DEUTSCHE BUNDESBANK
EUROSYSTEM

Technical Paper

Contributions to euro area inflation over arbitrary time periods

02/2026

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Internet http://www.bundesbank.de

DOI https://doi.org/10.71734/TP-2026-2

Non-technical summary

Research question

The inflation rate, as measured by the Harmonised Index of Consumer Prices (HICP), is the key measure of price stability in the euro area, and therefore helps to guide the monetary policy stance. For price analysis, identifying drivers of inflation is of key importance. This is usually achieved by calculating the contributions of individual products or sub-aggregates to inflation. In the literature, there are various approaches to calculating these contributions. Most of these approaches can be used to calculate contributions to price changes compared with the same month of the previous year. However, the HICP can be used to derive price changes over any arbitrary time period or on the basis of annual averages. This paper examines how such price changes can be decomposed into the contributions of individual products or sub-aggregates.

Contribution

Contributions of individual products or sub-aggregates to euro area inflation are calculated by the Statistical Office of the European Union (Eurostat) using the approach developed by Ribe in 1999. This approach can generally be applied to the annual change in the HICP (inflation rate), which is published monthly, but can also be used for monthly price changes. In addition, a method proposed by Brunetti in 2010 can be used to calculate contributions to annual change rates based on averages (quarterly and annual averages). This paper develops a generalisation of the methods of Ribe and Brunetti that allows contributions to change rates to be calculated for any arbitrary time period.

Results

The developed approach makes it possible to perform an exact decomposition of the HICP price change for any arbitrary period of time into the contributions of individual items or sub-aggregates. This is also true of price changes calculated on the basis of averages or over multiple years, and the method can generally be applied to annually chain-linked Laspeyres-type indices. The results of the empirical analyses show that services have been the main driver of inflation in the euro area since 2002. By contrast, food and energy prices made only moderate contributions. Prices for (non-energy) industrial goods contributed the least to the price change in the euro area, despite their relatively large weight. However, this relationship may change in shorter periods of high or low inflation.

Nichttechnische Zusammenfassung

Fragestellung

Die Inflationsrate, gemessen am Harmonisierten Verbrauchpreisindex (HVPI), stellt im Euroraum die zentrale Größe zur Messung von Preisstabilität dar und dient damit der Ausrichtung der Geldpolitik. Aus Sicht der Preisanalyse ist es von zentraler Bedeutung, Inflationstreiber zu identifizieren. Dies geschieht üblicherweise über die Berechnung von Inflationsbeiträgen einzelner Produkte oder Unteraggregate. Zur Berechnung dieser Beiträge existieren diverse Ansätze in der Literatur. Die meisten dieser Ansätze erlauben eine Berechnung von Beiträgen zur Preisveränderung gegenüber dem Vorjahresmonat. Preisveränderungen können allerdings auch über beliebig lange Zeiträume oder auf Jahresdurchschnitten basierend vom HVPI abgeleitet werden. In der vorliegenden Arbeit wird untersucht, wie sich solche Preisveränderungen in die Beiträge einzelner Produkte oder Unteraggregate zerlegen lassen.

Beitrag

Beiträge einzelner Produkte oder Unteraggregate zur Inflation im Euroraum werden vom Europäischen Statistikamt (Eurostat) unter Verwendung des Ansatzes von Ribe aus dem Jahr 1999 berechnet. Dieser Ansatz ist generell für die monatlich veröffentlichte Vorjahresveränderung (Inflationsrate) des HVPI anwendbar, kann aber auch auf die Preisveränderungen gegenüber dem Vormonat übertragen werden. Darüber hinaus ist es mittels einer Methode von Brunetti aus dem Jahr 2010 möglich, Beiträge zu Vorjahresveränderungsraten auf Basis von Durchschnittswerten (Quartals- und Jahresdurchschnitte) zu berechnen. In der vorliegenden Arbeit werden die Methoden von Ribe und Brunetti so verallgemeinert, dass Beiträge zu Veränderungsraten beliebig langer Zeiträume berechnet werden können.

Ergebnisse

Mittels des entwickelten Ansatzes ist es möglich, die am HVPI gemessene Preisveränderung für beliebige Zeiträume präzise in die Beiträge einzelner Positionen oder Unteraggregate zu zerlegen. Dies gilt auch für Preisveränderungen, die auf Basis von Durchschnittswerten bzw. über mehrere Jahre hinweg berechnet wurden, und lässt sich generell auf jährlich verkettete Laspeyres-Typ Indizes übertragen. Die Ergebnisse der empirischen Analysen zeigen, dass die Dienstleistungspreise seit 2002 am meisten zur Preisveränderung im Euroraum beitrugen. Preise für Nahrungsmittel und Energie wiesen hingegen nur moderate Beiträge auf. Preise für Industrieerzeugnisse (ohne Energie) lieferten trotz ihres relativ hohen Gewichtes den geringsten Beitrag zur Preisveränderung im Euroraum. In kürzeren Phasen hoher oder niedriger Inflation kann sich dieses Verhältnis jedoch ändern.

Contributions to euro area inflation over arbitrary time periods

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April 2026

Abstract

In the euro area, inflation is measured by the Harmonised Index of Consumer Prices (HICP). Contributions of specific products to the overall inflation rate are derived by what is known as the Ribe approach. While this approach can be applied to the monthly HICP indices, it cannot be used for the annual HICP averages published by statistical offices, nor can it be used to calculate contributions to inflation over multiple years. This paper develops a generalization of Ribe's approach that overcomes both limitations. For annually chain-linked Laspeyres-type indices and their quarterly and annual averages, the proposed method allows contributions to price changes to be derived over arbitrary time periods. The resulting contributions consistently sum to the overall price change. As such, the method provides a useful tool for long-term monetary policy analysis. An application to HICP data shows that services have been the main driver of inflation in the euro area since 2002.

Keywords: chain index · HICP · inflation measurement · Ribe approach

JEL classification: E31 · C43

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Acknowledgements: The authors wish to thank Thomas Knetsch (Deutsche Bundesbank) for helpful comments. Any shortcomings are our own. The views expressed in this paper are solely those of the authors and do not necessarily reflect the views of the Deutsche Bundesbank or the European Commission (Eurostat).

1 Motivation

In the euro area, inflation is measured by the annual percentage change of the Harmonised Index of Consumer Prices (HICP). For analytical purposes, the drivers of inflation are of great importance (e.g. Ferrara, 2019; Höynck et al., 2025). However, as the sample of products underlying the HICP and their weights are updated annually, this is not a trivial exercise. Ribe (1999) developed an approach to derive the contributions of the products' price changes to the monthly and annual inflation rates. The statistical office of the European Union (Eurostat) publishes the contributions to annual inflation in the euro area according to this approach each month (Eurostat, 2024, Section 11.5.1).

In addition, Eurostat and many national statistical offices disseminate annual averages of the monthly HICP. However, Ribe's (1999) approach cannot be used to properly derive the contributions to the annual average change rates. As a solution, Brunetti (2010) proposed a generalization of the formulas underlying Ribe's (1999) approach to include arbitrarily defined averages within a calendar year. The results of Ribe (1999) and Brunetti (2010) thus make it possible to calculate contributions to the annual change rates derived from the monthly HICP as well as to corresponding annual (and quarterly) average change rates. What is still lacking in the literature, however, is a method to derive the contributions to the period-to-period *average* change rates (e.g. from one quarter to the next) and to inflation over longer periods (e.g. of several years).

Several related studies exist in the literature but none of them fills these gaps. For indices that are linked in each period to the previous one, Rentzsch (2019, Section 3.2) proposes a method to derive the contributions to the percentage change in arbitrary time intervals. The results for such "continuously chain-linked" indices, however, cannot be applied to the annually chain-linked HICP. Walschots (2016) compares Ribe's (1999) approach with a method formerly used by Eurostat to quantify the impact of individual products on the annual inflation rate.[1] The author highlights that the individual contributions derived by Ribe's (1999) approach consistently add up to the overall annual inflation rate. The Consumer Price Index Manual (IMF et al., 2025, pp. 53-55) presents an alternative exact decomposition in which a product's contribution is based on its annual change rate and weight. While more directly interpretable, this approach requires an additional parameter capturing the effect of annual weight changes to ensure exactness. Another approach is provided by the "Kirchner contributions", which, unlike the Ribe contributions, are not exact but have a direct interpretation (Eurostat, 2024, p. 280). For a given component, the Kirchner contributions are defined as the difference between the overall price change and a hypothetical one in which the component's price change is kept constant.

[1] Although not explicitly mentioned, it can be easily shown that Eq. (2) in Walschots (2016) corresponds to the formulas underlying Ribe's (1999) approach.

Two further studies may have been motivated by the observation that "there seems to be a trace of double counting" (Balk, 2018, p. 74) in Ribe's (1999) approach, since the contributions for the current year seem to be impacted by the price change in the previous year.[2] They propose alternatives to decompose the annual inflation rate of annually chain-linked indices. Balk (2006) develops a decomposition of the logarithm of the annual percentage change, where the contributions are solely based on their individual price changes and weights. While this approach is exact for the overall logarithmic price change, it is only approximate for the published inflation rate. Similarly, de Haan and Akem (2017) propose a logarithmic decomposition for the Australian consumer price index. The authors note, however, that the contributions of the products to the overall annual inflation rate do not necessarily add up to the contribution of their higher-level aggregates.

In this paper, we develop a framework for deriving the contributions to the overall price change over any arbitrary time interval. The underlying formulas include the formulas of Ribe's (1999) approach and its generalization developed by Brunetti (2010) as special cases. Our method can be applied to annually chain-linked Laspeyres-type indices of monthly frequency, such as the HICP, as well as to quarterly and yearly averages derived from these indices. It ensures that the contributions can be consistently added up to the overall percentage price change. We further show that our method can be similarly used for annually chain-linked Laspeyres-type indices of quarterly frequency like the European house price index (HPI) and owner-occupied housing price index (OOHPI).

The remainder of the paper is organized as follows. In Section 2, we introduce our method formally and relate the underlying formulas to those of Ribe's (1999) approach. In Section 3, we apply our method to publicly available HICP data. We derive the contributions of food, energy, non-energy industrial goods and services to the overall price change in the euro area. We show that services were the main driver for inflation since 2002. Section 4 concludes.

2 Method

The HICP is an annually chain-linked Laspeyres-type price index. The overall index in month m of year y, $P(y,m)$, is based on the price indices of the underlying products i ($i = 1, \dots, N$) in the same month, $P_i(y,m)$, and their weights, $w_i(y,0)$.[3] The weights are updated each year using expenditures from the national accounts and other data sources. They are expressed in terms of the price reference period 0, which is December of the

[2] In Appendix A, we present an alternative notation for the contribution formulas, which shows that double counting is eliminated if weights are adjusted to previous year's prices.

[3] The price indices $P(y,m)$ and $P_i(y,m)$ express the price level of month m in year y relative to the one of a common index reference period. Since this index reference period is not relevant for our derivations, we exclude it from the notation.

previous year. The following relation between the overall index and the sub-indices of the products holds:

$$P(y,m) = P(y,0)\left[\sum_{i=1}^{N} w_i(y,0)\,\frac{P_i(y,m)}{P_i(y,0)}\right] , \tag{1}$$

where the weights add up to one in each period, that is, $\sum_{i=1}^{N} w_i(y,0) = 1$. The weighted average in squared brackets measures the overall price change in the current period relative to the price reference period. To obtain the overall index in month m of year y, $P(y,m)$, it is multiplied (or "chained") with the overall index of the price reference period, $P(y,0)$.

Many statistical offices publish quarterly or yearly averages of the chained overall index, $P(y,m)$, and the chained sub-indices, $P_i(y,m)$. For the formal definition of such an average index, we introduce the following notation. We define the current period within a calendar year, λ, based on the index frequency, ϕ, as

$$\lambda = \begin{cases} m & \text{if } \phi = \text{monthly} \\ q & \text{if } \phi = \text{quarterly} \\ \cdot & \text{if } \phi = \text{yearly} , \end{cases} \tag{2}$$

where m ($m = 1,\ldots,12$) and q ($q = 1,\ldots,4$) refer to a specific month and quarter of a year. For yearly frequencies, $\lambda = \cdot$ indicates that no sub-periods exist within a year. In the same way, we define period τ, which must have the same frequency as λ.

Following this notation, we define the average index in period λ of year y, $\overline{P}(y,\lambda)$, as

$$\overline{P}(y,\lambda) = \frac{1}{L}\sum_{m} P(y,m) , \quad \text{with } L = \begin{cases} 1 & \text{if } \phi = \text{monthly} \\ 3 & \text{if } \phi = \text{quarterly} \\ 12 & \text{if } \phi = \text{yearly} , \end{cases} \tag{3}$$

where λ is given by Eq. (2). Hence, the average index in year y, $\overline{P}(y,\cdot)$, is based on the twelve monthly observations relating to that year. Similarly, the average index in quarter q of year y, $\overline{P}(y,q)$, is based on the three monthly observations belonging to that quarter. As the monthly average index relies on only one observation, it simplifies to $\overline{P}(y,m) = P(y,m)$. We denote the average sub-indices of the products as $\overline{P}_i(y,\lambda)$.

The inflation rate in an arbitrary time interval, $\pi^{b(\tau)\to y(\lambda)}$, can be derived from the average index in the current period λ of year y compared to period τ of the base year b.[4] In Appendix A, it is shown that it can be additively decomposed into the contributions, $C_i^{b(\tau)\to y(\lambda)}$, of the individual products i ($i = 1,\ldots,N$):

$$\pi^{b(\tau)\to y(\lambda)} = \frac{\overline{P}(y,\lambda)}{\overline{P}(b,\tau)} - 1 = \sum_{i=1}^{N} C_i^{b(\tau)\to y(\lambda)} \tag{4}$$

[4] The base year b refers to the first year of the considered time interval. In general, $b < y$ must hold. For monthly and quarterly frequencies, $b = y$ is also allowed, provided that $\tau < \lambda$.

The contribution of each product depends on the time interval over which the inflation rate is calculated. It is the sum of one or multiple terms,

$$C_i^{b(\tau)\to y(\lambda)} = \begin{cases} I_i^y & \text{if } y = b \\ B_i^b + T_i^y & \text{if } y - b = 1 \\ B_i^b + \sum\limits_{k=1}^{y-b-1} M_i^{b+k} + T_i^y & \text{if } y - b > 1 \ , \end{cases} \tag{5}$$

where the *base-year term*, B_i^b, captures product i's contribution to the price change in the base year, b. The *intra-year term*, I_i^y, and *this-year term*, T_i^y, quantify the contribution to the price change in the current year, y. Their distinction is needed because the price change within this year can be measured either from the price reference period or a later period. The *mid-year terms*, M_i^{b+k}, measure the contributions to the calendar years in between the base year b and the current year y. The terms are defined as

$$B_i^b = w_i(b,\tau) \left(\frac{P_i(b{+}1,0)}{\overline{P}_i(b,\tau)} - 1 \right) \tag{6a}$$

$$M_i^{b+k} = w_i(b{+}k,0)\, \frac{P(b{+}k,0)}{\overline{P}(b,\tau)} \left(\frac{P_i(b{+}k{+}1,0)}{P_i(b{+}k,0)} - 1 \right) \tag{6b}$$

$$T_i^y = w_i(y,0)\, \frac{P(y,0)}{\overline{P}(b,\tau)} \left(\frac{\overline{P}_i(y,\lambda)}{P_i(y,0)} - 1 \right) \tag{6c}$$

$$I_i^y = w_i(b,\tau) \left(\frac{\overline{P}_i(y,\lambda)}{\overline{P}_i(b,\tau)} - 1 \right) \ , \tag{6d}$$

where $P(y,0)$ and $P_i(y,0)$ refer to the *monthly* index values in the price reference period, irrespective of the frequency ϕ. The price-updated weight of product i, $w_i(b,\tau)$, is given by

$$w_i(b,\tau) = w_i(b,0)\, \frac{\overline{P}_i(b,\tau) \big/ P_i(b,0)}{\overline{P}(b,\tau) \big/ P(b,0)} \ . \tag{7}$$

The price updating ensures that the weights refer to the price reference period of the corresponding price relatives. The sum of the weights equals one, that is, $\sum_{i=1}^{N} w_i(b,\tau) = 1$ (see Appendix A).

Formula (5) can be used to derive the contributions of an individual product to the overall inflation rate for any arbitrary time interval. For multi-annual inflation rates covering more than two years ($y - b > 1$), the overall contribution of a product includes *mid-year terms* measuring the product's contribution to years between the base year and the current year. Eq. (6b) shows that these terms span from one price reference period to the next, which is the only annual change rate in the HICP that is unaffected by changes in the weights (e.g. Knetsch et al., 2025, Section 3.1; Ståhl, 2025, Section 3.2).

For annual inflation rates ($y - b = 1$), *mid-year terms* do not exist by definition. If the annual inflation rate is derived from the monthly HICP, $\pi^{y-1(m)\to y(m)}$, the *base-year term* simplifies to what is known in the literature as the *last-year term* (Eurostat, 2024, Section 8.6.3). The definition of this term as well as the definition of the *this-year term* coincide with those underlying Ribe's (1999) approach. If the annual inflation rate is derived from the yearly average of the HICP, $\pi^{y-1(\cdot)\to y(\cdot)}$, the two terms match Brunetti's (2010) derivations (see Appendix A). For price changes within a year ($y = b$), there is no *base-year term*. The contributions are solely derived from the *intra-year term*. Although the monthly change rate in January, $\pi^{y-1(12)\to y(1)}$, spans two years, its *base-year term* simplifies to zero.[5]

The overall price change in Eq. (4) is the sum of the contributions of all products ($i = 1, \ldots, N$). The contribution of an individual product in Eq. (5) is the sum of one or multiple terms measuring the impact of a specific year on this product's contribution. For periods of more than one year, formulas (6a), (6b) and (6c) reveal that this impact is zero if the price change or weight is zero in the respective year.[6] Hence, product i's contribution to the overall price change is zero if its price index does not change over the complete period. By contrast, if there are changes in between, product i's contribution could deviate from zero even if the price index is the same in the current and base periods, $\overline{P}_i(y, \lambda) = \overline{P}_i(b, \tau)$. According to Formula (6d), a change rate of zero during the year indicates that the contribution to the overall inflation must also be zero.

Formulas (6a), (6b) and (6c) further show that it is not possible to sum the contributions of several shorter periods to receive the contribution of the entire period, since the *base-year term* and the *this-year term* of the subperiods would then have to be equal to the *mid-year terms* of the entire period. This is not true, since the *mid-year terms* span from one December to the next, whereas the *base-year term* and the *this-year term* do not. Even the *mid-year terms* of subperiods differ from those of the overall period as they depend on the yearly average of a base year b which differs for each subperiod.[7]

Formula (5) can be used regardless of whether the change rates were derived from the monthly chain-linked index or its quarterly or yearly average. Moreover, formula (5) can be similarly used for annually chain-linked indices of quarterly frequency and annual averages derived from such indices. Prominent examples are the European HPI and OOHPI, where the fourth quarter of the previous year acts as the price reference period $(y, 0)$. In such cases, it is only the definition of the average index in Eq. (3) that must be

[5] This is not true for the quarterly average change rate in the first quarter, $\pi^{y-1(4)\to y(1)}$, which is based on two different sets of weights and thus includes both the *base-year term* and the *this-year term*.

[6] Products that are newly introduced or removed from the sample would have a zero weight before or afterwards.

[7] The first subperiod would be an exception having the same base year as the overall period and thus the same value for $\overline{P}(b, \tau)$.

adjusted to:

$$\overline{P}(y,\lambda) = \frac{1}{L}\sum_{q} P(y,q)\ , \quad \text{with } L = \begin{cases} 1 & \text{if } \phi = \text{quarterly} \\ 4 & \text{if } \phi = \text{yearly}\ , \end{cases} \tag{8}$$

where the annual average index in year y, $\overline{P}(y,\cdot)$, is based on the four quarterly observations relating to that year. The quarterly average index corresponds to the initial quarterly index, i.e. $\overline{P}(y,q) = P(y,q)$.

3 Application

In the previous section, we developed a method to derive the contributions of an individual product or sub-aggregate to the overall inflation rate for an arbitrary period. In this section, we apply this method to publicly available HICP data for the euro area.[8] We derive the contributions of food (including alcohol and tobacco), energy, non-energy industrial goods and services to the overall price change of the annual average index of the euro area. Given that these four "special aggregates" of the HICP constitute the overall index, their contributions should add up to the overall inflation rate. The data available for the euro area special aggregates allow an analysis starting in 2002.

We begin with a long-term analysis from 2002 to 2025. The second column of Table 1 contains the contributions of the four aggregates to the overall price change of 61.8% in this period. With 26.8 percentage points (more than 40%), services contributed the most to this price change. This finding is not surprising as services also have the largest weight of the four aggregates. By contrast, though non-energy industrial goods possess the second largest weight, they made the smallest contribution to the overall price change with 7.6 percentage points (less than 15%). Energy (nearly 20%) contributed almost as much as food (more than 25%), even though the weight accounted for food is roughly twice as high.

Aggregate	**2002-2025**	**2007-2009**	**2013-2016**	**2021-2023**
Food, alcohol & tobacco	16.6	1.1	0.5	4.3
Energy	10.8	0.2	-1.5	3.6
Non-energy industrial goods	7.6	0.4	0.2	2.6
Services	26.8	1.9	1.7	3.7
All-items HICP	61.8	3.6	0.9	14.3

Table 1: Inflation in the euro area measured by the annual average HICP (in %) and the contributions of its four main aggregates (in percentage points).

[8] For the analysis, we use the monthly HICP indices (https://doi.org/10.2908/PRC_HICP_MINR), annual average indices (https://doi.org/10.2908/PRC_HICP_AINR) and item weights (https://doi.org/10.2908/PRC_HICP_IW) for the euro area floating composition.

Following Eq. (5), each contribution reported in the second column of in Table 1 is the sum of one *base-year term* for 2002, multiple *mid-year terms* for the years 2003 to 2024 and one *this-year term* for 2025. Each term thus quantifies the *impact* of a year on the aggregates' overall contribution, which makes it possible to identify dominant periods and changes over time.[9] Figure 1 depicts the terms for the four special aggregates as coloured bars.[10]

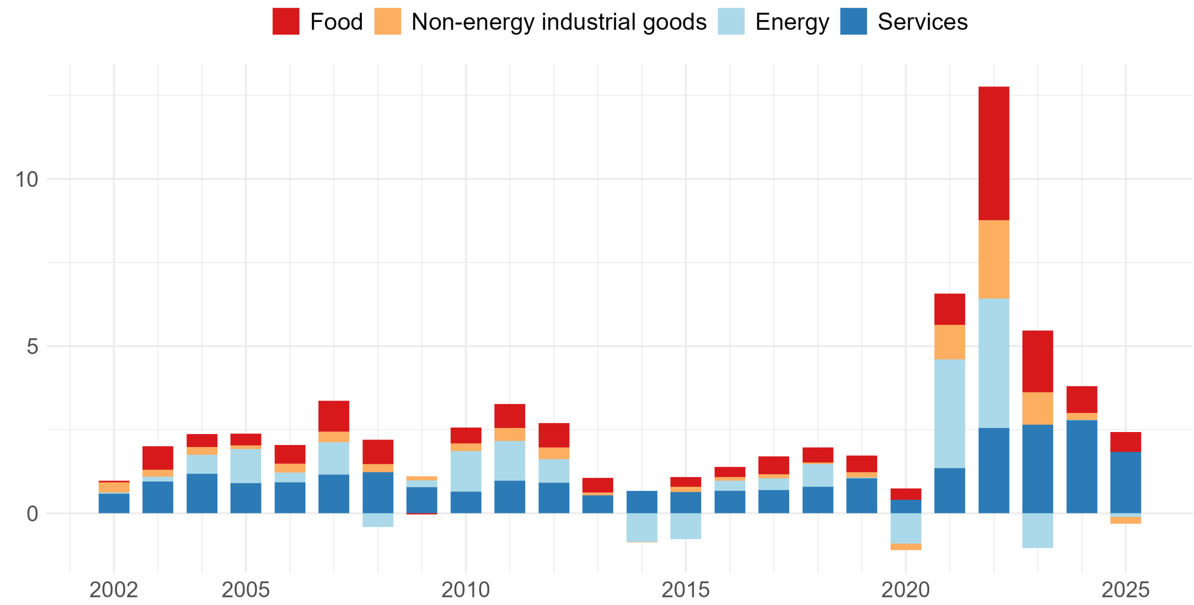

Figure 1: *Base-year*, *mid-year* and *this-year terms* underlying the contribution of the HICP's four main aggregates (in percentage points) to the overall annual average price change in the euro area between 2002 and 2025 as reported in Table 1.

Without exception, services positively impacted the overall price change in all years. Its largest impacts can be observed in the most recent years. Food had very small negative impacts in only two years. The more volatile energy prices, however, show noticeable negative impacts in six years but also extraordinarily large positive ones in 2021 and 2022. Except for these two years, the impacts of non-energy industrial goods were relatively small over the entire period.

Table 1 shows that the contributions of the four aggregates calculated with our approach sum exactly to the overall price change of 61.8% between 2002 and 2025. So far, an intuitive though only approximate approach would have involved summing the contributions to the annual average change rates for each year in the period from 2003 to 2025. This approach may provide a reasonable approximation for shorter periods. However, for the period from 2002 to 2025, the "approximated" contributions of the four aggregates would have deviated on average by -3.2 percentage points from those reported in

[9] It is worth noting that the terms depend on the considered time period. Changing the base year of the time period would therefore also change the terms for the remaining years.

[10] Adding up all bars would yield the overall price change of 61.8% between 2002 and 2025 as reported in Table 1, while adding up the bars of a specific colour would give the contribution of the corresponding aggregate to this price change.

Table 1. Moreover, they would have summed up to only a 49.0% increase in prices. This comparison demonstrates the necessity of an exact derivation of the contributions.

As highlighted by our analysis, contributions to inflation depend on the underlying period and must therefore be separately derived for any considered time interval. In Table 1, results are reported for three additional, but shorter, periods of particular economic interest: a period covering the financial crisis (2007–2009), a period of low inflation after the euro area sovereign debt crisis (2013–2016) and a period of high inflation after the COVID-19 pandemic (2021–2023).

In the financial crisis period, the overall price change between 2007 and 2009 amounted to 3.6% in the euro area. With a contribution of 1.9 percentage points, more than half of the inflation in this period can be attributed to services, while energy prices had virtually no impact (0.2 percentage points). In the low inflation period from 2013 to 2016, prices increased by only 0.9%. The extraordinarily high negative contribution of energy (-1.5 percentage points) in this period, was primarily outweighed by services (1.7 percentage points), which again had the highest contribution among the four aggregates. During the high inflation period from 2021 to 2023, prices in the euro area rose about 14.3%, with food having the largest contribution of 4.3 percentage points. Services contributed roughly a quarter to this overall price change, which was relatively low in comparison to the long-term period. Energy contributed to a similar extent, even though its weight of around one-tenth was noticeably lower.

4 Conclusions

The annual percentage change of the HICP is the key indicator for inflation in the euro area. It can be decomposed into the contributions of the underlying products using Ribe's (1999) approach. The contributions to the annual change rate derived from the average HICP can be calculated according to a method proposed by Brunetti (2010). In this paper, we developed a generic framework including these two approaches as special cases. For annually chain-linked Laspeyres-type indices, our method can be used to derive the contributions to the overall price change from any month or quarter of one year to any month or quarter of the same or another year, even if the years are not consecutive (e.g. from April 2023 to May 2025). It can be similarly applied to the change rates derived from the average indices published by statistical offices (e.g. annual averages of HICP, HPI, or OOHPI). The resulting contributions consistently add up to the overall price change.

Applying our method to HICP data for the euro area shows that services have been the main driver of inflation since 2002. This also applies to the financial crisis and low inflation periods. In the low inflation period, the inflation rate was largely affected by energy prices, which made an extraordinarily strong negative contribution. In the high inflation period, the contribution of services was relatively small, while that of food and energy increased. Prices for non-energy industrial goods played a minor role in all considered periods. Although the analysis is based on the annual average HICP, it still required the original monthly indices. This "additional" data requirement stems from the chain-linking of the HICP over December of the previous year, which must be properly considered in the calculations. It generally applies to the derivation of contributions to the *average* change rates of such annually chain-linked indices.

In the HICP, price indices are gradually aggregated through all higher levels of the European Classification of Individual Consumption according to Purpose (ECOICOP) into the overall index using the Laspeyres-type formula. In the paper, we derived the contributions to the price change of this overall index. Since the Laspeyres-type formula is consistent in aggregation (e.g. Mehrhoff, 2011), it is similarly possible to derive the contributions of lower-level indices (e.g. milk) to the price change of their respective higher-level aggregate (e.g. food). In this case, it is only the weights that need to be normalized such that their sum equals one.

A Derivations

In this appendix, we derive the formulas presented in Section 2. We adopt the same notation as in the main text. In Section A.1, we derive a product's contribution to the overall price change within one year ($b = y$). In Section A.2, we derive a product's contribution to the overall price change spanning more than two years ($y - b > 1$). We show that the contribution to the price change spanning exactly two years ($y - b = 1$) can be directly derived from these results. In Section A.3, we further show that Ribe's (1999) contributions to the annual change rate as well as Brunetti's (2010) contributions to the annual average change rate are special cases of our derivations. In Section A.4, we provide an alternative presentation of our contribution formulas. For the mathematical derivations, we first introduce the following useful equations.

Following Eq. (3), the average index in period τ of year b, $\overline{P}(b,\tau)$, can be written as

$$\begin{aligned}\overline{P}(b,\tau) &= P(b,0)\,\frac{1}{L}\sum_{m}\frac{P(b,m)}{P(b,0)}\\ &= P(b,0)\sum_{i=1}^{N} w_i(b,0)\,\frac{\overline{P}_i(b,\tau)}{P_i(b,0)}\;,\end{aligned} \tag{A.1}$$

with $\sum_{i=1}^{N} w_i(b,0) = 1$. The weights, $w_i(b,0)$, could be adjusted to the prices of period τ in year b and, subsequently, normalized with their sum according to

$$w_i(b,\tau) = \frac{w_i(b,0)\,\frac{\overline{P}_i(b,\tau)}{P_i(b,0)}}{\sum\limits_{j=1}^{N} w_j(b,0)\,\frac{\overline{P}_j(b,\tau)}{P_j(b,0)}}\;, \tag{A.2}$$

with $\sum_{i=1}^{N} w_i(b,\tau) = 1$. From Eq. (A.1), it follows that the denominator in Eq. (A.2) can be replaced with $\overline{P}(b,\tau)/P(b,0)$, which yields

$$w_i(b,\tau) = w_i(b,0)\ \frac{\overline{P}_i(b,\tau)\Big/P_i(b,0)}{\overline{P}(b,\tau)\Big/P(b,0)}\ . \tag{A.3}$$

A.1 Price changes within one year

For the inflation rate within one year ($y = b$), the average indices, $\overline{P}(y,\lambda)$ and $\overline{P}(b,\tau)$, in Eq. (4) can be replaced with their definitions in Eq. (A.1):

$$\begin{aligned}
\pi^{b(\tau)\to y(\lambda)} &= \frac{P(y,0)\ \sum\limits_{i=1}^{N} w_i(y,0)\ \frac{\overline{P}_i(y,\lambda)}{P_i(y,0)}}{P(b,0)\ \sum\limits_{i=1}^{N} w_i(b,0)\ \frac{\overline{P}_i(b,\tau)}{P_i(b,0)}} - 1 \\
&= \frac{\sum\limits_{i=1}^{N} w_i(b,0)\ \frac{\overline{P}_i(y,\lambda)}{P_i(b,0)}}{\sum\limits_{i=1}^{N} w_i(b,0)\ \frac{\overline{P}_i(b,\tau)}{P_i(b,0)}} - 1 \\
&= \sum_{i=1}^{N} \underbrace{\frac{w_i(b,0)\ \frac{\overline{P}_i(b,\tau)}{P_i(b,0)}}{\sum\limits_{j=1}^{N} w_j(b,0)\ \frac{\overline{P}_j(b,\tau)}{P_j(b,0)}}}_{=w_i(b,\tau)}\ \frac{\overline{P}_i(y,\lambda)}{\overline{P}_i(b,\tau)} - 1 \\
&= \sum_{i=1}^{N} w_i(b,\tau)\frac{\overline{P}_i(y,\lambda)}{\overline{P}_i(b,\tau)} - 1\ ,
\end{aligned} \tag{A.4}$$

where $w_i(y,0)$, $P_i(y,0)$ and $P(y,0)$ were replaced with $w_i(b,0)$, $P_i(b,0)$ and $P(b,0)$ in the second step. Since $\sum_{i=1}^{N} w_i(b,\tau) = 1$, the contribution of product i to the overall inflation rate, $\pi^{b(\tau)\to y(\lambda)}$ (with $y = b$) follows from the last line of Eq. (A.4) as:

$$C_i^{b(\tau)\to y(\lambda)} = w_i(b,\tau)\left(\frac{\overline{P}_i(y,\lambda)}{\overline{P}_i(b,\tau)} - 1\right)\ . \tag{A.5}$$

A.2 Price changes spanning more than two years

The inflation rate spanning more than two years ($y - b > 1$) can be expressed as the multiplicative product of the price changes in the base year b, the current year y, and the years in between:

$$\begin{aligned}
\pi^{b(\tau)\to y(\lambda)} &= \frac{\overline{P}(y,\lambda)}{\overline{P}(b,\tau)} - 1 \\
&= \frac{P(b+1,0)}{\overline{P}(b,\tau)} \frac{P(b+2,0)}{P(b+1,0)} \cdots \frac{P(y,0)}{P(y-1,0)} \frac{\overline{P}(y,\lambda)}{P(y,0)} - 1 \\
&= \frac{P(b+1,0)}{\overline{P}(b,\tau)} \left(\prod_{k=1}^{y-b-1} \frac{P(b+k+1,0)}{P(b+k,0)} \right) \frac{\overline{P}(y,\lambda)}{P(y,0)} - 1 \ .
\end{aligned} \tag{A.6}$$

Adding $\sum_{k=1}^{y-b} \frac{P(b+k,0)}{\overline{P}(b,\tau)}$ and $-\sum_{k=1}^{y-b} \frac{P(b+k,0)}{\overline{P}(b,\tau)}$ to the right-hand side of Eq. (A.6), allows us to rewrite it as a sum:

$$\begin{aligned}
\pi^{b(\tau)\to y(\lambda)} &= \underbrace{\left(\frac{P(b+1,0)}{\overline{P}(b,\tau)} - 1 \right)}_{B^b} \\
&\quad + \sum_{k=1}^{y-b-1} \underbrace{\left(\frac{P(b+k+1,0)}{P(b+k,0)} - 1 \right) \frac{P(b+k,0)}{\overline{P}(b,\tau)}}_{M^{b+k}} \\
&\quad + \underbrace{\left(\frac{\overline{P}(y,\lambda)}{P(y,0)} - 1 \right) \frac{P(y,0)}{\overline{P}(b,\tau)}}_{T^y} \\
&= B^b + \sum_{k=1}^{y-b-1} M^{b+k} + T^y \ .
\end{aligned} \tag{A.7}$$

For the derivations of the terms, B^b and T^y, we replace the average indices, $\overline{P}(y,\lambda)$ and $\overline{P}(b,\tau)$, in Eq. (A.7) with their definitions in Eq. (A.1). For the derivation of the term M^{b+k}, we replace $P(b+k+1,0)$ in Eq. (A.7) with its definition in Eq. (1). As a result, we receive

$$
\begin{aligned}
B^b &= \frac{P(b,0)\sum\limits_{i=1}^{N} w_i(b,0)\frac{P_i(b+1,0)}{P_i(b,0)}}{P(b,0)\sum\limits_{i=1}^{N} w_i(b,0)\frac{\overline{P}_i(b,\tau)}{P_i(b,0)}} - 1 \\
&= \sum_{i=1}^{N} \underbrace{\frac{w_i(b,0)\ \frac{\overline{P}_i(b,\tau)}{P_i(b,0)}}{\sum\limits_{j=1}^{N} w_j(b,0)\ \frac{\overline{P}_j(b,\tau)}{P_j(b,0)}}}_{=w_i(b,\tau)} \frac{P_i(b+1,0)}{\overline{P}_i(b,\tau)} - 1 \qquad \text{(A.8a)} \\
&= \sum_{i=1}^{N} w_i(b,\tau)\frac{P_i(b+1,0)}{\overline{P}_i(b,\tau)} - 1 \\
M^{b+k} &= \frac{P(b+k,0)}{\overline{P}(b,\tau)}\left(\sum_{i=1}^{N} w_i(b+k,0)\frac{\overline{P}_i(b+k+1,0)}{P_i(b+k,0)} - 1\right) \qquad \text{(A.8b)} \\
T^y &= \frac{P(y,0)}{\overline{P}(b,\tau)}\left(\sum_{i=1}^{N} w_i(y,0)\frac{\overline{P}_i(y,\lambda)}{P_i(y,0)} - 1\right) . \qquad \text{(A.8c)}
\end{aligned}
$$

Since $\sum_{i=1}^{N} w_i(b,\tau) = \sum_{i=1}^{N} w_i(y,0) = 1$, the contribution of product i to the overall inflation rate, $\pi^{b(\tau)\to y(\lambda)}$ (with $y-b>1$), follows from Eqs. (A.8a), (A.8b) and (A.8c) as

$$
\begin{aligned}
C_i^{b(\tau)\to y(\lambda)} &= \underbrace{w_i(b,\tau)\left(\frac{P_i(b+1,0)}{\overline{P}_i(b,\tau)} - 1\right)}_{=B_i^b} \\
&\quad + \sum_{k=1}^{y-b-1} \underbrace{w_i(b+k,0)\frac{P(b+k,0)}{\overline{P}(b,\tau)}\left(\frac{\overline{P}_i(b+k+1,0)}{P_i(b+k,0)} - 1\right)}_{=M_i^{b+k}} \\
&\quad + \underbrace{w_i(y,0)\frac{P(y,0)}{\overline{P}(b,\tau)}\left(\frac{\overline{P}_i(y,\lambda)}{P_i(y,0)} - 1\right)}_{=T_i^y} \qquad \text{(A.9)} \\
&= B_i^b + \sum_{k=1}^{y-b-1} M_i^{b+k} + T_i^y .
\end{aligned}
$$

Taking the sum over all products i ($i = 1, \ldots, N$) in Eq. (A.9), gives

$$
\begin{aligned}
\sum_{i=1}^{N} C_i^{b(\tau)\to y(\lambda)} &= B^b + \sum_{k=1}^{y-b-1} M^{b+k} + T^y \\
&= \pi^{b(\tau)\to y(\lambda)} .
\end{aligned} \qquad \text{(A.10)}
$$

Hence, the sum of the products' contributions equals the overall inflation rate.

It can be easily shown that the contributions to inflation rates spanning two years

$(y-b=1)$ can be directly derived from Eq. (A.9).[11] Since there are no years between the base year and the current year, the sum $\sum_{k=1}^{y-b-1} M_i^{b+k}$ in Eq. (A.9) is empty and, thus, by definition, zero. Consequently, the contribution of product i to the overall inflation rate, $\pi^{b(\tau)\to y(\lambda)}$ (with $y-b=1$) is

$$C_i^{b(\tau)\to y(\lambda)} = B_i^b + T_i^y \ ,$$

where B_i^b in Eq. (A.9) can be rewritten as

$$B_i^b = w_i(b,\tau)\left(\frac{P_i(y,0)}{\overline{P}_i(b,\tau)} - 1\right) \ ,$$

since $b = y-1$.

A.3 Special cases

For the prominent case of the annual percentage change, $\pi^{y-1(m)\to y(m)}$, we replace $\overline{P}(b,\tau)$ with $P(y-1,m)$, $\overline{P}_i(b,\tau)$ with $P_i(y-1,m)$ and $\overline{P}_i(y,\lambda)$ with $P_i(y,m)$ in the previous definitions of B_i^b and T_i^y. As a result, we receive

$$\begin{aligned} B_i^b &= w_i(y-1,m)\left(\frac{P_i(y,0)}{P_i(y-1,m)} - 1\right) \\ T_i^y &= w_i(y,0)\frac{P(y,0)}{P(y-1,m)}\left(\frac{P_i(y,m)}{P_i(y,0)} - 1\right) \ , \end{aligned}$$

which are the formulas underlying Ribe's (1999) approach (see also Eurostat, 2024, Section 8.6.3).

For the annual average percentage change, $\pi^{y-1(\cdot)\to y(\cdot)}$, we can further show that B_i^b and T_i^y coincide with the formulas derived by Brunetti (2010). Inserting Eq. (4) of this paper in Eq. (6) gives

$$\begin{aligned} C_i^{y-1(\cdot)\to y(\cdot)} &= \frac{\sum_{m=1}^{12} \frac{P(y-1,m)}{P(y-1,0)} \left(C_i^{y(0)\to y(m)} \frac{P(y,0)}{P(y-1,m)} + C_i^{y-1(m)\to y(0)}\right)}{\sum_{m=1}^{12} \frac{P(y-1,m)}{P(y-1,0)}} \\ &= \frac{\sum_{m=1}^{12} P(y-1,m) \left(C_i^{y(0)\to y(m)} \frac{P(y,0)}{P(y-1,m)} + C_i^{y-1(m)\to y(0)}\right)}{\underbrace{\sum_{m=1}^{12} P(y-1,m)}_{=12\overline{P}(y-1,\cdot)}} \\ &= \frac{1}{12}\sum_{m=1}^{12} \frac{P(y,0)}{\overline{P}(y-1,\cdot)} C_i^{y(0)\to y(m)} + \frac{1}{12}\sum_{m=1}^{12} \frac{P(y-1,m)}{\overline{P}(y-1,\cdot)} C_i^{y-1(m)\to y(0)} \ . \end{aligned} \tag{A.11}$$

[11] This case relates to the annual inflation rate and the price change from the first period of the current year to the last period of the previous year.

Following Eq. (2) in Brunetti (2010), $C_i^{y(0)\to y(m)}$ and $C_i^{y-1(m)\to y(0)}$ are defined as

$$C_i^{y(0)\to y(m)} = w_i(y,0)\left(\frac{P_i(y,m)}{P_i(y,0)} - 1\right) \tag{A.12a}$$

$$C_i^{y-1(m)\to y(0)} = w_i(y-1,0)\frac{P_i(y-1,m)\big/P_i(y-1,0)}{P(y-1,m)\big/P(y-1,0)}\left(\frac{P_i(y,0)}{P_i(y-1,m)} - 1\right) . \tag{A.12b}$$

Inserting Eqs. (A.12a) and (A.12b) in Eq. (A.11) yields after some transformations

$$C_i^{y-1(\cdot)\to y(\cdot)} = w_i(y-1,m)\left(\frac{P_i(y,0)}{\overline{P}_i(y-1,\cdot)} - 1\right) + w_i(y,0)\frac{P(y,0)}{\overline{P}(y-1,\cdot)}\left(\frac{\overline{P}_i(y,\cdot)}{P_i(y,0)} - 1\right) ,$$

where the first term on the right-hand side of the equation corresponds to the *base-year term* and the second term to the *this-year term* in Eqs. (6a) and (6c) for yearly frequencies (i.e. $\lambda = \cdot$).

A.4 Alternative formula notation

The *mid-year* and *this-year* terms, M_i^{b+k} and T_i^y, in Eq. (A.9) both include the overall price change from period τ of base year b to the price reference period. With respect to Ribe's (1999) approach, Balk (2018, p. 74) therefore noted that "there seems to be a trace of double counting". However, a different notation of the formulas underlying these terms reveals that the consideration of the overall price change can be understood as some form of "price-backdating" the weights of each year to the prices of period τ of the base year b. The price-backdated weights can be defined as:

$$\begin{aligned} w_i^{b(0)\to b(\tau)} &= w_i(b,0)\frac{\overline{P}_i(b,\tau)\big/P_i(b,0)}{\overline{P}(b,\tau)\big/P(b,0)} \\ w_i^{b+k(0)\to b(\tau)} &= w_i(b+k,0)\frac{\overline{P}_i(b,\tau)\big/P_i(b+k,0)}{\overline{P}(b,\tau)\big/P(b+k,0)} \\ w_i^{y(0)\to b(\tau)} &= w_i(y,0)\frac{\overline{P}_i(b,\tau)\big/P_i(y,0)}{\overline{P}(b,\tau)\big/P(y,0)} . \end{aligned} \tag{A.13}$$

As a consequence, the *base-year term*, the *mid-year term* and the *this-year term* in Eq. (A.9) can be rewritten to:

$$
\begin{aligned}
B_i^b &= w_i^{b(0)\to b(\tau)} \frac{P_i(b+1,0) - \overline{P}_i(b,\tau)}{\overline{P}_i(b,\tau)} \\
M_i^{b+k} &= w_i^{b+k(0)\to b(\tau)} \frac{P_i(b+k+1,0) - P_i(b+k,0)}{\overline{P}_i(b,\tau)} \\
T_i^y &= w_i^{y(0)\to b(\tau)} \frac{\overline{P}_i(y,\lambda) - P_i(y,0)}{\overline{P}_i(b,\tau)} \,.
\end{aligned}
\tag{A.14}
$$

Hence, each term is defined by its price-backdated weight multiplied with the partial price change in the considered year.

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