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Price setting in the euro area : insights from the PRISMA research network

by R. Faber, C. Fuss, J. Jonckheere and H. Zimmer

National Bank OF BELGIUM
Eurosystem

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Introduction

The primary objective of the Eurosystem is the maintenance of price stability. Therefore, the European Central Bank (ECB), the National Bank of Belgium (NBB) and the other national central banks of the Eurosystem monitor, forecast and study the determinants of inflation. Ultimately, inflation is determined by the behaviour of individual price setters. However, analyses often use data aggregated over firms and products. Studies using detailed micro-level data can complement these analyses and help us to better understand when, how and why firms change their prices (see, e.g., Blanas and Zimmer, 2020).

The Price-Setting Microdata Analysis Network (PRISMA) was set up in 2018 by the European System of Central Banks (ESCB) to expand knowledge of price setting in the euro area using micro-level price data[1]. The network continues and expands the work of the Inflation Persistence Network (IPN) from the early 2000s (see Dhyne, 2005). The intention is that PRISMA's results will feed back into macroeconomic theory and monetary policy practice.

In the past years, the network has brought together the central banks of the ESCB and facilitated collaboration on many topics including inflation measurement, nowcasting and firms' price-setting behaviour and its monetary policy implications. A key aspect of PRISMA's work has been collecting new micro price data and combining existing sources. More specifically, the network has been using microdata underlying the consumer price index (CPI), microdata underlying the producer price index (PPI), supermarket scanner data, household scanner data and web-scraped data. Each data source has its own advantages for answering different research questions. The data sources and examples of their applications are briefly described in the annex.

PRISMA's main results have been compiled in seven reports[2]. This article is based on these reports. We mainly focus on the NBB's contribution and more specifically on results based on the microdata underlying the official price indices. Section 1 analyses the frequency and size of consumer price changes in the euro area using micro-level CPI data. Section 2 does the same for producer prices by using micro-level PPI data. Section 3 examines price setting during the COVID-19 pandemic, in particular the challenges encountered for measuring inflation and the available evidence from micro-level CPI data.

1 https://www.ecb.europa.eu/pub/economic-research/research-networks/html/researcher_prisma.en.html

2 The seven reports are Dedola *et al.* (forthcoming), Gautier *et al.* (forthcoming), Henkel *et al.* (forthcoming), Messner *et al.* (forthcoming), Osbat *et al.* (forthcoming), Weber and Santoro (forthcoming) and Wieland *et al.* (forthcoming).

1. Consumer price setting [1]

1.1 A renewed research effort

How often and by how much individual prices change are basic statistics for understanding what drives aggregate monthly inflation. For example, is it common that the price of a large number of products changes a bit, or is it more common that the price of a small number of products changes a lot? In addition, according to economic theory these statistics are important for the impact of monetary policy on the real economy. The frequency of price adjustment determines the speed at which interest rate changes impact inflation. Similarly, price stickiness describes the extent to which prices do not immediately react to economic shocks. Most central bank DSGE models embed the Calvo (1983) model of price stickiness. In this model, the frequency of price adjustment is a key determinant of the slope of the price Phillips curve, and thus required for assessing the effects of monetary policy and macroeconomic shocks on economic activity and inflation. Estimates of the frequency of price adjustment that are based on micro data can help to calibrate DSGE models or help to estimate them (i.e., as a prior for Bayesian estimations or to sense check the estimation results).

The frequency and size of consumer price adjustments cannot be derived from the aggregate CPIs published by National Statistical Institutes (NSIs). The most direct way to measure them is to use the microdata underlying the CPI (which are not usually public). Nakamura and Steinsson (2008) follow this approach for the United States covering about 70 % of consumer expenditures. For the euro area, the main evidence is collected by the IPN and described by Dhyne *et al.* (2006). Using micro-level CPI data, they calculate the frequency and size of price adjustments for 50 products using data on ten euro area countries for the period 1996-2001. Although the 50 products are deemed to be representative for the whole consumption basket, they cover only around 10 % of the CPI. Other studies report findings for individual euro area countries using broader coverage of the CPI [2]. However, due to differences between these studies a cross-country comparison of the results is difficult, and it is hard to combine the national results into a euro area figure.

One of the PRISMA workstreams in which the NBB has participated provides new evidence on the frequency and size of price adjustments for the euro area. Compared to Dhyne *et al.* (2006), the product coverage is broader and more in line with the evidence for the United States. In addition, the period covered is longer and includes the recent period with low aggregate inflation for which results may differ from other periods. Furthermore, the authors of this contribution (Gautier *et al.*, 2022) present new statistics on price adjustments for the euro area, such as the effect of sales [3], the distribution of the size of price changes (instead of just the mean or median price change) and the development of the frequency and size of price changes over time. Finally, the authors have harmonised the method for each individual country as much as possible, so that the results are truly comparable across countries. For example, sales are consistently included or excluded from the sample (which is important as sales account for a substantial share of price changes).

1.2 Data description and methodology

The NSIs from Austria, Belgium, France, Germany, Greece, Italy, Latvia, Lithuania, Luxembourg, Slovakia and Spain provided their country's national central bank with the micro price data that they collected to compute the national CPI and HICP (Harmonised Index of Consumer Prices). For Belgium, Statbel made the microdata accessible to the NBB. The 11 countries account for about 90 % of the euro area HICP. In total, there are nearly 135 million price observations (including 8.5 million for Belgium), over a period that extends from 2010 to 2019

1 This section is based on section 1 of Gautier *et al.* (forthcoming). See Gautier *et al.* (2022) for details on the methodology and more results.

2 Early studies include for instance Aucremanne and Dhyne (2004) and Dhyne and Konieczny (2007) for Belgium, Hoffman and Kurz-Kim (2006) for Germany, Baudry *et al.* (2007) for France, Fabiani *et al.* (2005) for Italy, Benkovskis *et al.* (2012) for Latvia, Lünnemann and Mathä (2010) for Luxembourg, Álvarez and Hernando (2006) for Spain and Rumler *et al.* (2011) for Austria. Examples of more recent studies are Berardi *et al.* (2015) for France and Blanas and Zimmer (2020) for Belgium.

3 Throughout this article, the term "sales" covers both seasonal sales and temporary promotions.

for most countries[1]. The product coverage of the datasets provided varies across countries. The highest product coverage amounts to 97 % of the HICP (Luxembourg) while the lowest is 43 % (Belgium)[2].

The data collection method is in all countries framed by the common guidelines and recommendations laid down by Eurostat for constructing the HICP. Price quotes are collected on a monthly basis, so that for each item (a specific product at a specific store) price changes are monitored over time. Most national datasets contain flags that provide further information on a price quote, for instance, indicating whether an observation is a sale price or an imputed (estimated) price (e.g., for a product that is temporarily unavailable)[3]. For all countries, both seasonal sales and temporary promotions are included, except for Belgium for which the database only includes temporary promotions. Most prices are collected on site.

Prices are adjusted for quantity (for example, if the package size of a product is reduced while leaving its price unchanged, the consumer is actually facing a price increase). Outliers and imputed prices are removed[4]. All national central banks perform the calculations for their own country in the same way. The statistics are calculated at the most granular level of the HICP, which is the 5-digit level of the European Classification of Individual Consumption by Purpose (COICOP), e.g., "01.1.1.1 - Rice, incl. rice preparation". For example, to calculate the frequency of price changes, the authors calculate for each country the percentage of observations within "01.1.1.1 - Rice, incl. rice preparation" that are price changes. This is done for all COICOP-5 product categories available. The size of price increases and price decreases is calculated as the median of all non-zero price changes within a COICOP-5 product category[5].

The COICOP-5 product categories are restricted to a common product sample across countries to present comparable statistics across countries and to be able to aggregate the statistics at the euro area level. A COICOP-5 product category is included if it is available for at least three of the four largest euro area countries (Germany, France, Italy and Spain). This results in a common product sample of 166 COICOP-5 product categories. For most of these product categories there are data for all or almost all eleven countries. On average 9.8 countries are available per COICOP-5 product category and for 84 % of the COICOP-5 product categories at least nine countries are available. The 166 COICOP-5 product categories cover 59 % of the euro area HICP. There is good coverage of food and Non-Energy Industrial Goods (NEIG). However, the common product sample does not contain energy products and lacks data on around half of all services in the HICP, in particular rents, communication services and some travel-related services. Regarding NEIG, some centrally collected prices such as those for cars, pharmaceutical products and ICT products are excluded. Regarding food, some products with administered prices such as tobacco and alcohol are excluded.

COICOP-5 product category statistics are aggregated at the country level using euro area HICP product weights (average of the period 2017-2020) so that differences in price adjustments between countries are not driven by differences in national consumption patterns. Subsequently, country-specific results are aggregated at the euro area level using HICP country weights (averaged over 2017-2020).

Seasonal sales and temporary promotions may mean large temporary price changes, which may influence the price adjustment statistics. Therefore, the statistics are also computed excluding price changes due to sales

1 The longest periods are for Austria (2000-2017) and Greece (2002-2019) and the shortest period is for Latvia (2017-2019). For Belgium, the dataset covers the period from 2007 to 2015. Data collection during this period was mostly done by pollsters making regular visits to retail shops. By contrast, since 2016, Statbel has relied primarily on scanner data for a wide range of products sold at supermarkets. As these data could not be released to the NBB for confidentiality reasons, there is limited product coverage from 2016 onwards and these data are not used. The current exercise does not use data for the pandemic year 2020 for any of the countries. Section 3 presents results for the countries for which 2020 data are available.

2 The Belgian data cover all food products and a substantial share of the non-energy industrial goods (the items with the largest weight, i.e. clothes and cars, are in the sample). However, only some services are included (again the items with the largest weight, i.e. restaurants and cafés, are in the sample). Statbel was not able to provide the missing items because the data are confidential or stored and formatted in a specific manner.

3 The flags also indicate product replacements, i.e., whether an existing product is substituted for a similar but different product variety.

4 NSIs impute the price of a product when it is temporarily unavailable in the store.

5 In this article, the calculations are based on the country-specific sample period (that is, the longest period available for a country). The authors also present results for a shorter common period across countries. Results are robust to this change.

and promotions. Seasonal sales and temporary promotions are usually identified by a sales flag reported by the NSI. However, sales flags are not available for all countries, and the NSI definition of sales and promotions might depend on national practices. Therefore, as an alternative method, sales prices have also been selected using a sales filter following the approach by Nakamura and Steinsson (2008)[1].

1.3 How often do consumer prices change?

Over the observation period, on average 12.3 % of all prices in the euro area change in a given month (see table 1). Of all price observations, 4.4 % relate to a sale. Excluding these observations, the frequency of price adjustment is 8.5 %[2]. Using the sales filter instead of the NSI sales flag gives a similar result.

Differences between countries are relatively small: most countries have a frequency between 11 and 14 %. In Belgium, 14.5 % of prices change per month. This is a relatively high figure since the Belgian database does not include seasonal sales. In the scenario where sales and promotions are excluded, differences between countries are still limited. This scenario makes Belgium more comparable to other countries and confirms that the figure for Belgium is relatively high (13.3 %), as for other countries it never exceeds 10 %. Composition effects could play a role, as the Belgian sample has, compared to other countries, a lot of food products and these change prices relatively often (see below). However, when the authors use a smaller but identical product sample across countries, Belgium still has a high frequency compared to the euro area (respectively 10.0 % and 6.8 %).

By contrast, differences are much more pronounced across sectors[3]. For the euro area, the frequency of price adjustment is 31 % for unprocessed food and 6 % for services. Industrial goods and processed food are in between, with 13 and 15 % respectively. Excluding price changes due to sales has a substantial impact on the frequency of price changes in the unprocessed food, processed food and NEIG sectors, where the frequency is 5 to 7 percentage points lower. Sales have only a limited impact on services because the percentage of sales observations is only 0.5 % for services, compared to 8.6 % for NEIG, 7.4 % for unprocessed food and 4.3 % for processed food.

About two-thirds of all price changes are a price increase. So, price decreases happen less often, but still occur frequently. There are wide variations between sectors: in the services sector, price increases predominate, while in the industrial goods sector decreases are more common than increases. This sector includes, for example, clothing and electronics which are typical products with price reductions. As expected, the total share of price increases is higher when price changes due to sales are excluded (there are fewer price decreases). This is particularly apparent for NEIG, where that share is 10 percentage points higher.

1 For example, if a price drops for two months and then returns to its previous level, the filter labels this as a sale. Gautier *et al.* (2022) describe the filter in detail.

2 As some macro models require a quarterly instead of a monthly frequency for calibration and estimation, the authors also express the monthly frequency on a quarterly basis. Based on the monthly frequency, the quarterly frequency of price changes in the euro area is approximately 29.5 % including sales and 21.0 % excluding sales.

3 Throughout this article, the term "sector" refers to broad product categories, e.g., services and non-energy industrial goods.

Table 1

Frequency of consumer price changes[1]

(%)

	Including sales		Excluding sales		Percentage of sales
	Frequency of price changes	Percentage of price increases	Frequency of price changes	Percentage of price increases	
Euro area	**12.3**	**64.0**	**8.5**	**68.8**	**4.4**
By sector					
Unprocessed food	31.4	54.5	24.0	57.6	7.4
Processed food	15.4	57.0	10.4	61.8	4.3
NEIG	12.9	48.2	6.4	59.8	8.6
Services	6.0	82.5	5.7	82.4	0.5
By country					
Austria	11.1	64.5	7.2	72.0	5.1
Belgium	14.5	69.0	13.3	69.7	1.1
France	12.7	60.8	9.8	66.9	5.5
Germany	12.7	61.9	9.2	67.2	4.1
Greece	11.3	61.3	7.3	63.9	3.8
Italy	10.3	69.9	4.8	75.6	4.3
Latvia	18.6	60.0	7.9	71.1	10.7
Lithuania	12.8	62.3	9.7	68.4	2.3
Luxembourg	14.1	73.4	8.8	78.4	4.6
Slovakia	14.3	64.8	9.3	66.6	4.9
Spain	13.5	64.0	9.0	65.3	5.1

Source: Gautier *et al.* (2022).

1 Statistics are based on the country-specific period and on products that are available for at least three of the four largest countries (France, Germany, Italy and Spain). Price changes due to product replacements are excluded beforehand (except for Greece and Slovakia). Results excluding sales are based on the NSI sales flag, except for Greece, Luxembourg, Slovakia and Spain for which no such flag is available and for which sales are excluded by the sales filter. The percentage of sales (of all price observations) is for these countries also based on the sales filter. Seasonal sales are excluded from the Belgian dataset, but temporary promotions are included.

To better understand what drives these differences between products, Gautier *et al.* (2022) explain the frequency of price changes at the COICOP-5 level by possible determinants. More specifically, they explain the frequency of price changes (excluding sales) for a specific product in a specific country by the share of labour costs, the share of imported energy and raw material inputs, the share of all imported inputs, the percentage of individuals who buy the product online, a dummy for products which have a regulated price, and country dummies (table 2). The main conclusion is that the cost structure of a product matters. The frequency of price adjustment is lower for products with a higher share of labour costs, and higher for products for which energy and raw material inputs are more important. This may reflect that labour costs change relatively rarely, while the costs of energy and raw materials often change daily. More specifically, in the baseline regression (column 1), a 10 percentage point rise in the share of labour costs decreases the frequency of price adjustment by about 2 percentage points. In addition, keeping the share of all imported inputs constant, a 10 percentage point increase in the share of imported energy and raw material inputs increases the frequency of price adjustment by about 8 percentage points. The other variables do not have a significant impact. These results are robust to the inclusion of a retail market concentration variable (column 2).

Table 2

Determinants of the frequency and size of consumer price changes[1]

	Frequency		Size	
	I	II	III	IV
Share of labour costs	–0.166**	–0.486***	–0.087***	–0.109**
Share of imported energy and raw material inputs	0.800***	0.817***	–0.357***	–0.319***
Share of all imported inputs	–0.145	–0.201	–0.041	–0.038
% of online consumers	0.0002	0.0008**	0.0004***	0.0005***
Regulated price dummy	–0.008		0.002	
Retail market concentration (HHI)		0.003***		–0.0004*
Constant	0.162***	0.278***	0.106***	0.115***
Country dummies	Yes	Yes	Yes	Yes
Number of observations	1,620	1,293	1,622	1,293
R^2	0.20	0.34	0.28	0.38

Source: Gautier *et al.* (2022).

1 All regressions are estimated using OLS and are based on the country-specific period and on products that are common to at least three of the four largest countries (France, Germany, Italy and Spain). Standard errors are clustered at the product level. *, ** and *** denote significance at respectively 10 %, 5 % and 1 %. The dependent variable in Column I is the frequency of price changes excluding sales and excluding product replacements (for Greece, Luxembourg, Slovakia and Spain sales are excluded via the sales filter, Greece and Slovakia include product replacements). Column II adds the Herfindahl-Hirschman Index (HHI) of the retail sector as an 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. The dependent variable in Column III is the median size of the absolute non-zero price changes, excluding sales and excluding product replacements. Column IV adds the HHI of the retail sector as explanatory variable.

1.4 By how much do consumer prices change?

For the euro area, the median size of price increases is 9.6 % and the median size of price decreases is 13.0 % (table 3). So, price increases are more common than price decreases, but when they occur, price decreases are on average larger. When price changes due to sales are excluded, the size of price changes is, as expected, smaller. For the euro area it is 6.7 % for increases and 8.7 % for decreases. Hence, the typical price change at the product level is quite sizeable compared to the aggregate inflation over the period (the average inflation in the euro area is close to 1.5 % during the sample period).

Variation across countries is limited as regards the size of price changes, but exceeds the variation across countries as regards the frequency. The median increase is 7.5 to 9 % for France, Italy, Luxembourg and Spain, while in Austria, Germany, Latvia, Lithuania and Slovakia the median price increase is above 10 %. Price decreases follow the same pattern: the median decrease is 11 to 12 % for the first group and closer to 15 % for most countries in the second group. When price changes due to sales are excluded, differences between countries are still observable. For Belgium, the median size of price increases is 6.6 % and the median size of price decreases is 7.5 %, which does not differ a lot from the euro area figures (for Belgium, the results excluding sales are again more comparable to those for other countries as the figures including sales do not include seasonal sales).

As was the case for frequency, there are large differences between sectors: for services the size of the price increase is 6 %, while for unprocessed food and industrial goods it is 13 and 14 % respectively. Processed food is in the middle. The most notable change when excluding sales is that differences between sectors become smaller. For industrial goods, the size of the price decreases roughly halves when sales are excluded. Here, for example, large discounts on clothing could play a role.

Table 3

Size of consumer price changes[1]

(%)

	Including sales		Excluding sales	
	Median price increase	Median price decrease	Median price increase	Median price decrease
Euro area	9.6	13.0	6.7	8.7
By sector				
Unprocessed food	12.6	15.0	10.1	11.0
Processed food	9.2	12.0	5.8	6.5
NEIG	13.9	19.2	7.9	10.7
Services	5.6	8.2	5.5	7.9
By country				
Austria	10.4	14.6	6.9	8.7
Belgium	7.0	8.2	6.6	7.5
France	7.8	11.9	5.1	7.3
Germany	11.6	16.1	8.4	11.0
Greece	9.6	12.8	8.0	11.4
Italy	9.1	11.4	4.4	5.5
Latvia	15.9	14.8	7.9	6.2
Lithuania	13.5	17.2	11.8	12.8
Luxembourg	7.5	10.7	5.5	7.8
Slovakia	10.5	11.1	9.2	8.5
Spain	8.9	11.1	8.1	10.4

Source: Gautier *et al.* (2022).

1 Statistics are based on the country-specific period and on products that are available for at least three of the four largest countries (France, Germany, Italy and Spain). Price changes due to product replacements are excluded beforehand (except for Greece and Slovakia). Results excluding sales are based on the NSI sales flag, except for Greece, Luxembourg, Slovakia and Spain for which no such flag is available and for which sales are excluded by the sales filter. Seasonal sales are excluded from the Belgian dataset, but temporary promotions are included.

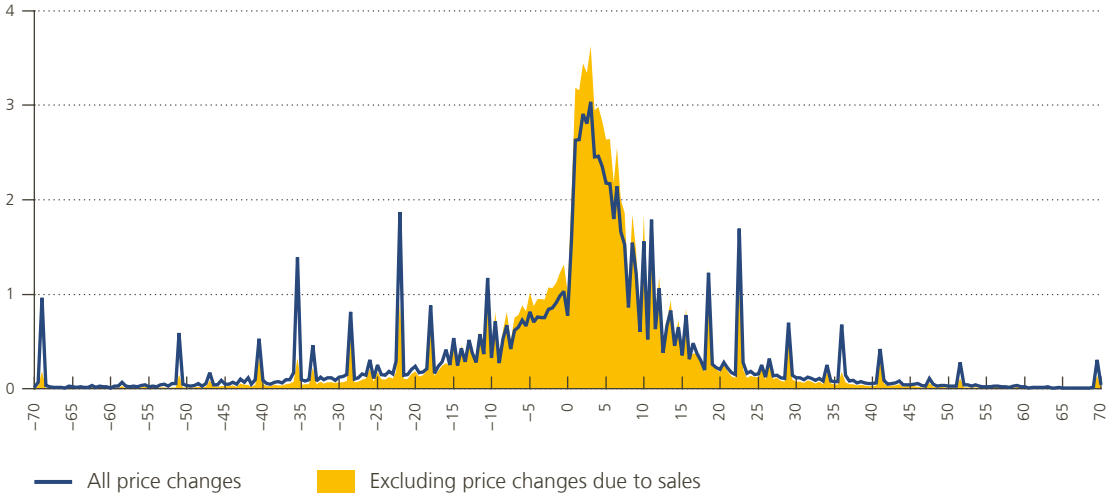
As was done for the frequency, Gautier *et al.* (2022) explain the absolute value of the median size of price changes by various possible determinants (table 2, column 3 and 4). Again, costs matter; price changes are smaller when the share of labour costs is larger or when energy and raw material inputs are more important. Combined with the results for frequency, this means that products for which labour is important undergo less frequent and smaller price changes. And products for which energy and raw material inputs are important undergo relatively many price adjustments that are relatively small.

Recent studies highlight the importance of the distribution of the size of price changes (see, e.g., Midrigan, 2011; Eichenbaum *et al.*, 2014; and Alvarez *et al.*, 2022). For example, a low share of small price changes may imply that menu costs are important for price setting, while a high share of large price changes may suggest that firm-specific shocks are more important for price setting than aggregate shocks (which tend to be relatively small). Chart 1 plots the distribution of price changes for the euro area, both including sales (the line) and excluding sales (the histogram). Many price changes are between +1 and +3 %. The distribution displays several peaks corresponding to price changes due to sales. When price changes due to sales are removed, the peaks are smaller but still observable. Large price changes are relatively common. Including sales, 10 % of the price changes are larger than 21 %, and 10 % are smaller than –21 %. However, small price changes are also quite common. For 11 % of the price changes the absolute value is smaller than 2 %.

Chart 1

Distribution of the size of consumer price changes in the euro area[1]

(%)



Source: Gautier *et al.* (2022).

1 The chart plots the distribution of price changes (log difference in %) calculated first at the product/country level for the common sample of products (bins of 0.5 percentage point), then aggregated at the country level using euro area HICP product weights and then aggregated at the euro area level using HICP country weights. Results excluding sales are based on the NSI sales flag if available and the sales filter otherwise.

1.5 Comparison with previous evidence

The findings from the previous ESCB network as reported by Dhyne *et al.* (2006) are based on ten countries over the period 1996-2001 and a sample of 50 products chosen to be representative of the consumption basket. To see whether the picture has changed since then, the PRISMA study has calculated the frequency and size of price changes using the same method. This was possible for 43 of the 50 products from five countries (Austria, Belgium, France, Germany and Italy) and the period 2011-2017. The frequency of price changes has increased since Dhyne *et al.* (2006) from 8 % to 10 %. This increase is observed in all sectors covered but is largest for NEIG products. The size of price changes has remained relatively stable, for both price increases and decreases. However, general conclusions on price-setting behaviour are hampered by the low product coverage (compared to what is available in the PRISMA sample).

Gautier *et al.* (2022) also compare the new euro area results with evidence for the United States, using the product-level results of Nakamura and Steinsson (2008). The comparison is restricted to the same products to control for possible differences in the composition of the consumption basket. To control for variability in the relative weights of products, euro area HICP weights are applied to derive aggregate statistics for both regions. It follows that prices change more often in the United States than in the euro area[1]. The frequency of price changes is 19 and 12 % respectively (chart 2). However, if sales are excluded, frequencies in the two economies are much closer: 10.0 % in the United States against 8.5 % in the euro area. This is because the share of sales is higher in the United States (7.4 % against 4.4 % in the euro area). The share of price increases (of all price changes) is approximately the same in the euro area and the United States.

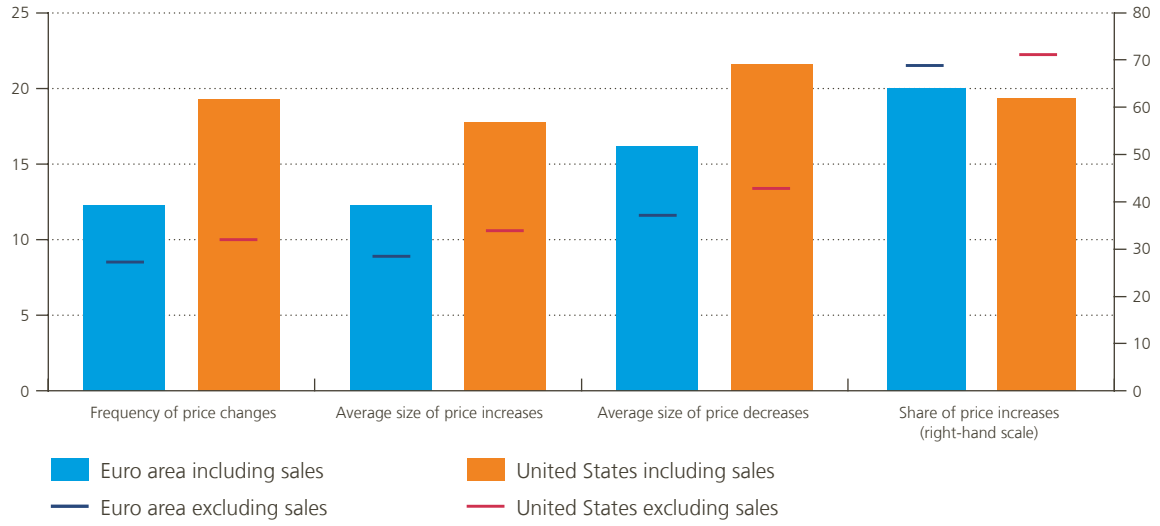
1 An important caveat is that the statistics for the United States are for the period 1998-2005 while most euro area statistics are for a more recent period.

Chart 2 shows that the average size of price changes is substantially larger in the United States than in the euro area, with a gap of about 5.5 percentage points for both price increases and price decreases. However, when sales are excluded, the difference is again much smaller, namely less than 2 percentage points. Hence, both for frequency and size the difference between the euro area and United States is mostly caused by sales.

Chart 2

Comparison between the euro area and the United States

(%)



Source: Gautier *et al.* (2022).

1.6 Changes over time in the frequency and size of price changes

So far we have described cross-section results. Now we turn to time-series evidence. All the statistics at the COICOP-5 product category level have also been calculated by month and year. This section describes the variation in the frequency and size of price changes in the euro area, first within a given year (i.e. seasonality) and second over the years 2005-2019[1].

Gautier *et al.* (2022) estimate panel OLS regressions that relate the frequency and size of price changes at the product category-country level to month and year dummies. The upper part of chart 3 plots the coefficients of the month dummies (where January is the reference month).

1 Data are not available for all countries for all years.

Chart 3

Month and year effects in the frequency and size of consumer price adjustments[1]

(percentage points)

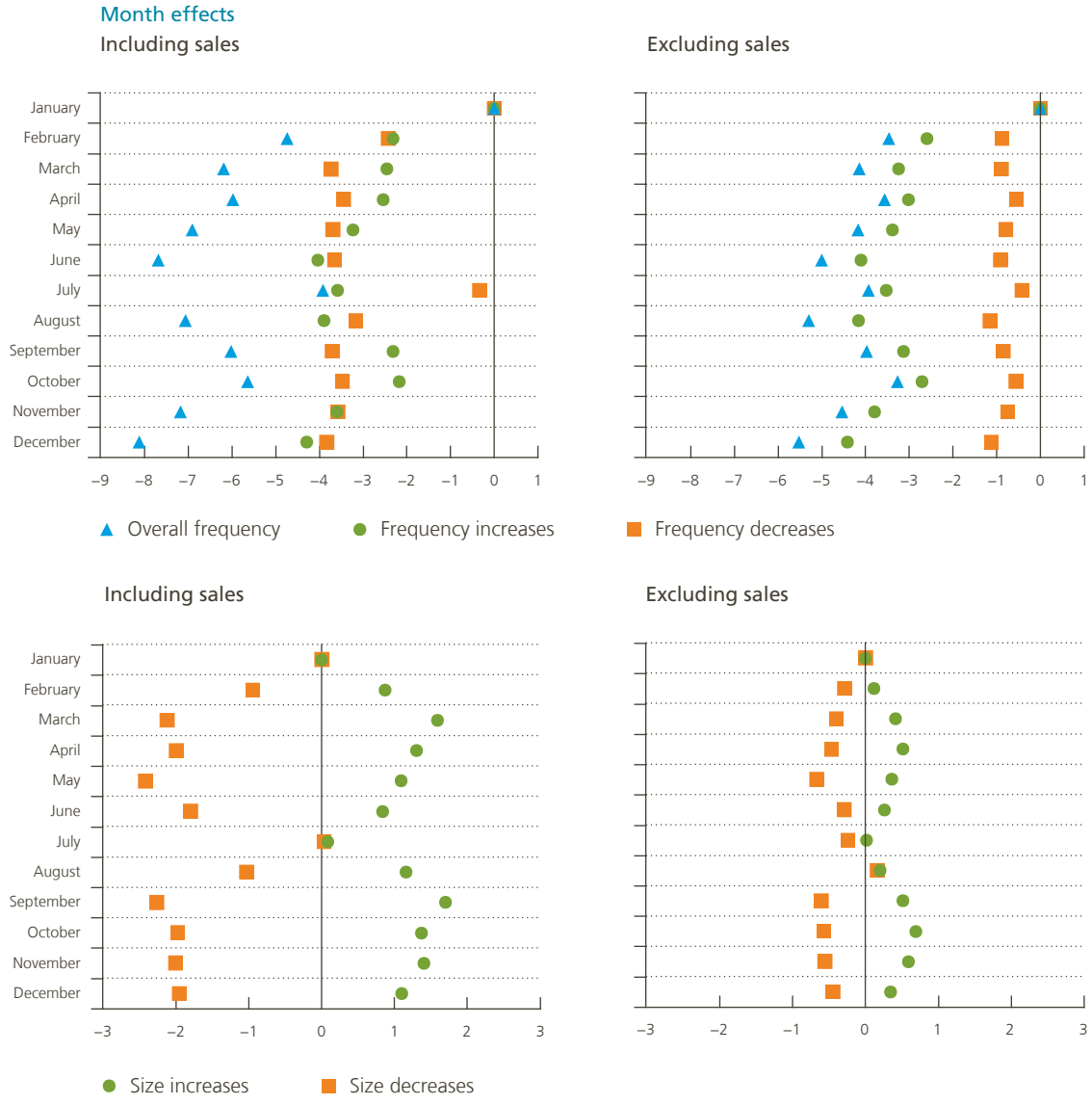
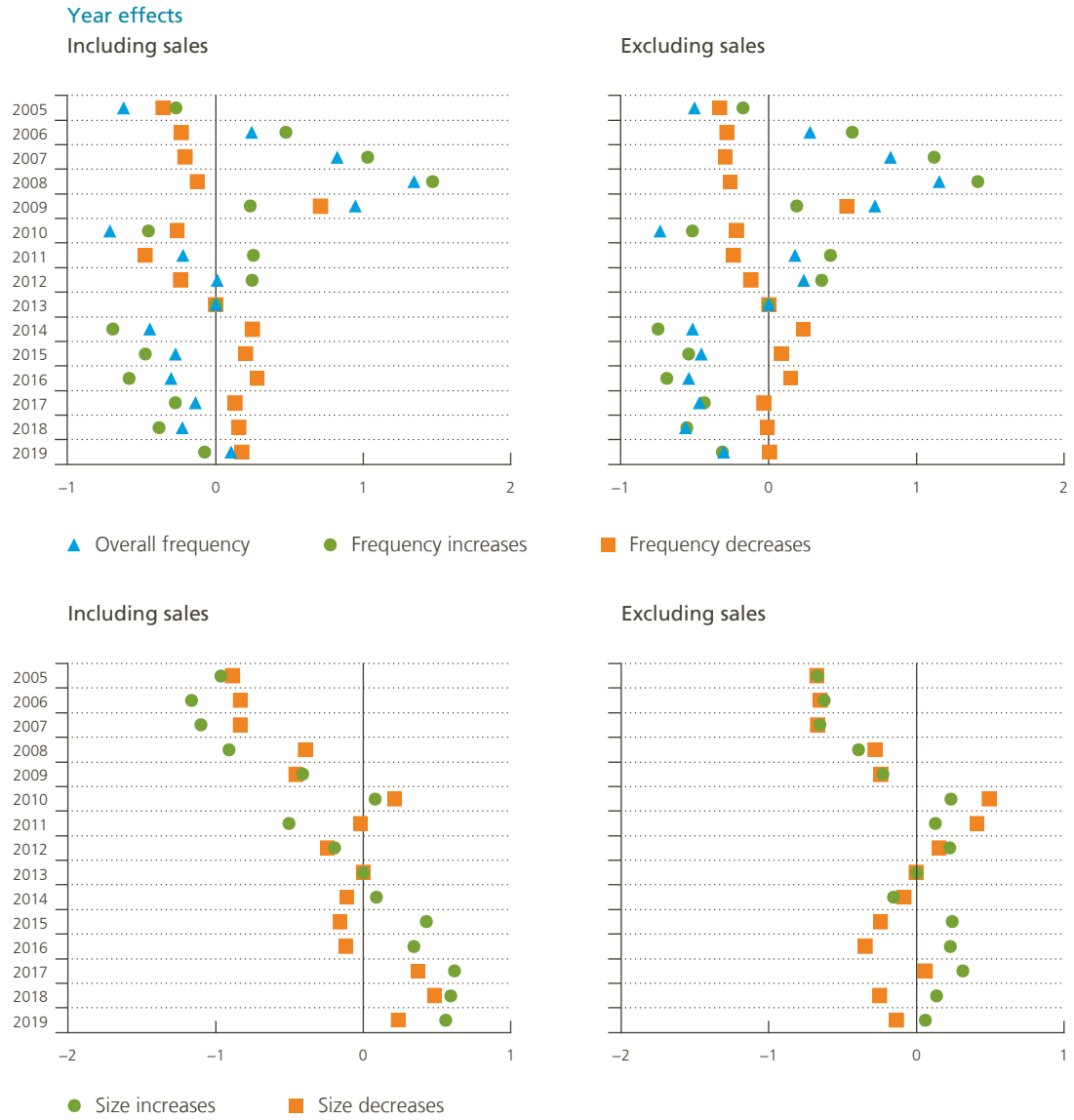


Chart 3 (continued)

Year effects



Source: Gautier *et al.* (2022).

1 Coefficient plots from weighted panel regressions with COICOP, country and time fixed effects and a 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), using euro area HICP country weights (2017-2020 average) and robust standard errors. The dependent variables are the frequency and size of price adjustment. Regressions are based on the country-specific period and on products that are common to at least three of the four largest countries. The figures only show the years 2005-2019. The reference month is January and the reference year is 2013. Price changes due to product replacements are excluded beforehand (except for Greece and Slovakia). Results excluding sales are based on the NSI sales flag if available and the sales filter otherwise. Outliers are adjusted beforehand.

The frequency of price changes exhibits a clear seasonal pattern (the first row of the panel with month effects). In most months of the year, the price adjustment frequency is about 6 percentage points lower than in January, indicating that firms often adjust their prices in that month. Prices are also relatively often adjusted in July, although less often than in January. A part of this pattern is explained by sales. However, when sales are excluded, the frequency of price changes is still about 4 percentage points higher in January[1].

The size of the price increases and decreases also follows a clear seasonal pattern (the second row of the panel with month effects). In January and July (and to a lesser extent in February and August), absolute price decreases are about 2 percentage points larger than in other months. Price increases are relatively small in these months. This pattern is mostly explained by sales.

When sales are not taken into account, the "January effect" is mainly driven by the frequency of price increases. In particular, prices of services tend to be updated much more frequently at the start of the year. This finding is in line with "time-dependent price setting" (as opposed to "state-dependent price setting"[2]), where firms change their prices at regular time intervals (i.e., prices remain unchanged for a fixed period).

The lower part of chart 3 plots the coefficients of the year dummies (where 2013 is the reference year). The frequency of price changes differs somewhat over the years but there is no strong trend and the changes are limited (the first row of the panel with year effects). More specifically, compared to 2013, the frequency of price changes is approximately 1 percentage point higher during the Global Financial Crisis, when euro area inflation exceeded 4 % in July 2008 and dropped to –0.6 % in July 2009. Furthermore, the frequency is somewhat lower after 2013 when euro area inflation was rather low[3]. This variation is mainly driven by changes in the frequency of price increases. The frequency of price decreases is relatively constant over time. Results are similar when sales are excluded.

The size of price increases and price decreases displays a small upward trend over the years (the second row of the panel with year effects). This small upward trend is partly caused by sales, as it partly disappears when sales prices are excluded.

2. Producer price setting[4]

2.1 What can we learn from producer prices?

To supplement the analysis of the CPI data, PRISMA also investigated producer price-setting behaviour based on individual price quotes from the Producer Price Index (PPI).

Firstly, producer price datasets typically cover a broader set of sectors and goods than the ones covered by CPI data, including, for example, intermediate production goods and capital goods as well as consumer goods. This allows us to characterise price-setting features at different stages of the production chain.

Secondly, although not examined in the present article, producer prices help us to investigate how marginal production costs are incorporated into firms' output prices. This relationship can be examined at the detailed individual firm price level, as the producer's identity is known. It is therefore possible to isolate the detailed production costs and relate them directly to the producer price. A couple of recent papers provide

1 This effect cannot be explained by VAT changes coming into force at the start of the year as the regressions include dummies for VAT changes.
2 As presented by Dotsey *et al.* (1999), "if there are fixed costs to changing prices, the timing and magnitude of an individual firm's price adjustment depends on the state of the economy".
3 Before 2013, euro area inflation was relatively close to 2 % (excluding energy, 1.7 % on average). After 2013, euro area inflation was 1 % on average.
4 This section is based on section 2 of Gautier *et al.* (forthcoming).

interesting examples of such analysis. Some of them have examined producer price setting based on the unit values that can be computed from the information from the Industrial Production (Prodcom) Survey[1]. Combined with transaction trade data, some papers then compute the unit values charged on the domestic market and relate these to marginal costs. One finding of these econometric analyses is that pass-through of marginal costs into prices can be incomplete (for Belgium, see for example Amiti, Itskhoki and Konings, 2019; Duprez and Magerman, 2018; or Fuss, 2020)[2].

Thirdly, information on producer prices can supplement data on consumer prices for the calibration and estimation of macroeconomic models that include both a production sector and a retail sector.

Lastly, the analysis undertaken by PRISMA and summarised here is an update of the findings of the previous ESCB network (IPN), see Vermeulen *et al.* (2012) and Cornille and Dossche (2008) for Belgium[3].

2.2 Data description and methodology

The analysis is performed on six countries in the euro area: Belgium, France, Greece, Lithuania, the Netherlands and Portugal. The period covered varies across countries: 2001-2014 for Belgium, 2013-2019 for France, 2008-2020 for Greece, 2010-2018 for Lithuania, 2000-2019 for the Netherlands and 2010-2020 for Portugal.

Producer price data are collected through surveys of firms conducted by NSIs, following EU legislation and Eurostat recommendations (Eurostat, 2012). Using annual firm surveys, the NSI sets up a representative sample of firms producing each product considered in the PPI index. For each surveyed company, the most representative transactions in terms of product and customer are selected, and the price for a specific product to a specific customer is collected every month. In principle, individual price quotes underlying the PPI are specific not only to a product and a firm but also to a customer. The price should refer to an actual transaction price and not a list price. It should refer to orders booked during the relevant period and not at the time the products leave the factory gates. Prices should refer to ex-factory base prices which include all duties and taxes including subsidies on products received, but exclude VAT, other similar deductible taxes directly linked to turnover, and subsidies on products received, as well as transport costs (unless otherwise stated).

There are some discrepancies across countries in the way the guidelines are applied, the survey is conducted and the data are collected. Measurement issues may include the reporting of average prices (over customers or transactions) or even unit values, unflagged or imperfectly flagged product replacement or substitution, or unflagged sales. In addition, the market coverage may differ across countries, and include foreign markets in addition to the domestic market. Lastly, in the specific case of the Netherlands, about 60 % of the prices are collected once a quarter, while the other prices are collected on a monthly, semi-annual or annual basis.

These methodological features of the PPI surveys may cause differences in the observed frequency of price changes as well as in the observed size of price changes across countries. In order to minimise the

1 This survey collects information on the total quantities and values sold by each firm for each industrial product. Unit values are computed as the ratio of values and quantities; they therefore represent an average over customers and markets.

2 Amiti, Itskhoki and Konings (2019) show, among other things, that the elasticity of firms' output prices to marginal costs is around 0.6, and that to competitors' prices is also around 0.6. Duprez and Magerman (2018) analyse the propagation of a (domestic or imported) input price shock from one supplier to the output prices of firms throughout the entire production chain. Their results point to incomplete pass-through of input price shocks and some reaction to competitors' price changes, and that common cost shocks are fully passed on in firm prices, contrary to idiosyncratic cost shocks. Fuss (2020) estimates firm-product marginal costs and firm-product-market markups; her results indicate that exported products have a cost advantage over products sold only domestically; and that this cost advantage is only partially translated into lower prices and essentially yields higher margins. Analyses for other countries include Carlsson and Nordström Skans (2012) and Carlsson (2017) for Sweden, Dedola *et al.* (2021) for Denmark, and a couple of papers based on qualitative information on price changes from business survey data, such as Loupias and Sevestre (2013) for France. This type of data was also used to assess price stickiness (see Andrade *et al.*, 2022; Bachmann *et al.*, 2019; Harris *et al.*, 2020; and Lein, 2010).

3 Other national papers include Álvarez *et al.* (2010) for Spain, Dias *et al.* (2004) for Portugal, Gautier (2008) for France, Stahl (2006) for Germany, and Sabattini *et al.* (2005) for Italy.

discrepancies, they have been corrected or controlled for wherever possible. More specifically, in most of the cases including Belgium, the focus is on the domestic market, except in Greece, Lithuania and – after 2015 – Portugal. Observations related to product replacement are excluded when the information is available. For the Netherlands, only observations with a monthly or quarterly frequency have been used. Two alternative strategies have been applied to estimate the monthly frequency of price changes from the quarterly observations. The first, referred to as *option 1* in the tables and figures below, assumes that prices do not change within the quarter ; this may underestimate the monthly frequency of price changes. The second, referred to as *option 2*, assumes that, when a price change is observed at the quarterly frequency, it changes every month during that quarter ; this may overestimate the monthly frequency of price changes (see Gautier *et al.*, forthcoming, for more details).

For Belgium, the data used relate to the period 2001-2014 as the collection method remained unchanged during that period. Excessive price changes (a price five times higher or five time lower than its previous month's value) are excluded, as are price changes smaller than 1/100,000. The Belgian sample covers 154,972 monthly firm-product price observations, 607 industrial products defined at the 8-digit Prodcom classification level and 1,079 firms[1].

Statistics on the frequency and size of price changes are computed in two steps. First, they are calculated for each country at the 4-digit NACE Rev2.0 level. Second, they are aggregated at the country level using French PPI weights (as a proxy for euro area PPI weights). This allows us to obtain aggregate country statistics that are comparable across countries independently of the country-specific economic sector structure. Statistics are computed for the entire sample of countries and sectors. Table 4 below reports statistics on the frequency of price changes in the left panel and statistics on the size of price changes in the right panel.

2.3 How often do producer prices change ?

The first stylised fact to emerge from the analysis is that producer prices change more frequently than consumer prices. Following Gautier *et al.* (forthcoming) and Jouvanceau (2022), Table 4 reports the average frequency of price changes which is between 20 % and 27 % in Belgium, France, Greece and the Netherlands (option 2) but is somewhat higher in Portugal (34 %) and substantially higher in Lithuania (41 %). Except for those two countries, the figures are in line with those reported by Vermeulen *et al.* (2012) for the IPN which amount to 21 % on average and 20 % for Belgium, although the analysis covers a different period and a different set of countries[2]. By contrast, the frequency of producer price changes is much higher than the frequency of consumer price changes for the euro area, both including sales (12.3 %) and excluding sales (8.5 %). For Belgium these figures are respectively 14.5 % and 13.3 % (see the CPI results in section 1.3).

1 Firms report prices for a given product that refer to a given customer, but the data dimensions that are collected are firm-product-month (a customer identifier is not collected).

2 Vermeulen *et al.* (2012) consider Belgium, France, Germany, Italy, Portugal and Spain, over a period that ranges from the early 1990s to the mid-2000s.

Table 4

Frequency and size of producer price changes[1]

(%)

		Frequency of price changes		Average size of price changes		Median size of price changes	
	Total	Increases	Decreases	Increases	Decreases	Increases	Decreases
Belgium	22.5	12.5	10.0	5.8	5.4	3.9	3.8
France	26.6	14.0	12.6	2.3	2.8	1.5	1.4
Greece	20.6	11.3	9.3	4.6	5.3	3.1	3.5
Lithuania	40.6	20.7	20.0	9.0	9.6	5.3	5.9
The Netherlands option 1	13.7	8.1	5.6	4.9	5.3	3.5	3.0
The Netherlands option 2	26.6	16.5	10.0				
Portugal	33.8	17.0	16.9	7.8	5.4	2.6	2.5

Source: Gautier *et al.* (forthcoming).

1 Statistics are first calculated at the disaggregated product level (NACE 4-digit) and then aggregated at the country level using French PPI weights (as a proxy for euro area PPI weights). For the Netherlands, monthly and quarterly data have been used to compute the statistics. Two methods have been applied to estimate the monthly frequency of price changes when only quarterly data are available. Option 1 divides the quarterly frequencies by 3 whereas option 2 uses unadjusted quarterly frequencies.

Another fact that emerges from table 4 is that price increases are more frequent than price decreases. Price increases account for 50 to 63 % of the price changes (55.5 % for Belgium). This is again consistent with the results of the IPN.

Time-series evidence (not presented in this article for the sake of brevity) shows a January effect, as is the case for consumer prices. Prices are most frequently adjusted in the first month of the year. For Belgium, for example, the average frequency of price changes is 43 % in January and 17 % in the other months.

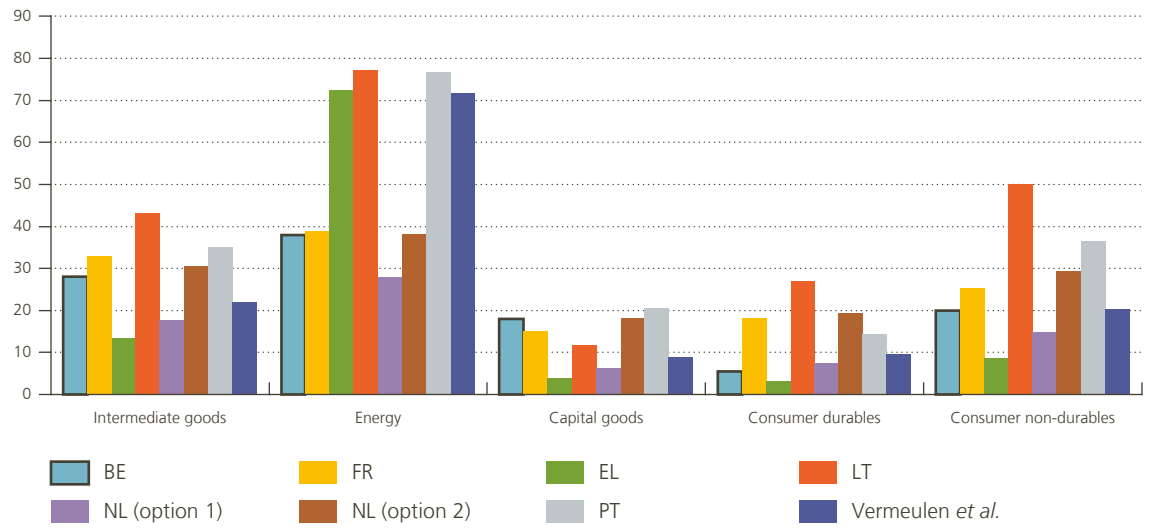
Heterogeneity across sectors is much more striking than heterogeneity across countries[1]. As shown in chart 4, the frequency of price changes is highest in the energy sector, and lowest for consumer durables and capital goods; intermediate goods and non-durable consumer goods are in between. These results are again consistent with those reported by Vermeulen *et al.* (2012) for the IPN.

1 Note that heterogeneity in the frequency of price changes across countries does not result from differences in PPI product baskets.

Chart 4

Frequency of producer price changes across Main Industrial Goods (MIG) sectors [1]

(%)



Source: Gautier *et al.* (forthcoming).

1 The frequency is first calculated at the disaggregated product level (NACE 4-digit) and then weighted using French PPI weights (as a proxy for euro area PPI weights). For the Netherlands, monthly and quarterly data have been used to compute the frequency. Two methods have been applied to estimate the monthly frequency of price changes when only quarterly data are available. Option 1 divides the quarterly frequencies by 3 whereas option 2 uses unadjusted quarterly frequencies.

2.4 By how much do producer prices change?

While producer prices change more frequently than consumer prices, the size of price changes is smaller for producer goods than for consumer goods. As shown in table 4, the median producer price increase ranges from 1.5 % in France to 5.3 % in Lithuania and is 3.9 % in Belgium, while the median consumer price increase in the euro area is 9.6 % if sales are included, and 6.7 % excluding sales [1].

The median sizes of price changes reported here are slightly higher than the ones reported in Vermeulen *et al.* (2012) which amount to 2 to 3 %. Both the average and the median size point to a relatively symmetric distribution of the size of price changes; price increases and price decreases are of the same order of magnitude. Heterogeneity across sectors is limited compared to the differences observed for the frequency of price changes.

3. Price setting during the COVID-19 pandemic [2]

3.1 Challenges in inflation measurement due to COVID-19

The COVID-19 pandemic has induced two main problems in the way inflation is measured. A first problem arose from the fact that, specifically during lockdowns, price collection in brick-and-mortar shops was forbidden. The way in which prices were collected had to be adapted: prices were web-scraped, or inquiries

1 If we only consider non-energy industrial goods, which are more comparable to the basket of PPI products, these figures increase to respectively 14 % including sales and 8 % excluding sales.

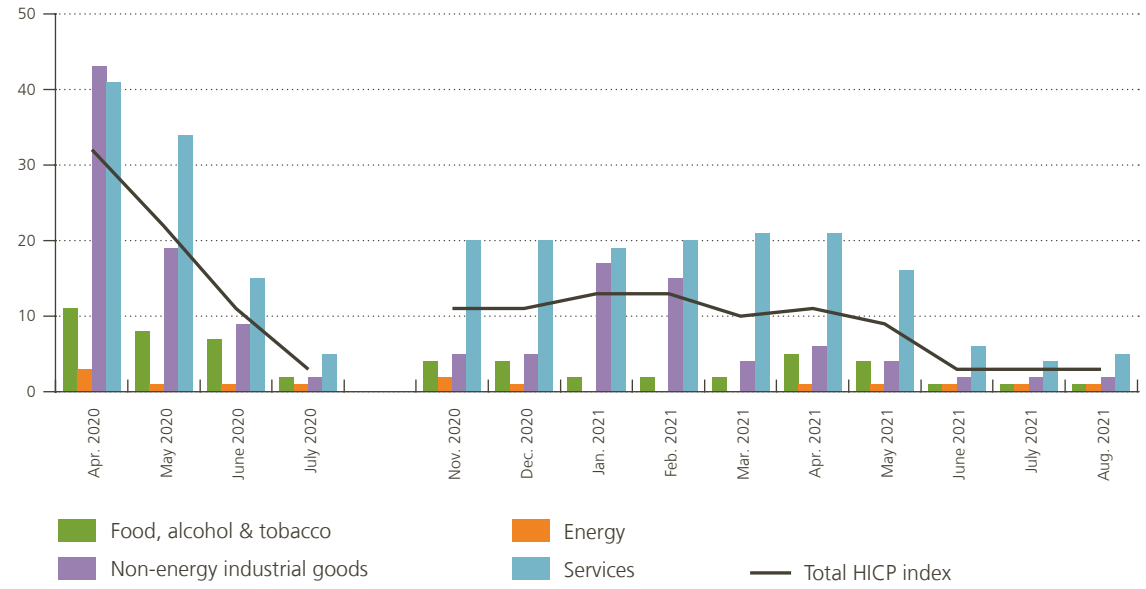
2 This section is based on Henkel *et al.* (forthcoming).

were conducted by phone or via email whenever possible. This could have led to some product substitutions, posing a possible problem for the comparability of prices from one month to another[1]. What was more, some transactions – mostly services – did not take place at all anymore, as some activities were completely forbidden (hairdressing, restaurants and bars, cultural activities, etc.). Hence, their prices could no longer be observed and had to be estimated ("imputed") by the NSIs in order to preserve the continuity of the consumer price sub-indices. According to Eurostat figures, the share of imputations in the HICP of the euro area peaked at 32 % in April 2020, after which it fell gradually to about 3 % in July. Eurostat stopped publishing the imputation rate between August and October 2020. By November 2020, the share went up again to 11 % and rose further to 13 % in January 2021, before gradually subsiding to 3 % in June 2021 (and staying low from then onwards). As the number of imputations remained small, Eurostat did not publish the share of imputations anymore as of September 2021.

Chart 5

Share of imputations in the euro area HICP due to COVID-19

(%)



Sources: Henkel *et al.* (forthcoming), Eurostat.

A second consequence for inflation measurement was that consumers were forced to change their consumption pattern drastically, in some cases due to the prohibition of some activities. For instance, the relative share of food increased during the hard lockdowns in March and April 2020. The relative share of services, by contrast, diminished. Therefore, the weights of the various items of the consumption basket, that are usually adapted each year and represent the consumption pattern of the previous year, were temporarily unrepresentative (as from March 2020) of the actual consumption patterns. That is, the consumption weights of the HICP are mainly based on the national accounts of two years before (due to the publications lag between the national accounts and the HICP). The expenditure shares are also adjusted with the price change between year t-1 and December of year t-1 (European Commission, 2020, article 3). In normal times, the consumption pattern of the previous year based on national accounts of two years ago reflects the current consumption patterns quite well.

1 For example, online prices may include delivery costs, if they are not billed separately.

This unusual change in consumption patterns during the year prompted various studies that calculated an alternative inflation rate, using monthly varying – and more representative – weights[1]. These weights were derived from data sources other than the usual ones, such as debit and credit card data, or turnover rates. All studies found that the alternative inflation rates with monthly varying weights would have been higher in 2020 than the officially published inflation rates.

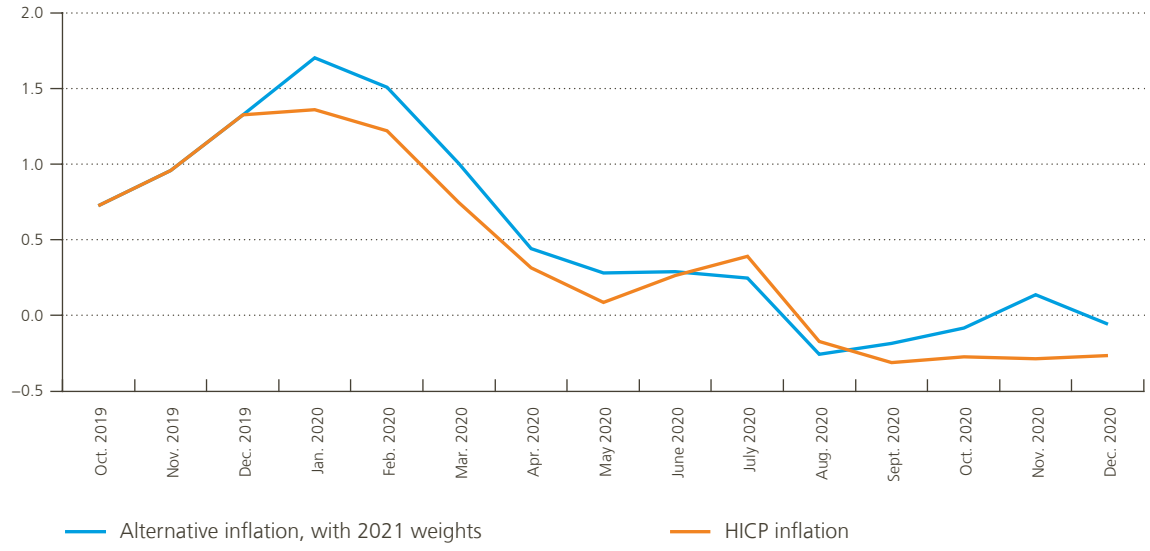
The problem of the unrepresentativeness of the 2020 HICP weights was partly addressed in the year 2021. As consumption patterns in 2021 still differed from those in pre-crisis times, Eurostat recommended using the preliminary national accounts for the crisis-year 2020, rather than (only) those for 2019[2] (Eurostat, 2020). The weight changes of the various product categories were in fact unusually drastic in 2021: food gained in importance, especially with respect to most services such as recreation (Gonçalves *et al.*, 2021).

Given the unusual changes in consumption in the year 2020 that are not reflected in the HICP weights for that year, we can calculate an alternative inflation rate for 2020 for the euro area, using the official HICP weights for the year 2021. Indeed, the latter are more representative for the year 2020 than the officially published weights as they are based on 2020 national accounts. This alternative inflation measure is on average 0.2 percentage points higher.

Chart 6

Euro area HICP inflation and alternative inflation measure[1]

(year-on-year price changes, %)



Sources: Henkel *et al.* (forthcoming), Eurostat, own calculations.

1 The inflation rate with 2021 weighting scheme is the ex-post calculated inflation rate, in which the 2021 weighting scheme is applied to calculate the total index for 2020.

One reason for this alternative inflation rate being higher is that food inflation rose significantly throughout the year 2020, due to both COVID-19 and non-COVID-19 related factors (see Jonckheere and Zimmer, 2020, for the Belgian case). Another category that contributes to the gap is transport. The 2021 weight of motor fuels,

1 Cavallo (2020) for the United States, Jonckheere and Zimmer (2020) for Belgium, Kouvavas *et al.* (2020) for the euro area, Gautier *et al.* (2021) for France, etc.

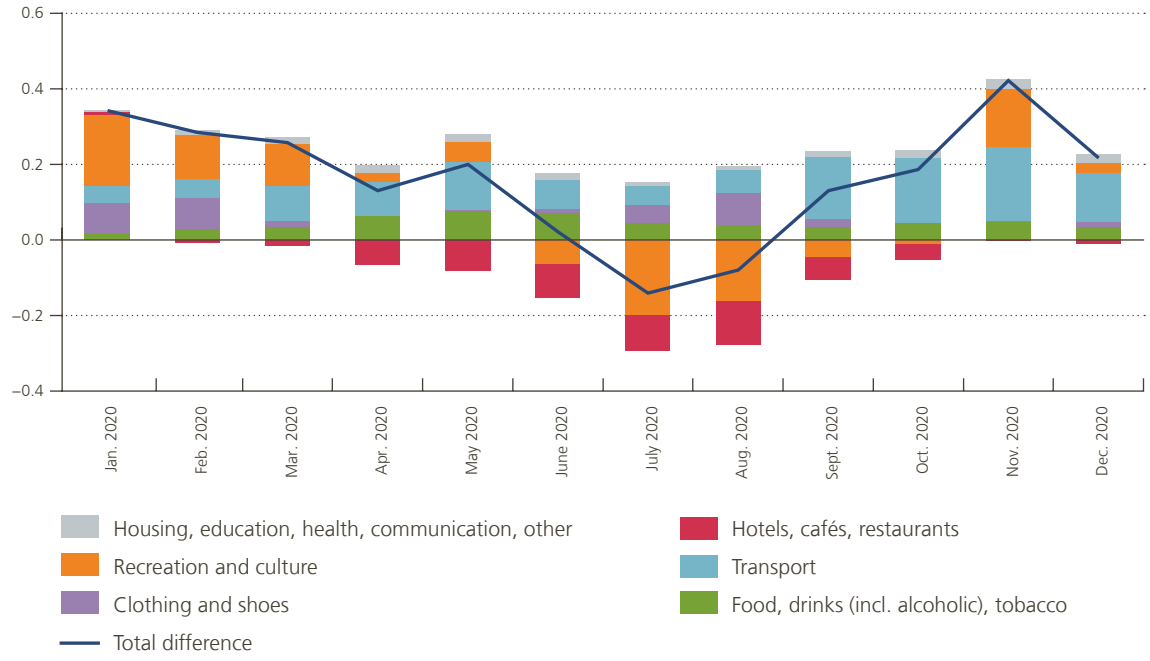
2 For the 2022 HICP weights, preliminary national accounts for 2021 were used to supplement the information from the 2020 national accounts.

for instance, declined significantly (due to the lockdowns curbing the need for road transport). Since motor fuel inflation rates were negative on average in 2020 (as the oil price slumped at the start of the year), that drives up the alternative inflation rate. Lastly, categories with a strong seasonal pattern have a large impact on the gap between the official inflation rate and the alternatively calculated inflation rate. The weight of services such as package holidays (part of "recreation and culture" in chart 7), air transport (part of "transport") or hotels, cafés and restaurants diminished significantly in the 2021 weighting scheme. Together with the fact that their prices usually fluctuate a lot, these items make a substantial (positive or negative) contribution to the gap between the two inflation rates (see, for instance, Deutsche Bundesbank, 2020).

Chart 7

Contribution to differences between euro area HICP inflation and alternative inflation measure

(percentage points)



Sources: Henkel *et al.* (forthcoming), Eurostat, own calculations.

3.2 Evidence from CPI microdata

This section is an extension of the analysis presented in section 1. It uses CPI microdata to compare the frequency of price changes over the course of the first pandemic year (2020) to the frequency during the years before the pandemic (2015-2019). Data for 2020 are available for four euro area countries, namely Germany, Italy, Latvia and Slovakia. Together, these four countries cover 46 % of euro area consumption expenditures. The available data for these countries cover 60 to 90 % of the national HICP expenditures.

First of all, note that the COVID-19 pandemic varied in its impact on the four countries. However, in all cases, on-site price collection was seriously hampered due to lockdown restrictions and the temporary unavailability of certain products. This resulted in a lower number of price quotes in some countries and a higher share of price imputations in all countries[1].

1 As in section 1, imputed prices (according to a flag by the NSI) have been excluded.

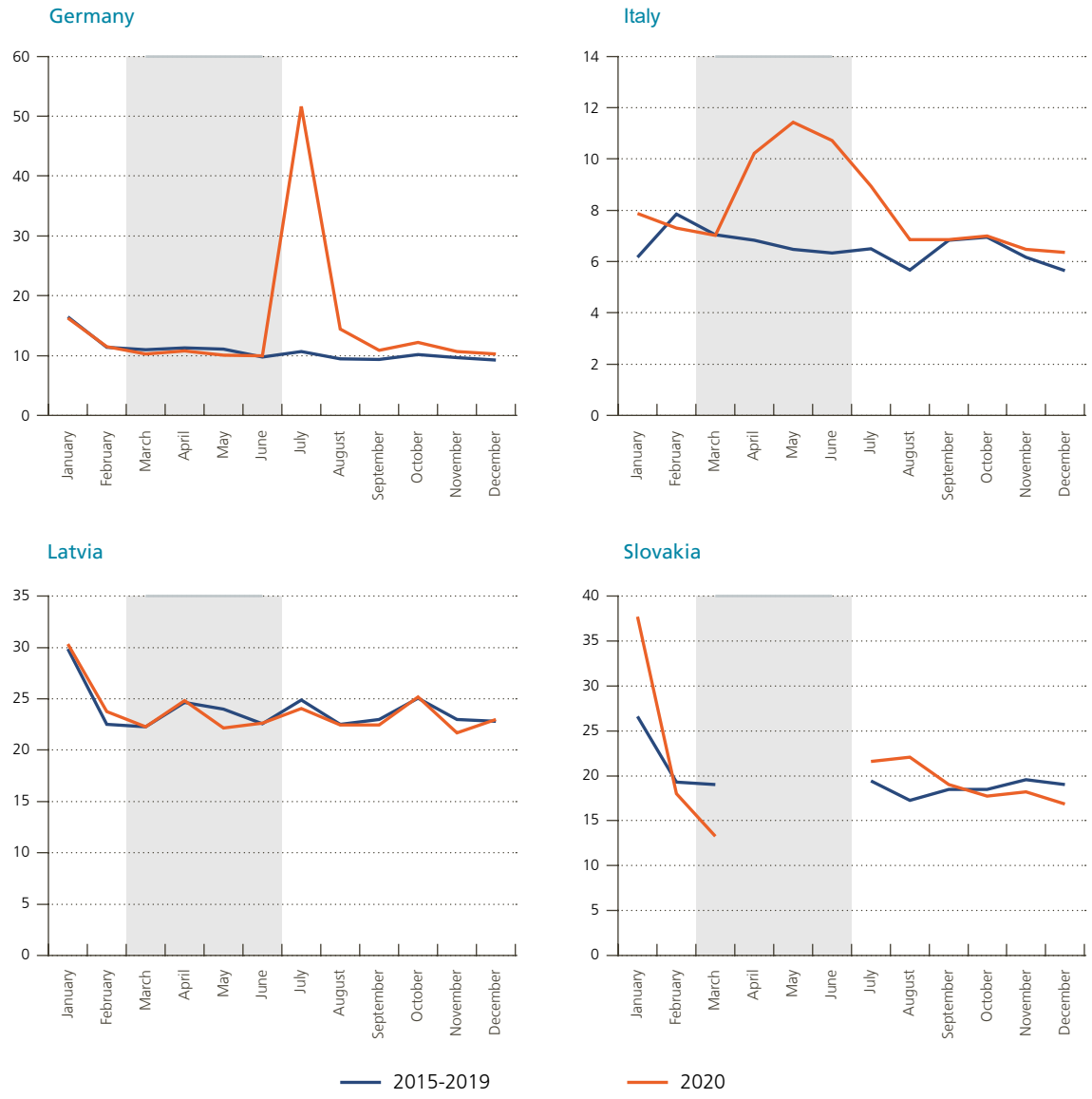
The Slovakian dataset does not contain price quotes for food and only a small fraction for NEIG and services in April-June 2020, so this period is excluded from the analysis for Slovakia. Italy switched to scanner data collection for most processed food products in 2020, making it difficult to compare products over the years. Germany temporarily reduced the VAT rates from 1 July to 31 December 2020, greatly affecting the statistics. The standard VAT rate had been lowered from 19 to 16 % and the reduced VAT rate from 7 to 5 %.

The method to compute the price statistics and aggregate the results is the same as in section 1, except that this time the authors do not select a common product sample across countries. They only use products that are available during 2015-2020 for a given month, thus obtaining a constant product sample per month by country.

Chart 8

Frequency of price changes before and during the COVID-19 pandemic [1]

(including sales, %)



Source: Henkel *et al.* (forthcoming).

1 The shaded area marks the first wave of the COVID-19 pandemic in Europe (March to June 2020). For Slovakia there are no observations available for April-June 2020.

Chart 8 presents the results. In Italy the frequency was higher during the first wave of the pandemic (from March to June 2020, the shaded area in the chart) than during the same months in the preceding years. It was the country most severely hit during the first wave. The overall frequency increased by around 5 and 4 percentage points in respectively May and June 2020.

The other countries do not show a substantial change in the frequency of price changes during the first wave of the pandemic. The rise in the frequency of price changes in Germany in the summer of 2020 clearly reflects the temporary VAT cut: the frequency jumped to more than 50 % in July 2020. More specifically, the reduction in the VAT rates is reflected by a sharp increase in the frequency of price cuts (which drives the increase in the overall frequency).

3.3 Evidence from web-scraped and scanner data

In addition to evidence based on the (micro)data underlying the official CPI, PRISMA has analysed price setting during the pandemic using web-scraped data and scanner data.

The central bank of Poland (Narodowy Bank Polski) has developed expertise in web-scraping since 2009 and has analysed, among other things, the rate of repricing and product availability during the pandemic. Their analysis is based on online prices for processed and unprocessed food, hygiene products and electronics.

From mid-February to early April 2020, the availability of food, hygiene products and electronics in online stores declined quickly. The phenomenon was temporary, except for electronics (laptops and printers). However, the limited availability was not accompanied by significant price increases.

The outbreak of the pandemic affected product groups differently in terms of price setting. For food, the monthly frequency of price changes declined compared to the average level of 2019 and to the long-term average for this category of products. Regarding the size of price adjustments, excluding sales, the absolute value of the size of increases and the size of decreases became larger during the pandemic. In contrast, for hygiene products, both the frequency and the size of price changes increased. Turning to electronics, the frequency and size of price changes increased slightly for printers during the pandemic, while for laptops the frequency and size mostly declined.

Finally, on the basis of supermarket scanner data, price responses of German and Italian retailers to the first COVID-19 wave in 2020 were analysed. These data contain information on quantities in addition to prices (see the annex). It appears that supermarkets faced increased demand during the lockdown measures. This rise was particularly pronounced during the weeks preceding the introduction of the lockdowns ("stock-up shock"). Over the period from mid-February to mid-May 2020, supermarket prices increased more in Italy (1.9 %) than in Germany (1 %). This rise is caused by supermarkets responding to the shock by reducing both the frequency and the magnitude of their temporary sales. While the COVID-19 induced demand shock did not significantly increase the overall frequency of reference (i.e. regular) price changes, it increased the share of price increases relative to price decreases.

Conclusion

This article summarises the analyses of the frequency and size of consumer and producer price changes in the euro area using micro-level CPI and PPI data, as carried out by PRISMA. The network's seven reports show the richness of the data sources collected and used (microdata underlying the official price indices, scanner data, web-scraped data) and the numerous collaborations within the ESCB that led to new insights, in particular with regard to firms' pricing behaviour and monetary policy implications.

The frequency and size of price adjustment are important statistics to understand inflation and assess the impact of monetary policy on the real economy. PRISMA has improved and extended these statistics for Belgium and the euro area, and thus helps to better understand the impact of monetary policy, in particular the speed at which interest rate changes and other aggregate shocks impact inflation. A direct application of the statistics is that they help to calibrate and estimate central bank DSGE models.

The main findings on consumer prices are as follows. Over the observation period, the average monthly frequency of consumer price changes in the euro area is 12.3 %. Heterogeneity across countries is limited, but the frequency of price changes differs substantially across sectors. When price changes due to seasonal sales and promotions are excluded, the average frequency declines to 8.5 %. The frequency of price changes is relatively high for Belgium (13.3 % when excluding sales), but composition effects could play a role. The cost structure matters for how often firms adjust prices. Products with a higher share of labour costs have a lower frequency of price adjustment. And products for which energy and raw material inputs are more important have a higher frequency of price adjustment.

Compared to the results from the previous ESCB network as reported by Dhyne *et al.* (2006), the frequency of price changes for the same set of 50 products is about 2 percentage points higher in the period 2011-2017 than in the period 1996-2001 (it is hard to generalise this result to the whole consumption basket). Using the results from Nakamura and Steinsson (2008), prices change more frequently in the United States than in the euro area (19.3 % versus 12.3 %). However, when sales are excluded, the results are similar for both economies (10.0 % in the United States against 8.5 % in the euro area).

Turning to the size of price changes, the median price increase is 9.6 % in the euro area, whereas the median price decrease is 13.0 %. Although the dispersion across euro area countries is limited, it is greater than the dispersion observed for frequencies. Differences across sectors are relatively large. The distribution of price changes is highly dispersed : both large and small price changes are relatively common. When sales are excluded, the median price increase is 6.7 % and the median price decrease is 8.7 % in the euro area. These figures are in line with the results for Belgium. Price changes are larger in the United States than in the euro area. However, differences are much smaller when price changes due to sales are excluded.

The frequency and size of price changes exhibit a clear seasonality, with firms changing their prices relatively often in January. Sales explain only part of this seasonal pattern. This finding is in line with "time-dependent price setting" (as opposed to "state-dependent price setting"), where firms change their prices at regular intervals.

The frequency and size of price changes do not exhibit a strong time trend and do not differ much over the years 2005-2019. Nevertheless, the frequency of price increases was somewhat higher during the Global Financial Crisis than after 2013 when the aggregate inflation rate was rather low in the euro area. In addition, the size of price increases and decreases rises a bit over the years (partly because of sales).

The main findings on producer prices are as follows. Producer prices change much more frequently than consumer prices. The monthly frequency of price changes is between 20 and 27 % in Belgium, France, Greece and the Netherlands (depending on the method) and is higher in Portugal and Lithuania (respectively 34 and

41 %). For the first set of countries this is in line with the results of the previous ESCB network as reported by Vermeulen *et al.* (2012). The size of producer price changes is smaller than the size of consumer price changes. The median size of producer price increases ranges from 1.5 % in France to 5.3 % in Lithuania. Belgium is in the middle with 3.9 %. Results for the median size of price decreases are very similar. Heterogeneity across sectors manifests itself in the frequency rather than in the size of price changes. Energy prices change the most frequently and prices of consumer durables and capital goods the least. Furthermore, producer prices are characterised by a peak in the frequency of price changes in January, similar to consumer prices.

Finally, we turn to inflation measurement and price-setting behaviour during the COVID-19 pandemic. As regards inflation measurement, two main problems arose. First, on-site price collection was seriously hampered due to lockdown restrictions, hence prices were collected via alternative methods (e.g., online or telephone). Also, certain products were temporarily unavailable, so their prices had to be "imputed" in order to preserve continuity in the data series. Second, the annually updated HICP weights, based on the consumption pattern of the previous years, were unrepresentative, in particular during the lockdowns. Alternative measures of inflation that use more representative weights generally conclude that the inflation rate would have been higher than the officially published rates.

For Germany, Italy, Latvia and to some extent Slovakia, it is possible to compare the frequency of price changes during the first year of the COVID-19 pandemic (2020) to the frequency during the preceding years (2015-2019). For Italy, the frequency increased during the first wave of the pandemic (March to June 2020) compared to the same months in the preceding years. Italy was the country most severely hit by COVID-19 during the first wave. The temporary VAT reduction in Germany resulted in a strong rise in the frequency of price decreases.

All in all, building on the work of the IPN, PRISMA has expanded the knowledge of price setting in the euro area using micro-level price data. The work does not end with publication of the PRISMA reports. Recently, the euro area moved from a long period with low inflation to a period with high inflation. The PRISMA insights can help us to understand these new circumstances and make policy in response.

Annex

Data sources used by PRISMA and examples of their applications

1. Data underlying the official price indices

National Statistical Institutes (NSIs) in the euro area have provided the micro price data underlying the CPI and PPI to their country's national central bank. This is for research purposes and, for most countries concerned, under the condition that confidentiality is guaranteed. Regarding the CPI (whose underlying data are also used to construct the Harmonised Index of Consumer Prices – HICP), individual prices are generally collected on site (although the process is changing in some countries[1]) across different outlet types and on a monthly basis, usually during a specific week. Because the price collection process serves the construction of the official euro area inflation measure, price information is highly reliable and products are carefully sampled by NSIs to be representative of the consumption basket. In addition, the process is framed in all euro area countries by the same general recommendations and regulations defined at the European level.

Producer price data are collected through NSI surveys of a set of representative firms in order to construct the Production Price Index (PPI), following EU legislation and Eurostat recommendations (Eurostat, 2012). For each firm the price of the most representative transaction is collected on a monthly basis, where representativeness is defined with respect to the firm's product and customer.

PRISMA has used CPI and PPI microdata to calculate price-setting statistics for a wide range of products in the euro area and to analyse how these statistics change over time (Gautier *et al.*, forthcoming). CPI micro price data have also been used to estimate optimal inflation rates (Weber and Santoro, forthcoming). In addition, micro evidence has been used to help to calibrate macro models (Dedola *et al.*, forthcoming).

2. Scanner data

Two kinds of scanner data have been used within PRISMA. First, store scanner data (bought by the ECB from the firm IRI) record weekly unit prices and quantities sold at the store level. Second, GfK-Homescan data (also called household scanner data) record the quantities bought at a given price for a particular product (at a specific retailer) by an individual household. The panellist records the purchase using a smartphone application (previously with a hand-held scanner). In addition, the panellist provides household characteristics, e.g., age, income and location. Both types of scanner data cover mostly food and personal/household care, which have a substantial weight in the HICP (around 20 %).

PRISMA has used these data to study, for example, the probability of prices being reset depending on price misalignment (Gautier *et al.*, forthcoming), the response of supermarket prices to the demand shock caused by the COVID-19 pandemic (Henkel *et al.*, forthcoming) and border effects across the euro area, and more generally, inflation differences between households (Messner *et al.*, forthcoming).

3. Web-scraped data

One PRISMA deliverable is the Daily Price Dataset (DPD). The DPD project (in progress) aims at providing daily time series of product prices by scraping retailers' websites. The data will be made available to ESCB staff for monitoring and nowcasting inflation and for ad-hoc research. Consumer prices scraped from the internet are available in real-time (thus price data can be derived at any desired frequency) and can cover a wide variety of goods and services, at a time when the importance of online purchases is growing. Another advantage of

1 For instance, in Belgium food prices are collected from supermarket scanner data. Web-scraping is also becoming more common for the collection of price data.

using web-scraping for collecting prices is that it is often possible to collect additional product information (information on discounts, specific product features, etc.). Furthermore, collecting comparable data across countries is relatively straightforward (e.g., by scraping data from shops that operate internationally and sell relatively standardised products).

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Conventional signs

e.g.	*exempli gratia* (for example)
etc.	*et cetera*
i.e.	*id est* (that is)

List of abbreviations

Countries or regions

BE	Belgium
EL	Greece
FR	France
LT	Lithuania
NL	The Netherlands
PT	Portugal

Abbreviations

COICOP	Classification of Individual Consumption according to Purpose
COVID-19	Coronavirus Disease-19
CPI	Consumer Price Index
DPD	Daily Price Dataset
DSGE	Dynamic Stochastic General Equilibrium
ECB	European Central Bank
ESCB	European System of Central Banks
EU	European Union
HHI	Herfindahl-Hirschman Index
HICP	Harmonised Index of Consumer Prices
ICT	Information and Communication Technology
IPN	Inflation Persistence Network
MIG	Main Industrial Goods
NACE	Statistical Classification of Economic Activities in the European Community
NBB	National Bank of Belgium
NEIG	Non-Energy Industrial Goods
NSI	National Statistical Institute
OLS	Ordinary Least Squares
PPI	Producer Price Index
PRISMA	Price-Setting Microdata Analysis Network

Statbel	Belgian Statistical Office
VAT	Value Added Tax

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