regressions

Variable	Description	Source	Comments
Share of labour costs	The compensation of employees (aggregated over all parts of the domestic part of the production chain) that is required as input for domestically manufactured products from a certain product category that are consumed by households, divided by household expenditures on domestically manufactured products from that product category	Euro area input-output table, year 2015, Eurostat	We use the inverted symmetric input-output table by product (65), classified by CPA, that is the EU official classification of products by activity. In order to match each COICOP with its corresponding CPA, we use the Reference And Management Of Nomenclatures (RAMON) by Eurostat. When the matching is not unique, we use the average of the corresponding CPA products
Share of imported energy and raw material inputs	The value of imported raw materials (including energy) that are required as input for domestically manufactured products from a certain product category that are consumed by households, divided by household expenditures on domestically manufactured products from that product category	Euro area input-output table, year 2015, Eurostat	See note on "Share of labour costs"
Share of all imported inputs	The value of all imported products that are required as input for domestically manufactured products from a certain product category that are consumed by households, divided by household expenditures on domestically manufactured products from that product category	Euro area input-output table, year 2015, Eurostat	See note on "Share of labour costs"
% of online consumers	Percentage of individuals that bought a certain type of product online in the last 12 months	European Union survey on ICT usage in households and by individuals, country-specific data, year 2015, Eurostat	There are 16 possible answers on the types of products bought. Each COICOP has been matched to the closest product type when possible
Regulated price dummy	Administered prices cover all goods and services of which the prices are fully ("directly") set or mainly ("to a significant extent") influenced by the government (central, regional, local government including national regulators)	Country-specific data and country-specific sample period, Eurostat	Each COICOP is assigned a value of 1 or 0 indicating whether it is administered or not
Retail market concentration (HHI)	$HHI = \frac{\sum_{i=1}^{N} s_i^2}{100}$ where s_i is the market share of firm i in the market, and N is the number of firms. The measure can range between 0 and 100 (0 being where there are an "infinite" number of "infinitely" small firms, and 100 being where there is a monopoly with a market share of 100%)	Country-specific data, average 2004-2009, ECB, Structural features of distributive trades and their impact on prices in the euro area, Occasional paper, September 2011	The markets are grocery; health and beauty; clothing and footwear; house and gardening; electronics and appliances; leisure and personal. Each COICOP has been matched to the closest product type when possible

B.11 Regression of the Size of Price Changes

Table A18: Some Determinants of the Median Size of Price Changes in the Euro Area

	I	II	III	IV
Share of labour costs	-0.089***	-0.098**	-0.093***	-0.097***
Share of imported energy and raw material inputs	-0.358***	-0.347***	-0.034	-0.337***
Share of all imported inputs	-0.034	-0.049	0.091*	-0.098
% of online consumers	0.0005***	0.0005***	0.0019***	0.0004**
Regulated price dummy	0.009		-0.016	0.009
Retail market concentration (HHI)		-0.0004		
Unprocessed food dummy				0.010
Processed food dummy				-0.011**
Services dummy				-0.012
Constant	0.106***	0.114***	0.091***	0.125***
Country dummies	✓	✓	✓	✓
Number of observations	1,622	1,293	1,622	1,622
R^2	0.280	0.385	0.294	0.293

*Notes: All regressions are estimated using OLS and are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries. Standard errors are clustered at the product level. *, **, and *** denote significance at respectively 10%, 5%, and 1%. The dependent variable in Column I is the median size of the absolute non-zero price changes, excluding sales and excluding product replacements (for Greece, Luxembourg, Slovakia, and Spain sales are excluded via the sales filter, Greece and Slovakia include product replacements). Column II adds the Herfindahl–Hirschman Index (HHI) of the retail sector as explanatory variable. This regression uses fewer observations as the HHI is not available for all products (e.g., non-retail products). The regulated price dummy is not included in this regression as there is only one observation available for estimation. In Column III the dependent variable is the median size of price changes including sales and excluding product replacements (instead of excluding sales and excluding product replacements). Column IV adds sector dummies to the regression in Column I. The reference sector is NEIG.*

C Comparison with Dhyne et al. (2006)

To be consistent with Dhyne et al. (2006), three main adjustments of our calculations based on the micro price data were necessary. First, the statistics in Dhyne et al. (2006) were derived from the same set of 50 single products across countries. However, for Luxembourg and Spain, our micro dataset does not allow identification of products at the same level of disaggregation as in Dhyne et al. (2006), e.g. due to missing product id information. Thus, we have to limit our comparison to five countries (Austria, Belgium, France, Germany and Italy). In terms of product groups, only one (out of four) unprocessed food item is available for France and Italy. Additionally, no energy products are available for Belgium and Italy. Thus, we drop unprocessed food and energy from our comparison. This leaves us with a sample of 43 of the original 50 products which is further reduced due to unavailability of certain products for some countries (see Table A19). The coverage of processed food, NEIG and services items, however, is quite good across countries, with the exception of Belgium for which only five out of 17 NEIG and eight out of 19 Services items are available. Although in the dataset underlying Dhyne et al. (2006) more products are available for most countries, we only include those products in our comparison that are available in both samples.

A factor hampering comparability across countries already in Dhyne et al. (2006) was the fact that – due to data availability at that time – their frequency statistics included price changes due to sales for some countries (Austria and France) but excluded them for other countries (Belgium, Germany and Italy). In order to be consistent with this pattern, we also excluded sales from the frequencies in our results for Belgium, Germany and Italy but included them for Austria and France.[64] With this in mind, the resulting frequencies should not be compared across countries but rather across time, i.e. between the older and the more recent results.

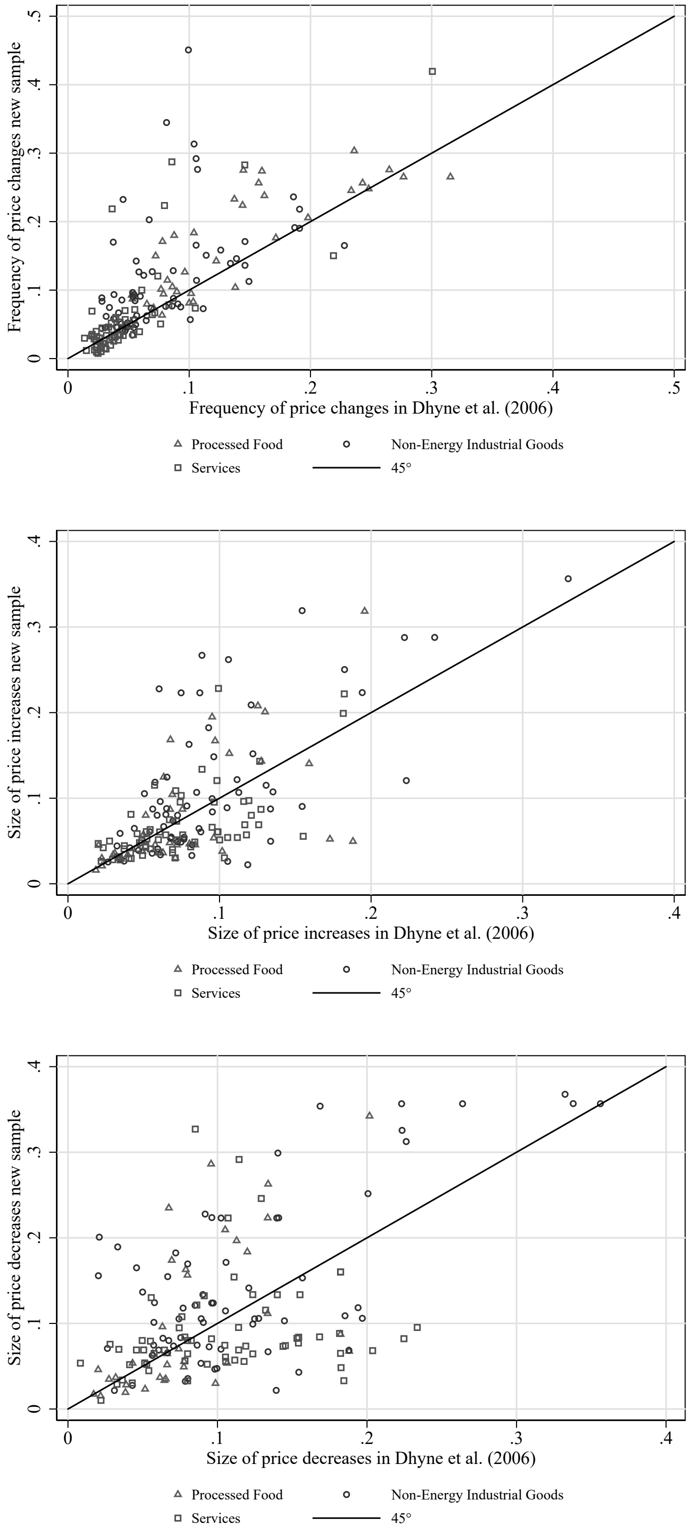
Furthermore, to perform a clean, i.e. non-overlapping, comparison of the older with more recent evidence, we restrict the sample period of our analysis to the time span 2011-2017 harmonised across countries (with the exception of Belgium for which the sample runs only until 2015), while the results from Dhyne et al. (2006) cover the period 1996-2001 for most countries. Finally, to control for changes in the weighting structure over time, we apply the same country-specific product and product-group weights as well as country weights (average of 2011-2017) in the aggregation for both samples. As a result, the reported numbers in Dhyne et al. (2006) diverge slightly from the ones reported in Table 6.

[64]For Germany, the old dataset lacked only information on seasonal sales which mainly affects clothing and footwear, so our comparison for processed food in Germany includes sales. See Dhyne et al. (2005), footnote 21 of their Technical Appendix.

Table A19: Availability of the 50 Products from Dhyne et al. (2006) in Our Dataset

	Austria	Belgium	France	Germany	Italy
Unprocessed food					
Steak	x	x	x	x	x
Fresh fish	x	x		x	
Lettuce	x	x		x	
Banana	x	x		x	
Processed food					
Milk	x	x	x	x	x
Sugar	x	x	x	x	x
Frozen spinach	x	x	x	x	x
Mineral water	x	x	x	x	x
Coffee	x	x	x	x	x
Whisky	x	x	x	x	x
Beer in a shop	x	x	x	x	x
Energy					
Heating oil	x		x	x	
Fuel type 1	x		x	x	
Fuel type 2	x		x	x	
Non-energy industrial goods					
Socks	x	x		x	x
Jeans	x	x	x	x	x
Sport shoes	x	x	x	x	x
Shirt (men)	x	x	x	x	x
Acrylic painting	x		x	x	x
Cement	x		x	x	x
Toaster	x		x	x	x
Electric bulb	x			x	x
Type of furniture	x		x	x	x
Towel	x		x	x	x
Car tyre	x			x	x
Television set	x			x	
Dog food	x		x	x	x
Tennis ball	x		x	x	x
Construction game (Lego)	x	x	x	x	x
Toothpaste	x		x	x	x
Suitcase	x		x	x	x
Services					
Dry cleaning	x		x	x	x
Hourly rate of an electrician	x			x	
Hourly rate of a plumber	x			x	
Domestic services	x				x
Hourly rate in a garage	x	x	x	x	x
Car wash	x	x	x	x	x
Balancing of wheels	x	x		x	x
Taxi	x			x	
Telephone/Fax machine	x		x	x	x
Movie	x			x	x
Videotape hiring				x	
Photo development	x			x	x
Hotel room	x			x	x
Glass of beer in a café	x	x	x	x	x
Meal in a restaurant	x	x	x	x	
Hot-dog	x		x		x
Cola based lemonade in a café	x	x	x	x	x
Haircut (men)	x	x	x	x	
Hairdressing (ladies)	x	x	x	x	x
Total	49	24	34	48	37
Total excl. Unproc. Food and Energy	**42**	**20**	**30**	**41**	**36**

Figure A8: Frequency and Size of Price Changes – Period 2011-2017 vs. Dhyne et al. (2006)



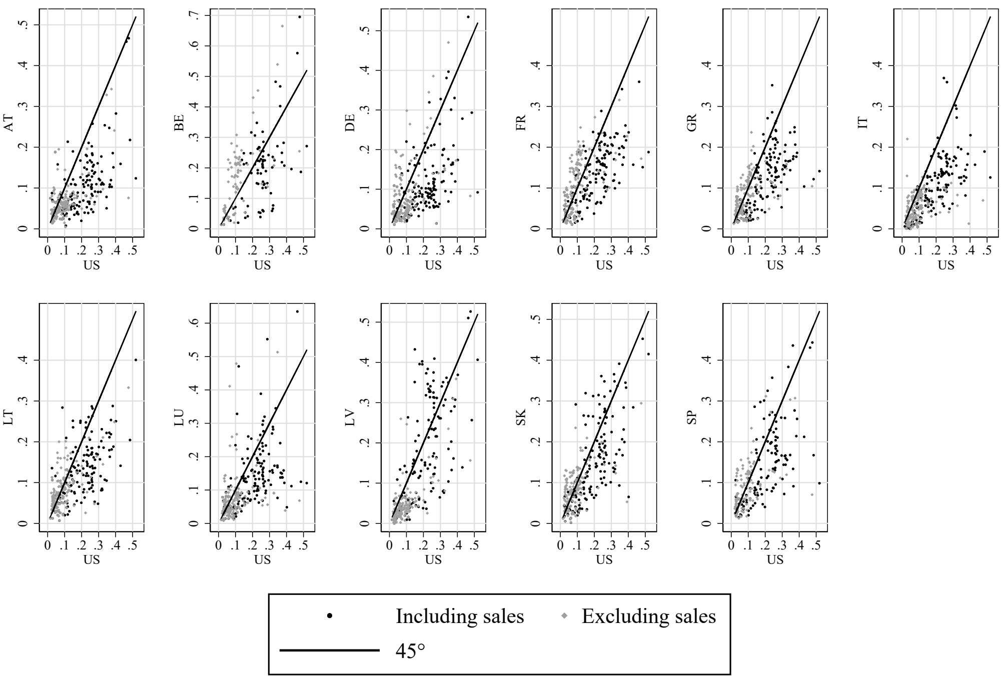
Notes: Frequencies and size of price changes at the product level for Processed Food, NEIG and Services items (at most 43 products depending on availability). Countries covered are Austria, Belgium, France, Germany and Italy.

D Comparison with US Evidence

To compare our results with the results for the United States from Nakamura and Steinsson (2008*a*), we downloaded the data tables from the authors' websites, which are part of the supplementary materials of the published paper. In particular, we extracted data from the ELI-level tables on frequency of price changes including and excluding sales (Table 19 in their paper), the absolute size of price changes for consumer prices (Table 22), and moments of the distribution of price changes (Table 26). For the mapping to the European data, we created correspondence tables between ELI and COICOP nomenclatures (available as online material), and stored the US results using the corresponding COICOP classification. For the comparison, we applied euro area HICP weights to all products in order to derive aggregate statistics for both economic areas.

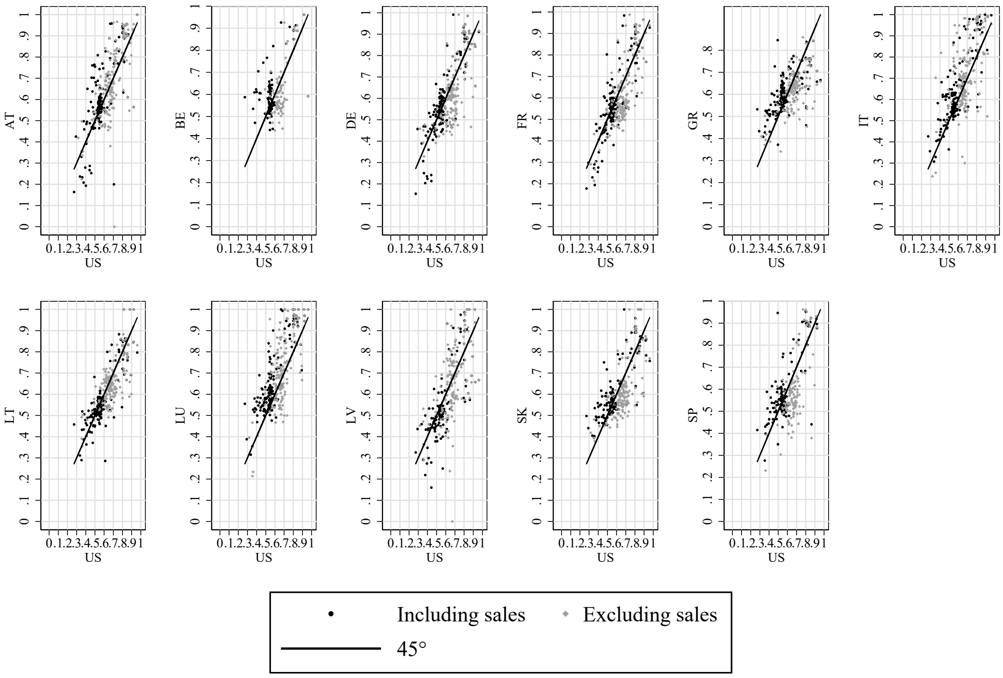
In the following figures, we report country-specific scatter plots for the frequency of price changes (Figure A9), the share of price increases (Figure A10), the size of price increases (Figure A11), and the size of price decreases (Figure A12).

Figure A9: Frequency of Price Changes at the Product Level: Euro Area countries vs United States



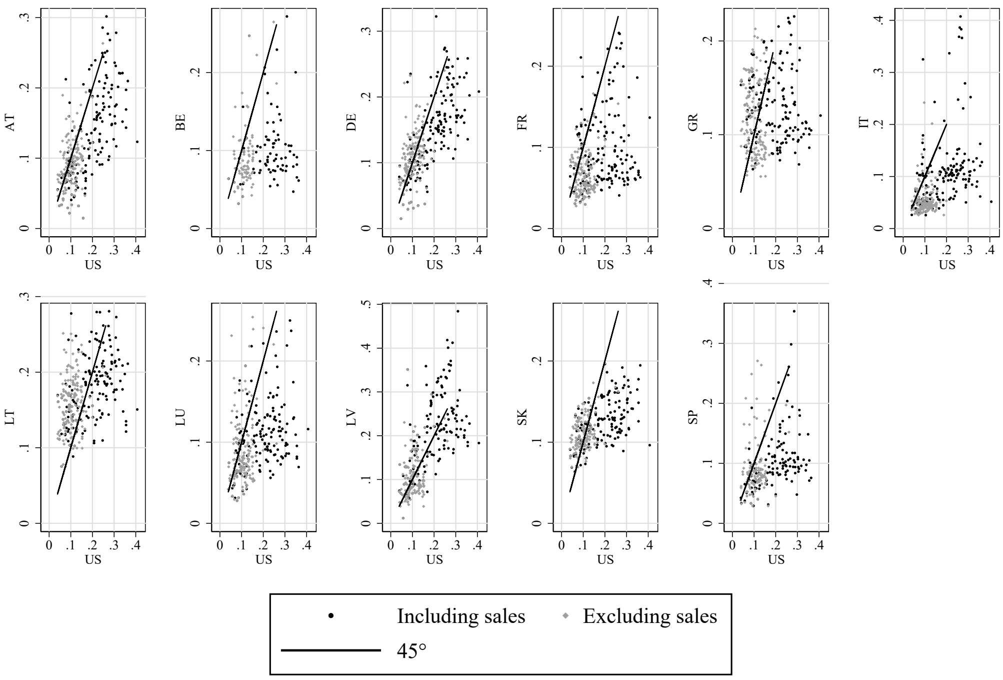
Notes: US product results are taken from Nakamura and Steinsson (2008a). Euro area statistics are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries.

Figure A10: Average Share of Price Increases at the Product Level: Euro Area countries vs United States



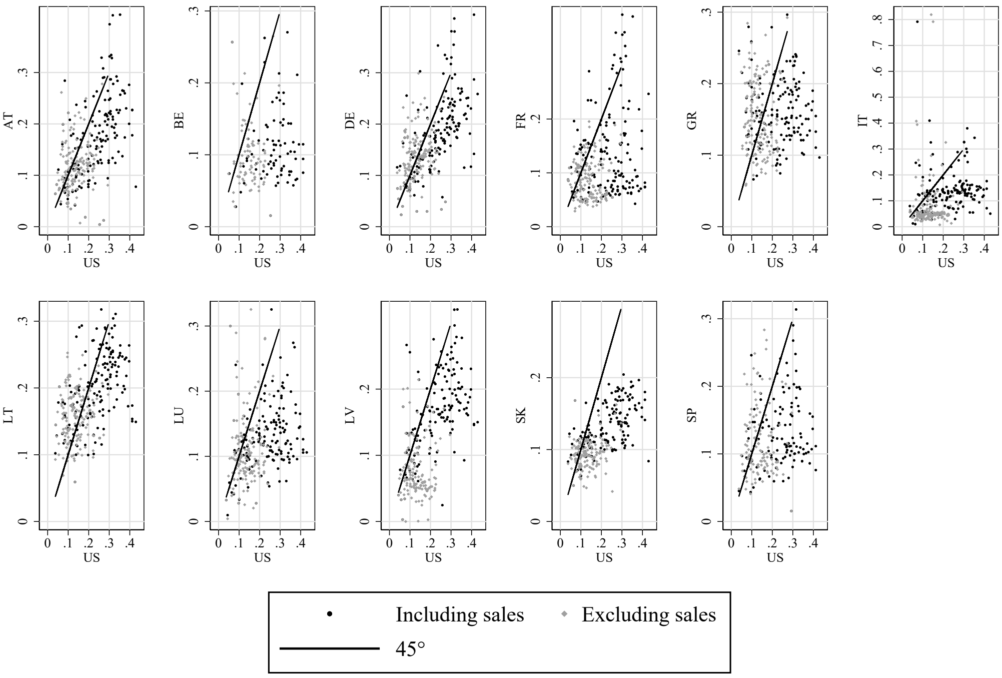
Notes: US product results are taken from Nakamura and Steinsson (2008a). Euro area statistics are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries.

Figure A11: Average Size of Price Increases at the Product Level: Euro Area countries vs United States



Notes: US product results are taken from Nakamura and Steinsson (2008a). Euro area statistics are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries.

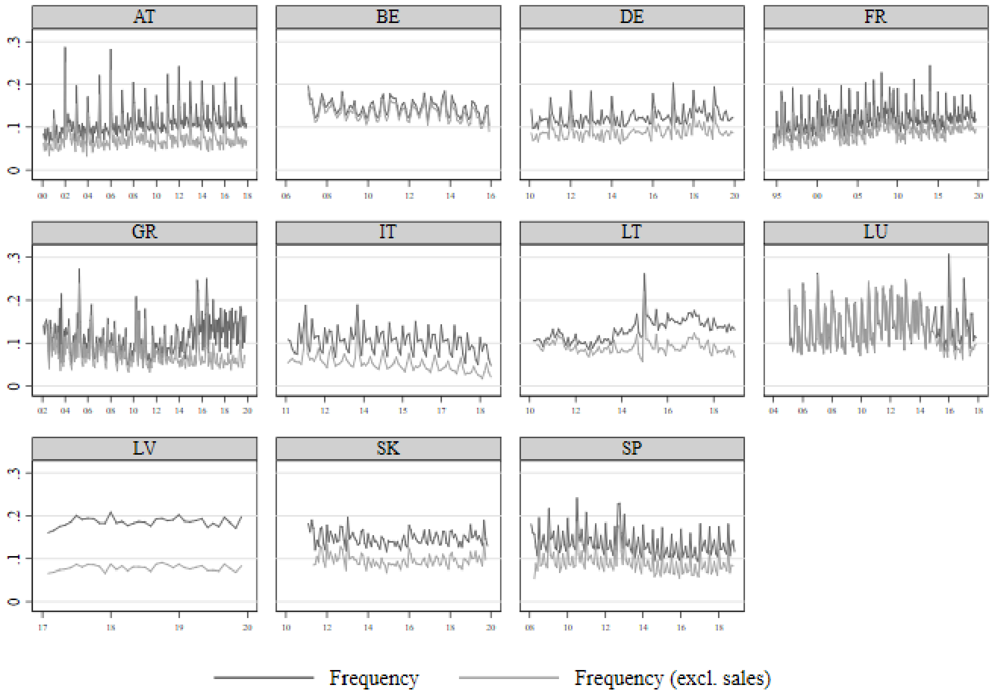
Figure A12: Average Size of Price Decreases at the Product Level: Euro Area countries vs United States



Notes: US product results are taken from Nakamura and Steinsson (2008a). Euro area statistics are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries.

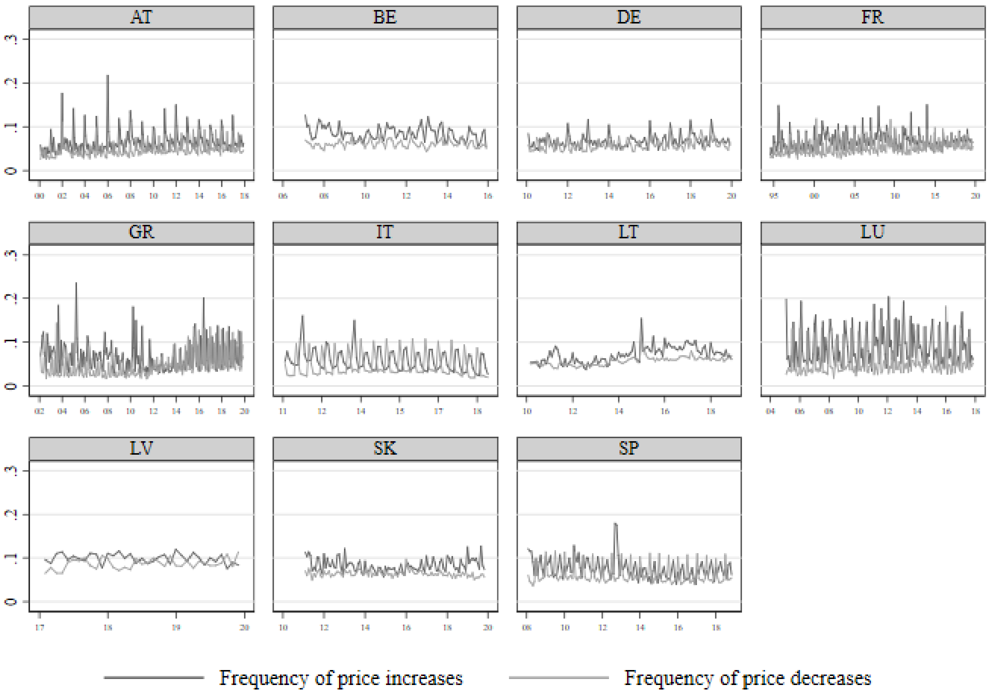
E Additional Results on Time Series Statistics

Figure A13: Frequency by Country over Time



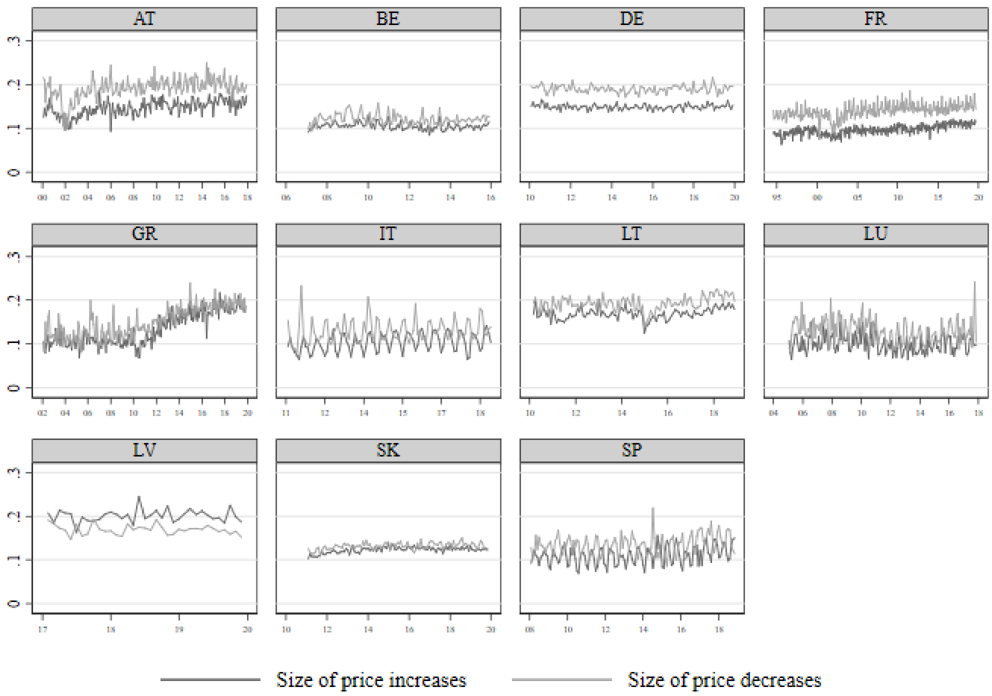
Notes: Statistics are based on products that are common to at least 3 of the 4 largest countries and calculated using euro area product weights at the COICOP-5 level (2017-2020 average). For the trend, a HP filter is applied. Price changes due to replacement are excluded beforehand (except Greece and Slovakia). Outliers adjusted beforehand.

Figure A14: Frequencies of Price Increases and Decreases by Country over Time



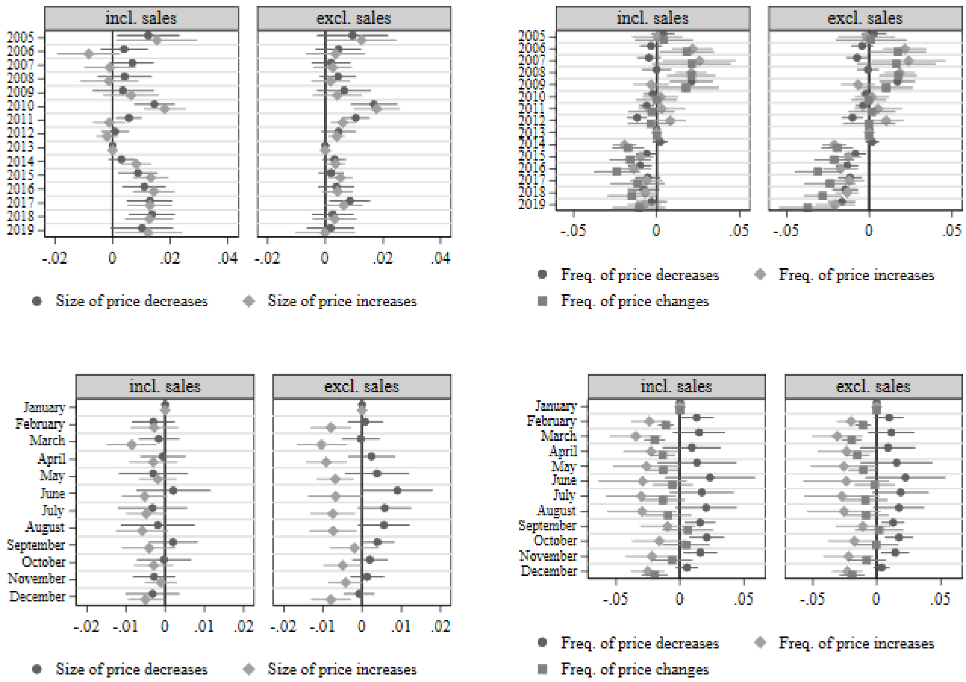
Notes: Statistics are based on products that are common to at least 3 of the 4 largest countries and calculated using euro area product weights at the COICOP-5 level (2017-2020 average). For the trend, a HP filter is applied. Price changes due to replacement are excluded beforehand (except Greece and Slovakia). Outliers adjusted beforehand.

Figure A15: Mean Size of Price Increases and Decreases by Country over Time



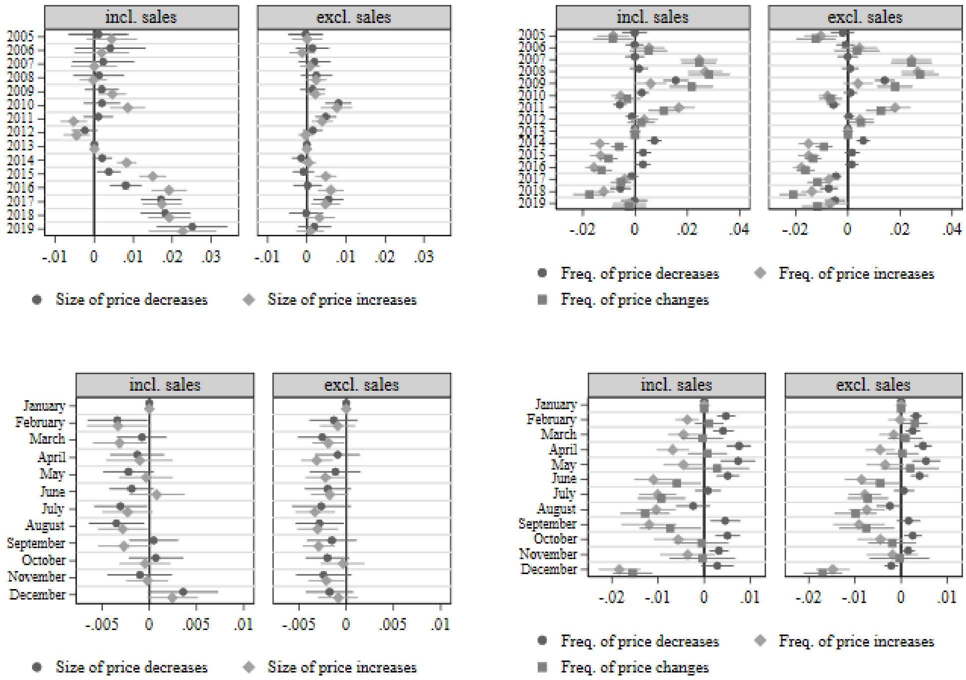
Notes: The chart shows the mean size of non-zero price changes. Statistics are based on products that are common to at least 3 of the 4 largest countries and calculated using euro area product weights at the COICOP-5 level (2017-2020 average). Price changes due to replacement are excluded beforehand (except Greece and Slovakia). Outliers adjusted beforehand.

Figure A16: Seasonal Patterns, Annual Changes, and Effect of Sales: Unprocessed Food



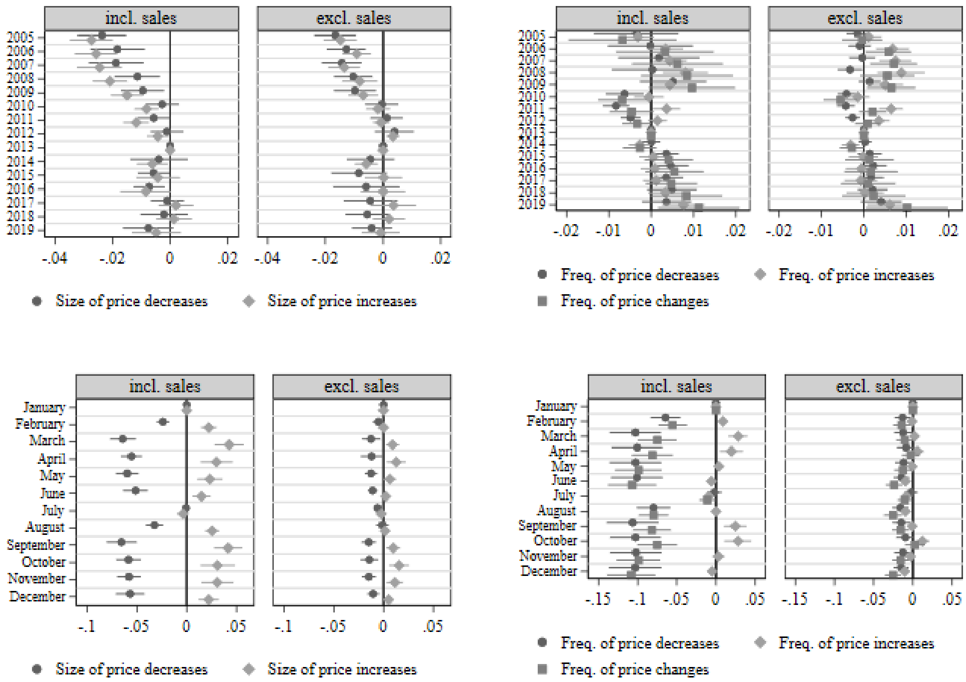
Notes: Coefficient plots from weighted panel regressions with COICOP, country, and time fixed effects and dummy for VAT changes in France (04/00, 01/12, 01/14), Italy (09/11), Slovakia (01/11), and Spain (09/12, 07-09/10), with country weights in euro area HICP (2017-2020 average) and robust standard errors. Dependent variables are frequency and size of price adjustment. Regressions are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries. Displayed are only the years 2005-2019, with the base year 2013, and base month January. Price changes due to replacement are excluded beforehand (except Greece and Slovakia). Results excluding sales are based on 1) NSI sales flag if available or 2) common sales filter. Outliers adjusted beforehand.

Figure A17: Seasonal Patterns, Annual Changes, and Effect of Sales: Processed Food



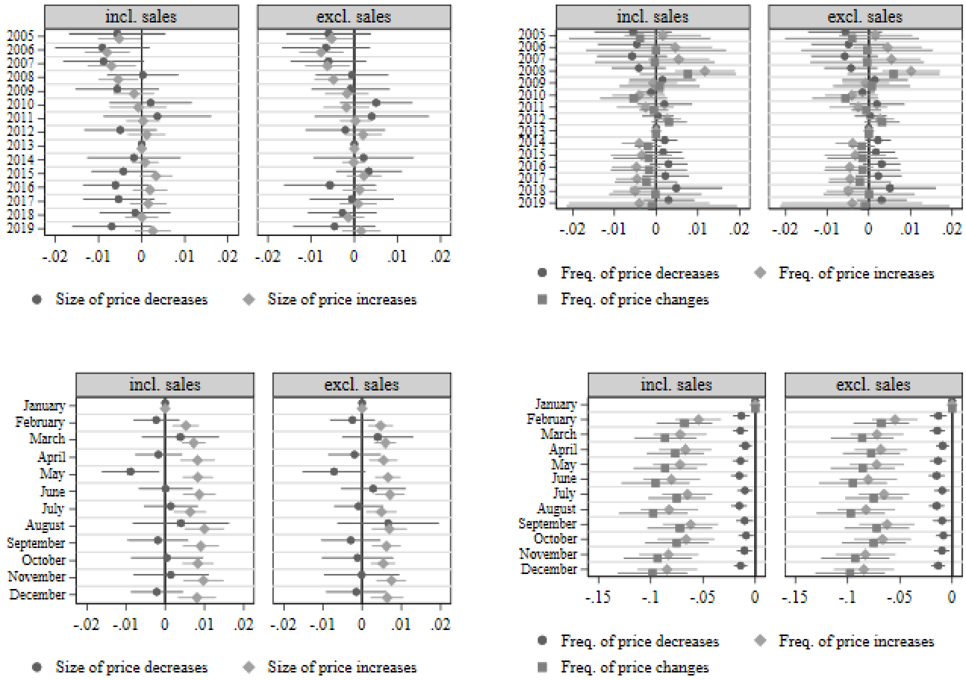
Notes: Coefficient plots from weighted panel regressions with COICOP, country, and time fixed effects and dummy for VAT changes in France (04/00, 01/12, 01/14), Italy (09/11), Slovakia (01/11), and Spain (09/12, 07-09/10), with country weights in euro area HICP (2017-2020 average) and robust standard errors. Dependent variables are frequency and size of price adjustment. Regressions are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries. Displayed are only the years 2005-2019, with the base year 2013, and base month January. Price changes due to replacement are excluded beforehand (except Greece and Slovakia). Results excluding sales are based on 1) NSI sales flag if available or 2) common sales filter. Outliers adjusted beforehand.

Figure A18: Seasonal Patterns, Annual Changes, and Effect of Sales: NEIG



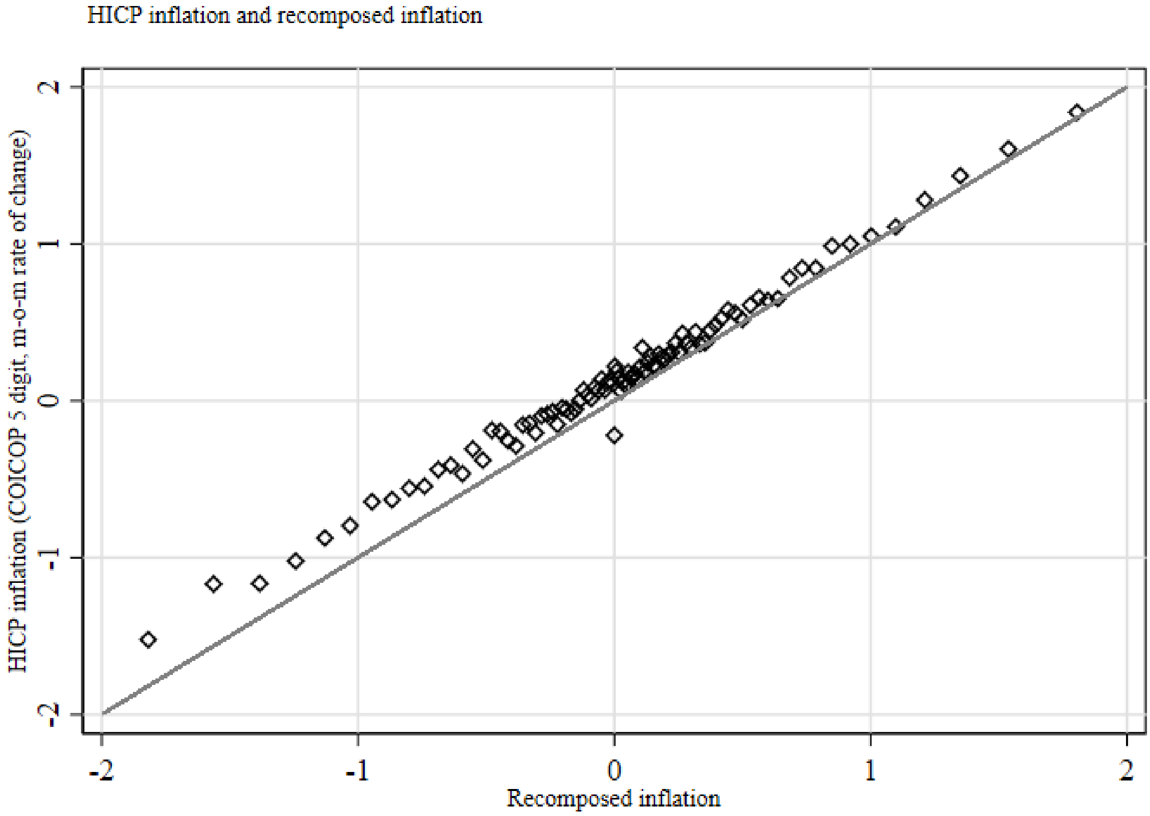
Notes: Coefficient plots from weighted panel regressions with COICOP, country, and time fixed effects and dummy for VAT changes in France (04/00, 01/12, 01/14), Italy (09/11), Slovakia (01/11), and Spain (09/12, 07-09/10), with country weights in euro area HICP (2017-2020 average) and robust standard errors. Dependent variables are frequency and size of price adjustment. Regressions are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries. Displayed are only the years 2005-2019, with the base year 2013, and base month January. Price changes due to replacement are excluded beforehand (except Greece and Slovakia). Results excluding sales are based on 1) NSI sales flag if available or 2) common sales filter. Outliers adjusted beforehand.

Figure A19: Seasonal Patterns, Annual Changes, and Effect of Sales: Services



Notes: Coefficient plots from weighted panel regressions with COICOP, country, and time fixed effects and dummy for VAT changes in France (04/00, 01/12, 01/14), Italy (09/11), Slovakia (01/11), and Spain (09/12, 07-09/10), with country weights in euro area HICP (2017-2020 average) and robust standard errors. Dependent variables are frequency and size of price adjustment. Regressions are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries. Displayed are only the years 2005-2019, with the base year 2013, and base month January. Price changes due to replacement are excluded beforehand (except Greece and Slovakia). Results excluding sales are based on 1) NSI sales flag if available or 2) common sales filter. Outliers adjusted beforehand.

Figure A20: Recomposed and HICP Inflation



Notes: The figure compares the recomposed inflation, as in Equation 3, and m-o-m HICP inflation at the COICOP 5-digit level. Price changes due to replacement are excluded beforehand (except Greece and Slovakia). Statistics are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries.

Table A20: Cross-Correlation between Recomposed Inflation and Its Components

	f_{jt}	dp_{jt}	f^{+}_{jt}	f^{-}_{jt}	dp^{+}_{jt}	dp^{-}_{jt}	f^{+}_{jt}/f_{jt}
EURO AREA							
π_{jt} (incl. sales)	-0.160	0.793	0.373	-0.612	0.065	-0.381	0.557
π_{jt} (excl. sales)	0.018	0.628	0.340	-0.378	0.122	-0.180	0.405
By Sector							
Unprocessed Food	-0.000	0.909	0.426	-0.419	0.121	-0.178	0.674
Processed Food	0.083	0.796	0.486	-0.448	0.070	-0.067	0.634
NEIG	-0.367	0.819	0.554	-0.804	0.172	-0.481	0.695
Services	0.148	0.571	0.372	-0.272	0.132	-0.196	0.417
COUNTRY							
Austria	-0.184	0.762	0.286	-0.602	-0.044	-0.359	0.547
Belgium	0.012	0.656	0.310	-0.301	0.129	-0.163	0.310
France	-0.306	0.836	0.260	-0.706	-0.260	-0.534	0.576
Germany	-0.109	0.806	0.294	-0.494	-0.171	-0.438	0.607
Greece	-0.034	0.678	0.529	-0.629	0.046	-0.083	0.565
Italy	-0.184	0.861	0.667	-0.752	0.555	-0.299	0.630
Lithuania	0.024	0.709	0.387	-0.383	0.082	-0.251	0.585
Luxembourg	-0.075	0.780	0.410	-0.528	0.171	-0.185	0.496
Latvia	0.211	0.718	0.579	-0.235	0.223	-0.159	0.554
Slovakia	0.119	0.653	0.424	-0.236	0.143	-0.165	0.502
Spain	-0.156	0.784	0.422	-0.640	0.328	-0.319	0.644

Notes: The table shows correlations between recomposed inflation (π_{jt}), as in Equation 3, and its components (all product-country level statistics are pooled together, statistics are weighted using product-country HICP weights). Statistics are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries. Price changes due to replacement are excluded beforehand (except Greece and Slovakia). Seasonal sales are excluded in the Belgian dataset but temporary promotions are included. Results excluding sales are based on the NSI sales flag if available, and the common sales filter otherwise.

F More on Local Projection Exercises

F.1 Data Sources

This section documents the main sources for shocks used in the local projection exercises.

Monetary policy:

The series of euro area monetary policy shocks used is the one estimated by Jarociński and Karadi (2020) (available over the period March 1999 - December 2016). IRFs are rescaled to produce an inflation reaction to a positive surprise in the 3-month EONIA swap rate of 25 basis points.

The shock series has been downloaded from AEJ Macro web site (additional materials - Data Set of Jarociński and Karadi (2020)).

Oil:

The oil shock is the shock to the growth rate of monthly world crude oil production, estimated using the methodology of Baumeister and Hamilton (2019). The shock series (vintage ending in August 2020) has been downloaded from Christiane Baumeister's web site:

https://sites.google.com/site/cjsbaumeister/research.

Global demand:

The global demand shock is the shock to economic activity estimated using the methodology of Baumeister and Hamilton (2019). The shock series (vintage ending in August 2020) has been downloaded from Christiane Baumeister's web site:

https://sites.google.com/site/cjsbaumeister/research.

In both cases, the IRFs give the price reaction to a 1-standard deviation positive shock to the oil supply or to the global demand.

VAT:

VAT shocks are defined as the monthly rate difference between the HICP and the HICP at constant taxes. Per definition, the National Statistical Institutes (NSI's) assume full and immediate pass-through of tax changes, thus any difference in inflation rates is equal to the tax change. The series are available at the COICOP-5 level post 2015, while prior to 2015 they are approximated by the same series at the COICOP-4 level. The data are available at: `https://ec.europa.eu/eurostat/databrowser/view/prc_hicp_cmon/default/table?lang=en`. The exception to the above data source are France and Greece, for which, more complete data where available. Specifically, for the former, historical VAT rates and rate changes, have been provided for France at the COICOP-5 level while for the latter, historical data at the product level, have been provided by the Bank of Greece and were aggregated up to the COICOP-5 level. Out of 1402 non-zero VAT changes in the total sample, about 80 percent are from the three countries: France, Spain and Greece. By contrast, Belgium, Germany and Slovakia did not have a VAT change for the relevant period and are thus excluded.

In this exercise, the IRF gives the price reaction to a 1-pp increase in the VAT rate.

Local demand:

Unemployment - first difference of monthly seasonally adjusted (not calendar adjusted) unemployment rate measured as percentage of active population; EUROSTAT table *une_rt_m*.[65]

In this exercise, the IRF gives the price reaction to a 1-pp increase in the unemployment rate.

F.2 Decomposition of the Effects on IRF

In this subsection, we document how a shock is transmitted through the different price adjustment margins (intensive and extensive margins). Recall that for each shock S_t, the local-linear projection is:

$$\pi_{j,t,t+h} = \alpha_{j,h} + \alpha_{m,h} + \beta_h S_t + \gamma_y X_{j,t} + \epsilon_{j,t_h} \tag{A8}$$

where $\pi_{j,t,t+h}$ is the cumulative inflation for a product-country specific j between $t-1$ and $t+h$ (calculated as the sum of monthly inflation rates between date t and $t+h$ $= \sum_{\tau=0}^{h} \pi_{j,t+\tau,t+\tau+1}$), $\alpha_{j,m,h}$ are fixed-effects and X_{jt} are control variables. The β_h are the IRF of interest.

In our empirical exercise, we then calculate for each product j, monthly recomposed inflation rates, a first counterfactual inflation rate where frequency is constant to its average and inflation varies with size $\pi_{jt}^{\bar{f}} = f_{j.} \times dp_{jt}$ and a second one where the average size is constant $\pi_{jt}^{\bar{dp}} = f_{jt} \times dp_{j.}$. We can approximate counterfactual inflation rates over the horizon t - t+h by summing the monthly rates:

$$\pi_{j,t,t+h}^{\bar{f}} = \sum_{\tau=0}^{h} \pi_{j,t+\tau-1,t+\tau}^{\bar{f}} = f_{j.} \sum_{\tau=0}^{h} dp_{j,t+\tau-1,t+\tau} \tag{A9}$$

We can construct the same cumulative counterfactual inflation rate when assuming

[65] https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=une_rt_m&lang=en

constant size:

$$\pi^{\bar{dp}}_{j,t,t+h} = \sum_{\tau=0}^{h} \pi^{\bar{dp}}_{j,t+\tau-1,t+\tau} = dp_{j.} \sum_{\tau=0}^{h} f_{j,t+\tau} \tag{A10}$$

We then use these two variables as left-hand side variables in the local projection estimations.

As previous decomposition, in our empirical exercises, we will compute for each product j, a counterfactual inflation rate where frequencies of price increases and decreases are constant to their average and inflation varies with sizes of price increases and decreases $\pi^{\bar{f}^+,\bar{f}^-}_{jt} = f^+_{j.} \times dp^+_{jt} - f^-_{j.} \times dp^-_{jt}$ and a second one where the average sizes of increases and decreases are constant $\pi^{\bar{dp}^+,\bar{dp}^-}_{jt} = f^+_{jt} \times dp^+_{j.} - f^-_{jt} \times dp^-_{j.}$. We can approximate counterfactual inflation rates over the horizon t - t+h by summing the monthly rates:

$$\pi^{\bar{f}^+,\bar{f}^-}_{j,t,t+h} = \sum_{\tau=0}^{h} \pi^{\bar{f}^+,\bar{f}^-}_{j,t+\tau-1,t+\tau} = f^+_{j.} \sum_{\tau=0}^{h} dp^+_{j,t+\tau-1,t+\tau} - f^-_{j.} \sum_{\tau=0}^{h} dp^-_{j,t+\tau-1,t+\tau} \tag{A11}$$

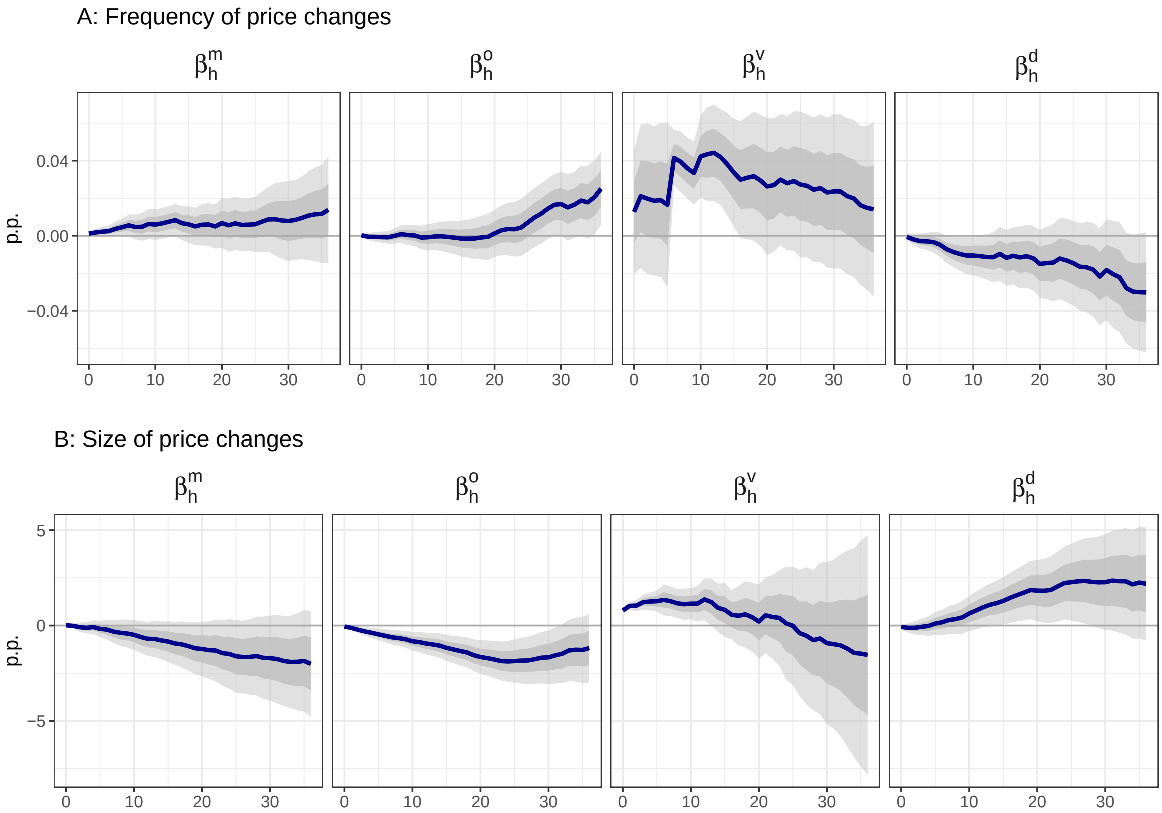
We can construct the same cumulative counterfactual inflation rate when assuming constant size:

$$\pi^{\bar{dp}^+,\bar{dp}^-}_{j,t,t+h} = \sum_{\tau=0}^{h} \pi^{\bar{dp}^+,\bar{dp}^-}_{j,t+\tau-1,t+\tau} = dp^+_{j.} \sum_{\tau=0}^{h} f^+_{j,t+\tau} - dp^-_{j.} \sum_{\tau=0}^{h} f^-_{j,t+\tau} \tag{A12}$$

We then use these two variables as left-hand side variables in the local projection estimations.

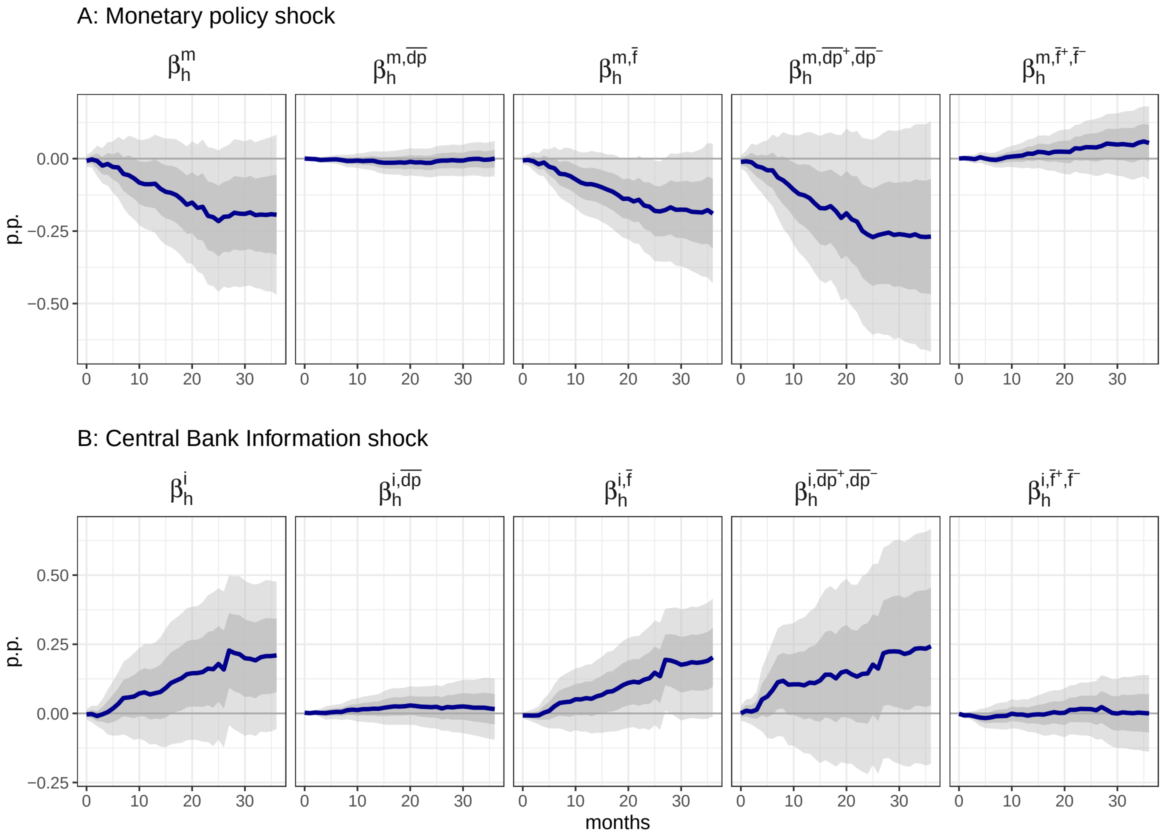
F.3 Impulse Response Functions - Robustness

Figure A21: Conditional Responses of Frequency and Size of Price Adjustment to Positive Aggregate Shocks



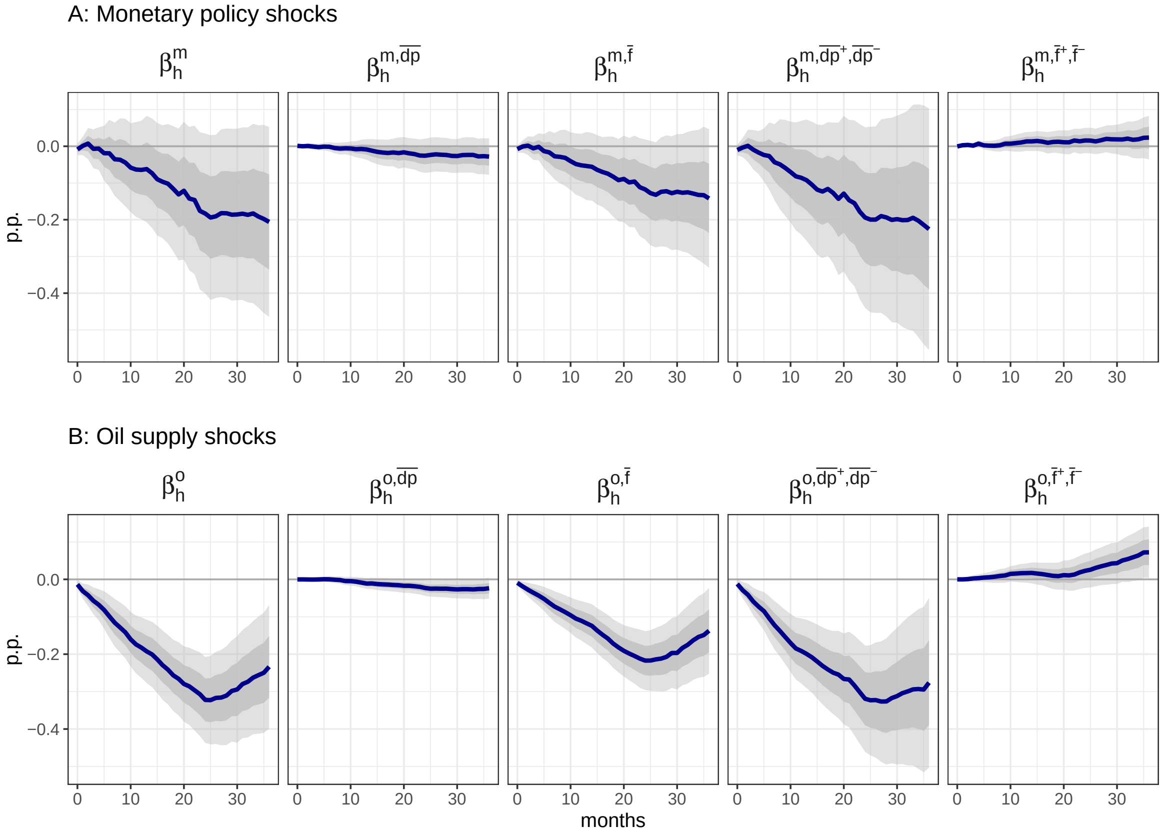
Notes: Local projections are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries. Price changes due to replacement are excluded beforehand (except Greece and Slovakia). Superscripts $x \in \{m, o, v, d\}$ represent the monetary, oil, VAT and demand shocks respectively. The models are specified in equation (11). The light and dark gray areas correspond to one and two standard error bands, assuming calendar-based clusters.

Figure A22: Conditional Responses to Monetary Shocks - Monetary Policy Shock vs Central Bank Information Shock



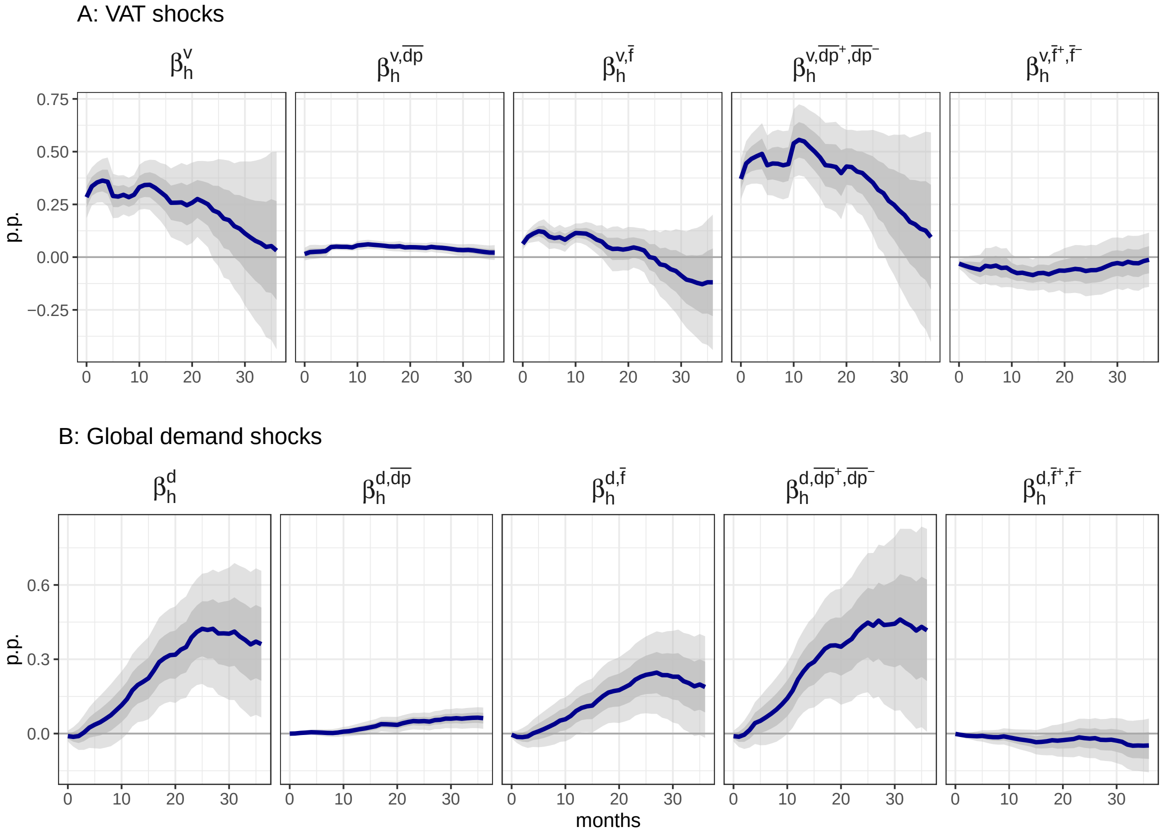
Notes: Local projections are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries. Price changes due to replacement are excluded beforehand (except Greece and Slovakia). Superscripts $x \in \{m, i\}$ *represent the monetary policy shocks (as in the baseline case) and CB information shock respectively. The models are specified in equation (11). In the order of the panels, the coefficients correspond to: The recomposed inflation* β_h^x*, counterfactual inflation assuming constant sizes of price changes* $\beta_h^{x,\bar{dp}}$*, counterfactual inflation assuming constant frequency of price changes* $\beta_h^{x,\bar{f}}$*, counterfactual inflation assuming constant sizes of price increases and decreases* $\beta_h^{x,\bar{dp}^+,\bar{dp}^-}$ *and counterfactual inflation assuming constant frequencies of price increases and decreases* $\beta_h^{x,\bar{f}^+,\bar{f}^-}$*. The light and dark gray areas correspond to one and two standard error bands, assuming calendar-based clusters.*

Figure A23: Conditional Responses to Positive Aggregate Shocks - excluding Sales - Monetary Policy and Oil Supply Shocks



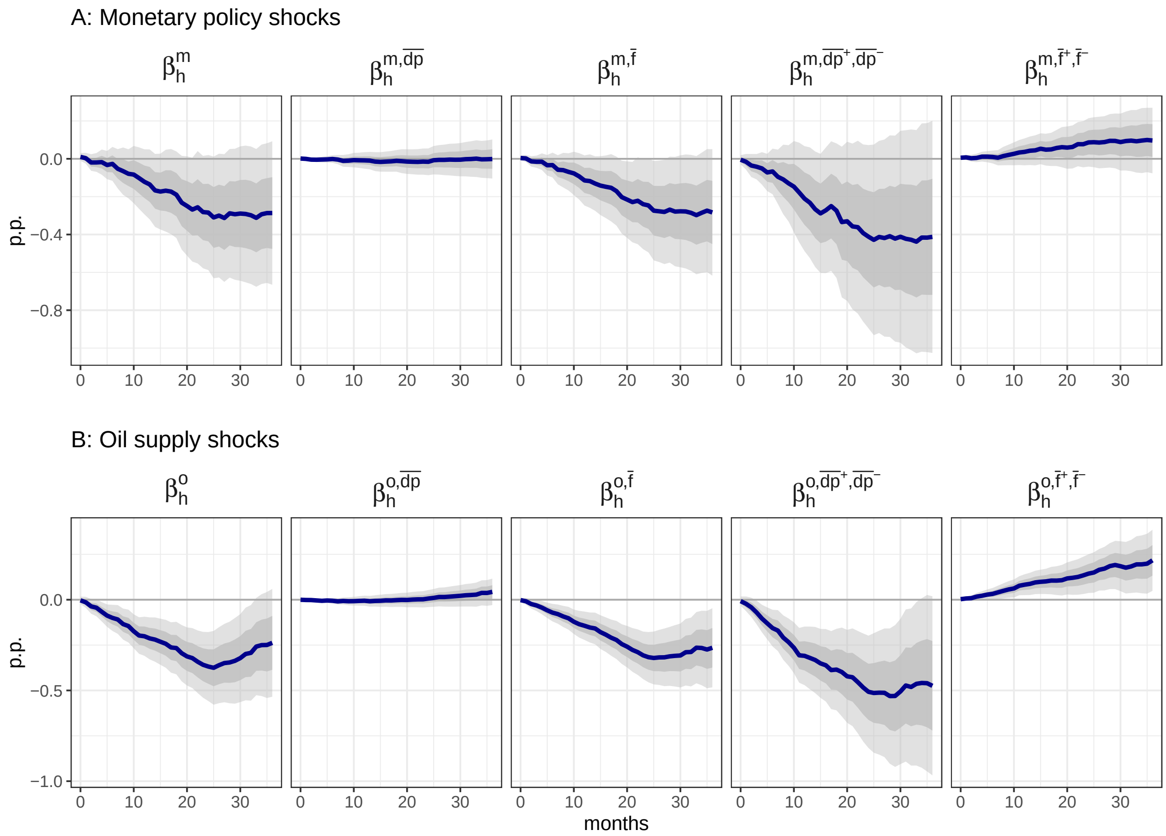
Notes: Local projections are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries. Price changes due to replacement are excluded beforehand (except Greece and Slovakia). Superscripts $x \in \{m, o\}$ represent the monetary and oil shocks respectively. The models are specified in equation (11). In the order of the panels, the coefficients correspond to: The recomposed inflation β_h^x, counterfactual inflation assuming constant sizes of price changes $\beta_h^{x,\bar{dp}}$, counterfactual inflation assuming constant frequency of price changes $\beta_h^{x,\bar{f}}$, counterfactual inflation assuming constant sizes of price increases and decreases $\beta_h^{x,\bar{dp}^+,\bar{dp}^-}$ and counterfactual inflation assuming constant frequencies of price increases and decreases $\beta_h^{x,\bar{f}^+,\bar{f}^-}$. The light and dark gray areas correspond to one and two standard error bands, assuming calendar-based clusters.

Figure A24: Conditional Responses to Positive Aggregate Shocks - excluding Sales - VAT and Global Demand Shocks



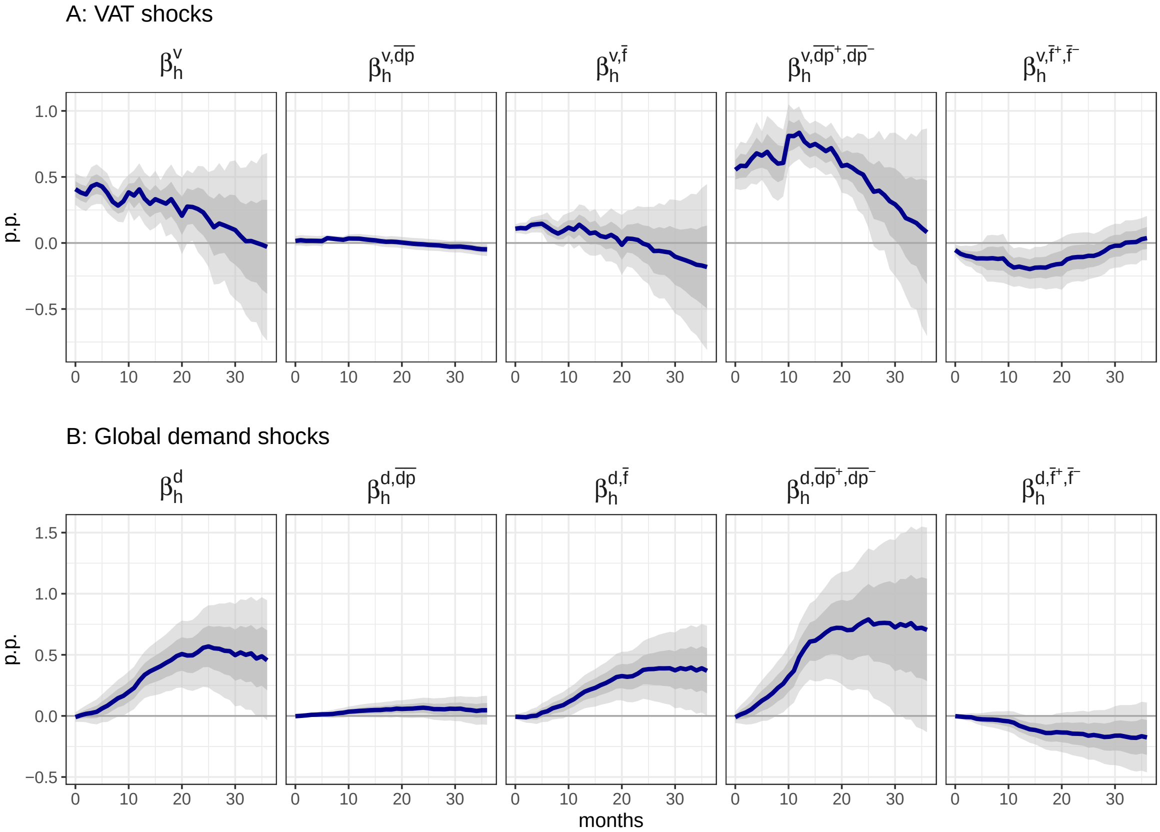
Notes: Local projections are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries. Price changes due to replacement are excluded beforehand (except Greece and Slovakia). Superscripts $x \in \{v, d\}$ represent the VAT and global demand shocks respectively. The models are specified in equation (11). In the order of the panels, the coefficients correspond to: The recomposed inflation β_h^x, counterfactual inflation assuming constant sizes of price changes $\beta_h^{x,\bar{d}p}$, counterfactual inflation assuming constant frequency of price changes $\beta_h^{x,\bar{f}}$, counterfactual inflation assuming constant sizes of price increases and decreases $\beta_h^{x,\bar{d}p^+,\bar{d}p^-}$ and counterfactual inflation assuming constant frequencies of price increases and decreases $\beta_h^{x,\bar{f}^+,\bar{f}^-}$. The light and dark gray areas correspond to one and two standard error bands, assuming calendar-based clusters.

Figure A25: Conditional Responses to Positive Aggregate Shocks - Three Countries with Longer Sample (AT, FR, GR) - Monetary Policy and Oil Supply Shocks



Notes: Local projections are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries. Price changes due to replacement are excluded beforehand (except Greece). Superscripts $x \in \{m, o\}$ *represent the monetary and oil supply shocks respectively. The models are specified in equation (11). In the order of the panels, the coefficients correspond to: The recomposed inflation* β_h^x*, counterfactual inflation assuming constant sizes of price changes* $\beta_h^{x,\bar{dp}}$*, counterfactual inflation assuming constant frequency of price changes* $\beta_h^{x,\bar{f}}$*, counterfactual inflation assuming constant sizes of price increases and decreases* $\beta_h^{x,\bar{dp}^+,\bar{dp}^-}$ *and counterfactual inflation assuming constant frequencies of price increases and decreases* $\beta_h^{x,\bar{f}^+,\bar{f}^-}$*. The light and dark gray areas correspond to one and two standard error bands, assuming calendar-based clusters.*

Figure A26: Conditional Responses to Positive Aggregate Shocks - Three Countries with Longer Sample (AT, FR, GR) - VAT and Global Demand Shocks



Notes: Local projections are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries. Price changes due to replacement are excluded beforehand (except Greece). Superscripts $x \in \{v, d\}$ *represent the VAT and global demand shocks respectively. The models are specified in equation (11). In the order of the panels, the coefficients correspond to: The recomposed inflation* β_h^x*, counterfactual inflation assuming constant sizes of price changes* $\beta_h^{x,\bar{dp}}$*, counterfactual inflation assuming constant frequency of price changes* $\beta_h^{x,\bar{f}}$*, counterfactual inflation assuming constant sizes of price increases and decreases* $\beta_h^{x,\bar{dp}^+,\bar{dp}^-}$ *and counterfactual inflation assuming constant frequencies of price increases and decreases* $\beta_h^{x,\bar{f}^+,\bar{f}^-}$*. The light and dark gray areas correspond to one and two standard error bands, assuming calendar-based clusters.*