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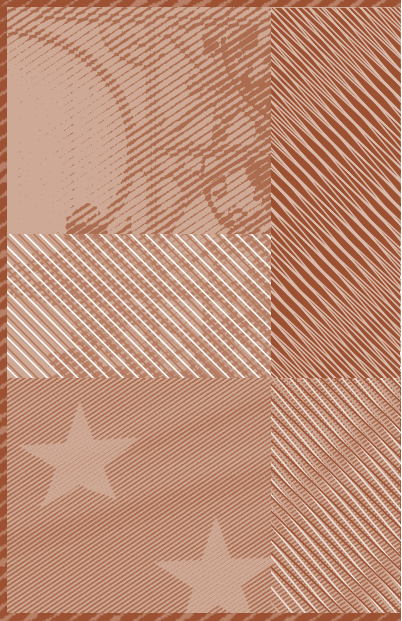

Documentos de Trabajo
N.º 0528

BANCO DE **ESPAÑA**

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Emmanuel Dhyne, Luis J. Álvarez, Hervé Le Bihan, Giovanni Veronese, Daniel Dias, Johannes Hoffmann, Nicole Jonker, Patrick Lünnemann, Fabio Rumler, Jouko Vilmunen (**) (***)

(*) The views expressed in this paper are those of the authors and do not necessarily reflect the views of the National Central Bank to which they are affiliated. This paper employs individual information on price setting based on a set of euro area country studies, conducted in the context of a Eurosystem project (Inflation Persistence Network, hereafter IPN). The authors belong to National Central Banks that have been involved in the research group of the IPN devoted to the Analysis of Consumer Prices. The contribution of co authors of country studies –L. Aucremanne, L. Baudry, J. Baumgartner, H. Blijenberg, M. Dias, S. Fabiani, C. Folkertsma, A. Gattulli, E. Glatzer, I. Hernando, J. R. Kurz-Kim, H. Laakkonen, T. Mathä, P. Neves, R. Sabbatini, P. Sevestre, A. Stiglbauer and S. Tarrieu–, without whom this paper would not have been possible, is strongly acknowledged. The authors would also like to thank the national statistical institutes for providing the data, the members of the IPN, especially I. Angeloni, S. Cecchetti, J. Galí and A. Levin, the participants to the "Inflation Persistence in the Euro Area" ECB conference, especially A. Kashyap, S. Rebelo and R. Reis for their stimulating comments, as well as the participants in the 2005 Annual Meeting of the American Economic Association. The authors would also like to thank an anonymous ECB Working Paper Series' referee for his/her very constructive comments.

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Documentos de Trabajo. N.º 0528
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ISSN: 0213-2710 (print)
ISSN: 1579-8666 (on line)
Depósito legal:
Imprenta del Banco de España

Abstract

This paper documents patterns of price setting at the retail level in the euro area. A set of stylized facts on the frequency and size of price changes is presented along with an econometric investigation of their main determinants. Price adjustment in the euro area can be summarized in six stylized facts. First, prices of most products change rarely. The average monthly frequency of price adjustment is 15 p.c., compared to about 25 p.c. in the US. Second, the frequency of price changes is characterized by substantial cross-product heterogeneity and pronounced sectoral patterns: prices of oil-related) energy and unprocessed food products change very often, while price adjustments are less frequent for processed food products, non-energy industrial goods and services. Third, cross-country heterogeneity exists but is less pronounced. Fourth, price decreases are not uncommon. Fifth, price increases and decreases are sizeable compared to aggregate and sectoral inflation rates. Sixth, price changes are not highly synchronized across price-setters. Moreover, the frequency of price changes in the euro area is related to a number of factors, in particular seasonality, outlet type, indirect taxation, use of attractive prices as well as aggregate or product-specific inflation.

JEL Codes: E31, D40, C25

Keywords: Price-setting, consumer price, frequency of price change.

Non technical summary

Prices of goods and services do not adjust immediately in response to changing demand and supply conditions. This fact is not controversial and is a standard assumption in macroeconomic modeling. In fact, a large strand of theoretical literature has been devoted to analyzing the sources of price stickiness and the implications of alternative forms of nominal rigidities on the dynamic behavior of aggregate inflation and output. This literature has shown that the nature of nominal rigidities determines the response of the economy to a broad range of disturbances and has several implications for the conduct of monetary policy.

However, despite the relevance of these issues for monetary policy, empirical assessment of price setting behavior using individual price data has remained relatively limited. This lack of micro-economic evidence reflects the scarcity of available statistical information on prices at the individual level. Indeed, most existing micro-studies are quite partial and focus on very specific products or markets. In recent years, statistical offices have started to make available to researchers large-scale data sets of individual prices that are regularly collected to compute consumer price indices. Such data sets are particularly well suited for the analysis of the key features of price setting behavior given that household consumption expenditure is generally fully covered. Moreover, they typically contain a huge number of price quotes that add up to reach several millions. Bils and Klenow (2004) for the US is an example of this line of research. Similar CPI data have also been exploited for most euro area countries within the framework of the Eurosystem Inflation Persistence Network (IPN).

This paper, building on IPN evidence, aims at characterizing the basic features of price adjustment in the euro area economy and its member countries and to compare it, to the extent possible, with available US evidence. To our knowledge, this paper is the first study to provide quantitative measures of the frequency and size of price adjustments in the euro area based on the analysis of 50 narrowly defined products, which are representative of the full CPI basket.

Based on the analysis of a common sample of 50 products, several stylized facts have been found:

1. Prices change rarely. The frequency of price changes for the euro area is 15.1 percent (i.e. on average, a given month 15.1 percent of prices are changed) and the average duration of a price spell ranges from 4 to 5 quarters. These figures mean that price adjustment in the euro area is considerably less frequent than in the US,

2. There is a marked degree of heterogeneity in the frequency of price changes across products. Specifically, price changes are very frequent for energy (oil products) and unprocessed food, while they are relatively infrequent for non-energy industrial goods and services.

3. Heterogeneity across countries is relevant but less important than cross-sector heterogeneity. It is, to some extent, related to differences in the consumption structure and the statistical treatment of sales.

4. There is no evidence of a general downward rigidity in the euro area. In fact, price decreases are not uncommon, except in services. On average, 40 percent of the price changes are price reductions.

5. Price changes, either increases or decreases, are sizeable compared to the inflation rate prevailing in each country. The magnitude of price reductions is roughly similar to that of price increases.

6. Synchronization of price changes across price setters does not seem to be large at the product level, even within the same country.

Some further common patterns of price adjustment data have been observed in the different country studies summarized in this paper. In particular, there is some evidence of time dependency in price setting behavior as the frequency of price changes exhibits seasonal patterns, even in sectors without marked seasonality in their demand and supply conditions. Price changes mostly occur at the beginning of the year (especially in the service sector) and after the summer period. Moreover, the hazard function of price changes in most euro area countries is characterized by mass points every 12 months. However, there are also strong indications of elements of state-dependent behavior as aggregate and sectoral inflation seem to affect the frequency of price changes. This impact is further strengthened when price increases and price decreases are analyzed separately. Additionally, firms appear to respond quickly to shocks such as indirect tax rate and input price changes. This coexistence of firms with time and state dependent pricing strategies is also found in the national surveys on price setting summarized in Fabiani et al. (2005).

These findings are generally substantiated by a cross-country cross-section econometric analysis of the 50 products. First, inflation has a positive effect on the frequency of price increases and a negative effect on the frequency of price decreases. Second, inflation volatility has an impact on the frequency of price adjustment. Third, there is cross-product and cross-country heterogeneity even when controlling for differences in inflation and commercial practices (regulated prices, sales, attractive pricing).

The facts put forward in this paper provide a benchmark against which to calibrate and to assess micro-founded price setting models in the euro area. In particular, results stress the importance of sectoral heterogeneity in price setting behavior. This suggests that developing macroeconomic models that consider explicitly such heterogeneity may improve the understanding of our economic fluctuations and inflation dynamics.

1. INTRODUCTION

Prices of goods and services do not adjust immediately in response to changing demand and supply conditions. This fact is not controversial and is a standard assumption in macroeconomic modeling. In fact, a large strand of theoretical literature has been devoted to analyzing the sources of price stickiness and the implications of alternative forms of nominal rigidities on the dynamic behavior of inflation and output. This literature has shown that the nature of nominal rigidities determines the response of the economy to a broad range of disturbances and has several implications for the conduct of monetary policy.

However, despite the relevance of these issues for monetary policy, empirical assessment of price setting behavior using individual price data has remained relatively limited. This lack of micro-economic evidence reflects the scarcity of available statistical information on prices at the individual level. Indeed, most existing micro-studies are quite partial and focus on very specific products or markets. Relevant contributions to this literature are Cecchetti (1986) on newsstand prices of magazines, Lach and Tsiddon (1992) and Eden (2001) on food product prices, Kashyap (1995) on catalogue prices, Levy et al. (1997) on supermarket prices or Genesove (2003) on apartment rents.

In recent years, statistical offices have started to make available to researchers large-scale data sets of individual prices that are regularly collected to compute consumer price indices. Such data sets are particularly well suited for the analysis of the key features of price setting behavior given that household consumption expenditure both in terms of goods and services and type of outlets is generally fully covered. Moreover, they typically contain a huge number of price quotes that may add up to several millions. Bils and Klenow (2004) for the US and Baharad and Eden (2004) for Israel are examples of this line of research. Similar CPI data have also been exploited for most euro area countries within the framework of the Eurosystem Inflation Persistence Network (IPN). The aim of this paper is to characterize the basic features of price adjustment in the euro area and its member countries and to compare it, to the extent possible, with available US evidence. To this end, we focus on the analysis of 50 narrowly defined products, which are considered to be approximately representative of the full CPI basket.

The remainder of this paper is organized as follows. Section 2 describes the individual consumer price data used and discusses the harmonized methodology followed to make country results comparable. Section 3 presents the stylized facts characterizing price setting behavior in the euro area. Section 4 is devoted to the determinants of the probability of a price change. A pooled regression econometric analysis and a summary of findings from individual country studies are presented. Finally, Section 5 summarizes and points out some issues for further research.

2. MICRO CONSUMER PRICE DATA FOR THE EURO AREA

The main objective of this paper is to present some original evidence that characterizes the dynamics of individual price setting at the euro area level, as well as to perform a cross-country comparison based on a harmonized approach. Thanks to the unique opportunity offered by the collective nature of this project and by the nature of the data analyzed, this paper is, to our knowledge, the first to document price setting behavior for the euro area and to provide quantitative measures of the degree of price stickiness for the euro area.

The stylized facts documented in this paper are based on evidence from individual price data recorded at the outlet level in 10 euro area countries: Austria, Belgium, Finland, France, Germany, Italy, Luxembourg, Netherlands, Portugal, and Spain. These ten countries account for around 97 p.c. of euro area GDP.

The data used for this purpose are the monthly price records underlying the computation of the Consumer Price Index. These are high-quality data, which cover a large number of items based on extensive Household Budget Surveys. This type of data has been used to characterize price-setting patterns in the US, using the data produced by the BLS.[1]

In the case of the euro area, the collection of individual price reports underlying the computation of the Harmonized Consumer Price Index (HICP) is done in a decentralized way by the statistical institutes of each member state. These national collections of price reports are subject to statistical confidentiality restrictions and are not brought together at Eurostat. Therefore, there is no single dataset available that provides monthly individual price reports covering a wide variety of products and services across the entire euro area. For the purpose of the IPN, the national databases were released by the statistical institutes of each euro area member state on an individual basis to a specific research team and subject to specific restrictions. Consequently, the analysis of individual records has first been conducted in a decentralized way by each national research team. The result of this research is documented in various papers, that exploit to the maximum extent possible the comparative advantages of each national database [Álvarez, Burriel and Hernando (2005), Álvarez and Hernando (2004), Aucremanne and Dhyne (2004 and 2005), Baudry, Le Bihan, Sevestre and Tarrieu (2004), Baumgartner, Glatzer, Rumler and Stiglbauer (2005), Dias, Dias and Neves (2004), Dias, Robalo Marques and Santos Silva (2005), Fougère, Le Bihan, Sevestre (2005), Hoffmann and Kurz-Kim (2005), Jonker, Blijenberg and Folkertsma (2004), Lünnemann and Mathä (2005b), Veronese, Fabiani, Gattulli and Sabbatini (2005), Vilmunen and Laakkonen (2005)].

[1] The BLS maintains a database called the "CPI Research Database" that is used by Bils and Klenow (2004) and Klenow and Kryvtsov (2005). This database covers all prices in the Commodities and Services Surveys from January 1988 through December 2003.

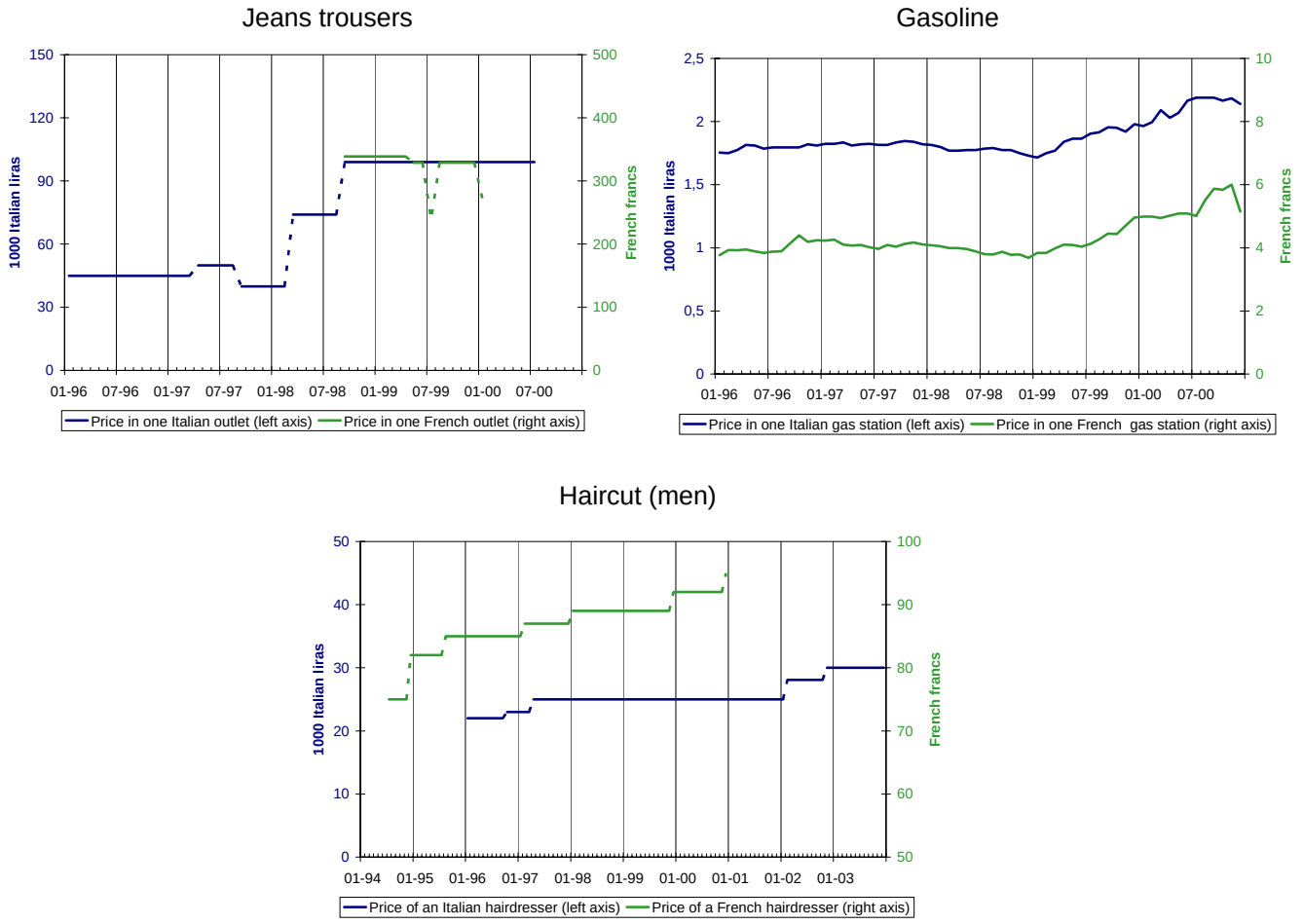
Table 1 - Coverage of the national databases

Country	Paper	Percentage of CPI covered or number of product categories	Period covered
Austria	Baumgartner, Glatzer, Rumler and Stiglbauer (2005)	90 p.c. (80 p.c. considered)	January 1996 – December 2003
Belgium	Aucremanne and Dhyne (2004)	68 p.c.	January 1989 - December 2001
Finland	Vilmunen and Laakkonen (2005)	100 p.c.	January 1997 – December 2003
France	Baudry, Le Bihan, Sevestre and Tarrieu (2004)	65 p.c.	July 1994 - February 2003
Germany	Hoffmann and Kurz-Kim (2005)	52 product categories (20 p.c.)	January 1998 - January 2004
Italy	Veronese, Fabiani, Gattulli and Sabbatini (2005)	50 product categories (20 p.c.)	January 1996 - December 2003
Luxembourg	Lünnemann and Mathä (2005b)	100 p.c.	January 1999-December 2004
Netherlands	Jonker, Folkertsma and Blijenberg (2004)	49 product categories (8 p.c.)	November 1998 - April 2003
Portugal	Dias, Dias and Neves (2004)	100 p.c. (95 p.c. considered)	January 1992 - January 2001
Spain	Álvarez and Hernando (2004)	70 p.c.	January 1993 - December 2001

A detailed description of each national database is provided in the above-mentioned country analyses. In each case, the raw data consist of individual price trajectories, i.e. sequences of price quotes for a specific product in a specific outlet. Examples of price trajectories, selected for their typical patterns and extracted from the French and Italian CPI data, are plotted in Figure 1.

In order to minimize differences across countries in both the coverage of the databases and the price-reporting conventions, each team provided a specific set of statistics for this research project, using a harmonized methodology. It has to be emphasized that the sharing of raw data on price reports across countries was not possible because of confidentiality restrictions imposed by the National Statistical Institutes. Euro area results and statistics presented in this paper are therefore not directly drawn from raw individual price data, but are obtained by aggregating country results computed by each research team.

Figure 1 - Examples of individual price trajectories (French and Italian CPI data)



Note : Actual examples of trajectories, extracted from the French and Italian CPI databases. The databases are described in Baudry et al. (2004) and Veronese et al. (2005). Prices are in levels, denominated in French Francs and Italian Lira respectively. The dotted lines indicate events of price changes.

As summarized in Table 1, the coverage of the national data sets was very heterogeneous across countries. Therefore, cross-country comparisons are performed using a comparable sample of 50 product categories[2] in each country. These product categories were selected to ensure representativity of results. The period covered by each country has also been harmonized, even if a full harmonization was not possible, as it was decided to focus on the period starting in January 1996 and not to cover the period affected by the euro-cash changeover, since this could bias frequencies of price adjustment. However, countries such as Finland and Luxembourg also

[2] The 50 product categories selected for this paper are : 4 unprocessed food categories (steak, 1 fresh fish, lettuce, and bananas), 7 processed food categories (milk, sugar, frozen spinach, mineral water, and coffee), 3 energy (oil) products (gasoline for heating purpose and 2 types of fuels), 17 non-energy industrial goods (socks, jeans, sport shoes, shirt, acrylic painting, cement, toaster, electric bulb, 1 type of furniture, towel, car tyre, television set, dog food, tennis ball, construction game Lego, toothpaste, and suitcase) and 19 services (dry cleaning, hourly rate of an electrician, hourly rate of a plumber, domestic services, hourly rate in a garage, car wash, balancing of wheels, taxi, movie, videotape rental, photo development, hotel room, glass of beer in a bar, 1 meal in a restaurant, hot-dog, cola based lemonade in a bar, men's haircut, and ladies' hairdressing). If one product category was not available in one country, it had to be replaced by a close substitute. A detailed presentation of the common sample can be found in the technical appendix, along with the discussion of some methodological options.

considered data after January 2001.[3] This could distort somewhat the comparability of the measures of the average frequency of price changes in these countries and, consequently, in the euro area as a whole.

To enhance comparability across countries, a common definition of the price level and of what is considered as a price change has also been used. In the following sections, the price of a specific product refers to the price per unit of product. As far as our definition of a price change is concerned, we have labeled as a price change either an observed price change or a forced product replacement as some countries were unable to discriminate between these events. A more appropriate but unfeasible treatment of product replacement would have implied a correction for quality change. Hoffmann and Kurz-Kim (2005) compare unadjusted and quality-adjusted data for Germany and find quite pronounced differences for some product categories. However, for their full sample, the differences are still significant but much smaller. Facing a similar issue, Klenow and Kryvstov (2005) decided to compute the frequency of price changes with and without product replacement "because it is not clear whether price changes associated to product turnover are what modelers of sticky prices have in mind".

Despite our commitment to produce comparable statistics, we were not able to fully account for some national specificities in the collection of price reports. One of the remaining major cross-country differences we could not avoid is related to the treatment of sales. For some countries, national statistical institutes report sales prices while in other countries the prices that are reported during the sales period are prices without rebates. Typically, price changes will appear to be less frequent and smaller in countries where sales prices are not reported. Therefore, this methodological difference has to be kept in mind when comparing results across countries.

Finally, the results presented in the following sections need to be analyzed with due regard for the fact that in the observation period low inflation rates prevailed in all countries considered. Aggregate inflation for the euro area averaged 1.9 percent y-o-y, while the sectoral inflation rates ranged from 0.9 percent for non-energy industrial goods to 3.0 percent for energy.

3. THE PATTERNS OF PRICE CHANGES IN THE EURO AREA

This section describes the patterns of individual price adjustments in the euro area which can be summarized by six stylized facts. These stylized facts have been established on the basis of seven main indicators: the frequency of price changes, the average duration of price spells, the frequency of price increases, the frequency of price decreases, the average size of price increases, the average size of price decreases and the degree of synchronization of price changes. The computation of these indicators is detailed in the technical appendix. The euro area figures

[3] The period covered by these countries ends in December 2001.

presented below are computed by aggregation using country weights from the HICP and (re-scaled) sectoral weights, so that each national sub-index has the same weight as in the national CPI. Euro area figures at the product category level for the 50 products of our common sample can be found in Appendix, in Table A.8.

Fact 1 – Prices change rarely. The frequency of price changes for the euro area is equal to 15.1 p.c. The average duration of a price spell, based on a set of indirect estimators for duration of price spells, ranges from 4 to 5 quarters. Compared to the US, price adjustment in the euro area occurs less frequently.

To obtain a euro area measure of the frequency of price changes or average price duration, we aggregated national figures, based on country-specific weighting schemes, using the relative share of private consumption. Based on this procedure, the frequency of price changes in the euro area is on average equal to 15.1 p.c. To check the robustness of this estimate, we considered two alternative measures. First, we computed the frequency of price changes using the figures reported in the country papers listed in Table 1 which used a much larger coverage of the CPI. The average frequency of price changes for the euro area is practically the same (even if some differences between both indicators may appear at the country level). Therefore, the use of the 50 products sample does not seem to have an impact on our results. Second, we estimated a trimmed-mean frequency in order to minimize the impact of outliers.

Table 2 - Frequency of price changes and average price duration in the Euro area and the US

	Euro area	US
Frequency of price changes		
50 product sample	15.1 p.c.	24.8 p.c.
Larger sample	15.3 p.c.	26.1 p.c.
Trimmed mean	16.9 p.c.	
Average duration		
Based on frequencies at the euro area product category level	13.0 months	6.7 months
Based on frequencies at the country-product category level	15.1 months	
Inverting the aggregate frequency of price changes	6.6 months	3.8 months
Median price duration	10.6 months	4.6 months

Sources: authors calculations based on NSIs data, and Bils and Klenow (2004). Median duration for the US relies on full CPI. Figures are weighted using CPI and country weights.

The trimmed mean is computed by considering the frequency of price changes by sub-index for all countries. For each sub-index, the countries with the highest and the lowest frequencies are disregarded for the estimation of the sub-indices' average. For instance, the frequency of price changes for energy in Portugal (which is an outlier because gasoline prices were regulated over the

sample period) is disregarded in this computation. In that case, the frequency of price changes for the euro area is equal to 16.9 p.c.

According to our estimates, prices seem to change far less frequently in the euro area than in the U.S. For the latter country, Bils and Klenow estimated an average frequency of price changes of 26.1 p.c., considering the US CPI over the 1995-1997 period. Similarly, using data covering the 1998-2003 period, Klenow and Kryvstov (2005) found a monthly frequency of price changes of 29.3 p.c. In order to ensure comparability between the euro area and the US estimates, we also computed a US figure relating to our 50 products sample, based on the product-specific estimates reported in Bils and Klenow (2004), which is very close to the figure for the aggregate given by the above-mentioned authors.

A similar difference is also observed when focusing on average price durations. The average price duration is estimated to be of 13 months in the euro area. This figure is based on an indirect approach, namely inverting the frequency of price changes at the product level for the euro area and aggregating.[4] Based on the 50 products sample in Bils and Klenow (2004), the corresponding figure for the US is 6.7 months. Note that the aggregation of the implied duration computed at the product level in each country yields an estimated average price duration of 15.1 months in the euro area. However, such a measure, which can be considered as an upper bound, is less suited for a comparison with the US, since the frequency measures in the latter case are consolidated across states before aggregation across products.

One striking feature is that our estimate of implied duration (13 months) is much larger than the "pseudo-average duration" which is obtained by inverting the average frequency (1/0.151 = 6.6 months). As documented in several of the papers listed in Table 1 and as illustrated in Section 5 of the Technical Appendix, this gap essentially reflects Jensen's inequality, together with cross-product heterogeneity. As a result, the inverse frequency is systematically much lower than the average duration.

Arguably, the implied average durations are affected by outliers, as product categories with a very low frequency of price changes translate into extremely high implied durations. Therefore, it is worthwhile to consider the weighted median as an alternative estimator of the typical duration. This measure gives 10.6 months. The corresponding figure for the US is 4.6 months from Bils and Klenow (2004), which confirms the contrast with euro area.

The higher frequency of price changes or lower price durations observed in the US can be partly explained by the slightly higher and slightly more volatile monthly inflation rates observed during

[4] See the technical appendix for details on the implied duration approach. The indirect approach is used instead of the direct measurement of duration because the latter approach involves censoring of the data, in particular for some countries for which the data sample was very short.

the 1996-2001 period in the US compared to the euro area (respective 0.21 p.c. and 0.12 p.c. average monthly inflation and 0.16 and 0.20 standard deviation of monthly inflation). The observed difference is, however, simply too pronounced to be explained solely by the differences in the mean and the variability of aggregate inflation.

Furthermore, the lower euro area frequency of price adjustments cannot be explained by differences in consumption patterns. The euro area consumption structure is characterized by a larger share of food products (which are characterized by frequent price changes, see below) and a smaller share of services (which are characterized by infrequent price changes, see below). Therefore, the difference in the frequency of price changes would be even larger if both economies shared the same consumption pattern.

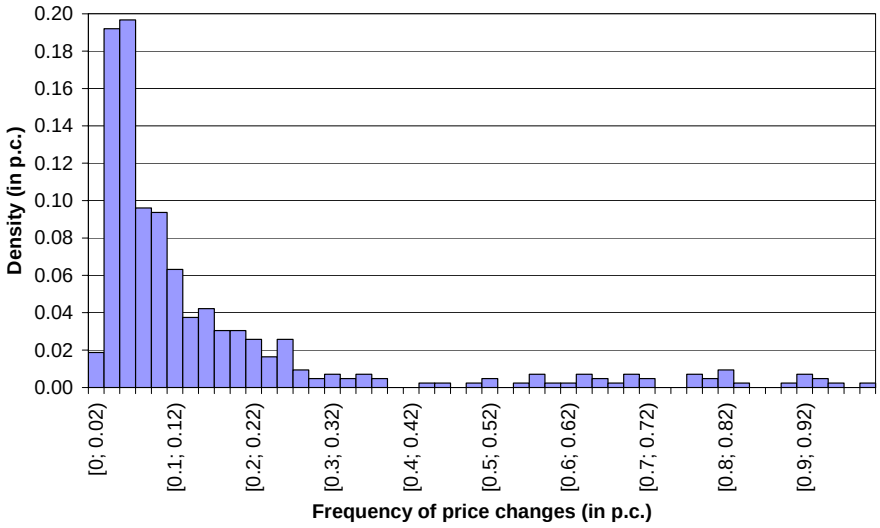
Finding lower frequencies of price adjustment and longer durations of price spells in the euro area than in the US seems therefore to be a robust result of the analysis presented. In addition, this difference is in line with available indirect estimates on price duration based on macro models. For instance, in Galí et al. (2003) the baseline estimate for the average duration of a price spell lies somewhere around 4 to 6 quarters in the euro area, which is approximately twice as high as their baseline estimate for the US (two to three quarters).

One last finding concerning duration is that in all of the euro area countries there is a noticeable right-tail of durations. In all datasets considered for the present paper, a small fraction of price spells with a very long duration of, say, several years is observed. This is exemplified in the lower-right panel of Figure 1 where it can be seen that the price of the selected haircut from the Italian CPI was set constant for more than 4 years over the period 1997-2001.

Fact 2 – There is a substantial degree of heterogeneity in the frequency of price changes across products. Price changes are very frequent for energy (oil products) and unprocessed food, while they are relatively infrequent for non-energy industrial goods and services.

Based on the frequency of price changes computed at the product level, a marked amount of heterogeneity is observed across products, as can be seen in Figure 2, which plots the unweighted distribution of the pooled frequencies of price changes. Each observation used for this histogram is the frequency for one product category in one country.

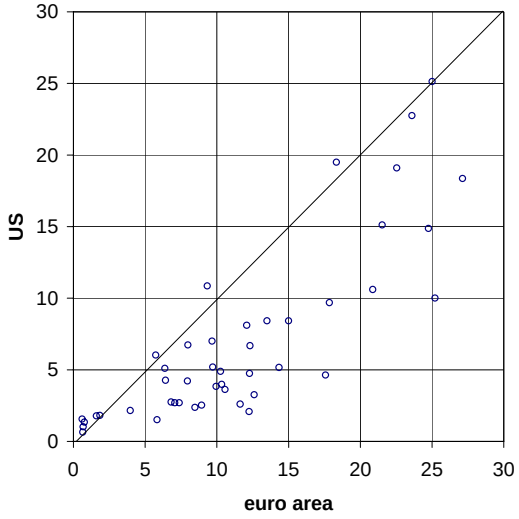
Figure 2 – Distribution of the frequency of price changes



Sources: authors calculations on NSIs data. Finland is not included. Unweighted data.

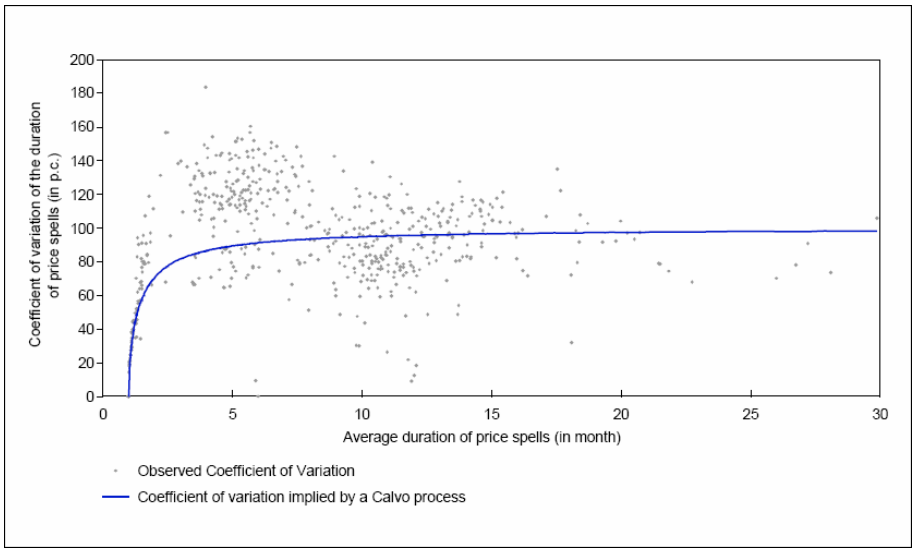
Compared with the US, it seems that the euro area is characterized by more heterogeneity in pricing behavior. In the euro area, 95 p.c. of the product categories considered are characterized by an average duration of price spells ranging from 1 to 32 months, whereas the same fraction of product categories in the US are only characterized by average durations between 1 to 22 months. Moreover, it can be seen from Figure 3 that the more pronounced heterogeneity observed in the euro area is mostly associated with the product categories characterized by longer price durations.

Figure 3 – Implied duration of price spells at the product category level - Comparing the euro area with the US



Sources: NCBs calculations on NSIs data.

Figure 4 – Variability and average duration of price spells per product category in the Belgian CPI data



Source : Aucremanne and Dhyne (2004).

Heterogeneity of price-setting behavior is not only important across product categories. There is also a substantial degree of heterogeneity of price-setting behavior within product categories. Among others, Aucremanne and Dhyne (2004) show that the standard deviations of the durations of price spells estimated at the product category level were often large, relative to the average. Figure 4, taken from Aucremanne and Dhyne (2004), summarizes this fact by plotting the (within) coefficient of variation against the average price duration by product category.[5]

Characterizing the heterogeneity across product categories, it can be seen from Table 3 that the euro area countries share a common ranking of the 5 main components of the CPI with respect to frequency of price change. Energy prices (gasoline and heating oil, in the common sample) and unprocessed food prices change very often (respectively 78.0 and 28.3 p.c.). This pricing behavior probably can be rationalized by the relative importance of supply shifts in these sectors. These two product types are followed by processed food (13.7 p.c.) and non-energy industrial goods' prices (9.2 p.c.). Prices of services change less often, their average frequency of price changes being equal to 5.6 p.c. Based on Bils and Klenow (2004), we have also computed aggregate results for these main components[6] in the US and the same ranking is obtained. This common ranking of the main components is made particularly clear in Figure 5.[7]

[5] In Figure 4, one observation is one product category, and the solid line represents the theoretical coefficient of variation that would be consistent with the Calvo model, conditional on the implied average duration obtained for each product. Denoting by p the probability of price change, predicted to be constant under the Calvo assumption, expected duration is then 1/p and the resulting coefficient of variation is $(1-p)^{1/2}$.

[6] Our definition of the main components follows European practices, which somewhat differ from those of the US.

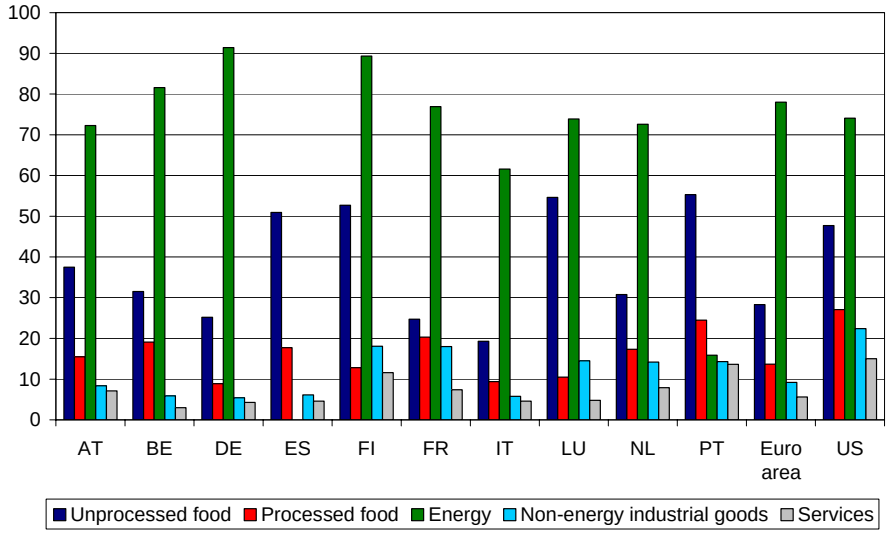
[7] The ranking across product categories is slightly different in Luxembourg. For this country, non-energy industrial goods are characterized by more frequent price changes than processed food. However, this result seems to be partly related to the relative importance of sales in the non-energy industrial goods in this country. Controlling for sales, the ranking across product types in Luxembourg becomes the same as in the other euro-area countries.

Table 3 – Frequency of price changes by product type[(1)]

	Unprocessed food	Processed food	Energy (oil products)	Non-energy industrial goods	Services	Total [(2)] country weights	Total [(3)] euro area weights
Austria (AT)	37.5	15.5	72.3	8.4	7.1	15.4	17.1
Belgium (BE)	31.5	19.1	81.6	5.9	3.0	17.6	15.6
Germany (DE)	25.2	8.9	91.4	5.4	4.3	13.5	15.0
Spain (ES)[4]	50.9	17.7	n.a.	6.1	4.6	13.3	11.5
Finland (FI)	52.7	12.8	89.3	18.1	11.6	20.3	-
France (FR)	24.7	20.3	76.9	18.0	7.4	20.9	20.4
Italy (IT)	19.3	9.4	61.6	5.8	4.6	10.0	12.0
Luxembourg (LU)	54.6	10.5	73.9	14.5	4.8	23.0	19.2
Netherlands (NL)	30.8	17.3	72.6	14.2	7.9	16.2	19.0
Portugal (PT)	55.3	24.5	15.9	14.3	13.6	21.1	18.7
Euro area	**28.3**	**13.7**	**78.0**	**9.2**	**5.6**	**15.1**	**15.8**
US	47.7	27.1	74.1	22.4	15.0	24.8	-

Sources: NCBs calculations on NSIs data.
(1) Figures presented in this table are computed on the basis of the 50 products sample, with the only exception of Finland for which figures derived from the entire CPI are presented. Figures based on a larger coverage of the CPI for each individual country, when available, are presented in their respective national paper mentioned in Table 1.
(2) The total is calculated using country-specific weights for each item.
(3) The total is calculated using common euro area weights for each sub-index. No figures are provided for Finland because of the lack of comparability of the sample of products used in this country.
(4) In the Spanish database no energy products are included, which biases downwards the aggregate frequency.

Figure 5 - Frequency of price changes - Analyzing cross-components differentials



Sources: NCBs calculations on NSIs data

There is some indication that the sectoral differences in terms of the degree of price flexibility, translate somehow into differences in the degree of persistence of inflation at the product category level. Using price indices at the product category level, Lünnemann and Mathä (2004 and 2005a) found a similar sectoral ranking in the degree of price rigidity and product-specific inflation

persistence (low for energy and unprocessed food and higher for non-energy industrial goods and services).

Fact 3 - Heterogeneity across countries is relevant but less important than cross-sector heterogeneity. It is partly related to the consumption structure and to the statistical treatment of sales.

There also exists a sizeable cross-country variation in the frequency of price change. In the period 1996-2001, on average, it ranged between 10 p.c. in Italy and 23.0 p.c. in Luxembourg. It has to be mentioned that the results based on the 50 products sample presented in Table 3 are not very different from the corresponding results based on the complete set of price reports available in each country. This indicates that 50 products sample is a good approximation of the CPI in the different countries.

The source of the cross-country variation is likely to be both structural (consumption patterns, structure of the retail sector[8]), methodological (e.g. the treatment of sales and of quality adjustment by each NSI) and a reflection of the differences in the relative importance of regulated prices across countries.

Part of the cross-country differences can be explained by the consumption structure. When using the euro area consumption structure to aggregate over products as is done in the last column of Table 3, differences across countries tend to narrow. Adopting identical consumption patterns across all euro area countries, the estimates of the average frequency of price changes range from 12 p.c. in Italy to 20.4 p.c. in France. The increase in the frequency of price changes in Italy is due to the fact that energy, which exhibits a high frequency of price changes, has a relatively low weight in Italian consumption compared to the euro area average.

Within some of the main components, cross-country differences in the frequency of price adjustment are still substantial. This is true for energy prices, in spite of their tight dependence on common oil price developments. In most euro area countries, the prices of oil products change very often, with the sole exception of Portugal which is characterized by a very low frequency of price changes in that particular category, which is due to the fact that gasoline prices in Portugal were administered during the sample period.

For non-energy industrial goods, different treatment and reporting by National Statistical Institutes of price cuts during sales periods are probably an important factor in explaining the observed differences in the frequency of price adjustments: in France, which records sales prices, 18 p.c. of these prices are found to change every month, as opposed to only around 6 p.c. in Belgium, Germany, Italy and Spain.

[8] Some countries like Italy may have stickier prices due to a larger market share of small traditional outlets.

Because a higher frequency of price changes in non-energy industrial goods due to the observation of sales translates into a higher frequency of price changes for the overall CPI, sales could be an explanatory factor for the difference, in terms of frequency, observed between France and countries which do not report sales. Based on specific experiments conducted using the French and Austrian databases, our assessment is that this factor can only account for, at most, 3 p.p. in the overall frequency of price change. Indeed, with the common sample data for Austria, the overall frequency of price changes decreases from 15.4 p.c. to 12.9 p.c. when leaving out price changes due to sales, while for France it decreases from 20.9 p.c. to 18.4 p.c. when leaving out sales and flagged temporary price cuts. This result is somewhat confirmed using the pooled regression framework of Section 4.2. Note that Klenow and Kryvtsov (2005) report a frequency of price changes of 23.3 p.c. on regular prices compared to 29.3 p.c. on all prices.

As far as services are concerned, results are relatively more homogeneous across European countries, except for Finland and Portugal.

Finally, cross-product heterogeneity seems to dominate cross-country heterogeneity. An analysis of variance shows that less than 5 p.c. of the variation in the frequency of price changes can be attributed to country effects, while about 90 p.c. of the variance of the frequency of price changes relates to product category effects.

Fact 4 – There is no evidence of general downward price rigidity in the euro area. In fact, price decreases are not uncommon, except in services. On average, 40 p.c. of the price changes are price reductions.

There is no sign of widespread downward nominal rigidity in any of the euro area countries. Figure 6 illustrates this stylized fact by presenting the scatter plot of the frequency of price decreases against the frequency of price increases computed at the product category level in each country. On average, price reductions are yet less frequent than price increases: four price changes out of ten are price decreases. This result appears to be close to what is reported by Klenow and Kryvtsov (2005) for US data (45 p.c. of price changes being decreases). It is worthwhile noticing that this stylized fact is not a mere reflection of sales and temporary promotions. First, in some countries the statistical institutes do not report the sales prices. Second, robustness tests carried out for some countries [e.g. Baudry et al. (2004)] indicate that excluding sales has a limited influence on the incidence of price decreases. Klenow and Kryvtsov (2005) report a similar finding for the US.

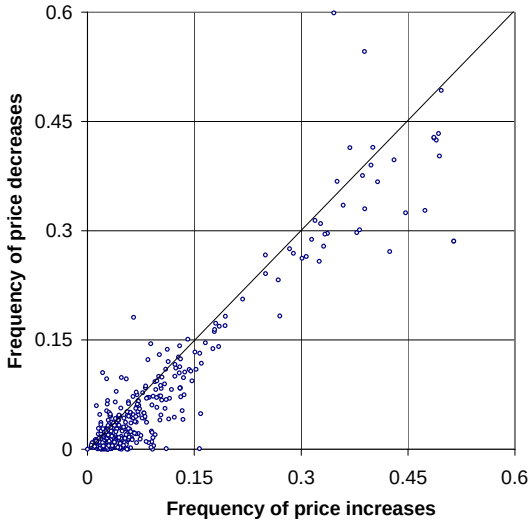
Table 4 - Euro area aggregate results [(1)]

	Unprocessed food	Processed Food	Energy	Non-energy industrial goods	Services	Total
Frequency of price changes	0.28	0.14	0.78	0.09	0.06	0.15
Frequency of price increases	0.15	0.07	0.42	0.04	0.04	0.08
Frequency of price decreases	0.13	0.06	0.36	0.03	0.01	0.06
Share of price increases	0.54	0.54	0.54	0.57	0.80	0.58

(1) Figures for the Total are computed using CPI sub-index weights in each country, in the period 1996-2001.

When considering the sectoral dimension, other common features emerge across countries. First, unprocessed food, processed food and energy are characterized by almost perfect symmetry between price increases and price decreases. The difference is much larger in the services sector. In this sector, there exists a large asymmetry between the frequency of increases and decreases as only 2 price changes out of ten are price decreases (frequency of price increases is 4 p.c. versus 1 p.c. for frequency of price decreases). This result may be partly related to the fact that the share of labor costs in the production costs of this type of goods is particularly important, and could therefore be construed as an indication that the development of wages is more steady than that of other input prices.

Figure 6 - Frequency of price increases and price decreases



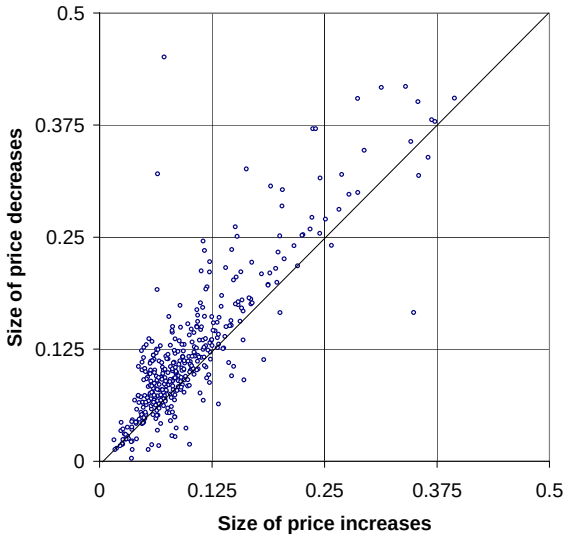
Note : pooled data of 50 product categories in 9 countries (Finland is not included).
Sources: NCBs calculations on NSIs data.

Fact 5 – Price changes, either increases or decreases, are sizeable compared to the inflation rate prevailing in each country. Price reductions and price increases have a similar order of magnitude, though price reductions are on average larger.

Although price increases are on average more frequent than price decreases, which is quite natural in an economic environment characterized by moderate inflation, this asymmetry does not carry over to the magnitude of price changes. On average, price decreases are actually larger than price increases (10 p.c. versus 8 p.c.).[9]

Klenow and Kryvstov (2005) report an average absolute size of price changes of 13 p.c. and of 8 p.c. when sales prices are not taken into consideration. These figures are in line with our estimates for the euro area. Note that sales-related price changes are usually larger than regular price changes, [see Baumgartner et al. (2005)]. The average size of price changes for countries in which the statistical office does not report the sales prices is thus expected to be smaller than for those in which the data incorporate observed sales prices.

Figure 7 - Average size of price increases and price decreases



Note : pooled data of 50 product categories in 9 countries (Finland is not included)
Sources: NCBs calculations on NSIs data

With regard to the sectoral dimension, we observe in the unprocessed food sector not only very frequent but also very large price changes. Furthermore, price increases and decreases tend to offset each other, since the frequency and the size of price increases and decreases are almost identical. This suggests that prices in this sector are driven largely by supply-side factors related to the seasonal nature of many unprocessed food items.

[9] Note that the size of price increases and decreases are computed as the difference of logarithm, so that the two successive price changes recorded during a temporary price cut are equal in absolute terms.

Energy prices change very often but by a limited amount in most countries. This is consistent with the pronounced variability of marginal costs (oil prices). However, with respect to the size of price adjustments, this variability is smoothed out by the large incidence of indirect taxation on these products.

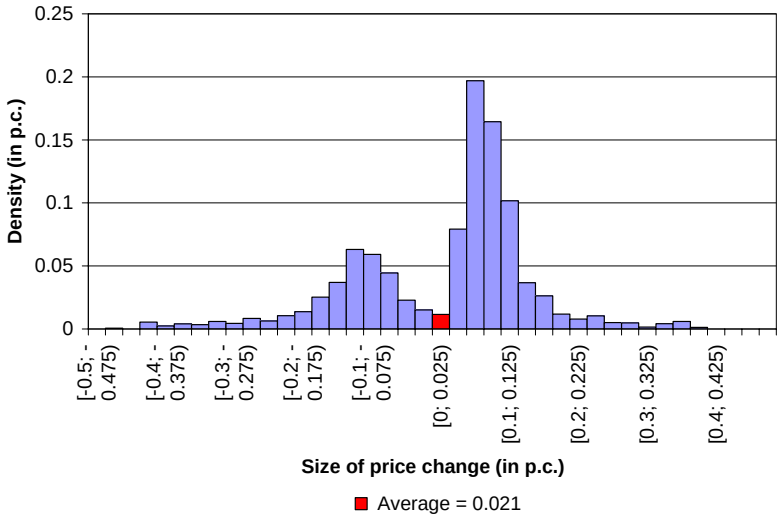
Table 5 - Average size of price changes in the euro area [(1)]

	Unprocessed Food	Processed Food	Energy	Non-energy industrial goods	Services	Total
Size of price increases	0.15	0.07	0.03	0.09	0.07	0.08
Size of price decreases	0.16	0.08	0.02	0.11	0.09	0.10

(1) Figures for the Total are computed using CPI sub-indices weights in each country, in the period 1996-2001.

The distribution of the average size of price changes across product categories presented in Figure 8 (each observation is an average size in a product category). The size of average price decreases appear to be concentrated in the [-0.15; -0.05] interval, while average price increases are mostly observed in the [0.025; 0.125] interval. Figure 8 indicates that, in some categories, price changes are on average very large.

Figure 8 - Distribution of the average size of price changes in the euro area



Sources: NCBs calculations on NSIs data (Finland is not included).

Finally, within product category heterogeneity in the size of price changes is also rather important, as it is shown for instance in Hoffmann and Kurz-Kim (2005).

Fact 6 – Synchronization of price changes across price-setters does not seem to be large at the product level, even within the same country.

Using the measure proposed by Fisher and Konieczny (2000), we can assess the degree of synchronization of price changes at the product level in each country (see point 4 of Technical Appendix for the formula). This index takes the value 1 in case of perfect synchronization of price changes, while it takes value 0 in the case of perfectly staggered price changes across price setters.

As can be seen from Table A.6 in appendix, the degree of synchronization of price changes is, in general, rather low except for energy prices: the median synchronization ratio across the 50 products in the common sample ranges between 0.13 in Germany and 0.48 in Luxembourg. The higher ratio observed in Luxembourg compared to Germany probably reflects the difference in the market's size upon which the index is computed and the relatively small number of outlets from which prices are collected in Luxembourg. This is supported by Italian results. Indeed, as shown in Veronese et al. (2005) in the Italian case, the low synchronization of price changes at the product level is perfectly compatible with higher synchronization rates computed within a given city.

Dias et al. (2004) suggested a structural interpretation for the Fisher and Konieczny (F&K) synchronization index. According to these authors, the F&K index can be seen as a method of moments estimator for the share of firms in the economy that are perfectly synchronized, or, the other way around, the complement of the F&K index estimates the share of firms in the economy whose pricing is uniformly staggered. For instance, the F&K index for the energy sector in Portugal is 0.82. In this sense, one may say that 82 p.c. of the energy retailers in Portugal are synchronized. Therefore, the hypothesis of uniform price staggering for the energy sector seems to be far from being realistic. The F&K index can be seen as an alternative to the Klenow and Kryvstov (2005) variance of inflation decomposition for assessing how far the Uniform Price Staggering hypothesis is from reality.

4. ACCOUNTING FOR THE FREQUENCY OF PRICE CHANGE

4.1. Individual country evidence

This sub-section summarizes the main results on the factors affecting the frequency of price changes presented in the various country papers. All these findings are summarized in Table 6.

These results were obtained using a wide variety of methodological approaches, considering both measures of the frequency of price changes and measures of the frequency of price changes conditional on the duration of price spells. Although the methodological approaches are very different across countries, most results are very similar.

Table 6 - Factors affecting the probability or the frequency of price changes

	AUT	BEL	FRA	GER	ITA	LUX	NED	POR	SPA
Seasonality	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Aggregate inflation	*na*	Yes	Yes	*Yes*	Yes	Yes + wage inflation	No but with wage inflation	Yes	Yes
Sectoral or product-specific inflation	Yes	Yes	Yes	Yes	Yes	Yes	*na*	Yes	Yes
VAT rate changes	*na*	Yes	Yes	Yes	Yes	*na*	Yes	Yes	Yes
Type of outlet	*na*	*na*	Yes	Yes	Yes	*na*	Yes (a)	Yes	*na*
Attractive prices	Yes	Yes	*na*	Yes	Yes	Yes	*na*	*na*	Yes
Euro cash changeover	Yes	Yes	Yes	Yes	Yes	Yes	Yes	*na*	*na*

Notes: na : not available (not tested). At the time this paper was completed no results were available for Finland.
(a) Type of outlet proxied by the number of employed persons.

1. Seasonal patterns

A first common result that has been put forward in all countries is that the monthly frequencies of price changes exhibit seasonal patterns. In general, price changes are more likely to take place during the first quarter (especially in January) or after the summer period (especially in September) and are less frequent in July and August (with the exception of France where price changes are less frequent in December). The higher frequency of price changes associated with January is particularly observed for services. Such patterns may reflect changes in costs or in demand that occur systematically at the start of the year and to which sellers are quick to adjust, or may reflect time-dependent behavior.

2. Inflation rate

Investigating the link between the frequency of price changes and inflation is particularly relevant when trying to assess whether or not price adjustment contains state-dependent features. With purely time-dependent pricing, the timing of price adjustments is exogenous, independent of the prevailing economic conditions. Only the size of price changes is expected to vary with inflation. With state-dependent pricing, one expects to find a positive relationship between the frequency of price adjustments on one hand and the prevailing inflation rate on the other hand. Furthermore, as the price-setting process of firms could depend on aggregate economic developments and/or on idiosyncratic conditions, it is relevant to test which type of developments has an influence on the frequency of price adjustments. Below this is done by making a distinction between (i) the impact of the aggregate inflation rate on the aggregate frequency of price adjustments and (ii) the link between sectoral inflation rates and the sector-specific probabilities of price adjustment.

The impact of aggregate inflation

Indications of aggregate state-dependence in price-setting behavior have been put forward in the various country contributions. On the one hand, Álvarez and Hernando (2004) and Veronese et al. (2005), using time series models, found that increases in aggregate inflation are associated with higher frequencies of price increases, and lower frequencies of price decreases. Other evidence, both graphical and by means of correlation analysis, of a positive relation between inflation and the frequency of price changes, has also been put forward in other euro area country studies (for instance in Austria, Belgium, Germany and Portugal). On the other hand, Jonker et al. (2004), using duration models, did not find any significant impact of the CPI inflation rate on the probability of observing a price change. However, their results indicate a significant relation between wage inflation and the frequency of price changes. Overall, there is some evidence of state dependent pricing in response to aggregate shocks. Lünnemann and Mathä (2005b) also found that the probability of observing a price change is significantly related to changes in wages, as they found that price changes are more frequent around the time when wage indexation sets in.

The impact of sectoral or product-specific inflation

There seems to be more and stronger evidence of state dependency in response to sectoral shocks. For instance, Álvarez and Hernando (2004) and Veronese et al. (2005), using fixed-effect Logit models, show that the frequency of price changes at the firm level reacts to changes in the inflation rate computed at the sectoral level. Such a result is corroborated by random effect Logit models in Aucremanne and Dhyne (2005) and Baumgartner et al. (2005). These studies indicate that the probability of observing a price change is positively affected by the absolute value of accumulated product-specific inflation since the occurrence of the last price change. Aucremanne and Dhyne (2005) emphasize the fact that the probability of observing a price increase is positively affected by the accumulated positive inflation while it is negatively affected by accumulated negative –product category level– inflation since the occurrence of the last price change. Reverse relations are obtained for the probability of observing a price decrease of a specific product in a specific outlet. Fougère et al. (2005) and Dias, Robalo Marques and Santos Silva (2005), using duration models, have also found a link between accumulated sectoral or product-specific inflation and the conditional hazard to observe a price change. Analyzing frequencies, Hoffmann and Kurz-Kim (2005) observe that a bunching of price changes occurs in periods which are affected by supply shocks and which drive product-specific inflation up (or down).

3. Indirect tax rate changes

Álvarez and Hernando (2004), Aucremanne and Dhyne (2004 and 2005), Baudry et al. (2004), Dias, Dias and Neves (2004), Hoffmann and Kurz-Kim (2005), and Jonker et al. (2004) have all stressed the impact of indirect tax rate changes on the frequency of price changes. These changes always lead to temporary increases in the frequency of price changes. As indirect tax rate changes can be considered as exogenous cost shocks, their impact on the frequency of price changes can be interpreted as evidence in favor of state-dependent aspects in price setting.

4. Type of outlets

Analyzing the impact of the type of outlet on the frequency of price changes, Baudry et al. (2004), Dias, Dias and Neves (2004), Jonker et al. (2004)[10] and Veronese et al. (2005) point out that the frequency of price changes tends to be significantly higher in super and hypermarkets than in traditional corner shops. This finding may reflect differences in the degree of competition, in the relative importance of menu costs, or in pricing strategies.

5. Attractive pricing

Some country studies have also analyzed the impact of the use of attractive pricing on the frequency of price adjustments. Attractive pricing could be a source of rigidity as outlets may (temporarily) decide not to reset their prices in response to a shock because their optimal response would result in a non-attractive price and a small deviation from optimality might not be very costly. The use of attractive pricing is a widespread practice. As mentioned by Bergen et al. (2003), more than 65 p.c. of the prices in the US retail food industry ends in 9 cents. Considering the situation in the euro area, the available empirical evidence also indicates a large use of attractive prices [e.g. Álvarez and Hernando (2004), Cornille (2003), Folkertsma (2002), Hoffmann and Kurz-Kim (2005) or Lünnemann and Mathä (2005b)].

As regards the impact of attractive pricing on the price setting behavior of European retailers, results presented in Álvarez and Hernando (2004), Aucremanne and Dhyne (2005), Baumgartner et al. (2005) and Lünnemann and Mathä (2005b) indicate that prices that are set at an attractive level are changed less frequently than ordinary prices.

[10] In Jonker et al. (2004), the type of outlet is proxied by the number of employed persons.

6. Euro cash changeover

In January 2002, euro area retailers had to change price from the national currency to the euro. Unlike an indirect tax rate change, the conversion to the euro was not as much a cost shock but rather a change in the monetary unit that forced firms to express their prices in a new currency. Moreover, this conversion was announced 2 years in advance and was accompanied by a period of dual display of prices (prices were quoted both in euro and in the national currency).

The country studies provide ample evidence that (correcting for the change in numéraire) price changes were more frequent in January 2002 or in the first quarter of 2002. This finding can be interpreted as an indication of significant menu costs which induced bunching of prices during that month. However, not all prices changed in January 2002. Most available studies [Baudry et al. (2004), Baumgartner et al. (2005), Cornille (2003), Jonker et al. (2004), Lünnemann and Mathä (2005b), and Veronese et al. (2005)] show that the euro cash changeover implied an increase of the frequency of price changes during a 6 month period before and/or after the conversion to the euro. This lack of a generalized concentration of price changes in January 2002 is not necessarily at odds with the existence of menu costs, given the widespread practice of dual pricing in the period surrounding the cash changeover and its subsequent disappearance. It has to be noted that price revisions associated with the cash changeover were not always upwards but to a significant extent also downwards.

7. Elapsed duration

Finally, special attention has been paid in several countries on the characterization of the hazard functions of price changes. Table 7 summarizes the main common characteristics observed across countries.

Table 7 – Aggregate hazard function patterns

	AUT	BEL	FRA	GER	ITA	LUX	NED	POR	SPA
Downward sloping	Yes	Yes	Yes	Yes	Yes	Yes	Yes	*na*	Yes
High for duration 1 month	Yes	Yes	Yes	Yes	Yes	Yes	*na*	*na*	Yes
Modes at 12, 24, 36 months	Yes	Yes	Yes	Yes	Yes	Yes	Yes	*na*	Yes

Notes: na : non-available (not tested). At the time this paper was completed no results were available for Finland.
(a) Type of outlet proxied by the number of employed persons.
(b) Aggregate hazard function estimated from the full population of price spells; unweigted.

The probability of a retailer adjusting its price is likely to be affected by the time elapsed since the last price change. A useful tool for characterizing this probability is the hazard rate of price changes, i.e. the probability that a price is changed in period k, provided that it has been kept unchanged for

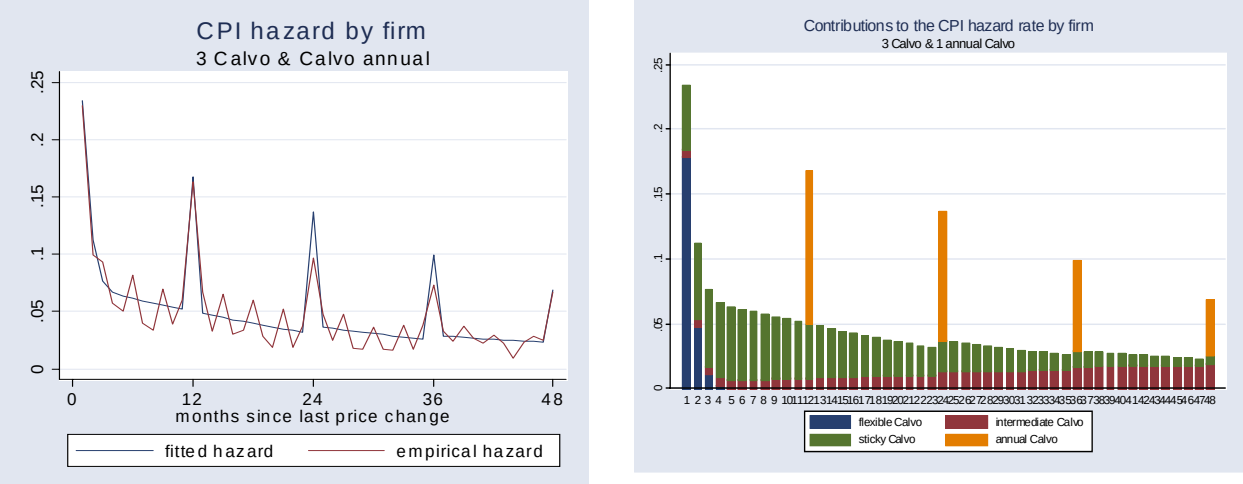
the previous k-1 periods. Available evidence on hazard functions for consumer prices suggests the three following common features.

- Hazard rates for price changes computed from the full sample of price spells display an overall decreasing pattern in all countries where this type of information has been analyzed;
- Hazard rates are also characterized by local modes at durations of 12, 24 and 36 months, indicating that a fraction of firms revise their prices on an annual basis;
- Hazard rate for duration one month is typically quite high, reflecting the share of price spells with very short durations (mainly oil products and unprocessed food retailers).

These features are illustrated in Figure 9 in the Spanish case.

Declining hazard functions are at odds with the theoretical pricing rules most widely considered in macroeconomic models [e.g. Calvo, Taylor, truncated Calvo or state-dependent pricing as in Dotsey, King and Wolman (1999)]. Nonetheless, it is a traditional result in the literature on duration models that downward sloping hazards may come out from aggregating heterogeneous populations [for a theoretical discussion on this issue, see for instance Heckman and Singer (1985)].

Figure 9 - Hazard function for Spanish CPI data(1)



(1) Source: Álvarez, Burriel and Hernando (2005). The hazard function is computed with a Kaplan-Meier estimator randomly selecting one price spell for each product trajectory.

Indeed, conditional estimations of the hazard function of price spells by Aucremanne and Dhyne (2005) and Dias et al. (2005) indicate that due allowance for the heterogeneity of products indeed reduces the negative slope of the hazard function. Moreover, Baumgartner et al. (2005) and Fougère et al. (2005) even show that estimating duration models at a very highly disaggregated

level leads mostly to non-decreasing hazard functions. These results are consistent with the hypothesis that the declining overall hazard is mainly a result of aggregation.

In this vein, Álvarez, Burriel and Hernando (2005) show analytically how the combination of different pricing rules such as Calvo, Taylor, truncated Calvo or that of Dotsey, King and Wolman may produce aggregate declining hazards. Estimating finite mixture models on Spanish data, they show that a parsimonious combination of time-dependent models (specifically, a combination of three different types of Calvo agents –highly flexible, intermediate and sticky– and some so-called annual Calvo price setters[11]) is successful in reproducing the empirical hazard rate (see left panel of Figure 9). However characterizing price-setting rule at the micro level by a combination of a limited set of time-dependent pricing rules is obviously an approximation. Indeed, evidence of state dependence was put forward for most euro area countries (see above).

4.2 A pooled regression analysis

The evidence collected so far points to various factors potentially relevant in determining the observed heterogeneity in price setting, including the structure of the retail market, the inflation rate, and the treatment of sales. The aim of this section is to empirically assess their relative importance. We exploit the full distribution of product level statistics on price setting (frequency and size of price changes) in order to perform a set of cross-country regressions.

The frequency (size) of price changes for each category is regressed on product type effects (*unprocessed and processed food, energy, non-energy industrial goods, and services)*, country dummies and a set of additional explanatory variables. The latter comprise, first, descriptive measures on the inflation process at the product category level (mean and standard deviation); second, an indicator of the incidence of sales or other temporary price offers for each product; third, the share of large retailers (hypermarkets and large chain stores) selling a specific product; fourth, an indicator signaling whether the price has a regulated/unregulated nature; last, the share of prices set at attractive (psychological and threshold) levels (see Table A7 in Appendix , for details).

When conducting regressions to explain fractional response variables such as the frequency of price changes (*freq*), linear models are not appropriate because fractions are by nature bounded between 0 and 1. The most common solution is to model the log-odds ratio, $\log\left(\frac{freq}{1-freq}\right)$, as a linear function of the conditioning variables and to estimate an equation of the form:

$$lfreq_{ij} = a_i + \sum_k b_k x_{kij} + \varepsilon_{ij}$$

[11] The annual Calvo rule states that a certain fraction of firms reset their prices every 12 months, but keep them constant in between. Annual Calvo agents allow to to explain the spikes at 12, 24, 36, … months.

where x_{kij} are explanatory variables related to product category i (i=1, … 50) in country j (j=1, … 9), such as a sub-index dummy. In order to measure the marginal effects of each variable on the frequency, coefficients from these linear regressions are transformed, according to $\beta_k = b_k \overline{freq}(1 - \overline{freq})$. Such estimates may be evaluated, for instance, at the corresponding sample averages. The untransformed left-hand side variable can be seen as the aggregation of binary variables indicating price changes within each product and country group, which suggests allowing for heteroscedasticity.[12] An alternative procedure is the quasi-maximum likelihood (QML) approach, of Papke and Wooldridge (1996). These authors suggest the direct estimation of a non-linear model where the right-hand side is a non-linear function (typically a cumulative distribution function of the conditioning variables). Their method involves specifying the observed frequency as a bounded non-linear function of the conditioning set and maximizing a likelihood based on the Bernoulli distribution. The corresponding estimator is consistent and asymptotically normal. We have conducted the analysis using both the standard log-odds model and the Bernoulli QML approach using the logistic cumulative distribution function. Table 8 reports the results from the QML estimation, as the marginal effects computed under the former may be inconsistent.

The results of the model (see Table 8) are broadly consistent with the results of the available euro area country studies summarized in the previous section. More specifically, the frequency of price changes is found to be significantly affected by the volatility of inflation, although not by its mean. This is not surprising since higher (lower) inflation should increase (decrease) the frequency of price increases, but also decrease (increase) the frequency of price reductions (rises). Indeed, the frequency of price increases is positively affected by inflation and the frequency of price reductions is negatively related to it.

The rest of the explanatory variables have the same sign for price changes, increases and decreases. Sales are found to raise the frequency of price changes significantly[13] and prices subject to some form of administrative control are indeed found to change less often, reflecting the annual nature of public budgets. Surprisingly, use of attractive prices and type of outlet are not significant, unlike in country studies. This may reflect the lack of detailed information on the market structure at such a detailed level in some countries, as well as some cross-country heterogeneity in the definition of these variables.

When controlling for all factors listed above, country and product effects remain significant. For instance, the country dummies are significant at the 5 p.c. level for 5 countries. The maximum spread is 15 p.p. (between Austria, –0.065 and Luxembourg, 0.085). This spread is slightly larger

[12] For a robustness check on our findings, we also performed a set of quantile regressions (Least Absolute Deviations) on the same models which should be less affected by outliers. The results are generally consistent with the ones reported here. Huber type robust regressions are also consistent with results in Table 8.

[13] Note that this coefficient measures the marginal effect of sales-reporting for the product category concerned, and is therefore higher than the overall impact of sales-reporting on average frequency (found above to be at most 3 p.p.)

than the one presented in Section 3. However, it has to be stressed that the figures presented in Table 8 are marginal effects and that they should not be interpreted as contributions to the weighted frequencies. The magnitude of cross-country differences is smaller when separately considering frequency of price increases and decreases. While it is not straightforward to disentangle the effects of data collection procedures, this difference suggests that there is indeed some structural heterogeneity in price setting within the euro area.

Table 8 – Explaining the frequency of price changes[14]

	Frequency of price changes	Frequency of price increases	Frequency of price decreases
Average Inflation	1.980	4.588 **	-3.396 **
Inflation volatility	0.975 **	0.299 **	0.355 **
Sales	0.092 **	0.024 *	0.055 *
Attractive prices	0.020	-0.010	-0.030
Regulated	-0.179 **	-0.062 **	-0.059 **
Services	-0.166 **	-0.068 **	-0.065 **
Non-energy industrial goods	-0.140 **	-0.062 **	-0.048 **
Processed food	-0.075 **	-0.027 **	-0.016 **
Unprocessed food	0.100 **	0.064 **	0.063 **
Energy	0.576 **	0.295 **	0.413 **
Austria	-0.065 **	-0.028 **	-0.030 **
Belgium	0.000	-0.010	0.010
Germany	-0.020	-0.020	0.000
Spain	0.048 **	0.023 **	0.031 **
France	0.042 **	0.000	0.000
Luxembourg	0.085 **	0.047 **	0.047 **
Italy	-0.040	-0.024 **	-0.020 *
The Netherlands	-0.050	-0.010	-0.020
Portugal	0.030	0.031 **	0.010 *
Number of observations	427	427	426
Log pseudo likelihood	-107.4	-80.3	-60.7
BIC	-551.7	-108.7	342.7
AIC	0.588	0.461	0.369

1) Reported coefficients are marginal effects of each variable on the frequency of price changes. 2) ** indicates significance at the 5 p.c. level, * indicates significance at the 10 p.c. level. Standard errors are computed using White's correction for heteroscedasticity. 3) Observations for Finland are excluded, because of lack of harmonisation in the constructions of some variables.

The same factors, which are found to determine the wide heterogeneity in the frequency of price changes, also determine their average size (increase or decrease), as it is shown in Table 9. This is indeed not surprising since the decisions to reset a price and the amount of its change are made

[14] Quasi maximum likelihood estimation as described in Papke and Wooldridge (1996).

jointly. We notice that cross-country differences are less important than for the frequency of price changes. Indeed, only in very few cases do the corresponding country dummies result in a statistically significant way in the regressions for the size of price increases/decreases.

Table 9 – Explaining the size of price changes

	Size of price increases	Size of price decreases
Average Inflation	2.029 **	-0.338 **
Inflation volatility	0.699 **	0.757 **
Sales	0.022 **	0.018 **
Attractive prices	0.043 **	0.057 **
Regulated	-0.004	0.027
Services	0.044	0.061 **
Non-energy industrial goods	0.007	0.011
Processed food	-0.007	-0.016 **
Unprocessed food	0.045 **	0.037 **
Energy	-0.043 **	-0.068 **
Austria	0.014 **	0.031 **
Belgium	-0.003	-0.019 **
Germany	0.002	-0.002
Spain	-0.004	-0.003
France	0.009	0.028 **
Luxembourg	-0.010 **	-0.021 **
Italy	-0.006	-0.015 **
The Netherlands	-0.009	-0.007
Portugal	0.006	0.008
Number of observations	426	414
Adjusted R^2	0.52	0.46

1) ** indicates significance at the 5 p.c. level, * indicates significance at the 10 p.c. level.
2) Standard errors are computed using White's correction for heteroscedasticity.
3) Observations for Finland are excluded, because of lack of harmonisation in the constructions of some variables.

Both the standard menu cost model and a Calvo model of price setting would predict the size of price changes to be negatively correlated with the frequency of price spells, in a cross section. With the data at hand, we can indeed check whether this prediction is confirmed in the euro area, by adding the frequency of price changes to the list of explanatory variables in the regressions reported in Table 9. The regressions results (not reported) however do not support this simple relationship when the entire sample is used; when focusing on the so-called "core components" (i.e. excluding unprocessed food and energy products) the relationship becomes significant and has the expected sign. This further substantiates the conclusion that the heterogeneity in price setting behavior across product categories is indeed important, and suggests that, as far as macroeconomic modeling is concerned, it is preferable to incorporate at least two sectors, i.e. a flexible price sector, covering unprocessed food and oil products, and one or more

sticky price sectors, as is for instance done in Aoki (2001), Álvarez, Burriel and Hernando (2005) or de Walque et al. (2004).

5. CONCLUSIONS

This paper makes available for the first time quantitative measures of the frequency and size of price adjustments within the euro area. To this end, we have taken advantage of the unique opportunity provided by the Inflation Persistence Network to bring together comparable figures characterizing price-setting practices for consumer goods and services.

Based on the analysis of a common sample of 50 products, several stylized facts have been found:

1. Prices change rarely. The frequency of price changes for the euro area is 15.1 p.c. and the average duration of a price spell ranges from 4 to 5 quarters. These figures mean that price adjustment in the euro area is considerably less frequent than in the US.

2. There is a marked degree of heterogeneity in the frequency of price changes across products. Specifically, price changes are very frequent for energy (oil products) and unprocessed food, while they are relatively infrequent for non-energy industrial goods and services.

3. Heterogeneity across countries is relevant but less important and is, to some extent, related to differences in the consumption structure and the statistical treatment of sales.

4. There is no evidence of a general downward rigidity in the euro area. In fact, price decreases are not uncommon, except in services. On average, 40 p.c. of the price changes are price reductions.

5. Price changes, either increases or decreases, are sizeable compared to the inflation rate prevailing in each country. The magnitude of price reductions is slightly higher than that of price increases.

6. Synchronization of price changes across price-setters does not seem to be large at the product level, even within the same country.

Some further common patterns of price adjustment data have been observed in the various country studies in this paper. In particular, there is some evidence of time dependency in price-setting behavior as the frequency of price changes exhibits seasonal patterns, even in sectors without marked seasonality in the demand and supply conditions. In particular, price changes mostly occur at the beginning of the year (especially in the services sector) and after the summer period.

Moreover, the hazard function of price changes in most euro area countries is characterized by mass points every 12 months. However, there are also strong indications of elements of state-dependent behavior as aggregate and sectoral inflation seem to affect the frequency of price changes. This impact is further strengthened when price increases and price decreases are analyzed separately. Additionally, some firms appear to respond quickly to shocks such as indirect tax rate and input price changes. This coexistence of firms with time and state dependent pricing strategies is also found in the national surveys on price setting summarized in Fabiani et al. (2005). Finally, national studies also show that firms temporarily increased their frequency of price changes around the euro-cash changeover period.

These findings are generally substantiated by a cross-country cross-section econometric analysis of the 50 products. First, inflation has a positive effect on the frequency of price increases and a negative effect on the frequency of price decreases. Second, inflation volatility has an impact on the frequency of price adjustment. Third, there is cross-product and cross-country heterogeneity even when controlling for differences in inflation and commercial practices (regulated prices, sales, attractive pricing). Cross-product heterogeneity is particularly important since there is a 74 p.p. difference between the frequency of price changes for oil products and that for services, which may be related to the heterogeneity in input price developments. Cross-country differences are less marked and the maximum spread, between Italy and Luxembourg, averages 15 p.p. at the product category level

The facts put forward in this paper provide a benchmark against which to assess and calibrate micro-founded price setting models in the euro area. In particular, results in this paper stress the importance of sectoral heterogeneity in price setting behavior. This suggests that developing macroeconomic models that consider explicitly such heterogeneity may also improve the understanding of economic fluctuations and inflation dynamics. In this respect, it seems worthwhile to build macroeconomic models with at least one sector with flexible price setting and one sector with sticky prices, as is done in Aoki (2001) or de Walque et al. (2004). Another interesting line of research does not identify *ex ante* the heterogeneous sectors but rather infers from micro data the composition of these sectors, as in Álvarez et al. (2005). These authors consider time dependent price setters, so a natural extension is to derive micro models also consistent with the available evidence on state dependent pricing strategies. Further research on micro price data, therefore, has to clarify whether the uncovered state-dependent features in price setting relate mainly to idiosyncratic or to macroeconomic developments. If idiosyncratic developments are important then it is interesting to examine to which extent they are transmitted to the aggregate level. In general, this research should assess, from a macro perspective, the quantitative importance of state-dependent relative to time-dependent features.

Further research should also study more thoroughly the available information regarding the size of the price changes. In particular, the link between the frequency of price changes and the size of the

changes should be examined in more detail. Moreover, a careful study of the distribution of price changes could address the question whether or not there are backward-looking features in the price-setting process.

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Technical appendix

1. The 50 products common sample

The common sample of 50 product categories is a stratified sample based on the following criteria.

First, the sample had to be representative of the different 2-digit COICOP (Classification Of Individual COnsumption by Purpose) categories, except for "Health Care Services" (COICOP 06) and "Education" (COICOP 10) since 8 countries out of 10 had no access to individual price reports for those two categories. Some goods or services (for instance housing rents, cars, electricity, gas, water and telecommunication services) were not taken into consideration either for similar reasons. This could somewhat bias upwards the estimates of the average frequencies of price changes for some sub-aggregates and for the total.[15] Note on the other hand that as we observe prices at a monthly frequency only, we miss intra-month price changes which biases downwards estimate of the frequency.

Second, for each COICOP category level, the sample had to be representative of the 5 main components of the CPI: unprocessed food (hereafter UNPF), processed food (hereafter PF), energy, non-energy industrial goods (hereafter NEIG) and services. Because of the restrictions mentioned in the first point, what is called energy only covers the price of oil products and what is called services does not cover heath care, educational or telecommunication services nor rentals.

Using the weights of the different COICOP categories in the euro area HICP in 2000, 50 product categories were randomly chosen within each stratum from the list of 7-digit COICOP product categories included in the Belgian CPI - base year 1996. Product categories that are not observed throughout the entire year by the statistical agency were not taken into account. The following table summarizes the structure of the stratified sample and presents the 50 selected product categories. If one of the selected individual products was not covered in a specific country, it was replaced by a similar product (e.g. hot-dog by hamburger).

As to the period covered for this investigation, it has already been mentioned that, even if full harmonization was not possible, it had been decided to focus on the period starting in January 1996 and not to include the period affected by the euro-cash changeover, since this could bias frequencies of price adjustment.

[15] On German data, Hoffmann and Kurz-Kim (2004) find that the frequency of changes in rents is significantly smaller than the frequency of price changes in most other services.

Structure and composition of the common sample

COICOP group	Type of product	Weight	Selected product categories
"01 Food and non-alcoholic beverages"	Unprocessed food	9.26 p.c.	Steak, 1 fresh fish, lettuce, banana,
	Processed food	9.64 p.c.	Milk, sugar, frozen spinach, mineral water, coffee
"02 Alcoholic beverages, tobacco and narcotics"	Processed food	4.7 p.c.	Whisky, beer in a shop
"03 Clothing and footwear"	Non-energy industrial goods	8.83 p.c.	Socks, jeans, sport shoes, shirt
	Services	0.27 p.c.	Dry cleaning (suit)
"04 Housing, water, electricity, gas and other fuels"	Energy	1.06 p.c.	Gasoline (heating purpose)
	Non-energy industrial goods	5.30 p.c.	Acrylic painting, cement
	Services	4.24 p.c.	Hourly rate of an electrician, hourly rate of a plumber,
"05 Furnishing, household equipment and routine"	Non-energy industrial goods	8.54 p.c.	Toaster, electric bulb, 1 type of furniture, towel
	Services	1.16 p.c.	Domestic services
"07 Transport"	Energy	4.75 p.c.	2 fuels
	Non-energy industrial goods	1.19 p.c.	Car tyre,
	Services	7.26	Hourly rate in a garage, car wash, balancing of wheels, taxi
"08 Communications"	Services	3.3 p.c.	Fax machine
"09 Recreation and culture"	Non-energy industrial goods	7.26 p.c.	Television set, dog food, tennis ball, construction game (Lego),
	Services	4.84 p.c.	Movie, videotape rental, photo development
"11 Restaurants and hotels"	Services	10.3 p.c.	Hotel room, glass of beer in a bar, 1 meal in a restaurant, hot-dog, cola based lemonade in a bar
"12 Miscellaneous goods and services"	Non-energy industrial goods	3.32 p.c.	Toothpaste, suitcase,
	Services	4.78 p.c.	Haircut (men), hairdressing (ladies)

Finally, it has to be mentioned that, in most countries, the database includes prices reported in both small and large urban areas, with the exception of the Italian database that refers only to large cities and the Spanish database (regional capital cities only).

2. The definition of a specific product and price trajectories

The amount of meta-data supplied with the price data differs across countries. In some databases, a specific code precisely identifies a specific item belonging to a broad product category that is sold in a specific outlet.[16] On the opposite, in some countries the only information available refers to a product category code that identifies a broad category of products such as "soft drinks" and an outlet code.[17] For these countries, in addition to the actual price changes, product replacements will

[16] For instance, a 25 cl soda can of brand X belonging to the "Soft drink" product category that is sold in outlet Y. This perfect identification of individual products was possible in Austria, Finland, France, Germany, Italy, the Netherlands.

[17] This is the case of the Portuguese and Spanish databases.

also be recorded as price changes when the price of the new product is different from the price of the old one. On the other hand, for countries where a complete identification of the product is available, the occurrence of a product replacement can be identified and considered distinctly from a price change.[18] For instance, in the case of the trajectory plotted in the upper-left panel of Figure 1, it is known that after January 2000 the specific pair of jeans model was no longer sold in the given outlet.

In order to compute frequencies of price changes that are comparable across countries, it has been decided to harmonize the treatment of product replacements. To do so, a distinction has been made between "forced" and "voluntary" product replacements.[19] We decided to impute a price change for each forced product replacement. The rationale is that the disappearance of the individual product (and its replacement) coincides with the end of the last price spell for that particular product. Overall, this methodological choice probably has a small positive impact on the frequency of price changes.

3. The treatment of seasonal sales

The statistical treatment of seasonal sales (for instance at the end of the winter or summer season) differs across countries. While sales prices (i.e. including the rebate) are reported in some countries,[20] prices reported during the sales period in other countries[21] are prices without the rebate. An illustration is provided by Figure 1: the price of the specific jeans in the case of France exhibits a price decrease that lasts for one month in July 1999, due to summer sales. It was not possible to control for these differences in national methodologies. Therefore, this difference in the treatment of seasonal sales may have some impact on both the frequency and the size of price changes, particularly for product categories such as clothing and footwear.

[18] The way price changes and product replacements are treated can have a considerable impact on the estimated frequency of price changes. Consider for example the case of a product that has a life cycle of one year and the price of which is kept constant during its entire selling period. For such a product, the frequency of price changes is equal to 0 p.c. if the occurrence of a product replacement is not considered as a price change, while it is equal to 8.33 p.c. (once every year) otherwise.

[19] For the computation of the CPI, statistical institutes follow the prices of specific products over time. When a consumer price index is defined (typically, during a base year), a stratified sample of products is drawn and is followed from month to month. However, some items may leave the sample because they are not sold anymore (product replacement) or because the outlets where they were sold close (outlet replacement). These items are replaced by new items. Such replacements are designated as "forced" replacements. Alternatively, the Statistical office can periodically revise its sample of products because the consumption habits have changed over time. These replacements are voluntary replacements.

[20] Austria, Finland, France, Luxembourg, the Netherlands and Portugal.

[21] Belgium, Germany, Italy and Spain. In Germany, only price cuts pre-empting the seasonal sales are observed.

4. Definition of the different statistical measures

We define P_{ijt} as the price at time t of the individual product sold in store i that belongs to product category j.

In order to characterize the price-setting behavior at the product category j level, the following variables are built:

- a binary variable indicating that Store i was observed in t and t-1.

$$x_{ijt} = \begin{cases} 1 & \text{if } P_{ijt} \text{ and } P_{ij,t-1} \text{ are observed} \\ 0 & \text{if } P_{ijt} \text{ exists but not } P_{ij,t-1} \end{cases}$$

- a binary variable indicating a price change in t[22]

$$y_{ijt} = \begin{cases} 1 & \text{if } P_{ijt} \neq P_{ij,t-1} \\ 0 & \text{otherwise} \end{cases}$$

- a binary variable indicating a price increase in t

$$y_{1ijt} = \begin{cases} 1 & \text{if } P_{ijt} > P_{ij,t-1} \\ 0 & \text{otherwise} \end{cases}$$

- a binary variable indicating a price decrease in t

$$y_{2ijt} = \begin{cases} 1 & \text{if } P_{ijt} < P_{ij,t-1} \\ 0 & \text{otherwise} \end{cases}$$

Using these 4 variables, the following indicators are defined:

- the frequency of price changes : $$F_j = \frac{\sum_{i=1}^{n_j} \sum_{t=2}^{\tau} y_{ijt}}{\sum_{i=1}^{n_j} \sum_{t=2}^{\tau} x_{ijt}}$$

where n_j represents the number of firms that sold a product belonging to product category j and t is the last month of observation of product category j.

[22] As mentioned in section 2, what is considered as a price change in this paper is either a price change or a forced product replacement.

- the frequency of price increases : $$F_j^+ = \frac{\sum_{i=1}^{n_j}\sum_{t=2}^{\tau} y_{1ijt}}{\sum_{i=1}^{n_j}\sum_{t=2}^{\tau} x_{ijt}}$$

- the frequency of price decreases : $$F_j^- = \frac{\sum_{i=1}^{n_j}\sum_{t=2}^{\tau} y_{2ijt}}{\sum_{i=1}^{n_j}\sum_{t=2}^{\tau} x_{ijt}}$$

The frequency of price changes represents the average share of prices that are revised in a given month. Similarly, the frequency of price increases (decreases) represents the average share of prices that rise (decrease) in a given month.

One can also compute the frequency of price changes at time t for product category j as

$$F_{jt} = \frac{\sum_{i=1}^{n_j} y_{ijt}}{\sum_{i=1}^{n_j} x_{ijt}}$$

Based on the frequency of price changes, we computed the average price duration at the product category j level under the assumption of continuous time:

$$\overline{T}_j = -\frac{1}{\ln(1-F_j)}$$

We also compute the average size of price increases and of price decreases as:

- average size of price increases: $$\overline{\Delta}_j^+ = \frac{\sum_{i=1}^{n_j}\sum_{t=2}^{\tau} y_{1ijt}\left(\ln P_{ijt} - \ln P_{ij,t-1}\right)}{\sum_{i=1}^{n_j}\sum_{t=2}^{\tau} y_{1ijt}}$$

- average size of price decreases: $$\overline{\Delta}_j^- = \frac{\sum_{i=1}^{n_j}\sum_{t=2}^{\tau} y_{2ijt}\left(\ln P_{ij,t-1} - \ln P_{ijt}\right)}{\sum_{i=1}^{n_j}\sum_{t=2}^{\tau} y_{2ijt}}$$

Finally, we compute the synchronization ratio proposed by Fisher and Konieczny (2000):

$$FK_j = \sqrt{\frac{1}{\tau - 1} \frac{\sum_{t==2}^{\tau} \left(F_{jt} - F_j\right)^2}{F_j\left(1 - F_j\right)}}$$

In the case of perfect synchronization, this index equals 1. In the case of perfect staggering, this ratio takes value 0.

5. Investigating the difference between the average of durations and the implied duration

Let us assume that the duration of price spells in an economy is distributed following a log-normal.

$$\log(D) \approx N\left(\mu, \sigma^2\right)$$

Therefore, the expected or average duration of the economy is given by $E[D] = e^{\mu + \frac{1}{2}\sigma^2}$

Using the simple relation between duration and frequency in discrete time, we can derive the distribution of the frequency of price changes in that particular economy.

$$f = \frac{1}{D}$$

Thus $$\log(f) = -\log(D)$$

which is distributed as $\log(f) \approx N\left(-\mu, \sigma^2\right)$

Therefore, the expected or average frequency of price changes of the economy is equal to $E[f] = e^{-\mu + \frac{1}{2}\sigma^2}$ which implies an inverse frequency of $\frac{1}{E[f]} = e^{\mu - \frac{1}{2}\sigma^2}$.

Comparing this implied duration with the average duration of the economy, the ratio of these two measures is an exponential function of the variance of the distribution of the duration of price spells.

$$\frac{E[D]}{\frac{1}{E[f]}} = \frac{e^{\mu + \frac{1}{2}\sigma^2}}{e^{\mu - \frac{1}{2}\sigma^2}} = e^{\sigma^2} \geq 1$$

Therefore, the average (implied) duration is always greater than the “pseudo-average” duration computed by inverting the average frequency of price change. The two concepts are only equal in

the case of an economy where all the sectors have the same average duration (in that case, $\sigma^2 = 0$). Otherwise, the average duration is always larger than what is implied by the inverse frequency.

As an illustration, in the log-normal example, if the variance of the distribution of duration is equal to unity, the average duration is close to 3 times higher than what is implied by the inverted frequency. Indeed, if $\sigma^2 = 1$, $E[D] = e\frac{1}{E[f]} \approx 2.7\frac{1}{E[f]}$.

Appendix: Country Results

Table A1: Frequency of price changes

	Unprocessed food	Processed food	Energy	Non energy industrial goods	Services	**Total**
at	37.5	15.5	72.3	8.4	7.1	15.4
be	31.5	19.1	81.6	5.9	3.0	17.6
de	25.2	8.9	91.4	5.4	4.3	13.5
es	50.9	17.7	0.0	6.1	4.6	13.3
fi	52.7	12.8	89.3	18.1	11.6	20.3
fr	24.7	20.3	76.9	18.0	7.4	20.9
it	19.3	9.4	61.6	5.8	4.6	10.0
lu	54.6	10.5	73.9	14.5	4.8	23.0
nl	30.8	17.3	72.6	14.2	7.9	16.2
pt	55.3	24.5	15.9	14.3	13.6	21.1
euro	**28.3**	**13.7**	**78.0**	**9.2**	**5.6**	**15.1**

Table A2: Frequency of price increases

	Unprocessed food	Processed food	Energy	Non energy industrial goods	Services	**Total**
at	18.6	7.6	35.9	3.4	4.7	7.8
be	16.8	10.3	43.0	3.4	2.9	9.8
de	13.1	4.0	48.7	3.3	3.3	7.7
es	26.6	9.9	0.0	4.2	4.1	8.0
fi	29.4	9.7	44.2	11.1	8.6	12.6
fr	12.8	10.6	44.7	5.3	5.2	10.5
it	10.0	4.9	33.1	2.9	3.3	5.6
lu	29.6	6.1	46.2	8.8	4.3	13.7
nl	16.8	10.7	30.3	8.2	6.4	9.5
pt	29.1	13.5	15.9	8.2	9.3	12.7
euro	**14.8**	**7.1**	**42.0**	**4.2**	**4.2**	**8.3**

Table A3: Frequency of price decreases

	Unprocessed food	Processed food	Energy	Non energy	Services	**Total**
at	18.0	7.3	36.3	2.7	1.7	6.4
be	15.0	8.7	38.7	2.5	0.3	7.9
de	12.1	4.9	42.7	2.1	1.0	5.8
es	24.2	7.8	0.0	1.9	0.4	5.2
fi	23.3	3.1	45.0	7.0	3.0	7.7
fr	11.2	8.5	32.2	6.4	1.1	7.8
it	8.8	2.7	27.5	0.9	0.7	3.1
lu	24.9	4.4	27.7	5.7	0.5	9.3
nl	13.9	6.6	42.3	6.0	1.5	6.7
pt	26.2	11.1	0.1	6.2	4.3	8.4
euro	**13.3**	**5.9**	**35.8**	**3.2**	**1.0**	**5.9**

Table A4: Size of price increases

	Unprocessed food	Processed food	Energy	Non energy	Services	**Total**
at	19.1	13.0	3.4	13.6	7.1	10.6
be	14.8	7.0	3.5	7.1	7.3	7.6
de	15.6	7.4	4.2	8.4	6.7	7.6
es	16.5	5.6	0.0	6.2	8.0	8.2
fi	17.4	3.9	4.2	13.6	8.3	9.4
fr	15.3	6.2	2.6	11.3	5.7	8.3
it	7.4	6.8	1.9	7.0	9.1	7.5
lu	16.5	9.0	5.1	9.7	7.0	10.0
nl	24.7	7.2	5.0	18.9	9.8	12.8
pt	16.7	6.6	4.5	11.0	8.7	10.1
euro	**14.7**	**6.9**	**3.4**	**9.4**	**7.3**	**8.2**

Table A5: Size of price decreases

size down	Unprocessed food	Processed food	Energy	Non energy	Services	**Total - 50 products**
at	18.9	13.6	3.0	17.8	11.8	13.9
be	15.8	7.6	2.9	8.3	6.4	7.8
de	17.2	10.0	2.7	9.8	8.6	9.1
es	17.2	6.2	0.0	8.2	10.5	10.0
fi	21.1	6.5	4.3	17.4	13.7	13.4
fr	17.7	6.6	2.1	15.2	9.3	11.0
it	8.0	6.3	1.5	7.0	11.5	8.5
lu	19.5	10.7	5.7	11.0	5.1	10.7
nl	28.7	10.2	3.2	23.6	10.1	14.8
pt	16.7	6.9	2.5	13.6	9.2	11.0
euro	**16.3**	**8.1**	**2.4**	**11.4**	**9.7**	**10.0**

Table A6: Synchronization Ratios

Synchronization Ratio	**min**	**median**	**max**
at	0.12	0.21	0.85
be	0.09	0.18	0.86
de	0.06	0.13	0.44
es	0.06	0.15	0.45
fi	0.16	0.36	1.00
fr	0.09	0.19	0.78
it	0.08	0.24	0.60
lu	0.19	0.48	1.00
nl	0.09	0.27	1.00
pt	0.11	0.17	0.90
euro	**0.08**	**0.18**	**0.62**

Synchronization ratios [Fisher and Konieczny (2000)] are calculated across the 50 products in the common sample.

Table A7: Data Description [1]

Variable	Description
Freq	Average frequency of price changes for each product category, calculated in each country. Product replacements, when available, are considered as price changes: this may result in Freq> (Freq_incr+Freq_decr) for some countries.
Freq_incr	Average frequency of price increases for each product category, calculated in each country.
Freq_decr	Average frequency of price decreases for each product category, calculated in each country.
size_incr	Average size of price increases for each product category, calculated in each country.
size_decr	Average size of price decreases for each product category, calculated in each country.
Infl_ave	Average of month-on-month inflation (approximated with the difference of log CPI), where the average is taken over each country sample
Infl_std	Standard deviation of month-on-month inflation (approximated with the difference of log CPI), where the average is taken over each country sample
Attractive	Share of "attractive and threshold prices" in the price quotes of product j. A price is defined to be attractive/threshold if its last figures are 0, 5, or 9 (this definition therefore includes psychological, fractional and exact prices). However, the definition of this variable can be tailored to each country to take into account of differences in the pre-euro currencies, or of the type of coins in circulation in each country (e.g. in Finland no 1 or 2 cents coins are in circulation).
Retail	Share of hypermarkets (or large chain-stores selling product j).
Sales	A dummy variable =0 if no sales are ever signaled for product j from the statistical institute, or are not believed to occur on the basis of some other indirect information, 1 otherwise.
Regulated	A dummy variable =1 if prices of product j are subject to some form of administrative control, 0 otherwise.

(1) See national studies [e.g. Baudry et al. (2004)] for a detailed description of the calculations of frequency and duration.

Table A8: Euro area product level statistics[1]

Product	Frequency of price change	Frequency of price increase	Frequency of price decrease	Average Price increase	Average price decrease
Steak	0.158	0.086	0.069	0.102	0.117
Fresh fish	0.419	0.221	0.197	0.145	0.147
Lettuce	0.768	0.384	0.384	0.313	0.322
Banana	0.462	0.239	0.222	0.181	0.198
Milk	0.111	0.063	0.044	0.060	0.077
Sugar	0.096	0.053	0.037	0.052	0.059
Frozen spinach	0.127	0.063	0.056	0.143	0.165
Mineral water	0.118	0.064	0.047	0.093	0.109
Coffee	0.223	0.099	0.119	0.098	0.099
Whisky	0.160	0.085	0.068	0.068	0.078
Beer in a shop	0.144	0.084	0.055	0.063	0.078
Socks	0.067	0.035	0.018	0.146	0.176
Jeans	0.076	0.040	0.026	0.114	0.134
Sport shoes	0.092	0.036	0.030	0.110	0.147
Shirt (men)	0.106	0.042	0.043	0.173	0.176
Dry cleaning	0.043	0.033	0.009	0.077	0.119
Acrylic painting	0.098	0.066	0.025	0.071	0.093
Cement	0.065	0.045	0.014	0.067	0.065
Hourly rate of an electrician	0.055	0.042	0.011	0.062	0.082
Hourly rate of a plumber	0.055	0.045	0.008	0.067	0.073
Heating oil	0.729	0.393	0.334	0.059	0.042
Toaster	0.078	0.028	0.031	0.070	0.087
Electric bulb	0.055	0.031	0.018	0.106	0.138
1 type of furniture	0.090	0.049	0.025	0.073	0.101
Towel	0.071	0.037	0.023	0.128	0.149
Domestic services	0.040	0.035	0.003	0.077	0.061
Fuel type 1	0.804	0.431	0.371	0.030	0.022
Fuel type 2	0.782	0.416	0.371	0.028	0.021
Car tyre	0.137	0.067	0.061	0.068	0.109
Hourly rate in a garage	0.079	0.064	0.013	0.059	0.081
Car wash	0.034	0.024	0.006	0.121	0.169
Balancing of wheels	0.093	0.067	0.021	0.073	0.142
Taxi	0.053	0.049	0.003	0.049	0.037
Fax machine	0.145	0.030	0.082	0.108	0.133
Television set	0.132	0.035	0.068	0.066	0.091
Dog food	0.098	0.048	0.041	0.092	0.118
Tennis ball	0.052	0.025	0.015	0.087	0.109
Construction game (Lego)	0.078	0.033	0.022	0.090	0.123
Movie	0.102	0.045	0.033	0.103	0.114
Videotape hiring	0.020	0.011	0.007	0.152	0.231
Photo development	0.036	0.023	0.010	0.104	0.107
Hotel room	0.078	0.051	0.023	0.084	0.113
Glass of beer in a café	0.045	0.036	0.006	0.086	0.085
1 meal in a restaurant	0.047	0.031	0.009	0.062	0.082
Hot-dog	0.039	0.028	0.005	0.106	0.132
Cola based lemonade in a café	0.030	0.024	0.004	0.087	0.091
Toothpaste	0.118	0.062	0.048	0.096	0.118
Suitcase	0.082	0.039	0.028	0.075	0.108
Haircut (men)	0.039	0.032	0.005	0.072	0.087
Hairdressing (ladies)	0.042	0.035	0.005	0.077	0.094

(1) Euro area statistics are obtained by aggregating product level figures obtained in each country, using country weights from the HICP weighting structure.
(2) The frequency of price changes may be higher than the sum of frequency of price increases and decreases, because of the treatment of product replacements (considered to be price changes).

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