New Facts on Consumer Price Rigidity in the Euro Area*

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Abstract

Using detailed CPI micro data for eleven euro area countries covering about 60% of the euro area consumption basket over the period 2010-2019, we document new findings on consumer price rigidity in the euro area: (i) each month on average 12% of prices change, which compares to 20% in the United States; when we exclude price changes due to sales, however, the fraction of prices adjusted each month is 8.4% in the euro area versus 10% in the United States; (ii) differences in price rigidity are rather limited across euro area countries but much larger across sectors; (iii) time variations in the frequencies of both price increases and decreases contribute most to inflation variations and to the reaction of inflation to various shocks; (iv) sales play a minor role in the transmission of shocks to prices; and (v) the low inflation period is associated with less frequent price increases.

Keywords: price rigidity, inflation, consumer prices.

JEL codes: D40, E31.

Non-Technical Summary

Inflation results from the aggregation of millions of individual firms' price adjustments. How often and to what extent prices are adjusted is of critical importance for the transmission of monetary policy. This paper documents new evidence on the adjustment of consumer prices at the micro level in the euro area.

For that, we use country micro price data sets provided by the National Statistics Institutes (NSI) of euro area countries, including millions of individual price trajectories collected for the construction of the national HICPs. Data are available for eleven countries (Austria, Belgium, France, Germany, Greece, Italy, Latvia, Lithuania, Luxembourg, Slovakia and Spain), which account for about 90% of the euro area aggregate HICP. The time periods covered by the national data sets differ somewhat from one country to another but most national data sets cover the period 2010 to 2019. Overall, our databases comprise about 135 million monthly price observations. Due to confidentiality restrictions, the analysis of these data sets were conducted in a decentralized way at the country level but following the same methodology and using the same sample of products. Our common sample includes all products that are available for at least three of the four largest euro area countries (Germany, France, Italy and Spain). This leaves us with 166 products at the COICOP-5 level, covering 59% of the total euro area HICP.

Our main findings are the following. In a given month, on average 12% of prices change in the euro area. When we exclude price changes due to sales, the frequency drops to about 8%. Moreover, when we also include price changes due to product replacements, the overall frequency of price changes is now 13% and 9.5% when we exclude price changes due to sales. Country differences in our results are relatively small whereas sectoral heterogeneity is much more pronounced. The highest frequency of price changes is found for Unprocessed Food with 31%, whereas the average frequency of price changes for Processed Food is 15% and 12.5% for NEIG. The lowest frequency of price changes is found in the Services sector (6%). When price changes due to sales and temporary promotions are excluded, however, sectoral heterogeneity is arguably smaller. Cross-sectoral differences in the frequency of price changes can partly be explained by the cost structure of products. The share of labour costs has a negative effect on the frequency whereas a relatively large share of energy and raw material inputs has a positive effect on the frequency of price changes.

We also find that prices are, on average, much more flexible in the United States than in the euro area. The average frequency of price change is 19% in the US for comparable products (vs 12% in the euro area). However, when excluding price changes due to sales, the frequencies of price changes are much closer in both economic areas (10% in the US and 8.4% in the euro area). We also compare our results with earlier evidence reported by Dhyne et al. (2006) for the same set of 50 products. We find that for the five euro area countries we can compare (Austria, Belgium, France, Germany, Italy) the frequency of price changes has increased since the 1990s and early 2000s, but the extent of this increase is heterogeneous across countries and the limited number of products makes it hard to generalize this result to the whole consumption basket.

On the size of price changes, we find that the typical price change is rather large: the median price increase equals 9% whereas the median price decrease amounts to 12%. This pattern is quite common to all euro area countries. Moreover, the median price change is smaller for services than for other products. When we exclude price changes due to sales and promotions, the median price decrease and the median price increase are lower: amounting to roughly 6% for price increases and, depending on the way we define sales, between 8% and 10% for price decreases. We also provide new results on the distribution of the size of price changes, in particular, we find that excluding sales, the smallest 10% of all price changes are less than 1.9% whereas the largest 10% of price changes are above 18%. Contrasting these results with existing US evidence, we find that on average price changes are somewhat larger in the US, for both including and excluding sales.

We also investigate how patterns of price adjustment have evolved between 2005 and 2019 and how they have contributed to inflation dynamics in the euro area. Overall, we find that the frequency and size of price adjustment have changed little. The most recent period of low inflation is associated with a somewhat lower frequency of price increases. More generally, we document that time variations in the frequency of price increases and in the frequency of price decreases (taken separately) contribute significantly to the time variation of inflation. Since the frequency of price increases and the frequency of price decreases move in opposite directions, their sum is quite stable over time and the frequency of price changes does not contribute to the time variation of inflation. Concerning the size of price changes, we also find that the sizes of price increases and decreases remain more or less stable over time and thus do not contribute to inflation variation. Finally, investigating how several types of aggregate shocks (i.e. monetary shocks, oil supply shocks, demand shocks and VAT shocks) are transmitted to prices, our results confirm that price setters respond to shocks by adjusting the frequency rather than the average size of price increases and decreases. We also find that regular (i.e. non-sales) prices respond the same way as all prices to the different shocks, which suggests that sales prices do not respond to aggregate shocks.

1 Introduction

How often and to what extent 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, existing evidence has been obtained for an harmonised subset of 50 representative products in Dhyne et al. (2006) as well as more recent results at the individual country level (see Berardi et al. (2015)) for France, Fabiani and Porqueddu (2017) for Italy or Blanas and Zimmer (2020) for Belgium). In this paper, we document new evidence on consumer price rigidity for the euro area using a data set of 135 million price quotes collected in 11 countries and covering about 60% of the euro area Harmonised Index of Consumer Prices (HICP) over a period going from 2010 to 2019 for most countries.

First, we find that on average, in the euro area 12% 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%. Country heterogeneity is still quite limited whereas sectoral heterogeneity is smaller when we exclude sales. When we compare these results with US evidence, we find that for similar CPI products, prices are more flexible in the US than in Europe but once we exclude sales, the degree of price rigidity is much more similar in both economic areas. We also compare our results with the ones reported by Dhyne et al. (2006) for the same set of 50 products. We find that for most euro area countries the frequency of price changes has increased since the 1990s, but the extent of this increase is heterogeneous across countries and the limited number of products makes it hard to generalize this result to the whole consumption basket.

On the size of price changes, we find that the typical price change is rather large: the median price increase is equal to 9% whereas the median price decrease is equal to 12%. This pattern is quite common to all euro area countries. Moreover, the median price change is smaller for services than for other products. When we exclude price changes due to sales and promotions, the median price increase and median price decrease are lower: about 6% for price increases and, depending on the way we define sales, between 8% and 10% for price decreases. The effect of sales on the size of price changes is particularly strong for manufactured goods and processed food. We also provide new results on the distribution of price changes, in particular, we find that excluding sales, 10% of all price changes are below 1.9% whereas 10% of price changes are larger than 18%. While the share of small price changes is quite homogeneous across sectors, the last decile of the distribution of price changes shows stronger differences across sectors. Contrasting these results with existing US evidence, we find that on average price changes are somewhat larger in the United States including or not sales.

We then investigate how patterns of price adjustment have evolved between 2005 and 2019 and how they have contributed to inflation dynamics in the euro area. We first find that the frequency and size of price adjustment have little changed. The most recent period of low inflation is associated with a somewhat lower frequency of price increases. More generally, we document that time variations in the frequency of price increases and in the frequency of price decreases (taken separately) contribute a lot to the time variation of inflation. Since the frequency of price increases and the frequency of price decreases move in opposite directions, their sum is quite stable over time and the frequency of price changes does not contribute to the time variation of inflation. Overall, higher inflation is associated with more frequent price increases and less frequent price decreases but the size of price increases or decreases remain more or less the same. Looking at 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 more their frequencies of price increases and prices decreases than the size of price increases or decreases. We also find that regular prices respond the same way as all prices to the different shocks, which suggests that price changes due to sales do not respond to aggregate shocks.

Our paper adds to the existing literature on price rigidity along three dimensions.

First, we document new empirical findings on consumer price rigidity for the euro area. A close contribution is Dhyne et al. (2006), which documents the first findings on euro area price rigidity for the period 1996-2001. In this paper, we extend this evidence in several dimensions. First, our product coverage of the CPI is much broader: we now cover more than half of the CPI basket (each national data set covering between 43% and almost 100% of the national CPI) whereas Dhyne et al. (2006) use a sample of 50 individual products which were assumed to be representative of the overall CPI but covered at maximum 14% of the CPI basket of products. Covering a larger share of the consumption basket makes our results more comparable to existing CPI studies in other countries which usually cover a large share of the CPI (in particular in the United States, see Bils and Klenow (2004), Klenow and Kryvtsov (2008) or Nakamura and Steinsson (2008*a*)). We also cover a longer and more recent period: for most countries, the data covers a period going from the late 2000s to 2019 but for Austria, France and Greece, national data sets cover nearly two decades from the early 2000s onwards. Second, we have more precise and detailed information on sales and promotions. In Dhyne et al. (2006), price changes due to sales were not observed in many national micro data sets including Belgium, Germany, Italy and Spain, which makes it more difficult to make cross country comparisons but also to assess the relevance of price changes due to sales for usual price rigidity measures. National data sets include now more sytematically the NSI sales flag, in particular it is now the case in Germany and Italy. Moreover, when the sales flag is missing, we have implemented a standard sales filter for all countries to be able to provide an harmonized assessment on the importance of sales and promotions for price rigidity in the euro area. Overall, this paper provides new estimates of price rigidity for the euro area as a whole and for the different euro area countries using an harmonised methodology. Our results will offer in particular more detailed results by sector and country to discipline micro funded macro models for the euro area assuming price rigidity (see also Gautier and Le Bihan (Forthcoming)).

We also contribute to a recent theoretical literature emphasizing the role of sales and of the distribution of price changes for the transmission of monetary policy. On sales, the existing literature focus mainly on the determinants of sales in the United States or in the United Kingdom and their aggregate implications (Kehoe and Midrigan 2007, Guimaraes and Sheedy 2011, Coibion et al. 2015, Anderson et al. 2017 or Kryvtsov and Vincent 2021). However, little evidence has been made available for the euro area as a whole.[1] We here document new findings on the role of sales for price rigidity in the euro area and how they shape the patterns of price adjustment in both the cross section and time series dimensions. Similarly, the recent literature on price rigidity has documented in particular for the United States the importance of both small and large price changes (see Eichenbaum et al. (2014) for small price changes and Midrigan (2011) for large price changes).[2] In a more recent contribution, Alvarez et al. (2020) show that the real effects of monetary policy are not only related to the frequency of price changes but also to the ratio between the kurtosis of price change over the frequency. This result implies that the whole distribution of price changes might be important for monetary policy transmission.

Our third contribution to the literature is to provide new findings for the euro area on how firms adjust their prices over time. An earlier literature has documented some empirical findings on how firms adjust prices over time and in different inflation regimes (see Gagnon 2009, Wulfsberg 2016, Nakamura et al. 2018, Alvarez et al. 2019). Moreover, a burgeoning literature investigates how firms adjust prices in response to observable aggregate shocks (see Balleer and Zorn (2019), Dedola et al. (2021) on PPI data, Karadi et al. (2019) on scanner data). We here contribute to this literature by

[1] One exception in the euro area is Berardi et al. (2015).

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

looking at how aggregate shocks are transmitted to all consumer prices via variation in the frequency and size of firms' price changes.

The structure of this paper is as follows. Section 2 describes the underlying micro price data sets and our harmonized approach to derive comparable results across euro area countries. Section 3 presents cross-sectoral results on price rigidity in the euro area and relates it to previous findings for the euro area and the United States. Moreover, it analyses the role of sales in shaping price rigidity. Section 4 documents changes in the frequency and size of price changes over a longer time horizon and discusses candidate structural drivers of these changes. Finally, Section 5 draws some conclusions and discusses implications for monetary policy.

2 Data and Methodology

We start with a description of the underlying country micro price data sets and our harmonisation approach (see section 2.1). Next, we present the definition of a common product sample across countries and aggregation procedures (section 2.2), and discuss the treatment of sales and substitutions in computing price rigidity statistics (section 2.3).

2.1 Country-Specific Micro Price Data

At the heart of our analysis are individual country micro price data sets provided by the National Statistics Institutes (NSIs). The data sets were released to research teams of the national central banks and the analysis of individual data was conducted in a decentralized way at the country level (see Appendix A.1 for a full description of national data sets). These data sets consist of sequences of individual prices collected in specific outlets for individual products, these series of price quotes are the ones underlying the construction of the national HICPs. Our sample consists of eleven countries (Austria, Belgium, France, Germany, Greece, Italy, Latvia, Lithuania, Luxembourg, Slovakia and Spain), which account for about 90% of the euro area aggregate (see Table 1). Overall, taken all together, our databases comprise 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 "offline" prices.[3]

[3] One exception is the German database, which also contains micro prices for the outlet type "Internet trade". Note that since the mid-2010, some NSIs also switched for some products from traditional on-site price collection to

[Table 1 about here]

One key feature of the data sets 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 official HICP following the same European recommendations, price information is highly reliable, and products are carefully sampled by NSIs to be representative of the consumption basket. In all data sets, we are able to track prices for the same product over time and the main differences across countries come from extra information on prices reported by NSIs: flags on imputed prices, on product replacements, flag on sales/promotions and information on quality adjustment.

Concerning data cleaning, outliers were removed beforehand in each country database on an individual basis, e.g. the 1^{st} and 99^{th} of (log) price changes. In addition, whenever possible, we exclude imputed prices from our samples. Generally, NSIs impute the price of a given product if it was temporarily unavailable in the store.[4] For the majority of countries, our data set contains a flag indicating whether a price has been imputed or not, and in order to avoid that our results are blurred by imputations, we drop them.[5]

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. On the contrary, if a product is sold at the same price but with higher quality, the consumer enjoys a price decrease. Hence, 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 data set contains quantity-adjusted prices in most countries[6] and quality-adjusted prices in Germany, France or Luxembourg. Nevertheless, the fraction of quality-adjusted prices in our sample is expected to be rather small.[7]

2.2 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

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.

[4]Seasonal items such as some fruits are a special case as their prices are regularly imputed during off-seasons.

[5]Exceptions are Greece, Lithuania, Luxembourg, Slovakia, and Spain.

[6]Exceptions are Spain, Greece, and Slovakia.

[7]For example, the share of quality-adjusted prices in the German CPI micro data base is only 0.2%. 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.

by different product compositions across countries. For this purpose, we define a common product sample that includes a product if data 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".[8] This leaves us with 166 COICOP-5 products covering 59% of the euro area HICP.[9] Table A1 in the Appendix provides some details of our common product sample with respect to the coverage of major product groups and corresponding subgroups ranging from Services (about 40%) over NEIG products (31%) to Food (29%). Note that centrally collected prices or administered prices are regularly excluded from the national micro price data sets. In particular, the missing 41% of products in our common sample consist of all Energy products (10%) and roughly half of all Services (21%), with most of the missing bulk pertaining 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 Non-Energy Industrial Goods (NEIG) (8% missing), such as new and used cars, pharmaceutical products and ICT products as well as some administered Food products (3%) such as tobacco and alcohol.

Finally, 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 to the country level by using euro area HICP weights averaged over the period 2017-2020 to avoid that differences between countries will not be caused by differences in national consumption patterns. Second, we aggregate the country-specific results using country weights (also averaged over 2017-2020) to derive the euro area aggregate results. This aggregation 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).[10]

2.3 Treatment of Sales and Substitutions

In terms of measuring price rigidity, one major challenge arises from the treatment of sales and temporary promotions.[11] As argued by Nakamura and Steinsson (2008*a*), sales and promotions play an important role in measuring price rigidity, as they usually

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

[9] The complete list of COICOP-5 products used in this paper is provided in an online Table appendix. 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.

[10] 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.

[11] 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.

come along with a large but temporary price change. The HICP regulation states that NSIs shall take into account discounts – e.g. temporal promotions or seasonal price reductions – in price collection at the time of the purchase.[12] Without controlling for sales, notable differences in national sales periods could affect seasonal patterns of price change frequencies and sizes.[13] For most countries in our sample, sales and promotions can be identified by a corresponding flag in the data base (see Table 1). Typically, the price collector assigns a sales flag in the NSI micro price database whenever a collected price is visibly tagged 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.[14] Moreover, in those countries where a sales flag is reported by the NSI, its definition might also depend on national practices. 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 et al. (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 tag for product replacements in their database.[15] 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). This is why we exclude replacements from our baseline statistics.[16]

3 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 and the individual countries (see section 3.1). We also document our findings regarding the distribution of the (non-zero) price changes (see section 3.2).

[12]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 of 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`.

[13]As regards national legislation, there are countries (Belgium, Spain, France, Greece, Italy and Luxembourg), where periods of seasonal sales are strictly defined (see Table A2 in Appendix), whereas in the remaining countries stores can choose sales periods freely.

[14]This holds true for Spain, Greece, 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.

[15]Exceptions are Belgium, Greece, Slovakia and Spain.

[16]As robustness, we also provide results on price rigidity measures based on price changes including sales and replacements in section B.1 in the Appendix.

Moreover, we compare our results with previous evidence on consumer price rigidity for the euro area and the US (section 3.3).

3.1 Frequency of Price Changes

Table 2 reports the frequency of price changes and the share of price increases for the euro area aggregate and the underlying eleven countries.[17] We present results both including and excluding price changes due to sales. When price changes due to sales are included, we find that the average frequency of price changes in the euro area is 12%. When we exclude price changes due to sales, which make up a little less than 5% of observations, the frequency drops to about 8%, independent of whether we define sales by the NSI flag or the common sales filter. Moreover, using the available information on product replacements, we find that when we include price changes due to product replacements, the frequency of price changes is 13% when we include sales and 9.5% when we exclude price changes due to sales (Table A4). For all cases, we find that roughly two-thirds of price changes are price increases, with the share increasing slightly when excluding price changes due to sales.

These findings are robust to several sensitivity checks. Instead of using the country-specific time period, we can restrict the underlying sample period to a shorter but common period of seven years (2011-2017), in which case the frequency of price changes is 11.9% (Table A5 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 (see Tables A6 and A8 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 A10). Finally, we investigate to which extent the aggregation method affects the results. For that, we calculate first euro area statistics at the product level (i.e., averaging over countries) and then aggregate over the products. The frequency of price changes is almost unchanged with respect to our baseline case: 12.1% for the case including sales and 8.4% for the case excluding sales using the NSI flags when available (Table A12 in the Appendix).

Across countries, differences in the frequency of price changes are limited, the frequency of price changes ranges from 10.3% in Italy to 18.6% in Latvia whereas for most countries this frequency is between 11 and 14% (Table 2). When we exclude sales, cross-country heterogeneity remains quite limited. For most countries, the frequency of price changes is between 7 and 10% whereas in Italy the frequency is the

[17] See Appendix A.3 for details on frequency computations.

lowest in the euro area (4.8%). When we use the sales filter instead of the flag, results are similar, and we also find a rather limited cross-country heterogeneity. The share of sales is quite the same in all countries, varying between only 4 to 5% according to the common filter. The only exception is Latvia where the share of sales is 7.5% 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 ad-hoc 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 with 31%, whereas the average frequency of price changes is 15% for Processed Food and 12.5% for NEIG. The lowest frequency of price changes is found in the Services sector (6%). For all sectors except NEIG, a majority of price changes are price increases, notably in the Services sector where more than 85% 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 sector where the frequency is lowered by about 5 to 8 percentage points, but a small impact on the Services sector. The share of sales and promotions is highly concentrated in some specific sectors: sales make up 7.5% in Unprocessed Food and 8.5% in NEIG (using information from NSI flags when available). Moreover, within main aggregate sectors, the share of sales is highly concentrated to 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 NEIG, the share of sales is higher than 18% for 10% of the products (mainly in the "Clothing and Shoes" sector) whereas for one quarter of NEIG products, the share of sales is lower than 3%.

[Figure 1 about here]

This cross-sectoral heterogeneity in the frequency of price changes is also pervasive within broad sectors. Figure 1 shows that the spread in the frequency is large in sectors like Unprocessed Food or NEIG even once we control for sales. Finally, we find that this cross-product heterogeneity is very similar across countries. In Table A14 in the Appendix, we report correlations of the 5-digit COICOP frequencies across countries and find a correlation coefficient higher than 0.5 for most country pairs.

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 et al. (2010)).[18] By inverting the input-output table, we get the cumulated cost structure for each product group, which gives a more complete image of the inputs potentially influencing the price-setting behaviour (we look at the "inputs of the inputs" over the production chain).[19] Overall, we relate the frequency of price changes (excluding price changes due to sales) for a specific product in a specific country to the share of labour costs (i.e. the share of household consumption expenditure that reflects compensation of employees), the share of imported energy and raw material inputs, and the share of all imported inputs.[20] We also add non-cost explanatory variables (including a dummy for regulated prices following Eurostat's classification of administered prices, and the percentage of individuals that bought a certain type of product online) and country dummies. The sources and a detailed description of the variables are provided in Table A15.

Table 3 reports the main results. We find that the cost structure matters for 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 percentage points increase in the share of labour costs decreases the frequency of price adjustment by about 2 percentage points. This might reflect 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. On the contrary, 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 percentage points increase in the share of imported energy and raw material inputs increases the frequency of price adjustment by about 5 percentage points.[21] The share of all imported inputs, the percentage of online consumers, and whether prices are regulated are not important for 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

[18] We match product groups (classification of products by activity – CPA) to the 5-digit COICOP. See Table A15 for more details.

[19] For example, we do not only take into account that food requires plastic products (for packaging), but also that plastic products require chemicals. And hence that food indirectly requires chemicals. In this case, the compensation (wages) used in the product food also takes into account the compensation of the product chemicals.

[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 is 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 hence these measure exchange rate costs better.

[21] The share of labour costs varies between 0.3 and 1.0 in our sample. The share of imported energy and raw material inputs varies between 0 and 0.2.

considering all price changes including sales (col. 3). When we include broad sector dummies (col. 4), 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.

3.2 The Distribution of Price Changes

Recent studies highlight the importance of the patterns of the non-zero price change distribution for price rigidity models (see Klenow and Malin (2010)). In the following, we present some findings to fully characterize the distribution of (non-zero) price changes in the euro area.

Table 4 reports the median increase and decrease of price changes. In our baseline case (price changes including sales), the median price increase amounts to 9%, while the median price decrease is larger in absolute values at 12%. When excluding sales, both median price increases and price decreases are smaller in absolute values: the median increase is 6% and the median decrease is between 8 and 10% depending on the way we define sales. In the Appendix, we report results including price changes due to replacements and results are only slightly modified (Table A4). We also report sensitivity checks of the time period (Table A5), product sample definition (Tables A7 and A9), weighting structure (Table A11), and aggregation method (Table A13). Overall, in these robustness exercises, the median sizes at the euro area level range between 8% to 10% for price increases and 11.5% to 13% for price decreases including sales and about 6.5% for price increases and 8% to 10% for price decreases excluding sales.

From Table 4, cross-country heterogeneity is found to be rather low; in most countries, the median increase is between 7% and 10% whereas the median decrease is between 11% and 15%. Some countries fall outside these ranges. In Belgium, the median price change is much lower since price changes due to seasonal sales are not reported in the national micro price data set. In Latvia and Lithuania, price changes are much larger. For Latvia, this might be explained by the higher importance of sales. When we exclude price changes due to sales, country differences again become smaller.

In contrast, Table 4 reflects sectoral differences of considerable magnitude: the median price increase (decrease) in the euro area is 5% (6%) in the Services sector and about 13% (18%) in the NEIG sector. Excluding price changes due to sales reduces the sectoral heterogeneity since this lowers the median increase and decrease for NEIG and to some extent for Processed and Unprocessed Food where most sales are concentrated. Figure A2 in the Appendix shows the distribution of the median size of price increases and decreases by sector. Within a given sector, price decreases are more dispersed than price increases, as reflected by a flatter distribution. Interestingly, this finding is consistent across all four sectors.

[Table 4 about here]

Similar as 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 A16. 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 adjustment. We also find that the estimated broad sector dummies have a small contribution, which confirms the lower degree of heterogeneity for size than for frequency.

The existing 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 characterize in more detail the distribution of price changes, Table 5 reports the absolute size of the 10^{th}, 25^{th}, 75^{th} and 90^{th} percentiles. We find that very small and very large price changes are quite common in the euro area; for our baseline case (including sales), the smallest 10% of observations fall below a value of 2.9%, and the highest 10% are well above 26.0%. The interquartile range is about 12%. Excluding sales leads to a significant drop in the interquartile range to less than 8%, but 10% of price changes are still higher than 18% and 10% of price changes are below 1.9%. These results are consistent across countries, with the smallest price changes excluding sales observed in France and Italy, and the largest price changes found for Lithuania, Slovakia and Spain. Across euro area sectors, Table 5 indicates that the share of small price changes is larger in Services and Processed Food whereas large price changes are more frequently observed in Unprocessed Food and NEIG. The largest dispersion of absolute price changes pertains to Unprocessed Food and NEIG products where the interquartile range is larger than 10% whereas this interquartile range is only 5.5% in Services.

[Table 5 about here]

3.3 Comparison with Previous Evidence on Consumer Price Rigidity

In the following, we contrast our findings on euro area price rigidity with previous evidence obtained for the euro area for the late nineties/early 2000 period based on a smaller sample of products, and with evidence from the US CPI.

3.3.1 Comparison with Previous Evidence for the Euro Area

Dhyne et al. (2006) presented the first harmonised cross-country study that characterises the 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.[22] 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 in our underlying country micro price data sets.[23]

To guarantee a consistent comparison with the results by Dhyne et al. (2006), several adjustments of our methodology were necessary.[24] 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 A17 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 before/after 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.[25] We find that for all countries the overall frequency of price changes has increased since Dhyne et al. (2006). The increase was most pronounced for Austria (+6 pp), followed by Belgium and Germany (about +2 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 1.6 pp, from 7.8% to 9.4%. Concerning sectoral heterogeneity, the increase mainly stems from NEIG products.

[Table 6 about here]

[22] 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 data set; in Austria, they are taken from about 800 elementary products.

[23] For example, the German CPI data set 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.

[24] See section C in the Appendix for a more detailed description of the technical adjustments and aggregation method.

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

Figure 2 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. Almost 60% of product-country combinations have a higher frequency in the more recent period (in particular for NEIG in Austria and Germany).[26]

[Figure 2 about here]

In the middle and lower panels of Table 6, we compare the median size of price increases and decreases from the period 2011-2017 with those of Dhyne et al. (2006). At the euro area level, the median size of price increases is very similar for both periods, while the size of price decreases is somewhat lower in the more recent period. The latter is mainly due to a strong decline in the size of price decreases in Germany (in particular for services) (see also middle and bottom panels of Figure 2, which plot the comparison of the size of price increases and decreases between the two sample periods 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 tendency for the size of price changes with increases in some countries counterbalanced by decreases in other countries. 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 3.1. In Section 4, we provide more robust evidence on time-series patterns of price rigidity.

3.3.2 Comparison with US results

In this section, we compare euro area price rigidity results at the product level with equivalent moments provided by Nakamura and Steinsson (2008*a*) for the United States. We restrict our comparison to the same equivalent products to control for possible differences in the composition of the consumption basket considered in both economic areas.[27] For that, we build a mapping table between the Entry Level Items (ELIs) classification of the US CPI as defined by the Bureau of Labor Statistics and the ECOICOP classification of euro area HICP as defined by Eurostat.[28] To control for possible differences in the composition of the consumption baskets between the two

[26] 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).

[27] One important caveat with this comparison is that US moments were computed on the period 1998-2005 whereas most EA 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.

[28] Almost all COICOP 5-digit products have a corresponding ELI product while some ELI products have no correspondence in our euro area data set. An online Appendix provides the mapping table and both detailed classifications.

economic areas, 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 the ones for the US. For our baseline case (including price changes due to sales), we find that prices are, on average, much more flexible in the United States than in the euro area. The average frequency of price change is 19% in the United States for comparable products whereas it is only 12% in Europe. However, when excluding price changes due to sales, we find that the frequencies of price changes in both economic areas are much closer: 10% in the United States versus 8.4% in the euro area. The share of sales is higher in the United States than in the euro area: 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.[29] The difference seems much larger for food products, suggesting that sales regulation might matter more in the euro area than in the United States for this type of products. 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 Europe. Concerning the share of price increases, both economic areas are quite similar 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 Europe. Like for the frequency results, when excluding price changes due to sales the difference is much less pronounced: the average price increase is 10.6% in the United States versus 8.3% in the euro area and a similar difference is obtained for price decreases. Sectoral differences are once again large between the two economic regions, with the largest gap found in the Food sector (both Unprocessed and Processed Food products) and the smallest ones 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 US decreases significantly, notably for non-energy industrial products.

When looking at the tails of the price change distribution, we can compare product by product the quartiles of the absolute price change distribution. We find that the 1st and 3rd quartiles are lower in the euro area than in the US 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 Europe. On other percentiles of the distribution, Eichenbaum et al. (2014) find on US CPI data that 14% of price changes are lower

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

than 2.5% and 5% are lower than 1% once 'problematic' products (including cars, cigarettes, electricity...) are removed which is the case in the euro area by construction of the data set. Midrigan (2011) reports for the US that the 10th percentile of the price distribution is equal to 3% and the 25th percentile is equal to 5% whereas the p75 and p90 are equal to 13 and 21%. These results are quite in line with the EA results on the distribution of price changes (see Table 5).

For a more disaggregated perspective, Figure 3 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 US and the euro area. Based on this, we find only very few products for which frequencies and sizes are larger in the euro area than in the United States. This observation remains true when we exclude price changes due to sales and promotions. Concerning cross-country heterogeneity, our main results hold for most countries: with some exceptions, prices are typically more flexible in the US and they change by a larger amount.[30]

[Figure 3 about here]

4 Time Series Evidence on Euro Area Price Rigidity

In this section, we investigate how price adjustment patterns (frequency and size) evolve over time (section 4.1). We analyse how variation in the frequency and size of price changes over time contribute to inflation variation and derive some possible implications for our understanding of aggregate price dynamics (section 4.2). Finally, using local projections, we explore how the various margins of price adjustment shape the response of inflation to aggregate shocks (section 4.3).

4.1 Frequency and Size of Price Changes Over Time

Inflation results from the aggregation of millions of individual firms' price changess. 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.

In particular, using micro price data, we can decompose the monthly product-level inflation rate as follows (see for example Klenow and Kryvtsov (2008)):

$$\pi_{jt} = f_{jt} \times dp_{jt} \tag{1}$$

[30] See section D in the Appendix for a detailed comparison between the US and each individual euro area country.

where j is a COICOP5 product-category, f_{jt} is the frequency of price changes at date t whereas 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 (-).

$$\pi_{jt} = f^{+}_{jt} \times dp^{+}_{jt} - f^{-}_{jt} \times dp^{-}_{jt} \tag{2}$$

where f^{+}_{jt} is the frequency of price increases, f^{-}_{jt} is the frequency of price decreases whereas dp^{+}_{jt} is the average of non-zero price increases and dp^{-}_{jt} is the average of non-zero price decreases (in absolute values) 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.

In a first step, we look at the aggregate time series of the frequency and size of price changes for the euro area depicted in Figure 4.[31] The frequency of price changes does not seem to show a strong upward or downward trend over the time period from 2005-2019. However, seasonal movements are clearly visible in the frequencies of price increases and decreases, and in the overall figures. As regards the frequency of price changes excluding sales, the pattern over time is similar. We also note that the main time variations in the frequency of price changes excluding sales seem to come from variations in the frequency of price increases.[32] With respect to the size of price adjustment, we document that average price increases including sales are slightly higher in the recent period (see Figure 5).[33]

[Figure 4 about here]

[Figure 5 about here]

To document in more detail the variation in frequency and size over time, 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. Figure 6 plots the respective coefficients and confidence intervals thereof.

[Figure 6 about here]

Two main results emerge from these regressions.

First, both the frequency and size of price changes show large seasonal movements (bottom panel), as the spikes in figures 4 and 5 suggested. Seasonality in the size of

[31] It should be borne in mind that in this graph the composition of countries over time changes as more and more countries enter the sample and therefore breaks may occur if big countries enter (like Germany in 2010).

[32] In the Appendix, we have reported the same figures plotting frequencies of price changes by country (Figures A7 and A8): the main conclusions are broadly consistent across countries.

[33] See also Appendix A9 for country-level evidence.

price decreases (left bottom panel) is slightly more pronounced than the one of price increases: in January and July (and to a lesser extent in February and August), price decreases are larger in absolute values by about 2pp, while price increases are smaller in these months. These movements are mostly explained by seasonal sales. If we exclude price changes due to sales and promotions, the pattern for both, price increases and decreases, persists, yet is considerably less pronounced. Similarly for the frequency of price changes, we find that sales and promotions in January and July also play a key role in explaining seasonality. However, when excluding 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 more than 75% of products of our sample and the average weighted effect is about 8 percentage points for the frequency of price changes including sales and 6 percentage points when sales are excluded. The January effect excluding sales is much larger of price increases (+5 pp) than for price decreases (+1 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).

Second, we find some variation in the frequency and size of price changes over the years of our sample period but they are rather limited. As regards the size of price changes we find a small trend increase for both increases and decreases, when including sales, but 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. Put differently, the average size of price increases and decreases is at most 1 pp larger after 2013.

The variation in the frequency of price changes across years is larger than for the size of price changes. The frequency of price changes is significantly higher (+1pp) in years 2008-2009 during the Great Recession when euro area inflation reached a maximum at 4.1% in July 2008 and then lowered to -0.6% in July 2009. The frequency of price changes is also lower after 2013 where the average inflation rate was rather low in the euro area (at about 1% vs 2% before 2007). These variations are mostly driven by the frequency of price increases. 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 changes and in particular less frequent price increases than before 2013 whereas the size of price changes has increased a little.

[Table 8 about here]

Looking at these patterns across product groups (Unprocessed and Processed Food, NEIG, and Services), we find small differences across sectors.[34] 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, January effects are robust to all sectors even when we exclude sales. In particular, January effects are very strong in the service sector where they are equal to about 11 percentage points whereas the average frequency in this sector is about 6% (Table 8). Over time, we do not find any trend in the size of price changes in any of the three sectors. For the frequency, we find the frequency of price increases is lower over the period 2014-2019 for Food and to a lower extent for Services.

4.2 Contribution of Frequency and Size of Price Changes to Inflation Variations

To investigate how variation in the frequency and size of price changes over time contributes 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). This assumption would be consistent with predictions of a pure Calvo (1983) model where the probability of price changes does not change over time and variation in inflation comes from variation in the size of price changes. Thus, counterfactual inflation with constant frequency $\pi_{jt}^{\bar{f}}$ is defined as:

$$\pi_{jt}^{\bar{f}} = f_{j.} \times dp_{jt} \tag{3}$$

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 ($dp_{j.}$):

$$\pi_{jt}^{\bar{dp}} = f_{jt} \times dp_{j.} \tag{4}$$

In this case, significant movements in the frequency of price changes over time would be consistent with predictions of a state-dependent model where firms adjust their prices in response to shocks through their probability of price adjustment.

In Table 9, we report correlation coefficients between our recomposed inflation at the product-country level (calculated following equations 2) and these two counterfactual

[34]Detailed results are reported in Appendix Figures A10 and A11 for Unprocessed and Processed Food, Figure A12 for NEIG and Figure A13 for Services.

inflation rates whereas Figure 7 plots the counterfactual inflation rates against recomposed inflation rates.[35]

The main finding of this exercise is that the recomposed inflation rates are much more correlated with counterfactual inflation assuming constant frequency (correlation coefficients of 0.8 irrespective of the inclusion price changes due to sales) than the counterfactual inflation rate assuming constant size of price changes (correlation coefficient of slightly above 0.2). This finding is very robust across sectors and across countries. Overall, most of short-term variation in inflation is due to variation in the size of price changes and not in the overall frequency. This pattern of the data would be consistent with standard predictions of a Calvo model. In Figure 7, this is reflected by the "flatness" of the scatter plot when we assume constant size (top-right panel), whereas when we assume constant frequency (top-left panel), the scatter plot is more aligned with the 45-degree line.

We can investigate further the relationship between inflation and frequency and size of price changes by splitting price changes into price increases and decreases and consider two other counterfactual inflation rates. The first one $\pi_{jt}^{\bar{f}^+,\bar{f}^-}$ assumes that not only the overall frequency is constant but also both, the frequency of price increases and the frequency of price decreases, are constant over time.

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

The second counterfactual inflation $\pi_{jt}^{\bar{dp}^-,\bar{dp}^+}$ assumes that the average size of price decreases (in absolute values) and the average size of price increases is constant over time. The adjustment will come from movements in the relative share of price increases and decreases.

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

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 coefficients of 0.8 to 0.9) than with the counterfactual inflation rate assuming constant frequencies of price increases and decreases (correlation coefficients of about 0.6) (see Table 9) This result is very robust across sectors and across countries. Figure 7 provides a similar conclusion: the scatter plot is more aligned with the 45°line when we assume constant sizes of price increases and decreases (bottom right panel).[36] This means that inflation varies over time because of time variation in the frequency of price increases and in the relative share of price increases.

[35]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.

[36]Similar patterns are observed in all broad sectors (see Figure A14 in Appendix).

[Table 9 about here]

4.3 Dissecting Inflation Adjustment in Response to Aggregate Shocks

In our last empirical exercise, we document how those four counterfactual inflation rates respond to aggregate shocks. Our aim is to investigate which margin of price adjustment is key for the inflation response to exogenous aggregate shocks. For that purpose, we use local projection regressions à la Jorda (2005) and we estimate the dynamic response of prices to different aggregate shocks S_t.[37] We will 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, some local observed changes like observed unemployment rates or retail sales) and country-specific VAT changes (series constructed by our own information).[38] For each shock, the estimated model is the following:

$$\pi^*_{j,t-1,t+h} = \alpha_{j,h} + \alpha_{m,h} + \beta_h S_t + \gamma_h X_{c,t} + \epsilon_{j,t_h} \tag{7}$$

where $\pi^*_{j,t+h}$ is the cumulated inflation rate for product j (product- and country-specific) between period $t-1$ and t+h[39], $\alpha_{j,h}$ are country-product fixed effects, $\alpha_{m,h}$ are country-month fixed effects (i.e capturing seasonal country-specific variations), $X_{c,t}$ are country specific controls (we use monthly changes in industrial production in all versions of this equation regardless of the shocks) , ϵ_{j,t_h} are i.i.d. error terms and β_h measures the effects of the S_t shock at horizon h after the shock. β_h are our parameters of interest and we derive from them the impulse response function of prices to aggregate shocks.

The cumulated inflation rate used as endogenous variable will differ according to specifications, it can be our baseline recomposed inflation or one of the 4 counterfactual inflation rates described in the previous subsection (see also Appendix F.2 for more details on this decomposition). We plot impulse responses functions corresponding to the different empirical exercises in Figures 8, 9 and 10. The top panel of Figure 8 reports IRF of prices to a restrictive monetary policy shock whereas the bottom panel reports IRF to a positive oil supply shock. The top panel of Figure 9 reports IRF to VAT increase whereas the bottom panel reports IRF to a positive global demand shock. The Figure 10 reports IRF to a positive local shock - unemployment and retail trade.

[37] See also Balleer and Zorn (2019) or Dedola et al. (2021) for a similar empirical approach using producer price data for Germany and Denmark.

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

[39] We run the regressions on cumulative inflation calculated as the sum of monthly inflation rates over the period t-1 - 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.

[Figure 8 about here]

[Figure 9 about here]

[Figure 10 about here]

Impulse response functions associated with our recomposed inflation rates are quite in line with theoretical predictions: a restrictive monetary policy shock and a positive supply shock have a long-term negative effect on prices whereas the VAT and the demand shocks have a positive long term effect on prices. The adjustment of prices to shocks is quite protracted for all shocks except VAT and takes about about 2 years to converge towards a long run effect. This exercise on recomposed inflation will be used as a benchmark to compare the IRFs obtained with counterfactual inflation rates.

Columns (2) and (3) of the Figures 8, 9 and 10 plot 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 counterfactual inflation when we assume constant size of price changes is not statistically different from 0 for all shocks and at all horizons. On the contrary, when we assume constant frequency, the IRF are very 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. This result is consistent with the unconditional decompositions of the previous subsections and in line with standard theoretical predictions of a Calvo model or a state-dependent model with small shocks where firms do not adjust the frequency of price changes in response to shocks.

Columns (4) and (5) 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 (last column). 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. When we assume constant sizes of price increases and decreases, the IRFs are quite close to the ones obtained in our benchmark case (column (1)). Overall, in response to an aggregate shock, firms adjust their relative frequency of price increases and decreases (which affects the overall size of price adjustment) but the typical size of price increase or the size of the typical price decrease is not affected by the shock. Comparing results assuming constant sizes of price increases and decreases (col. 4) and with results assuming constant frequency (col. 3), we conclude that the reaction of the frequency of price increases and the reaction of the frequency of price decreases offset each other.

Interestingly, the IRFs are quite similar whether or not sales are excluded (see Figures

11, 12 and 13). This suggests that regular prices adjust the same way as all prices to the aggregate shocks and that price changes due to sales or promotions do not react to aggregate shocks.

[Figure 11 about here]

[Figure 12 about here]

[Figure 13 about here]

To explore the role of sectoral heterogeneity, we split the sample between COICOP5 categories with a relatively higher frequency of price changes and the ones with a relatively low frequency of price changes (using the average frequency of price adjustment over the sample period for each COICOP5). The data point towards a stronger effect of shocks for the high frequency sample (see Figures 14 and 15).

Another robustness 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 (2003-2019) and Greece (2002-2019). Figures A15, A16 and A17 in Appendix plot the results which are very close to the ones obtained with all the EA countries.

5 Conclusion

In this paper, we have documented several new stylised facts on consumer price rigidity for the euro area. For this purpose, we followed a harmonised approach in compiling frequency statistics based on national CPI micro price spells in eleven euro area countries. Our final data set represents about 90% of the euro area aggregate in terms of countries and about 60% of the overall euro area consumption basket in terms of products.

Based on this novel data set, we document three stylised facts on the average price rigidity in the euro area, the distribution of price changes as well as changes in price rigidity over time. First, between 2005 and 2019, the average frequency of consumer price changes was 12% with limited heterogeneity across countries. In contrast, cross-sectoral heterogeneity is much more pronounced: each month, 6% of prices in the Services sector change whereas this proportion is about one third for Unprocessed Food. When price changes due to sales and promotions are excluded, the typical frequency of price changes drops to about 8%. We also find that costs matter for how often prices change: in particular, all other things equal, the price of a product changes less often if the share of labour costs is larger. Comparing our results with US evidence, we find that prices are much more flexible in the US when sales are included; however, once we exclude price changes due to sales, the degree of price rigidity is about the same in both economic areas (8.4% in the euro area vs 10% in the US). Compared to Dhyne et al. (2006), the only comprehensive study on moments of micro price adjustments in the euro area so far, we find that the frequency of price changes for the same set of 50 products is about 1.5 percentage points higher in the period 2011-2017 than in the period 1996-2003 covered in Dhyne et al. (2006).

Second, for the distribution of price changes, we find that the median price increase is about 9% in the euro area whereas the median price decrease is 12%. Dispersion of the aggregate median price changes is rather limited across euro area member countries and differences across sectors are much larger: the median price increase (resp. decrease) is about 5% (resp. 6%) in the Services sector and 13% (resp. 18%) for industrial goods. These differences are much smaller once we exclude sales: the median price increase is about 6% whereas the median price decrease is 8%. We also find that both very small and large price changes are not rare, with significant differences across sectors; moreover, excluding sales lowers the fat tails of the underlying distribution of price changes considerably. In comparison with US evidence, we find that price changes are somewhat larger in the US than in Europe: the difference is very large when including sales and less pronounced when we exclude them.

Third, over time, we find that the degree of price rigidity has remained quite the same between 2005 and 2019 in the euro area as a whole. Since 2013, the low inflation period in the euro area is however associated with a little less frequent price increases in several countries, whereas the size of price adjustments has remained quite the same. Moreover, we find that time variations in aggregate inflation are mainly due to time variations in the frequency of price increases and decreases whereas the size of price increases and decreases do not show large significant time variation for most CPI products. Finally, looking at the response of inflation to different aggregate shocks (monetary policy, oil supply, VAT changes, real demand shocks), we find that firms respond to shocks by adjusting the size of price adjustment rather than the frequency of their price adjustments. In particular, they adjust the relative frequency of price increases and decreases (i.e. making more frequent price increases and less frequent price decreases in response to a positive shock) whereas the average size of price increases and decreases is not affected by the shocks.

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Tables and Figures

Table 1: CPI Micro Database with country-specific periods

Country	Source	Period	% of EA products[1]	% of EA HICP[2]	Sales flag	OBS
AT	Statistik Austria	2000M1-2017M12	89.2	3.4	yes	10.98M
BE	Statbel	2007M1-2015M12	42.6	3.8	yes	8.50M
DE	Statistisches Bundesamt (Destatis)	2010M1-2019M12	87.3	27.9	yes	49.60M
ES	Instituto Nacional de Estadística (INE)	2008M1-2018M2	52.4	11.5	no	1.36M
FR	Institut National de la Statistique et des Études Économiques (Insee)	2003M4-2019M9	83.2	20.3	yes	17.05M
GR	*Ελληνική Στατιστική Αρχή*	2002M1-2019M12	64.0	2.2	no	7.68M
IT	Istituto Nazionale di Statistica (ISTAT)	2011M1-2018M12	61.1	17.3	yes	22.74M
LT	Lietuvos Statistikos Departamentas	2010M1-2018M12	82.3	0.5	yes	5.35M
LU	Institut national de la statistique et des études économiques (Le Statec)	2005M1-2017M12	97.0	0.3	no	1.15M
LV	Centrālā Statistikas Pārvalde	2017M1-2019M12	92.5	0.3	yes	0.66M
SK	Statisticky Urad Slovenskej Republiky	2011M1-2019M12	94.1	0.8	no	9.02M
Total		**2000M1-2019M12**	**58.9**	**88.3**		**134.03M**

Notes: ***1):*** *In terms of euro area product weights at the COICOP-5 level (2017-2020 average).* ***2):*** *Country weight in euro area HICP (2017-2020 average). OBS denotes the total number of monthly observations (in millions).*

Table 2: Euro Area Price Rigidity: Frequency of Price Changes (in %)

	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	**12.0**	**65.3**	**8.2**	**70.7**	**7.5**	**67.6**	**4.3**	**4.8**
by Sector								
Unprocessed Food	31.2	54.5	23.2	58.4	18.3	57.3	7.3	10.4
Processed Food	14.9	57.7	10.1	63.1	8.9	62.4	4.1	5.5
NEIG	12.5	48.6	6.2	61.3	6.4	55.3	8.2	7.2
Services	5.7	85.5	5.4	85.2	5.1	83.1	0.5	1.1
COUNTRY								
Austria	11.1	64.5	7.2	71.8	7.0	70.6	5.9	4.2
Belgium	14.5	68.9	13.3	69.6	10.9	70.9	1.1	3.8
France	12.7	60.8	9.8	66.9	8.1	64.8	5.5	5.1
Germany	11.5	66.2	8.2	73.1	6.7	70.4	3.6	4.3
Greece	11.3	61.3	7.3	63.9	7.3	63.9	.	3.8
Italy	10.3	69.9	4.8	75.6	6.1	67.0	4.3	5.4
Latvia	18.6	60.0	7.9	71.1	11.1	62.7	10.7	7.5
Lithuania	12.8	62.3	9.7	68.4	9.3	65.5	2.3	5.3
Luxembourg	14.1	73.4	8.8	78.4	8.8	78.4	.	4.6
Slovakia	14.3	64.7	9.3	66.6	9.3	66.6	.	4.9
Spain	13.5	64.0	9.0	65.3	9.0	65.3	.	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). Results excluding sales are based on ***1)*** *NSI sales flag (if available, and sales filter otherwise) or* ***2)*** *common sales filter for all coutries.*

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

	I	II	III	IV
Share of labour costs	-0.169**	-0.391***	-0.246***	-0.085*
Share of imported energy and raw material inputs	0.445***	0.445***	0.960***	-0.065
Share of all imported inputs	-0.128	-0.187	-0.109	-0.062
% of online consumers	0.000	0.000	0.001***	0.000
Regulated price dummy	-0.007		-0.024	0.006
Retail market concentration (HHI)		0.004***		
Unprocessed food dummy				0.132***
Processed food dummy				0.036***
Services dummy				-0.024
Constant	0.169***	0.248***	0.184***	0.139***
Country dummies	✓	✓	✓	✓
Number of observations	1,461	1,172	1,626	1,461
R^2	0.194	0.347	0.219	0.359

*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 reference country is France. The dependent variable in Column I is the frequency of price changes excluding sales and excluding product replacements (for Greece, Slovakia, and Spain sales are excluded via the sales filter, Greece includes 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 cannot be included in this regression as there are no regulated products in this sample. 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: Euro Area Price Rigidity: 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	**8.9**	**11.8**	**6.3**	**7.9**	**6.3**	**9.7**
by Sector						
Unprocessed Food	12.3	14.5	10.0	10.7	9.0	10.4
Processed Food	8.3	10.5	5.7	6.0	5.5	6.3
NEIG	13.2	18.2	7.5	9.9	7.7	12.6
Services	4.9	6.0	4.8	6.6	4.9	8.9
COUNTRY						
Austria	10.4	14.6	6.9	8.8	7.3	10.8
Belgium	7.0	8.2	6.6	7.5	6.6	7.3
France	7.8	12.0	5.1	7.3	5.6	10.0
Germany	9.4	12.2	7.1	8.2	6.1	9.1
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). Results excluding sales are based on ***1)*** *NSI sales flag (if available, and sales filter otherwise) or* ***2)*** *common sales filter for all coutries.*

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

	Absolute size of price changes (in %)							
	Including sales				**Excluding sales**[1]			
	10th	25th	75th	90th	10th	25th	75th	90th
EURO AREA	**2.9**	**5.7**	**17.2**	**26.0**	**1.9**	**3.6**	**11.4**	**18.1**
by Sector								
Unprocessed Food	3.5	6.8	24.6	36.9	3.0	5.7	17.8	27.0
Processed Food	2.3	4.3	17.1	25.9	1.9	3.3	9.7	15.7
NEIG	4.4	9.5	26.1	38.2	1.9	4.3	14.6	23.5
Services	1.7	3.0	8.5	13.6	1.7	2.9	8.2	12.8
COUNTRY								
Austria	3.3	6.7	21.1	31.5	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	17.2	27.7	1.3	2.7	10.0	17.1
Germany	3.4	6.3	17.8	24.7	2.3	4.3	12.1	18.2
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	21.6	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	18.0	25.1	2.7	5.0	16.0	23.5

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). 1) Results excluding sales are based on NSI sales flag, if available, or common sales filter.

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	15.0	12.7	5.7	9.4
Austria*	17.0	8.5	8.8	9.7	21.1	19.7	11.8	15.7
Belgium**	18.3	3.5	2.6	5.5	22.1	6.6	4.1	8.0
France*	20.2	16.8	6.4	12.0	24.6	18.6	5.3	12.7
Germany**	9.7	7.1	4.8	6.2	9.5	12.2	5.6	8.3
Italy**	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	7.1	9.3	5.2	6.8
Austria*	12.1	10.2	5.9	8.2	17.3	11.8	5.2	9.0
Belgium**	6.7	6.4	7.0	6.8	4.6	11.3	4.6	6.9
France*	3.9	8.7	4.3	5.7	2.8	15.6	4.4	7.8
Germany**	7.7	9.4	5.1	6.8	11.3	7.0	4.7	6.3
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	8.5	12.5	6.2	8.6
Austria*	12.7	13.2	9.0	10.9	20.6	15.8	7.2	11.8
Belgium**	7.0	8.0	6.7	7.2	3.9	14.3	4.7	7.8
France*	4.5	14.3	6.3	8.7	2.7	21.1	8.0	11.5
Germany**	9.4	12.7	13.5	12.7	14.2	8.6	3.4	6.5
Italy**	6.6	7.6	11.3	9.4	5.1	7.7	8.7	7.8

*Notes: *: Price changes including sales; **: 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		Decreases	
	Incl. sales	Excl. sales[1]	Incl. sales	Excl. sales[1]	Incl. sales	Excl. sales[1]	Incl. sales	Excl. sales[1]
Aggregate								
United States	19.3	10.0	62.0	71.2	17.8	10.6	21.6	13.4
Euro Area	12.3	8.4	64.3	69.8	11.3	8.3	14.5	10.1
by Sector								
Unprocessed Food								
United States	42.8	29.3	53.1	58.4	27.5	18.9	30.0	20.6
Euro Area	31.2	23.2	54.5	58.4	16.1	12.5	18.1	13.1
Processed Food								
United States	26.3	12.0	55.3	66.3	24.4	11.5	28.1	15.8
Euro Area	14.9	10.1	57.7	63.1	10.9	7.4	12.6	7.8
NEIG								
United States	22.0	5.7	46.9	66.0	21.5	9.8	26.4	12.2
Euro Area	12.5	6.2	48.6	61.1	15.7	9.8	20.4	12.5
Services								
United States	8.9	8.6	78.9	80.1	9.5	9.1	12.8	11.7
Euro Area	6.2	5.8	84.7	84.4	6.4	6.3	9.1	8.2

	Distribution of size of price changes 25th		50th		75th	
	Incl. sales	Excl. sales[1]	Incl. sales	Excl. sales[1]	Incl. sales	Excl. sales[1]
Aggregate						
United States	7.2	5.2	14.2	10.7	25.4	20.1
Euro Area	5.6	3.6	10.2	6.6	17.2	11.4
by Sector						
Unprocessed Food						
United States	11.7	9.9	22.4	17.6	38.5	30.9
Euro Area	6.8	5.7	13.1	10.4	24.6	17.8
Processed Food						
United States	8.2	5.1	17.7	10.4	35.6	23.9
Euro Area	4.3	3.2	9.0	5.7	17.1	9.9
NEIG						
United States	10.2	6.5	19.5	14.4	31.8	25.7
Euro Area	9.5	4.3	16.4	8.2	26.1	14.6
Services						
United States	3.4	3.4	6.7	6.6	12.5	11.8
Euro Area	2.9	2.9	5.0	4.9	8.4	8.1

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. Price changes due to replacement are excluded beforehand (except Greece). Results excluding sales are based on 1) 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
All sectors						
F_{jt}	0.082	108	76.6	0.060	120	86.9
F_{jt}^{m}	0.034	85	62.5	0.010	72	59.1
F_{jt}^{p}	0.048	101	71.7	0.050	106	73.2
By Sector						
F_{jt}^{FOOD}	0.018	22	40.0	0.023	39	73.8
F_{jt}^{NEIG}	0.103	48	82.4	0.029	44	84.5
F_{jt}^{SERV}	0.110	38	98.1	0.111	37	97.9
By Country						
Austria	0.133	86	76.4	0.108	81	67.3
Belgium	0.012	34	62.1	0.013	34	61.5
Germany	0.059	59	50.2	0.053	54	41.7
Spain	0.063	59	52.9	0.066	65	58.1
France	0.103	106	78.2	0.070	84	63.2
Greece	0.007	54	42.7	0.008	61	43.0
Italy	0.060	45	42.5	0.001	31	36.2
Lithuania	0.035	27	24.1	0.041	29	21.6
Luxembourg	0.155	70	51.2	0.141	68	50.2
Latvia	0.014	38	32.2	0.010	28	23.0
Slovakia	0.043	67	61.2	0.036	65	62.2

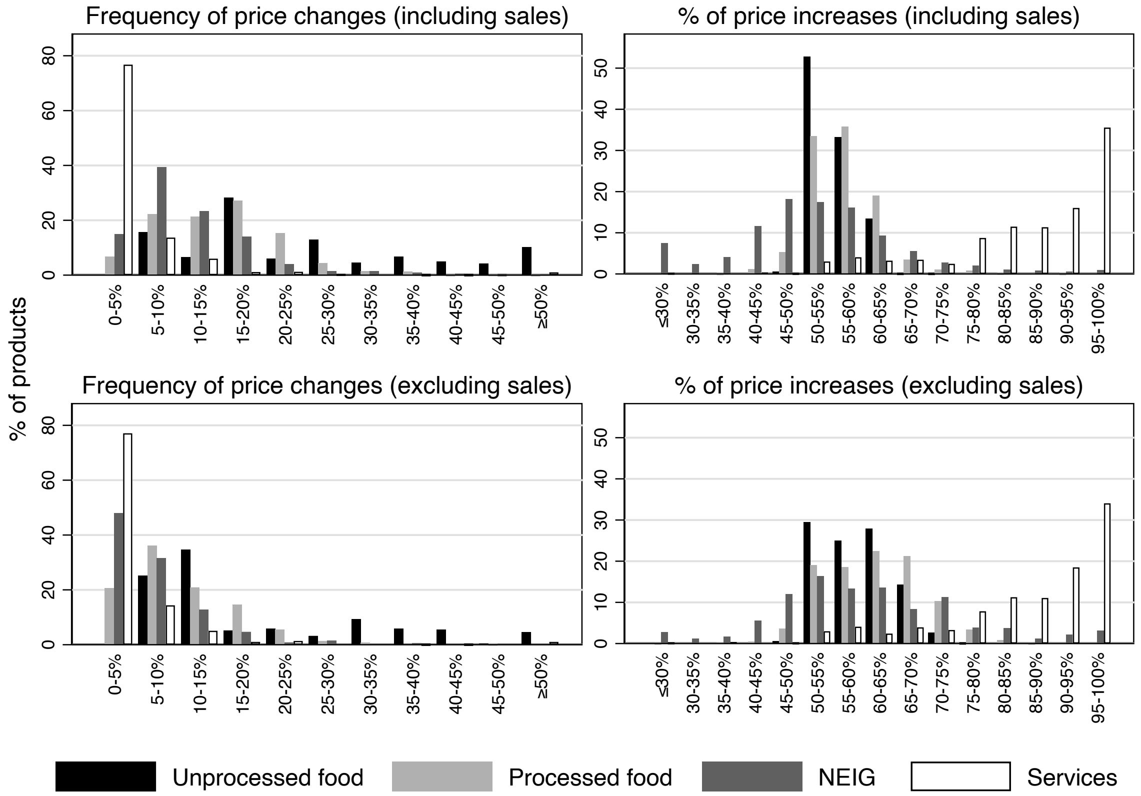
Notes: The table shows, the (weighted) average size of significant January-dummy coefficients of the COICOP-specific month-year regressions on the frequency of price changes (cols 1 and 4), the absolute number (cols 2 and 5) and weighted share of COICOP-5 groups for which the coefficient is positive 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). Results excluding sales are based on 1) NSI sales flag if available or 2) common sales filter. Outliers adjusted beforehand.

Table 9: Cross-correlation between recomposed inflation and counterfactual inflation rates

	Including sales				Excluding sales			
	$\pi_{jt}^{\bar{f}}$	$\pi_{jt}^{\bar{dp}}$	$\pi_{jt}^{\bar{f}^+,\bar{f}^-}$	$\pi_{jt}^{\bar{dp}^+,\bar{dp}^-}$	$\pi_{jt}^{\bar{f}}$	$\pi_{jt}^{\bar{dp}}$	$\pi_{jt}^{\bar{f}^+,\bar{f}^-}$	$\pi_{jt}^{\bar{dp}^+,\bar{dp}^-}$
	Overall				Overall			
π_{jt}^{r}	0.830	0.256	0.592	0.897	0.800	0.232	0.572	0.841
	by special aggregate				by special aggregate			
Unproc. food	0.968	0.086	0.625	0.890	0.960	0.136	0.625	0.897
Proc. food	0.876	0.150	0.474	0.804	0.812	0.254	0.502	0.804
NEIG	0.814	0.261	0.629	0.931	0.761	0.158	0.614	0.851
Services	0.639	0.443	0.509	0.779	0.623	0.472	0.503	0.780
	by country				by country			
Austria	0.788	0.514	0.521	0.861	0.750	0.313	0.482	0.782
Belgium	0.955	0.128	0.683	0.889	0.949	0.136	0.718	0.901
Germany	0.877	0.559	0.580	0.932	0.848	0.291	0.453	0.900
France	0.858	0.766	0.648	0.945	0.859	0.475	0.592	0.845
Greece	0.725	0.059	0.296	0.917	0.727	0.258	0.407	0.791
Italy	0.911	-0.156	0.882	0.983	0.807	0.257	0.582	0.663
Lithuania	0.869	0.244	0.484	0.859	0.764	0.407	0.510	0.840
Luxembourg	0.810	0.135	0.661	0.862	0.803	0.146	0.639	0.844
Latvia	0.940	0.311	0.600	0.875	0.884	0.332	0.675	0.855
Slovakia	0.913	0.204	0.481	0.836	0.829	0.367	0.456	0.785
Spain	0.821	-0.090	0.613	0.954	0.792	-0.014	0.589	0.942

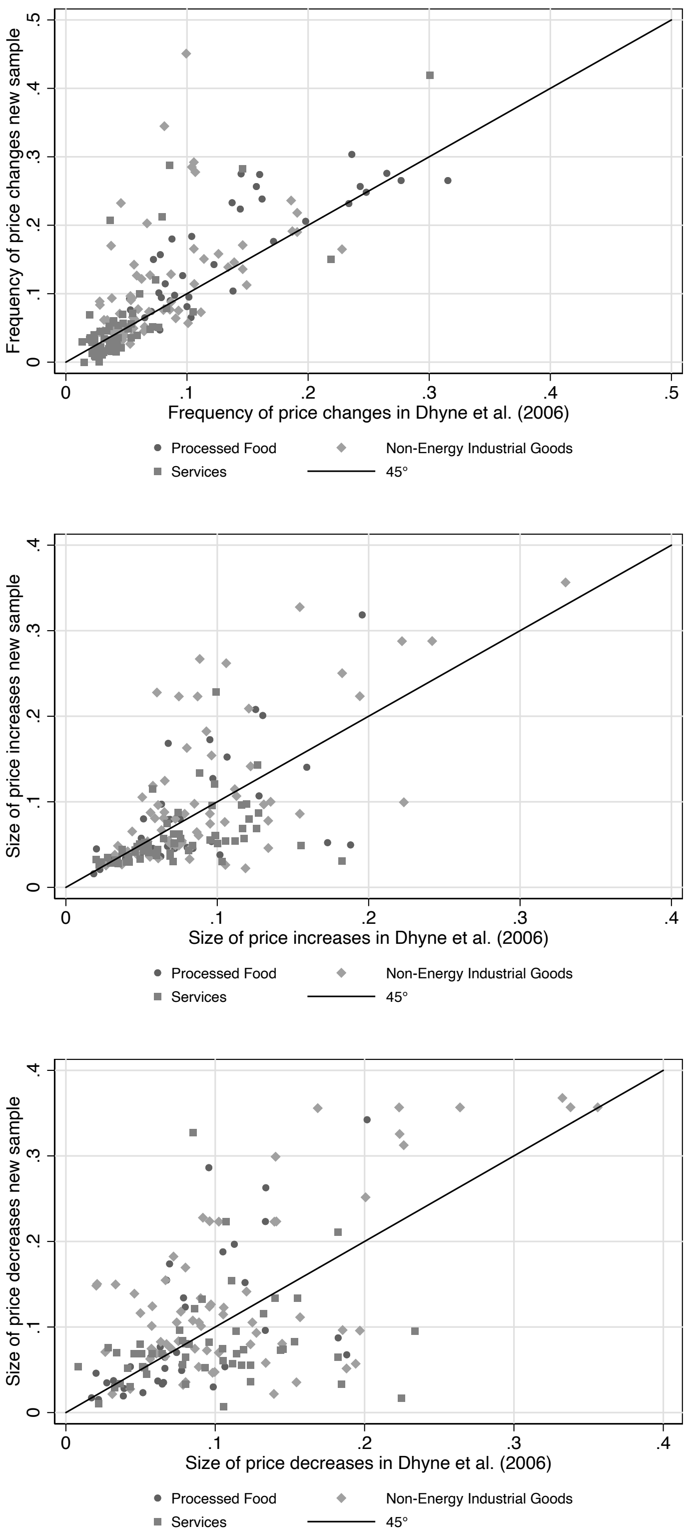
Notes: The table shows correlations between reconstructed inflation, as in Equation 2 and counterfactual inflation, as in Equation 5 and 6. Statistics are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries. Price changes due to replacement are excluded beforehand (except Greece). Results excluding sales are based on 1) NSI sales flag if available or 2) common sales filter. Outliers adjusted beforehand.

Figure 1: 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). Results excluding sales are based on ***1)*** *NSI sales flag (if available) or* ***2)*** *common sales filter.*

Figure 2: Frequency and size of price changes at the product level – Period 2011-2017 vs. Dhyne et al. (2006)

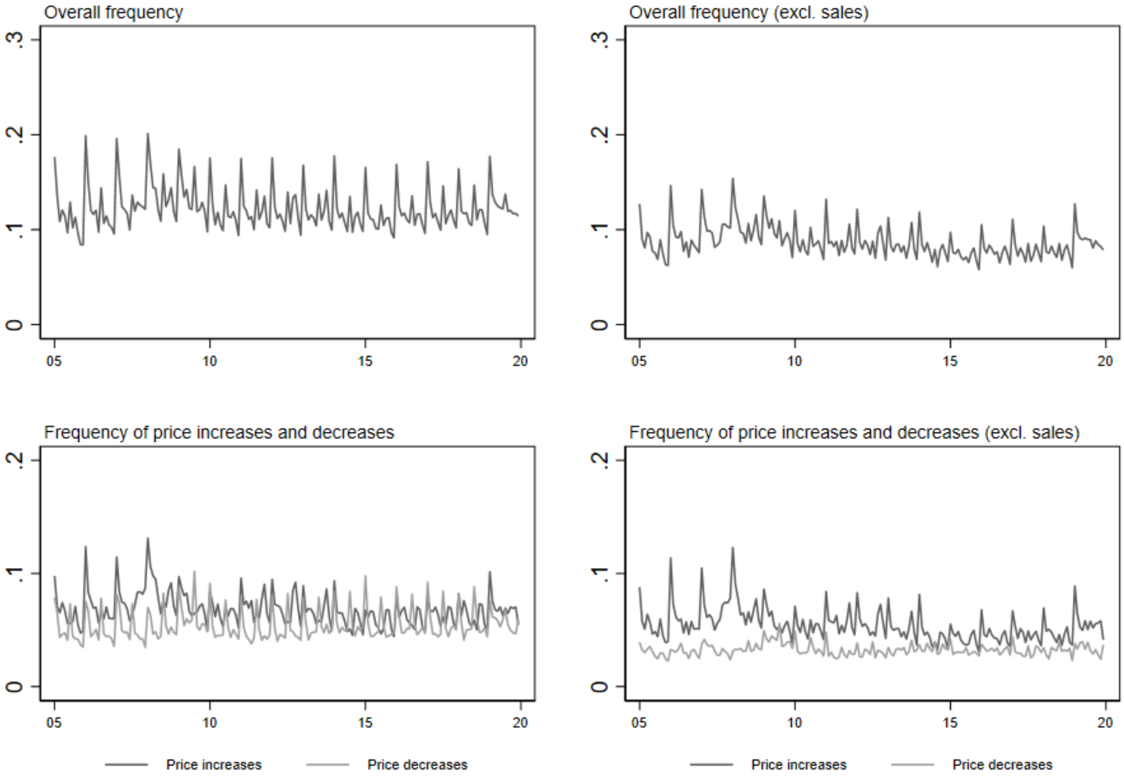


Notes: Frequencies and size of price changes at the product level for Processed Food, NEIG and Services items (at most 43 products depending on availability). Countries covered are Austria, Belgium, France, Germany and Italy.

Figure 3: Price rigidity statistics at the product level: Euro Area vs United States

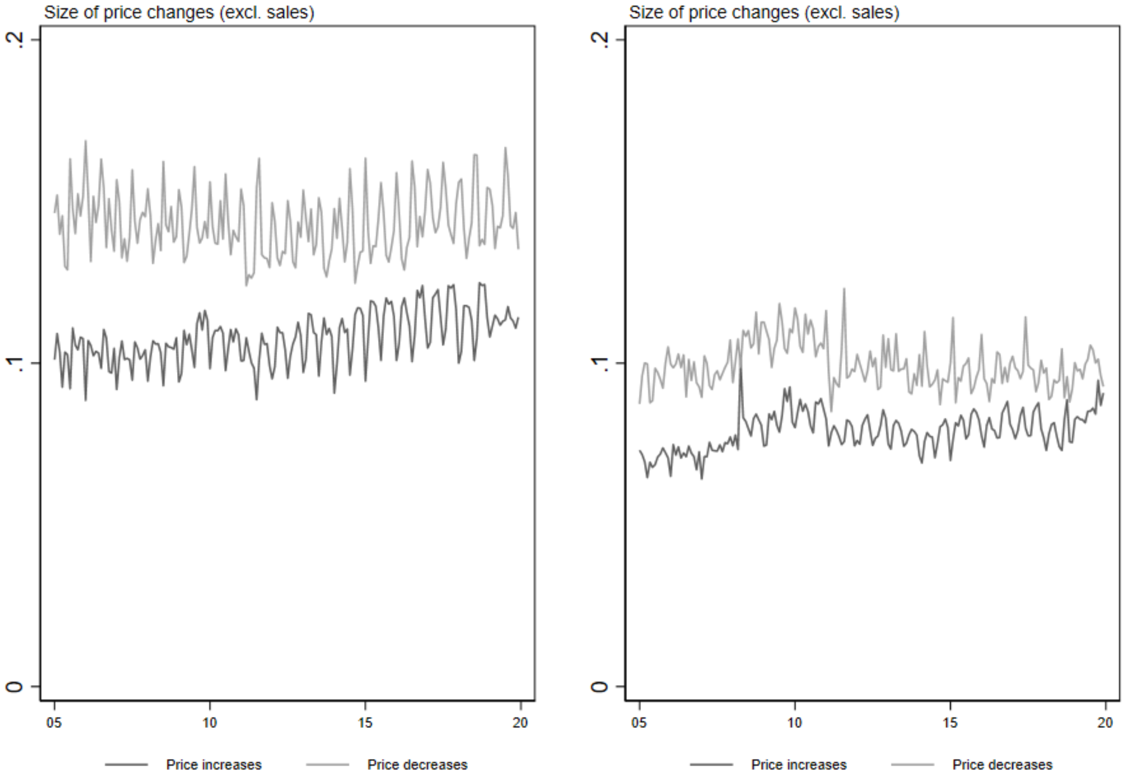
Note: US product results are taken from Nakamura and Steinsson (2008a). Euro area statistics are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries and calculated using euro area product weights at the COICOP-5 level (2017-2020 average) and country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

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



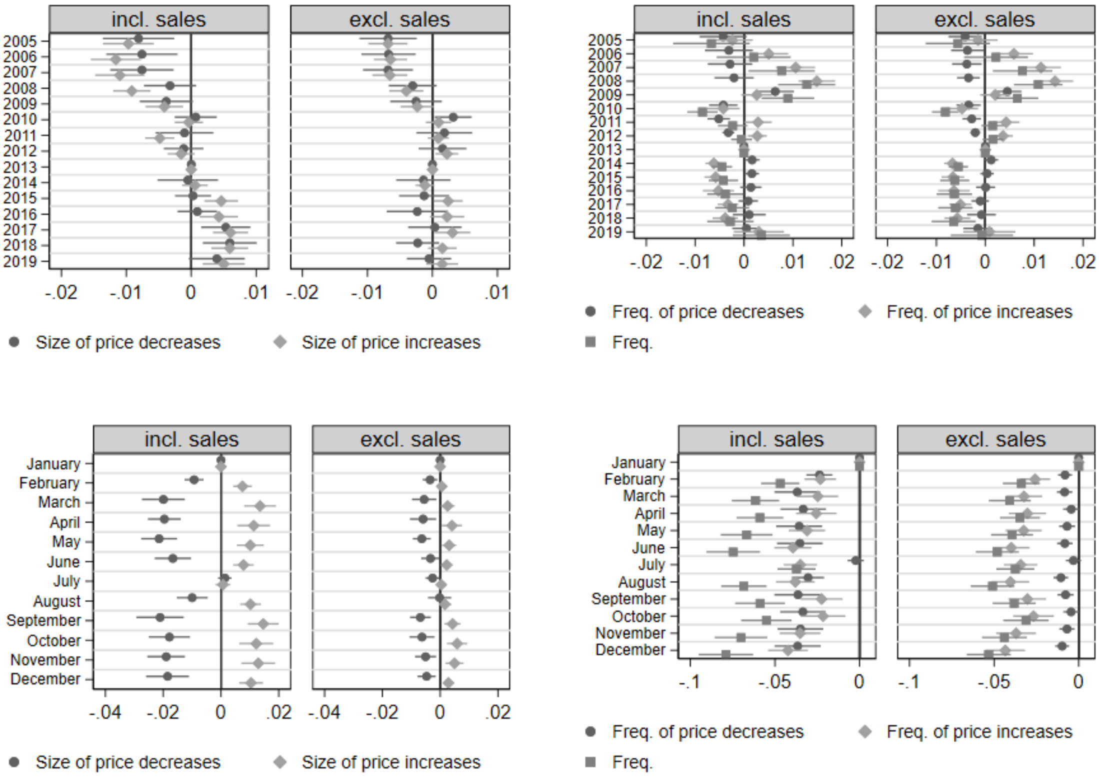
Notes: Statistics are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries and calculated using euro area product weights at the COICOP-5 level (2017-2020 average) and country weights in euro area HICP (2017-2020 average). Price changes due to replacement are excluded beforehand (except Greece). 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 Change in the Euro Area Over Time



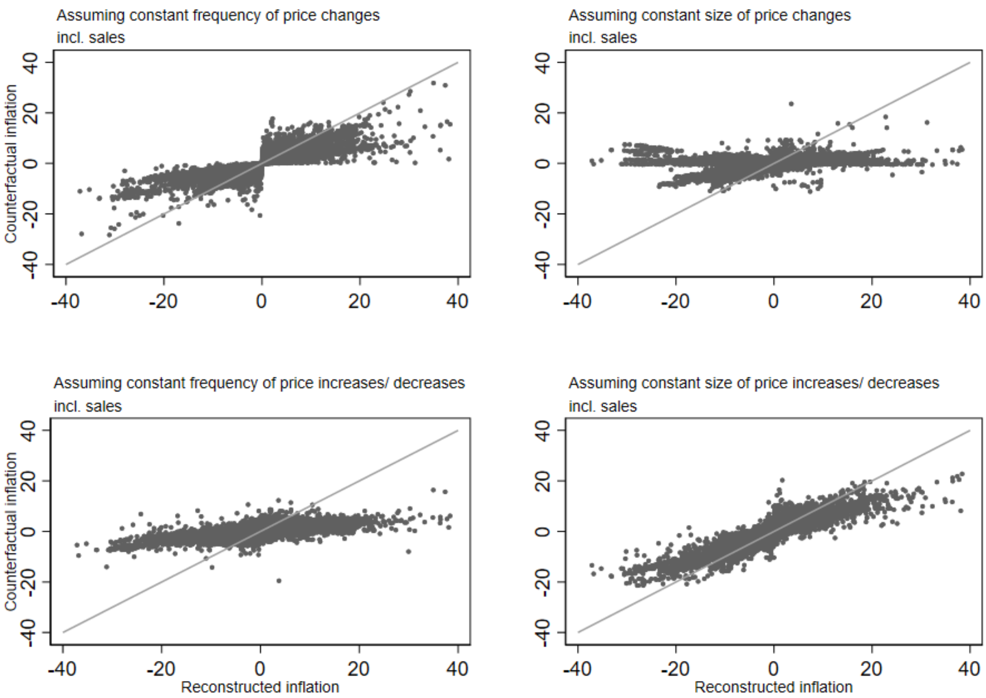
Notes: Statistics are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries and calculated using euro area product weights at the COICOP-5 level (2017-2020 average) and country weights in euro area HICP (2017-2020 average). Price changes due to replacement are excluded beforehand (except Greece). Results excluding sales are based on 1) NSI sales flag if available or 2) common sales filter. Outliers adjusted beforehand.

Figure 6: Variability over time and effect of sales



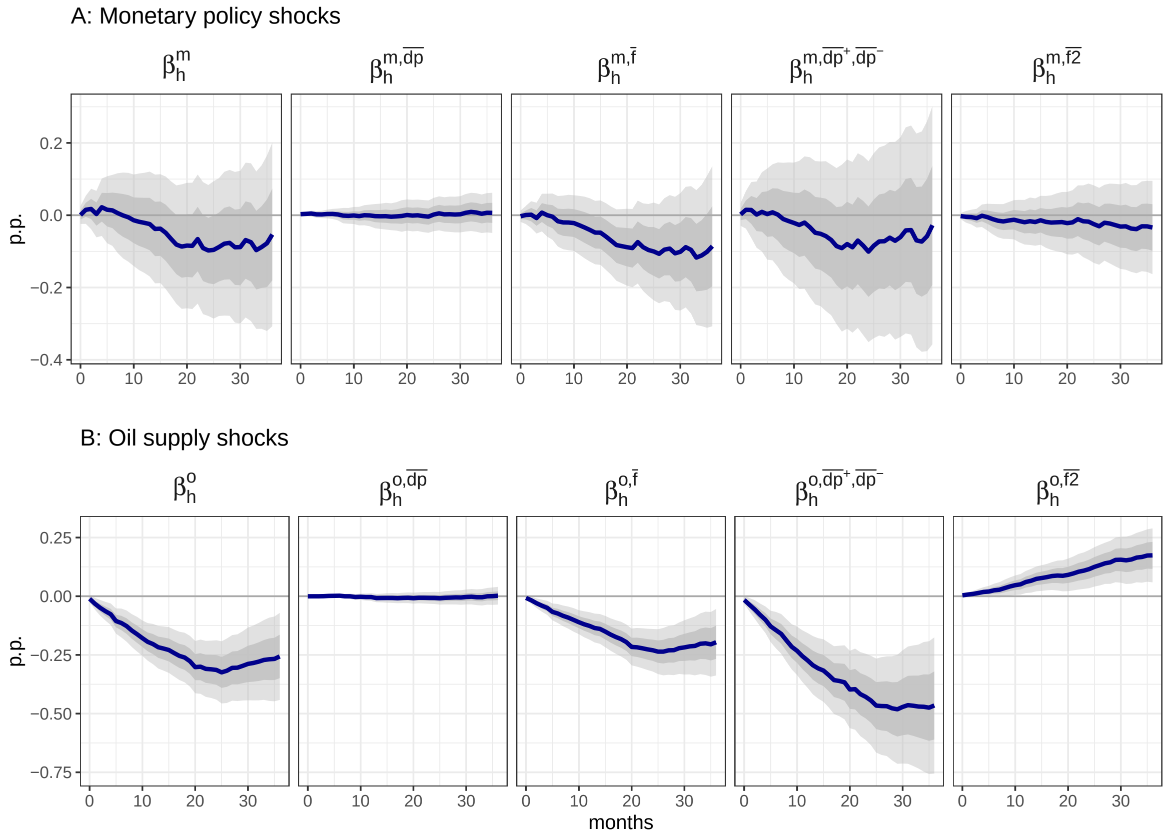
Notes: Coefficient plots from weighted panel regressions with COICOP, country, and time fixed effects and dummy for VAT changes in France (04/00, 01/12, 01/14), Italy (09/11), Slovakia (01/11), and Spain (09/12, 07-09/10), with country weights in euro area HICP (2017-2020 average) and robust standard 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). Results excluding sales are based on 1) NSI sales flag if available or 2) common sales filter. Outliers adjusted beforehand.

Figure 7: "Recomposed" and "counterfactual" inflation



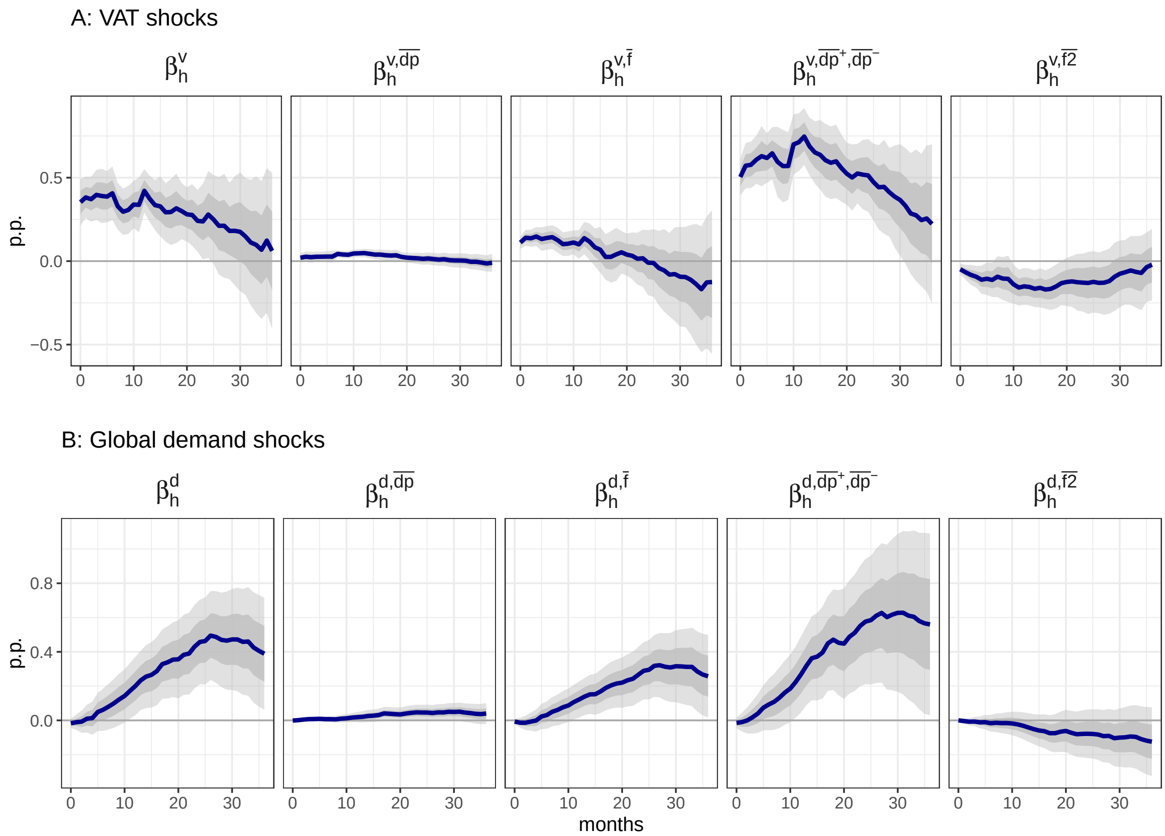
Notes: The figure shows scatter plots between recomposed inflation, as in Equation 2 and counterfactual inflation as in Equation 3 and 4, 5 and 6. Statistics are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries. Price changes due to replacement are excluded beforehand (except Greece). Outliers adjusted beforehand.

Figure 8: Conditional responses to positive aggregate shocks - Monetary Policy and Oil Supply Shocks



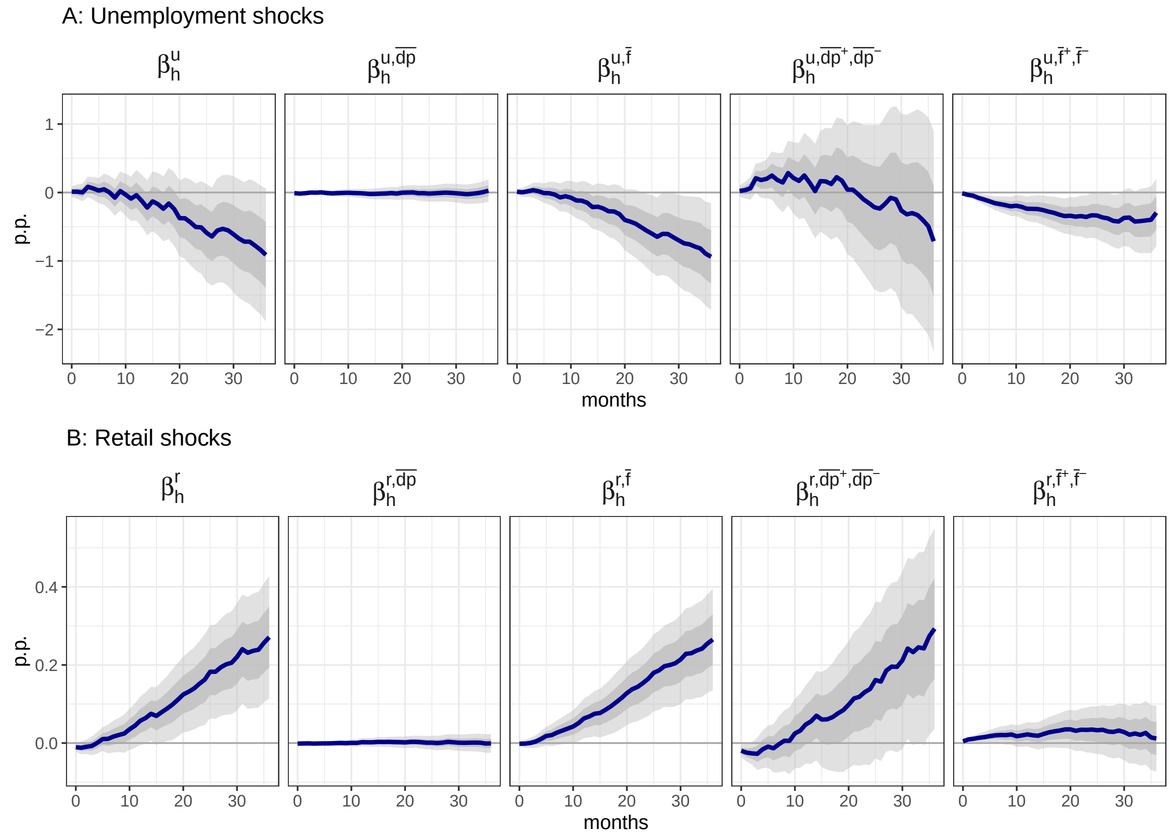
Notes: Local projections are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries. Price changes due to replacement are excluded beforehand (except Greece). Superscripts $x \in \{m, o\}$ represent the monetary and oil shocks respectively. The models are specified in equation (7). 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 9: Conditional responses to positive aggregate shocks - VAT and Global Demand Shocks



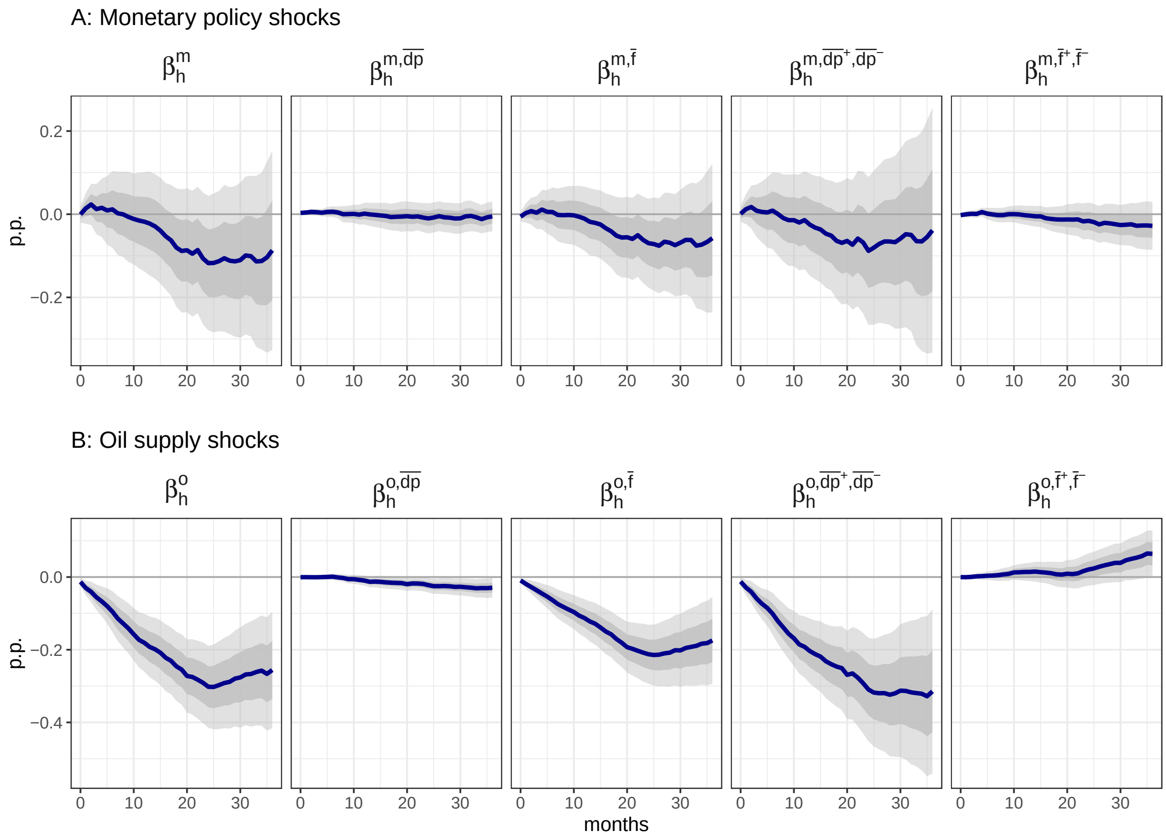
Notes: Local projections are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries. Price changes due to replacement are excluded beforehand (except Greece). Superscripts $x \in \{v, d\}$ *represent the VAT and global demand shocks respectively. The models are specified in equation (7). 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 10: Conditional responses to positive local shocks - Unemployment and Retail Trade Shocks



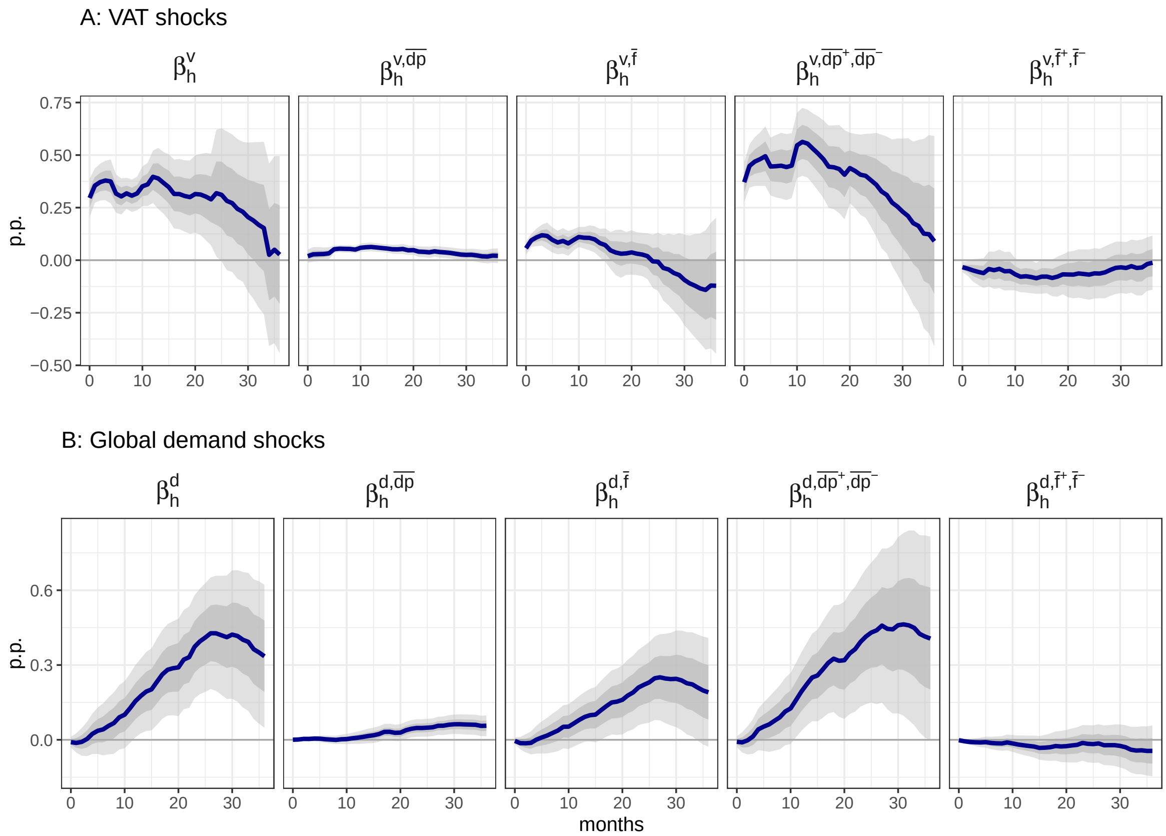
Notes: Local projections are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries. Price changes due to replacement are excluded beforehand (except Greece). Superscripts $x \in \{u, r\}$ represent the unemployment and retail trade respectively. The models are specified in equation (7). Since changes in unemployment and retail trade cannot be treated as shocks and contain autoregressive component, we add lags of corresponding variable into equation to control for it. In the order of the panels, the coefficients correspond to: The recomposed inflation β^x_h, counterfactual inflation assuming constant sizes of price changes $\beta^{x,\bar{dp}}_h$, counterfactual inflation assuming constant frequency of price changes $\beta^{x,\bar{f}}_h$, counterfactual inflation assuming constant sizes of price increases and decreases $\beta^{x,\bar{dp}^+,\bar{dp}^-}_h$ and counterfactual inflation assuming constant frequencies of price increases and decreases $\beta^{x,\bar{f}^+,\bar{f}^-}_h$. 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 - Excluding Sales - Monetary Policy and Oil Supply Shocks



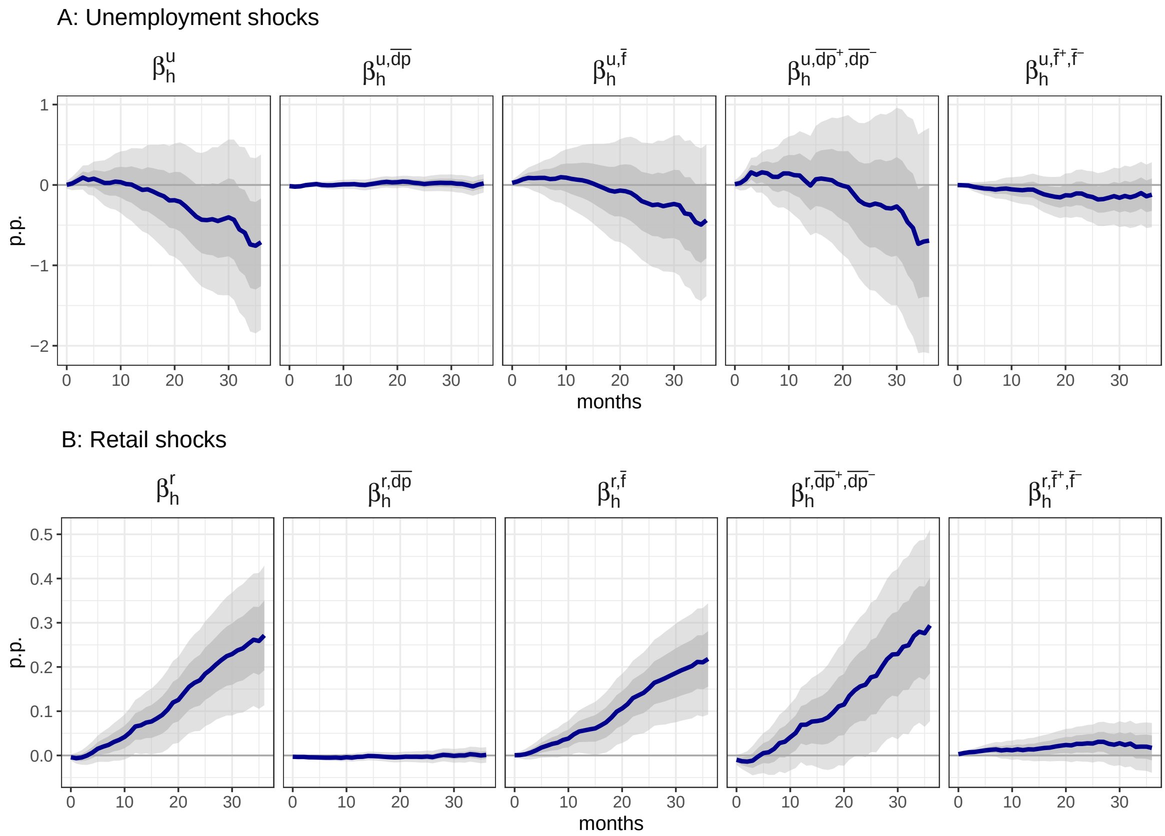
Notes: Local projections are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries. Price changes due to replacement are excluded beforehand (except Greece). Superscripts $x \in \{m, o\}$ represent the monetary and oil shocks respectively. The models are specified in equation (7). 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 positive aggregate shocks - Excluding Sales - VAT and Global Demand Shocks



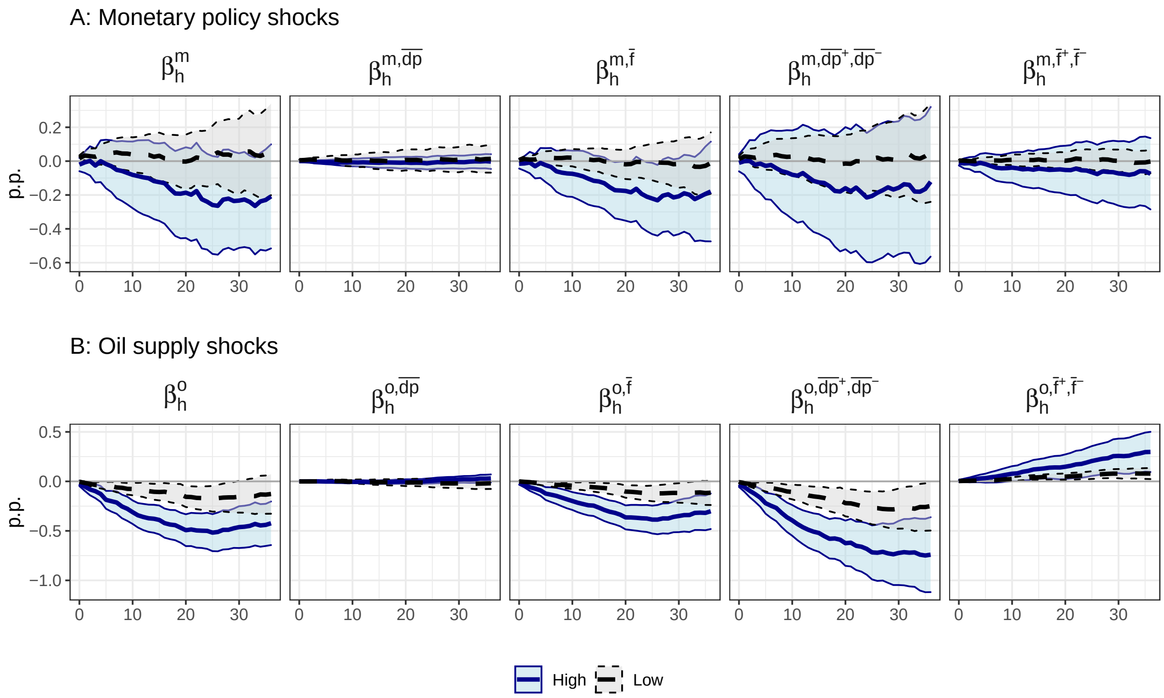
Notes: Local projections are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries. Price changes due to replacement are excluded beforehand (except Greece). Superscripts $x \in \{v, d\}$ represent the VAT and global demand shocks respectively. The models are specified in equation (7). 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 13: Conditional responses to positive local shocks - Excluding Sales - Unemployment and Retail Trade Shocks



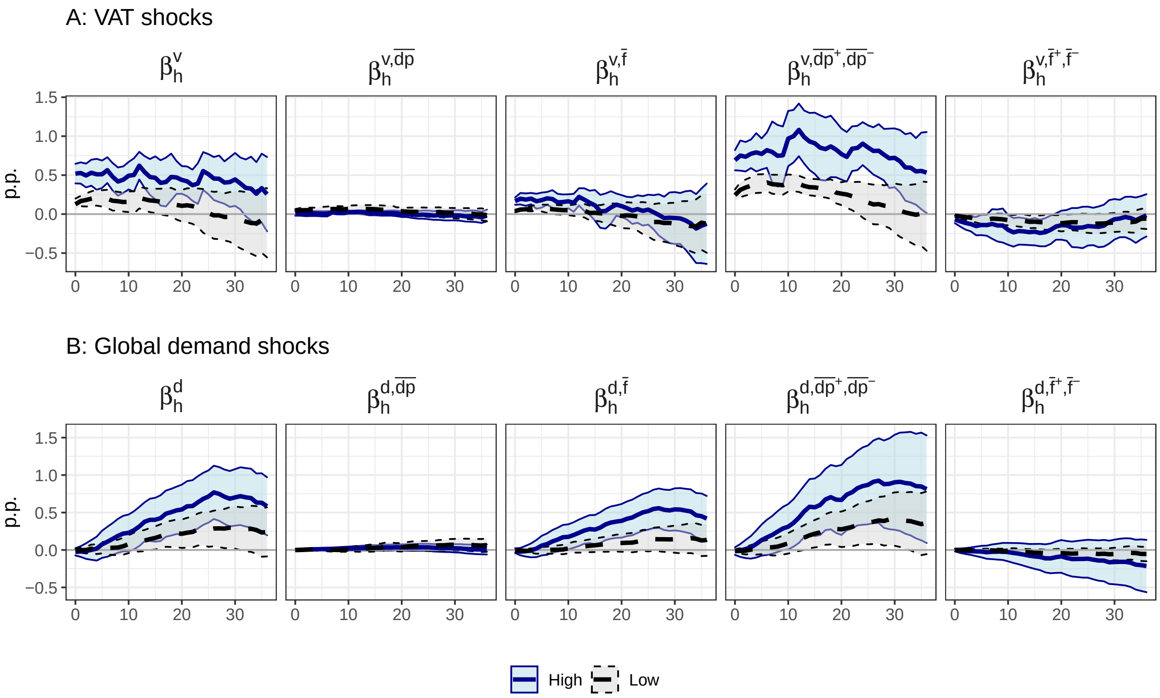
Notes: Local projections are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries. Price changes due to replacement are excluded beforehand (except Greece). Superscripts $x \in \{u, r\}$ represent the unemployment and retail trade respectively. The models are specified in equation (7). Since changes in unemployment and retail trade cannot be treated as shocks and contain autoregressive component, we add lags of corresponding variable into equation to control for it. 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 14: 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). 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 (7). 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 15: 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). 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 (7). 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.

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

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Not intended for publication

A Data and Methods

A.1 National CPI Micro Data Sets

Austria: 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 12 million price observation for 1,051 product categories (e.g. milk or men's t-shirt, no brand information), representing 96% of the Austrian CPI. The data set 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: 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: 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 are available to researchers after approval from the INSEE via a data access 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/). 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 data set. Since 2017, gasoline prices are collected through a dedicated website and are no longer available in the research data set. Prices collected on internet are not part of this data set. 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 data set 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: The German CPI micro data set contains more than 70 million of observations for the period 2010M1-2019M12. The data set is provided by the Statistical Offices of the Federation and the Federal States and publicly available for research purposes (see https://www.forschungsdatenzentrum.de/de/sonstige-wirtschaftsstatistiken/preise).[40] 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

[40] A detailed Meta Data Report is available for each calendar year, e.g. Statistical Offices of the Federation and the Federal States: Meta Data Report. Part II. Product-specific information concerning the micro data of the CPI 2015 (EVAS number: 61111) via scientific use file. DOI: https://doi.org/10.21242/61111.2015.00.00.3.1.0.

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 data set contains 710 product categories at the COICOP-10 level. 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 data set 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.

Greece: The Greek micro CPI data set 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 data set. 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: The Italian CPI micro prices includes about 22 million of observations for the period 2011M1-2018M12, collected by the Istituto Nazionale di Statistica (ISTAT). 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: The Latvian CPI micro prices are available to Latvijas Banka on the basis of a contract with the Central Statistical Bureau of the Republic of Latvia. The micro data is confidential and cannot be shared with researches 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: 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: The data set 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 data set covers a period going from 2005M1 to 2017M12. It contains about 1 million individual prices. Sales flags have been included in the data set only from 2015 onwards. A product replacement flag is available.

Slovakia: 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 – 2019M12 and contains over 8,3 million observations. 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: The Spanish CPI micro dataset was made available to Banco de España (BdE) by the Instituto Nacional de Estadística (INE), the Spanish national statistical agency. As per the contractual agreement between INE and BdE, the confidentiality of the dataset must be guaranteed, and our sample is therefore not publicly available for research purposes. The dataset covers the period from 2008M1 to 2018M12, it comes at the monthly frequency, and contains price information by outlet and province (e.g. Madrid, Barcelona or Valencia). Our sample contains 17 (out of 52) of the largest Spanish provinces. Price quotes are collected via regular in-person visits by pollsters to the specific establishments. For each product, a coefficient variable is available indicating changes in the quality of products. No sales flags are available in our sample. Individual products are classified into 188 COICOP categories at the 6-digit level and 129 ECOICOP categories at the 5-digit level. In terms of coverage, our sample contains on average about 10,300 price quotes per month (compared to 220,000 quotes each month used by INE to construct the HICP). The overall sample contains approximately 1.36 million observations in total. All COICOP-5 groups are represented in our sample, with the least represented group being Education Services (with 14.3% of the products that are used in the HICP calculations by INE being included in our sample), and the most represented one being Health (63.6%).

A.2 Common Product Sample

Table A1: CPI Coverage of the Common Product Sample

Special aggregate (SA)	Expenditure share in % (EA 2017-2020)	Relative share in %	Missing share of SA in %	No. of COICOP-5s covered
Food	16.8	28.5	13.1	59
Processed food	12.3	20.8	17.0	49
Unprocessed food	4.5	7.7	0.5	10
NEIG	18.4	31.2	30.3	66
Durables	4.1	6.9	55.8	23
Semi-durables	9.7	16.4	6.8	30
Non-durables	4.6	7.8	31.5	13
Services	23.7	40.3	46.7	41
Housing services	1.1	1.8	90.0	5
Transport services	5.8	9.9	20.0	9
Recreational services rel. to accommodation	1.6	2.7	56.3	2
Recreational services (others)	11.1	18.8	5.3	14
Miscellaneous services	4.2	7.1	50.5	11
Total	**58.9**	**100.0**	**41.1**	**166**

Notes: The micro data set 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. 'Relative share' denotes the the weight of the corresponding product group in the common product sample.

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:

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

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.[41]

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:

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

where n_j^+ is the total number of price increases for product j (ie $\sum_{i=1}^{n_j} \sum_{t=2}^{\tau} y_{i,j,t}^+$) and $dp_{i,j,t}^+$ 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

[41] 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 data set, 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 $P_{i,j,t}^{reg}$.

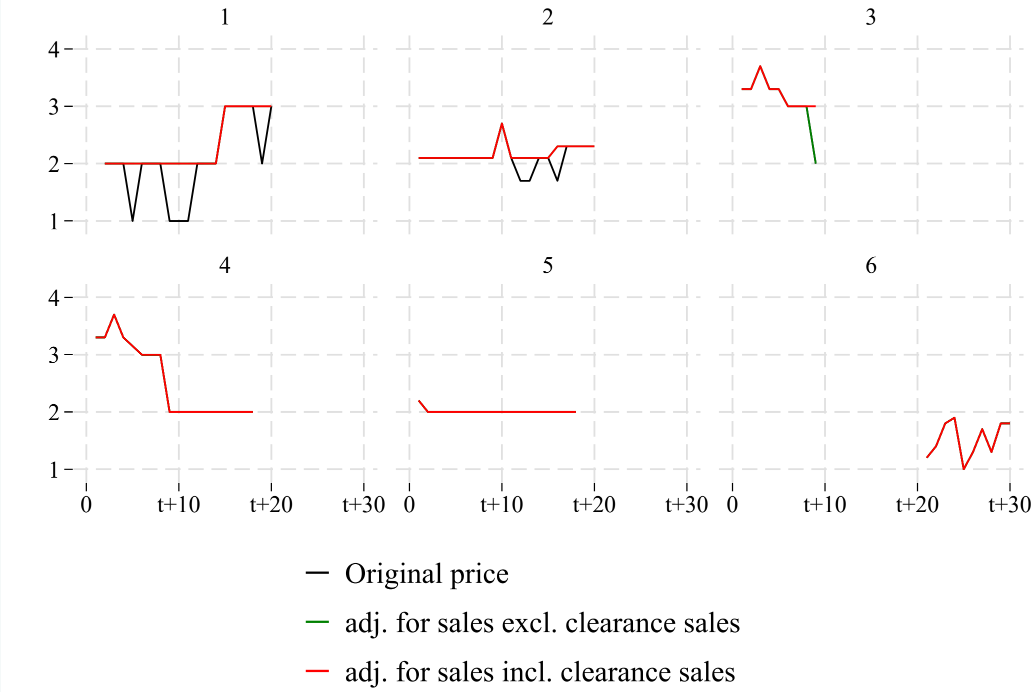
Sales filter In order to rule out that our results are driven by methodological differences in defining and flagging sales across euro area member states, we implement an algorithm that defines sales periods in our data set in a harmonised manner. Basically, we use the filter proposed by Nakamura and 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 on 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.

The sales filter depends on four parameters:[42]

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

Figure A1: Functioning of the sales filter including clearance sales.



Note: 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 (2008*a*) and the red solid line shows the price adjusted for sales and clearance sales.

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 (avaiable upon request), we have investigated the behaviour of the sales filter with respect to different parameter values for a subset of countries including AT, DE, FR, IT. Overall, 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.

A.3.3 Replacements

For country data sets 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 in the common sample of products.

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

A.4 Overview of National Sales Regulations

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.
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.	
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.
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.
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.
Latvia	No			Usually in the middle or at the end of the season.
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	**4.3**	**0.4**	**2.5**	**5.9**	**13.0**	**17.9**	**4.8**	**0.8**	**3.7**	**6.8**	**12.1**	**15.3**
by Sector												
Unprocessed Food	7.3	5.7	7.8	8.1	10.5	11.0	10.4	7.0	11.6	13.0	14.3	14.7
Processed Food	4.1	3.0	3.9	4.9	6.9	7.4	5.5	4.2	5.4	6.6	8.3	9.0
NEIG	8.2	2.7	4.9	15.6	18.3	20.6	7.2	3.3	6.0	12.1	14.1	16.1
Services	0.5	0.2	0.2	0.6	1.0	3.0	1.1	0.4	0.6	1.0	3.1	5.1
COUNTRY												
Austria	5.9	0.2	3.6	7.8	18.0	23.3	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	6.4	8.7	10.0
France	5.5	1.4	4.8	8.8	13.4	14.8	5.1	1.2	5.2	7.6	10.8	12.1
Germany	3.6	0.0	1.5	5.2	12.1	17.8	4.3	0.4	2.9	6.1	12.4	15.8
Greece	3.8	0.8	2.9	5.7	8.9	10.6	3.8	0.8	2.9	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 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 Robustness Analysis

B.1 Robustness: Product replacements

Table A4: 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	**13.2**	**65.4**	**9.4**	**69.4**	**9.4**	**12.2**	**6.9**	**8.4**
by Sector								
Unprocessed Food	31.7	54.5	23.8	58.0	12.5	14.7	10.3	10.9
Processed Food	15.6	57.3	10.7	62.1	8.7	11.0	5.9	6.5
NEIG	15.5	51.9	9.0	59.7	14.4	18.5	8.9	11.0
Services	6.4	83.1	6.2	83.6	5.1	6.4	5.0	6.2
COUNTRY								
Austria	13.9	62.7	10.1	64.3	11.8	16.4	8.3	11.9
France	14.9	61.9	12.1	64.5	8.8	12	6.5	8.6
Germany	12.2	67.4	8.9	73.0	9.4	12.2	7.1	7.6
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	64.7	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.2 Robustness: Common time period

Table A5: Euro Area Price Rigidity: 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	Decrease	Median Increase	Decrease
EURO AREA	**11.9**	**64.7**	**8.3**	**62.9**	**9.0**	**12.0**	**6.4**	**8.0**
by Sector								
Unprocessed Food	31.1	54.3	23.4	54.9	12.3	14.5	10.0	10.6
Processed Food	14.9	57.3	10.2	60.4	8.3	10.4	5.7	6.1
NEIG	12.4	48.2	6.3	56.0	13.5	18.4	7.8	10.2
Services	5.6	84.6	5.4	71.3	5.0	6.5	5.0	6.2
COUNTRY								
Austria	12.2	64.8	7.4	73.7	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	60.4	9.8	33.8	8.0	12.1	5.2	7.6
Germany	11.3	66.2	8.1	73.1	9.3	12.2	7.2	7.8
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	10.6	76.7	7.5	10.7	5.4	8.0
Slovakia	14.7	62.3	9.5	63.7	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 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). Belgium excludes seasonal sales.

B.3 Robustness: Sample of Products

Table A6: Euro Area Price Rigidity: Frequency of Price Changes based on each country's 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	**11.4**	**68.6**	**8.2**	**72.9**	**7.6**	**70.2**	**3.7**	**4.3**
by Sector								
Unprocessed food	31.1	54.5	23.2	58.4	18.2	57.3	7.3	10.4
Processed food	14.3	61.5	9.8	66.3	8.7	65.8	3.7	5.1
NEIG	12.1	53.2	6.5	64.2	6.5	58.9	7.2	6.6
Services	6.5	85.4	6.2	84.7	6.0	82.6	0.7	1.2
COUNTRY								
Austria	12.7	66.9	9.4	72.5	9.1	71.9	5.3	3.9
Belgium	13.6	71.7	12.6	72.3	10.4	73.5	1.0	3.6
France	13.8	64.4	11.4	69.3	9.8	67.9	5.0	4.7
Germany	9.5	72.8	7.0	77.7	5.8	75.6	2.7	3.4
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). Belgium excludes seasonal sales. Results excluding sales are based on 1) NSI sales flag if available or 2) common sales filter.

Table A7: Euro Area Price Rigidity: Size of Price Changes based on each country's 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	**7.9**	**10.8**	**5.7**	**7.2**	**5.8**	**9.3**
by Sector						
Unprocessed food	12.3	14.5	10.0	10.7	9.0	10.4
Processed food	7.8	10.3	5.5	5.9	5.3	6.2
NEIG	11.7	16.0	6.9	9.0	7.0	11.2
Services	4.5	5.7	4.4	5.4	4.5	9.1
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	6.6	10.1	4.5	6.4	4.9	8.4
Germany	7.7	11.1	6.0	7.0	5.2	9.3
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 products that are available in each country. Price changes due to replacement are excluded beforehand (except for Greece). Belgium excludes seasonal sales. Results excluding sales are based on 1) NSI sales flag if available or 2) common sales filter.

Table A8: Euro Area Price Rigidity: 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	**11.1**	**63.9**	**6.5**	**71.1**	**6.3**	**67.4**	**5.5**	**5.3**
by Sector								
Unprocessed food	19.3	56.5	11.2	62.6	9.7	61.6	6.8	7.8
Processed food	15.0	57.7	10.1	63.1	8.9	62.6	4.1	5.5
NEIG	14.4	38.9	4.7	60.5	5.7	49.5	13.8	10.5
Services	3.4	90.1	3.3	88.9	3.5	86.5	0.4	0.9
COUNTRY								
Austria	9.8	61.9	5.0	72.9	5.3	69.8	7.6	4.6
Belgium	11.0	70.3	10.0	71.0	8.2	72.3	0.9	3.1
France	12.4	58.7	8.6	67.6	7.4	63.5	6.1	5.4
Germany	8.4	64.8	4.2	75.1	3.9	71.6	4.8	4.6
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). Belgium excludes seasonal sales. Results excluding sales are based on 1) NSI sales flag if available or 2) common sales filter.

Table A9: Euro Area Price Rigidity: 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	**9.9**	**13.0**	**6.2**	**7.5**	**6.4**	**10.0**
by Sector						
Unprocessed food	9.6	12.7	6.2	6.8	5.9	7.4
Processed food	8.4	10.6	5.7	6.0	5.5	6.3
NEIG	18.8	26.3	8.9	12.7	9.7	17.8
Services	4.9	5.4	4.8	5.0	4.8	8.4
COUNTRY						
Austria	11.9	17.6	6.7	9.2	7.4	12.4
Belgium	6.3	7.6	6.0	6.9	5.8	6.6
France	8.3	12.7	4.4	6.7	5.3	10.7
Germany	10.5	14.0	7.3	7.7	6.6	9.6
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). Belgium excludes seasonal sales. Results excluding sales are based on 1) NSI sales flag if available or 2) common sales filter.

B.4 Robustness: Country weights

Table A10: Euro Area Price Rigidity: Frequency of Price Changes using country product weights for country 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	**12.1**	**65.6**	**8.4**	**70.8**	**7.6**	**68.1**	**4.3**	**4.7**
by Sector								
Unprocessed food	32.7	54.4	24.7	58.1	19.1	56.9	7.2	10.8
Processed food	14.9	57.6	10.1	63.0	8.9	62.4	4.1	5.5
NEIG	12.8	49.4	6.6	61.6	6.6	56.1	8.1	7.3
Services	6.0	85.7	5.6	85.4	5.3	83.7	0.5	1.1
COUNTRY								
Austria	10.1	65.7	6.9	72.9	6.6	71.8	5.4	3.9
Belgium	14.4	68.5	13.2	69.2	10.9	70.5	1.1	3.8
France	12.6	61.7	9.9	67.1	8.2	65.6	5.2	4.9
Germany	11.6	65.8	8.5	72.7	7.1	70.1	3.5	4.2
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 ofthe 4 largest countries. Price changes due to replacement are excluded beforehand (except for Greece). Belgium excludes seasonal sales. Results excluding sales are based on 1) NSI sales flag if available or 2) common sales filter.

Table A11: Euro Area Price Rigidity: Size of Price Changes using country product weights for country 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	**8.7**	**11.7**	**6.2**	**7.7**	**6.1**	**9.4**
by Sector						
Unprocessed food	12.5	14.7	10.4	11.0	9.1	10.5
Processed food	8.3	10.5	5.7	6.0	5.5	6.3
NEIG	13.1	17.9	7.5	9.8	7.7	12.3
Services	4.8	6.0	4.7	5.9	4.8	8.7
COUNTRY						
Austria	9.5	13.6	6.5	8.5	6.9	10.3
Belgium	6.9	8.2	6.5	7.4	6.5	7.2
France	7.3	11.3	5.0	6.9	5.4	9.1
Germany	9.1	12.2	6.9	7.7	6.0	9.1
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). Belgium excludes seasonal sales. Results excluding sales are based on 1) NSI sales flag if available or 2) common sales filter.

B.5 Robustness: EA Aggregation

Table A12: Euro Area Price Rigidity: 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	**12.1**	**65.6**	**8.4**	**70.9**	**7.6**	**67.7**	**4.3**	**4.8**
by Sector								
Unprocessed food	34.8	53.8	26.6	57.1	20.6	55.8	8.0	11.4
Processed food	14.9	57.8	10.1	63.1	8.9	62.5	4.1	5.5
NEIG	12.5	48.6	6.2	61.5	6.4	55.3	8.3	7.2
Services	6.0	85.1	5.7	84.7	5.4	82.3	0.5	1.2

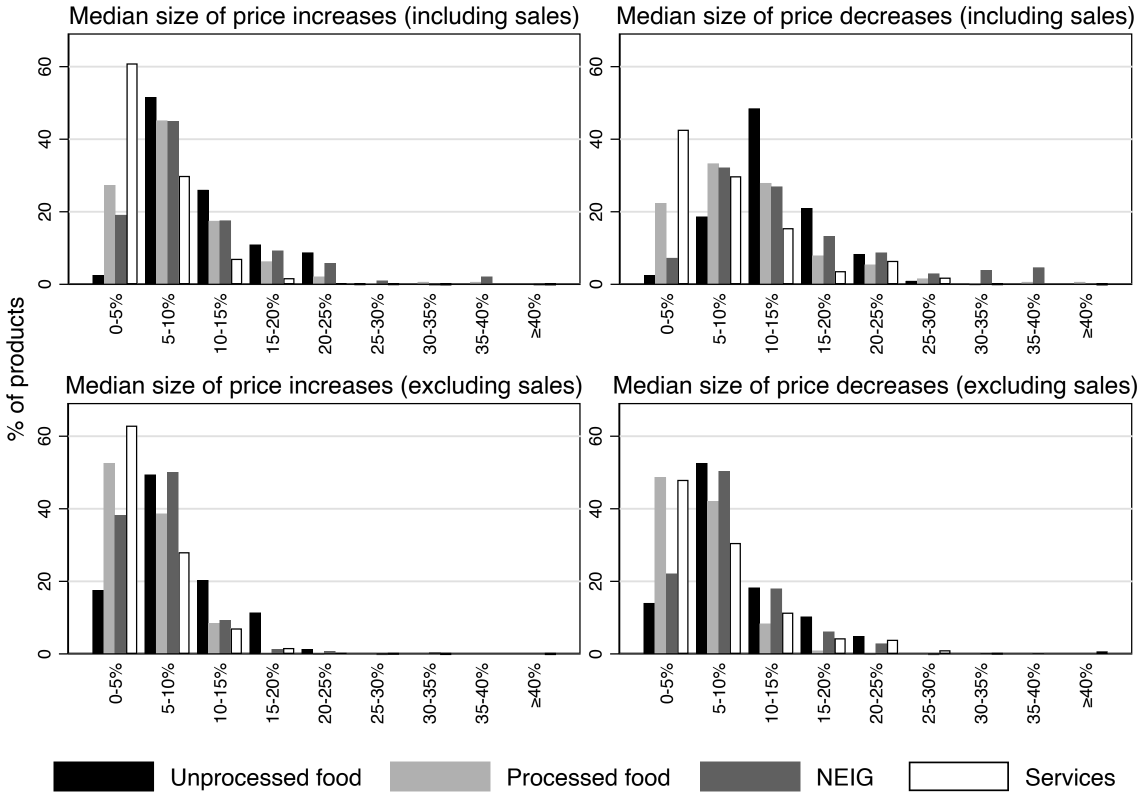
Notes: We first aggregate at the product level and then calculate the average over the products. Statistics are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries. Price changes due to replacement are excluded beforehand (except for Greece).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

Table A13: Euro Area Price Rigidity: 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	**8.8**	**11.6**	**6.3**	**7.7**	**6.2**	**9.7**
by Sector						
Unprocessed food	13.5	15.5	11.4	12.1	10.1	11.5
Processed food	8.3	10.5	5.7	6.0	5.5	6.3
NEIG	13.1	18.0	7.4	9.7	7.6	12.4
Services	4.9	6.5	4.8	6.2	5.0	9.1

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). Belgium excludes seasonal sales. Results excluding sales are based on 1) NSI sales flag if available or 2) common sales filter.

Figure A2: 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 Greece). Results excluding sales are based on **1)** NSI sales flag (if available) or **2)** common sales filter.*

B.6 Cross-country similarities

Table A14: Correlation between countries of the frequency of price changes at the product level

	Austria	Belgium	France	Germany	Greece	Italy	Latvia	Lithuania	Luxembourg	Slovakia	Spain
Austria	1										
Belgium	0.86	1									
France	0.73	0.87	1								
Germany	0.53	0.67	0.45	1							
Greece	0.38	0.61	0.78	0.37	1						
Italy	0.30	0.21	0.57	0.29	0.70	1					
Latvia	0.45	0.80	0.65	0.41	0.46	0.33	1				
Lithuania	0.61	0.78	0.74	0.44	0.52	0.43	0.73	1			
Luxembourg	0.50	0.59	0.62	0.44	0.54	0.60	0.34	0.51	1		
Slovakia	0.57	0.82	0.82	0.46	0.68	0.56	0.65	0.83	0.53	1	
Spain	0.58	0.80	0.82	0.49	0.82	0.58	0.59	0.62	0.63	0.78	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 sales are included, but price changes due to replacements are excluded beforehand (except Greece). Belgium excludes seasonal sales. Individual products can have a substantial impact on the overall correlation.

B.7 Explanatory variables of the frequency and size of price changes

Table A15: Description and sources of the explanatory variables used for the regression

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.8 Regression of the size of price changes

Table A16: Explanatory factors of the median size of price changes

	I	II	III	IV
Share of labour costs	-0.076***	-0.127***	-0.079***	-0.091***
Share of imported energy and raw material inputs	-0.165***	-0.131**	0.049	-0.100**
Share of all imported inputs	-0.044	-0.032	0.077	-0.098
% of online consumers	0.001***	0.001***	0.002***	0.001***
Regulated price dummy	-0.002		-0.012	-0.003
Retail market concentration (HHI)		-0.001***		
Unprocessed food dummy				0.006
Processed food dummy				-0.015***
Services dummy				-0.006
Constant	0.093***	0.111***	0.083***	0.111***
Country dummies	✓	✓	✓	✓
Number of observations	1,460	1,172	1,625	1,460
R^2	0.299	0.376	0.297	0.318

*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 reference country is France. 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, Slovakia, and Spain sales are excluded via the sales filter, Greece includes 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 data set 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 A17). 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 data set 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.[43] 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 1996-2003 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.

[43] For Germany, the old data set 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.

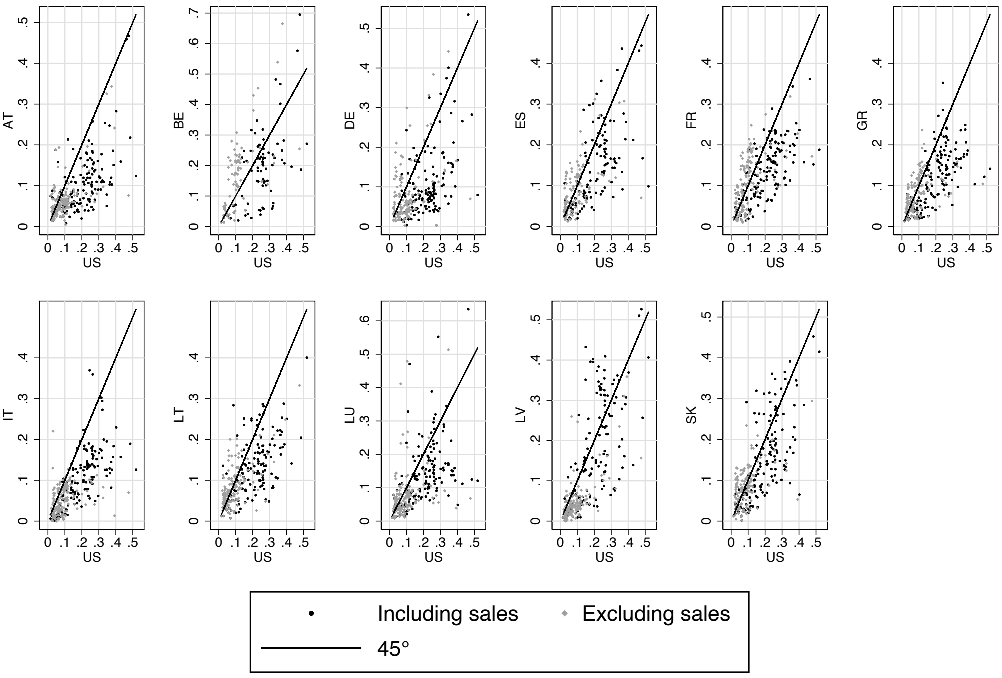
Table A17: Availability of the 50 products from Dhyne et al. (2006) in our data set

	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**

D Comparison with US Results

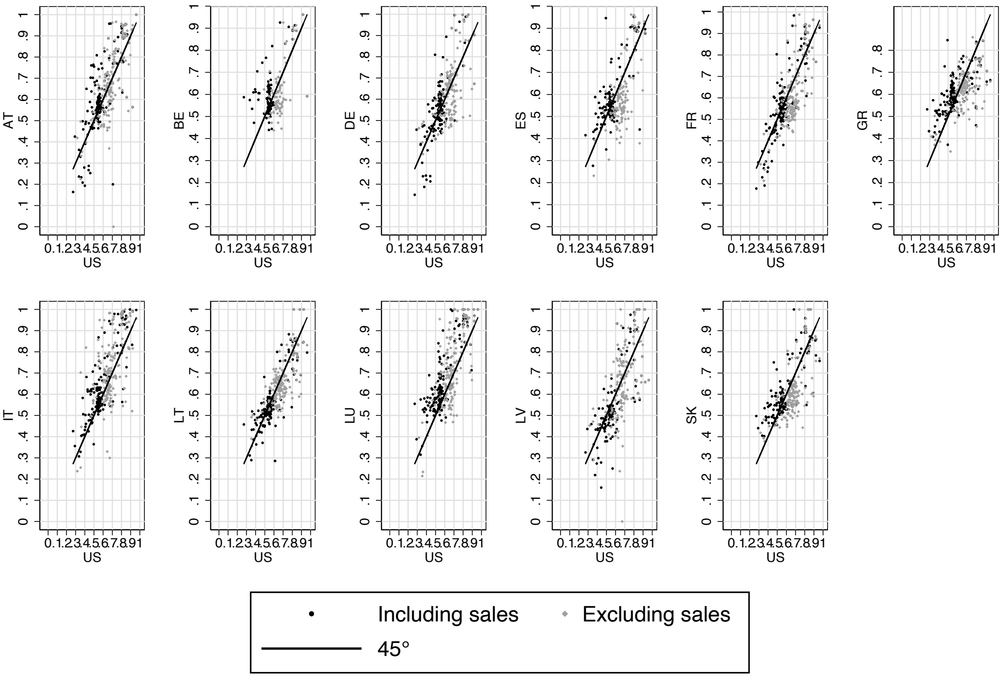
To compare our results with the results for the United States from Nakamura and Steinsson (2008*a*), we downloaded the data tables from the authors' websites, which are part of the supplementary materials of the published paper. In particular, we extracted data from the ELI-level tables on frequency of price changes including and excluding sales (Table 19), 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.

Figure A3: Frequency of price changes at the product level: Euro Area vs United States



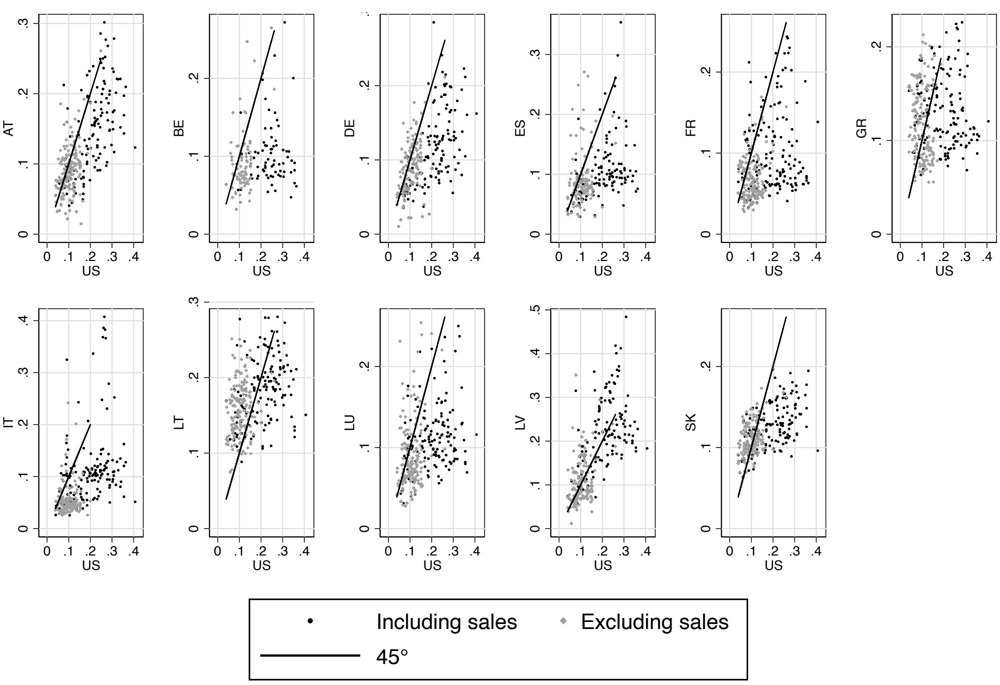
Notes: US product results are taken from Nakamura and Steinsson (2008a). Euro area statistics are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries.

Figure A4: Average share of price increases at the product level: Euro Area vs United States



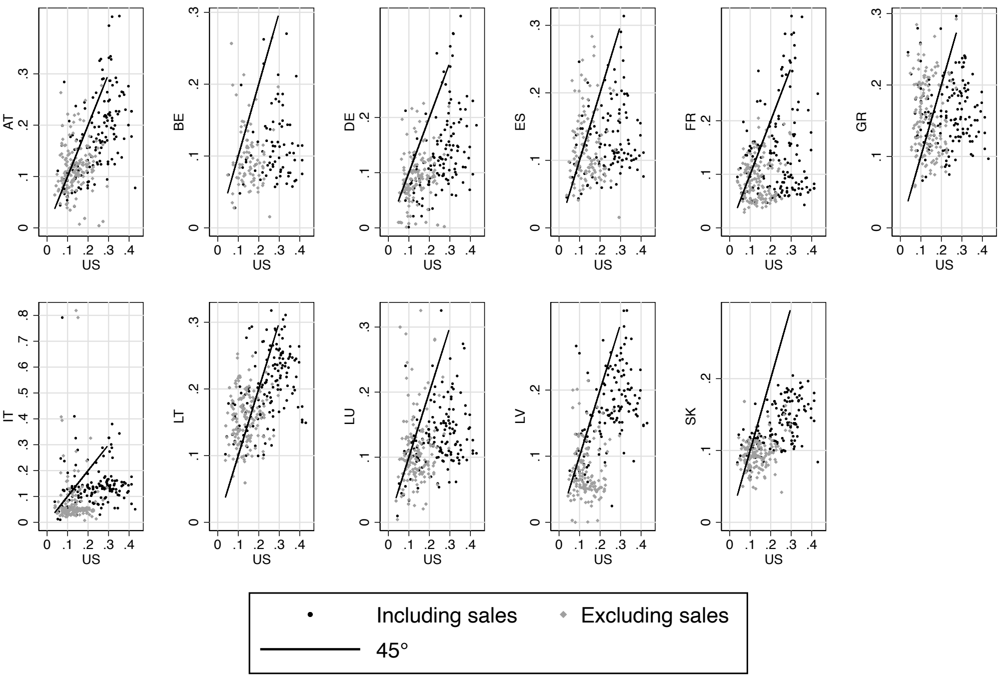
Notes: US product results are taken from Nakamura and Steinsson (2008a). Euro area statistics are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries.

Figure A5: Average size of price increases 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.

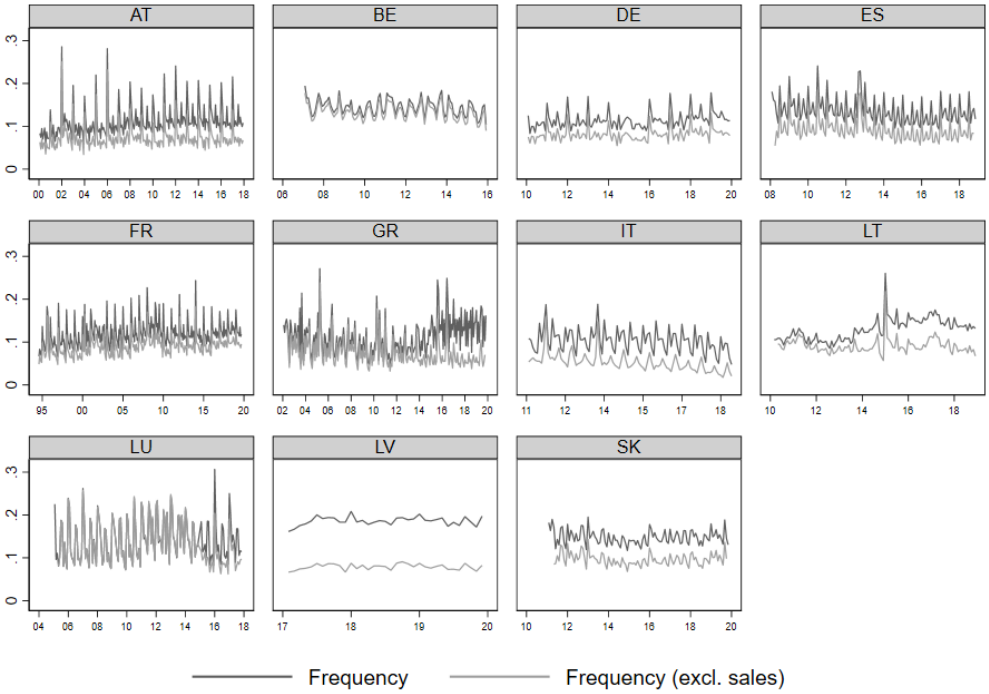
Figure A6: Average size of price decreases at the product level: Euro Area vs United States



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.

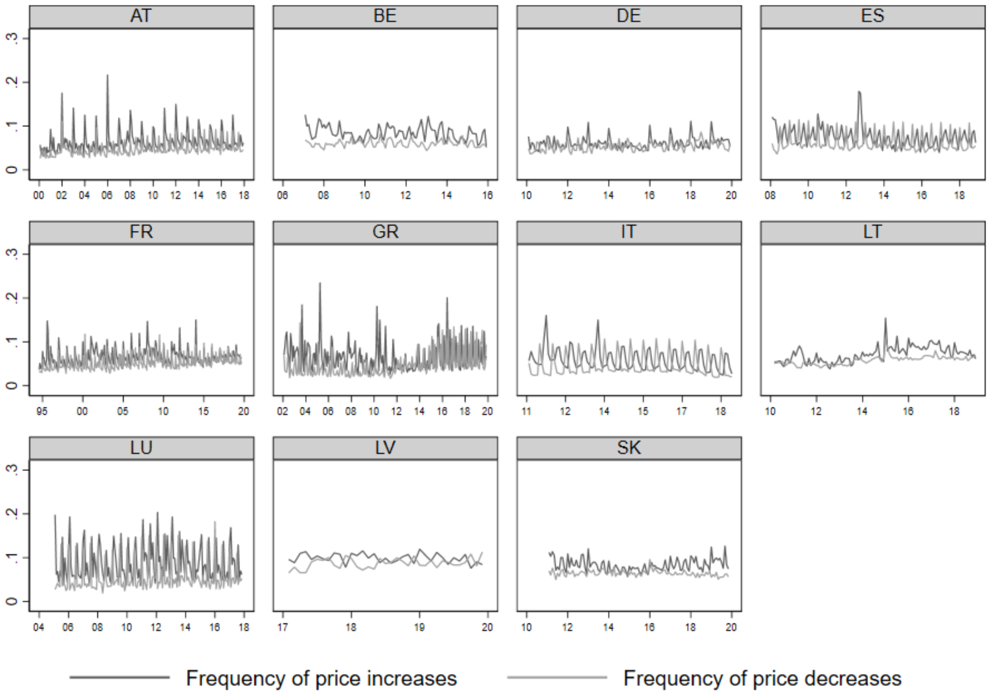
E Additional Results on Time Series Statistics

Figure A7: Frequency by country over time



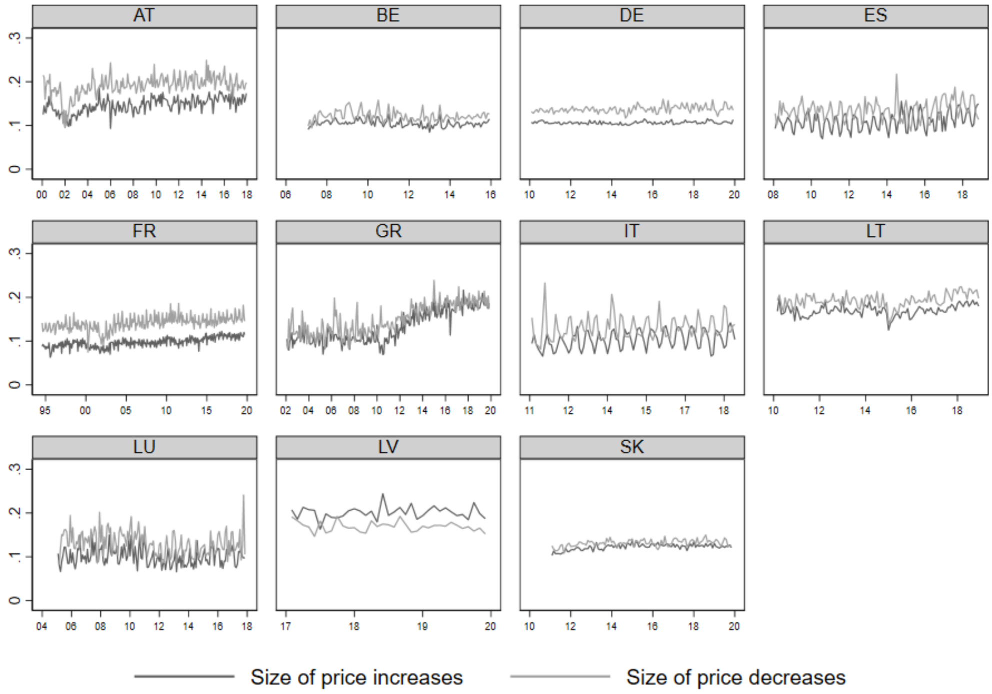
Notes: Statistics are based on products that are common to at least 3 of the 4 largest countries and calculated using euro area product weights at the COICOP-5 level (2017-2020 average). Price changes due to replacement are excluded beforehand (except Greece). Outliers adjusted beforehand.

Figure A8: Frequencies of price increases and decreases by country over time



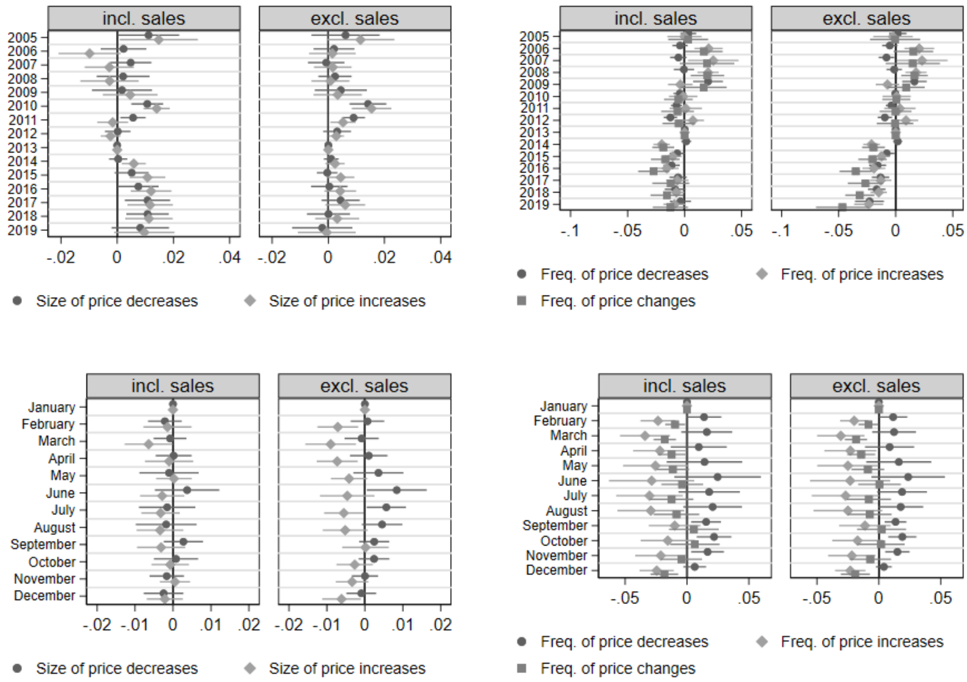
Notes:Statistics are based on products that are common to at least 3 of the 4 largest countries and calculated using euro area product weights at the COICOP-5 level (2017-2020 average). Price changes due to replacement are excluded beforehand (except Greece). Outliers adjusted beforehand.

Figure A9: Mean size of price increases and decreases by country over time



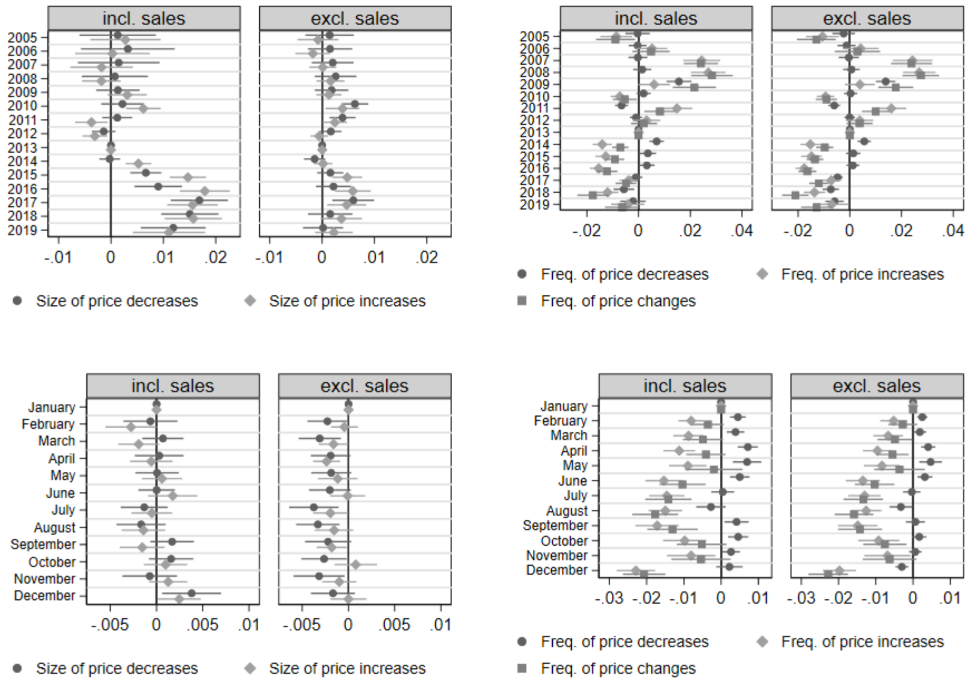
Notes: The chart shows the mean size of non-zero price changes. Statistics are based on products that are common to at least 3 of the 4 largest countries and calculated using euro area product weights at the COICOP-5 level (2017-2020 average). Price changes due to replacement are excluded beforehand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

Figure A10: Seasonal patterns, annual changes, and effect of sales: Unprocessed food



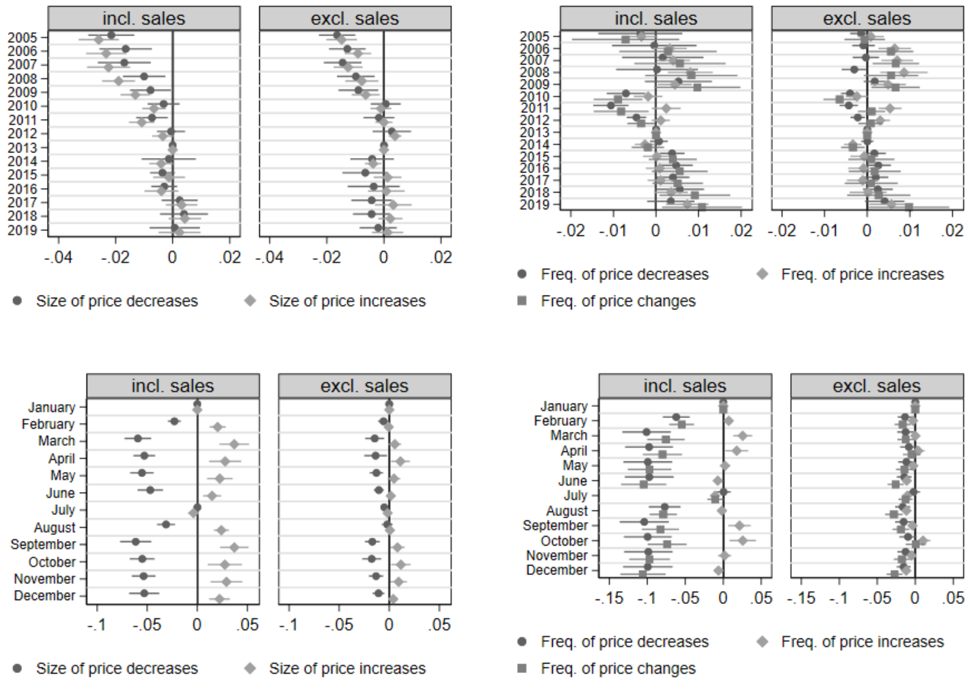
Notes: Coefficient plots from weighted panel regressions with COICOP, country, and time fixed effects and dummy for VAT changes in France (04/00, 01/12, 01/14), Italy (09/11), Slovakia (01/11), and Spain (09/12, 07-09/10), with country weights in euro area HICP (2017-2020 average) and robust standard 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). Results excluding sales are based on 1) NSI sales flag if available or 2) common sales filter. Outliers adjusted beforehand.

Figure A11: Seasonal patterns, annual changes, and effect of sales: Processed food



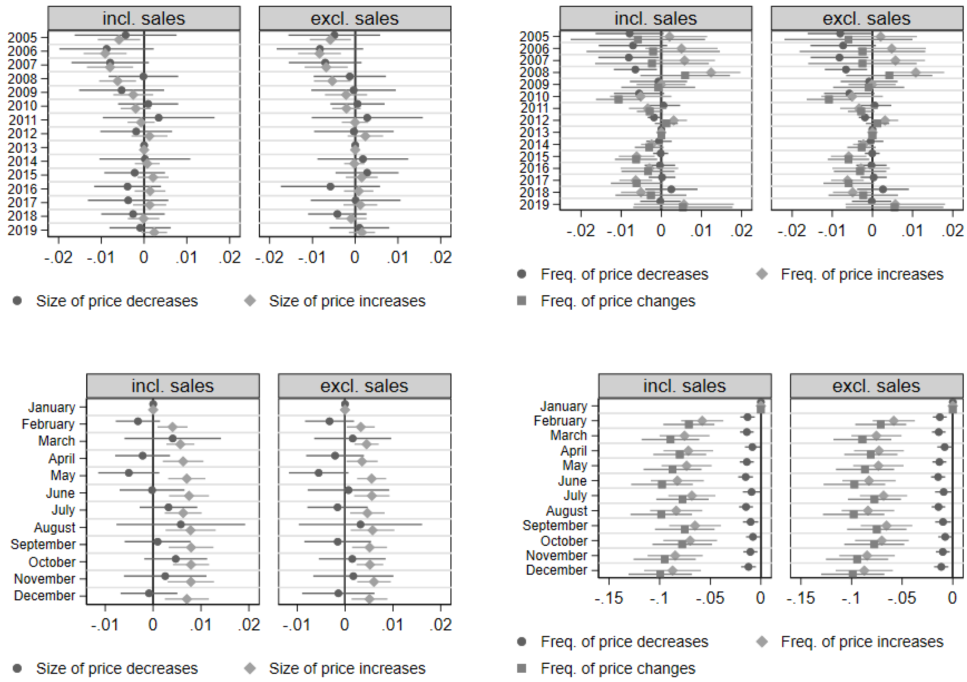
Notes: Coefficient plots from weighted panel regressions with COICOP, country, and time fixed effects and dummy for VAT changes in France (04/00, 01/12, 01/14), Italy (09/11), Slovakia (01/11), and Spain (09/12, 07-09/10), with country weights in euro area HICP (2017-2020 average) and robust standard 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). Results excluding sales are based on 1) NSI sales flag if available or 2) common sales filter. Outliers adjusted beforehand.

Figure A12: Seasonal patterns, annual changes, and effect of sales: NEIG



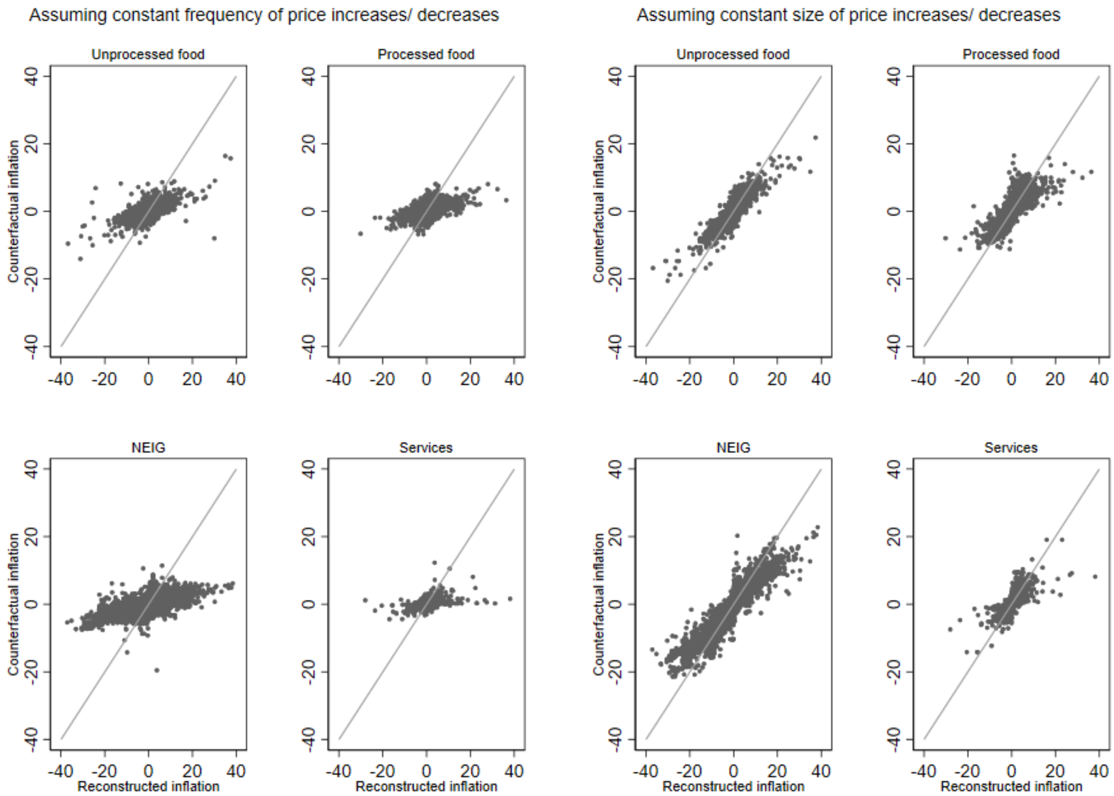
Notes: Coefficient plots from weighted panel regressions with COICOP, country, and time fixed effects and dummy for VAT changes in France (04/00, 01/12, 01/14), Italy (09/11), Slovakia (01/11), and Spain (09/12, 07-09/10), with country weights in euro area HICP (2017-2020 average) and robust standard 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). Results excluding sales are based on 1) NSI sales flag if available or 2) common sales filter. Outliers adjusted beforehand.

Figure A13: 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). Results excluding sales are based on 1) NSI sales flag if available or 2) common sales filter. Outliers adjusted beforehand.

Figure A14: "Reconstructed" and "counterfactual" inflation by special aggregate



Notes: The figure shows scatter plots between reconstructed inflation, as in Equation 2 and counterfactual inflation as in Equation 5 and 6. Price changes due to replacement are excluded beforehand (except Greece). Statistics are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries. Outliers adjusted beforehand.

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) whose identification is done by poor's man sign restriction. The IRFs are rescaled to produce a 0.15 p.p. increase in the 1-year money market interest rate.

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.

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.

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* [44]

Retail trade - seasonally and calendar adjusted index of deflated turnover (retail trade, except of motor vehicles and motorcycles) measured as percentage change on previous period; EUROSTAT table *sts_trtu_m* [45]

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 $t+h$, $\alpha_{j,m,h}$ are fixed-effects and X_{jt} are control variables. The β_h are the IRF of interest. In addition, the cumulative inflation can be decomposed into:

$$\pi_{j,t,t+h} = f_{j,t,t+h} \times dp_{j,t,t+h} \tag{A9}$$

and,

$$\pi_{j,t,t+h} = f^+_{j,t,t+h} \times dp^+_{j,t,t+h} - f^-_{j,t,t+h} \times dp^-_{j,t,t+h} \tag{A10}$$

A change in the linearisation around the j-specific means $(\bar{f}_{j,h}, \bar{dp}_{j,h})$ of the decomposition into (A9) leads to:

$$\pi_{j,t,t+h} - \bar{\pi}_{j,h} = \bar{f}_{j,h}(dp_{j,t,t+h} - \bar{dp}_{j,h}) + \bar{dp}_{j,h}(f_{j,t,t+h} - \bar{f}_{j,h}) \tag{A11}$$

where the first term is the IRF at j-constant frequency (net intensive margin) and the second is the IRF at j-constant size (net extensive margin). Decomposing the cumulative inflation into (A10), then producing a change in linearization around the j-specific means $(\bar{f}^+_{j,h}, \bar{f}^-_{j,h}, \bar{dp}^+_{j,h}, \bar{dp}^-_{j,h})$ results in:

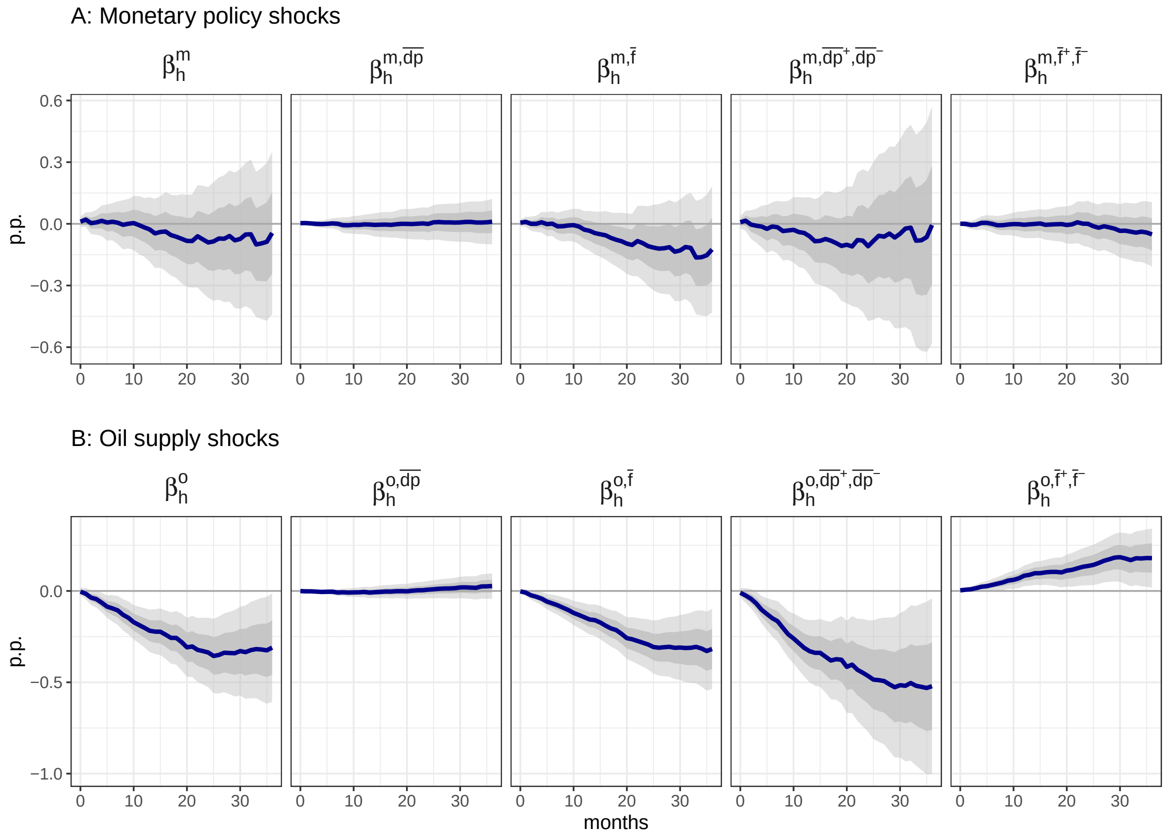
$$\begin{aligned}\pi_{j,t,t+h} - \bar{\pi}_{j,h} \;=\; & \Big(\bar{f}^+_{j,h}(dp^+_{j,t,t+h} - \bar{dp}^+_{j,h}) + \bar{f}^-_{j,h}(dp^-_{j,t,t+h} - \bar{dp}^-_{j,h})\Big) + \\ & \Big(\bar{dp}^+_{j,h}(f^+_{j,t,t+h} - \bar{f}^+_{j,h}) - \bar{dp}^-_{j,h}(f^-_{j,t,t+h} - \bar{f}^-_{j,h})\Big)\end{aligned} \tag{A12}$$

[44] https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=une$_r t_m lang = en$

[45] https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=sts$_t rtu_m lang = en$

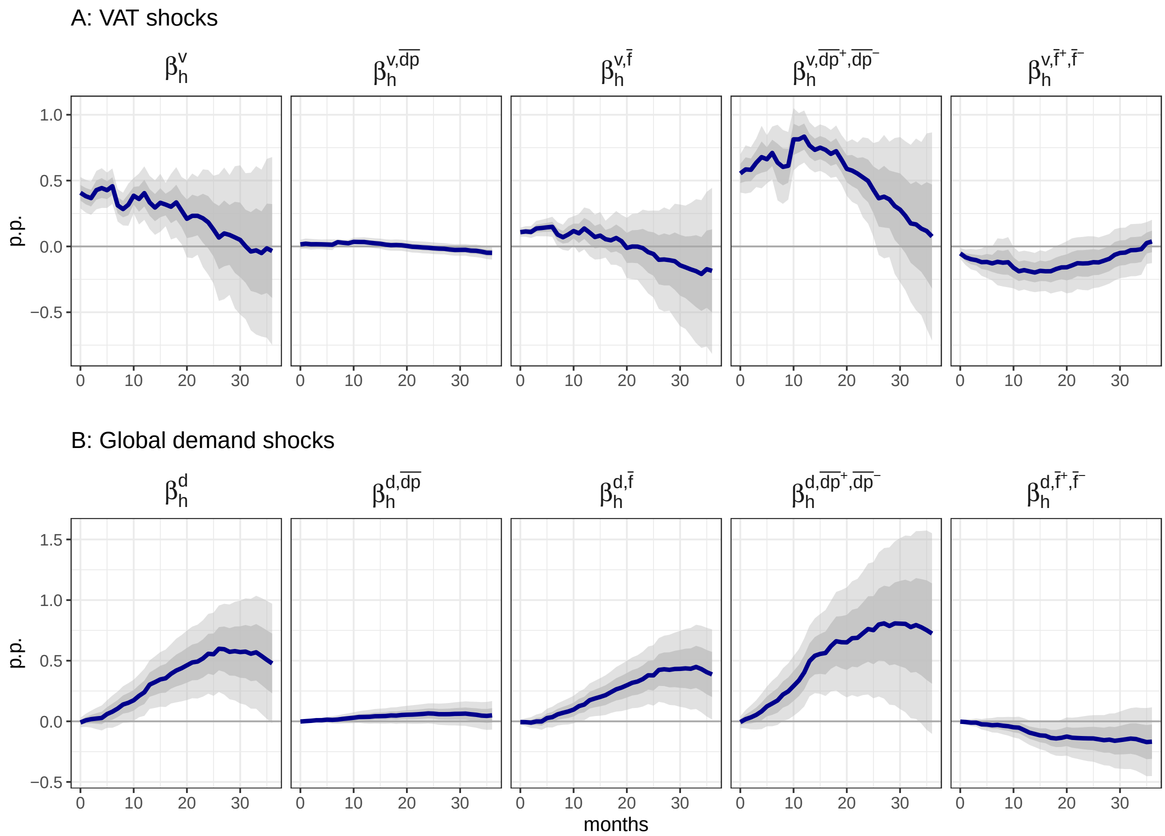
where the first term in parenthesis is the IRF at j-constant frequency of price increases and decreases (gross intensive margin). The second term in parenthesis is the IRF at j-constant size of price increases and decreases (gross extensive margin).

Figure A15: Conditional responses to positive aggregate shocks - 3 countries with longer sample (AT, FR, GR)- Monetary Policy and Oil Supply Shocks



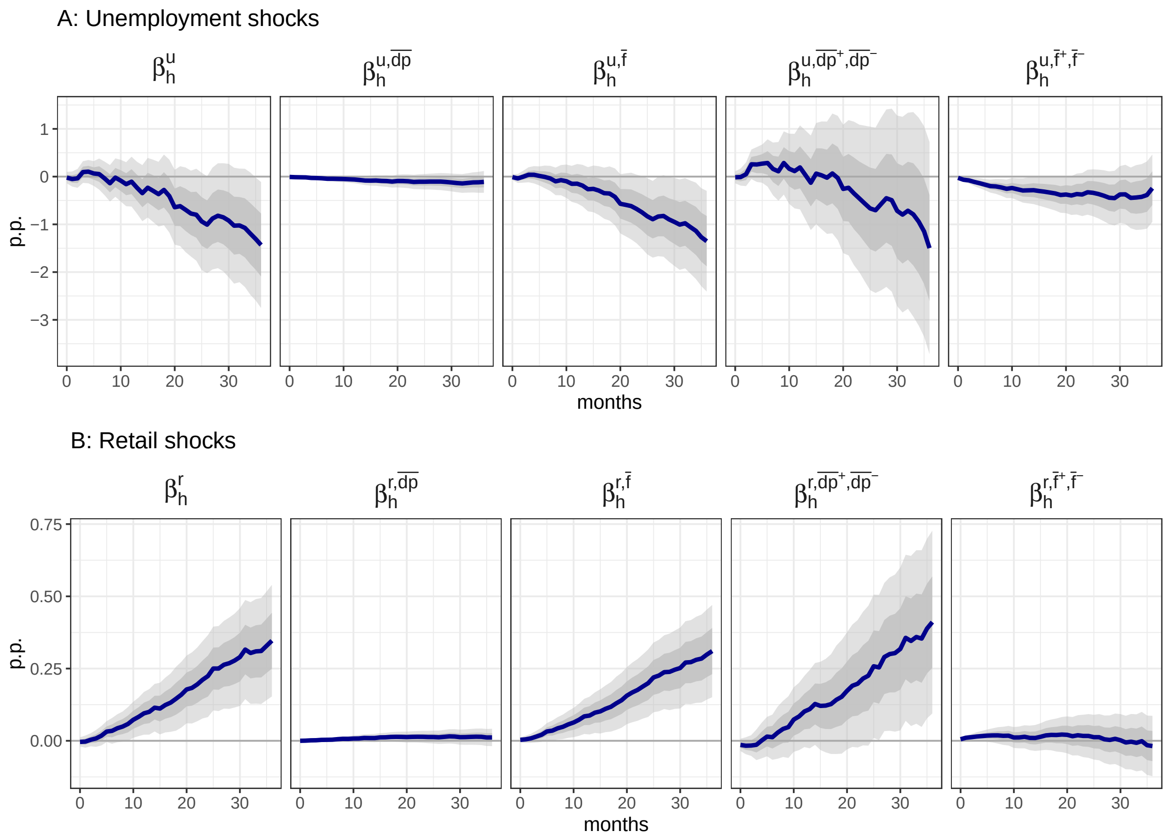
Notes: Local projections are based on the country-specific period and on products that are common to at least 3 of the 4 largest countries. Price changes due to replacement are excluded beforehand (except Greece). Superscripts $x \in \{m, o\}$ represent the monetary and oil supply shocks respectively. The models are specified in equation (7). 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 A16: Conditional responses to positive aggregate shocks - 3 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 (7). 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 A17: Conditional responses to positive local shocks - France, Austria and Greece - Unemployment and Retail Trade 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. Superscripts $x \in \{u, r\}$ represent the unemployment and retail trade respectively. The models are specified in equation (7). Since changes in unemployment and retail trade cannot be treated as shocks and contain autoregressive component, we add lags of corresponding variable into equation to control for it. In the order of the panels, the coefficients correspond to: The recomposed inflation β_h^x, the net intensive margin $\beta_h^{x,\bar{dp}}$, the net extensive margin $\beta_h^{x,\bar{f}}$, the gross intensive margin $\beta_h^{x,\bar{dp}^+\bar{dp}^-}$ and the gross extensive $\beta_h^{x,\bar{f}^+\bar{f}^-}$. The light and dark gray areas correspond to one and two standard error bands, assuming calendar-based clusters.