Dynamics of price level changes in the Visegrad group: comparative study

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Abstract

In Poland, as in many other countries, to measure inflation, expressed both by the CPI and HICP, the Laspeyres price index with weights from the base period is used. Thus calculated index does not take into account changes in the consumption structure which are caused by changes in prices in the analysed time interval (i.e.: a year). Therefore, in countries where the CPI is determined based on the Laspeyres index, there is a high probability of its bias due to substitution of goods, but not only. The value of the CPI or HICP should approximate the real inflation as accurately as possible, among others, because these indicators are used to index nominal values in the economy, which in turn is important in price decisions made by enterprises. Searching for an answer to the question about the possibility of effective reduction of the measurement bias in measuring inflation, the authors conducted an empirical study whose main aim was to assess diversity of the level of inflation in the Visegrad countries at different levels of aggregation, with particular emphasis on the scale of the bias in measuring inflation resulting from substitution of goods. The study concentrated on determining the size of differences arising from the change in the index formula used when estimating the level of inflation. The article consists of six parts in which sources and types of bias in inflation measurement are discussed, index formulas divided into weighted and unweighted ones are reviewed, statistics on inflation in the Visegrad countries are presented in a dynamic approach, and the results of empirical research are presented and discussed. For the purpose of the research part and the need to perform a comparative analysis, data on the HICP value from the Eurostat database from the years 2011–2018 were used. Therefore, it seems that both the choice of the calculation formula and the level of data aggregation in the analysis of inflation is significant in its estimates.

Keywords Consumer Price Index (CPI) · Harmonised Index of Consumer Prices (HICP) · Inflation · Price indices · Visegrad group

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1 Introduction

The Consumer Price Index (CPI) is one of the best known and most frequently used inflation measures in modern economics (see White 1999). The CPI is a narrowly targeted inflation indicator and focuses on a specific segment of the general price level in the economy. Determining the index level is based solely on the prices of goods and services purchased by consumers. This results in omitting the prices of investment goods and those purchased by entrepreneurs. Due to its primary purpose (measuring changes in the cost of living), the Consumer Price Index (CPI) approximates changes in the cost of household consumption/household living [COLI, *Cost of Living Index*, (Diewert 2004)]. The reason why the CPI should best approximate real inflation is the fact that the index is used to adjust (index) the nominal values in the economy, which in turn is important in price decisions made by enterprises (Hałka and Leszczyńska 2011). The CPI is an important indicator affecting the behaviour of business entities (Jedruchiewicz 2015) and households. In the case of enterprises, the rate and variability of inflation play an important role in long-term investment plans and capital allocation (Kwiatkowski 2019; Roszko-Wójtowicz et al. 2019), which in the long run helps to achieve broader economic goals, contributing to overall political stability. The significance of the CPI in the monetary policy is particularly important in the case of countries in which the central bank uses the strategy of direct inflation targeting (DIT) (Szyszko and Tura 2015; Janus 2019). It is a strategy in which the central bank of the country determines the level of inflation in a given period and its priority is to achieve this level (Walsh 2009). In Poland, it has been in force since 1998, and from the beginning the Consumer Price Index (CPI) has been the reference index. The current value of the inflation target for Poland was set in 2004 by the Monetary Policy Council at the level of 2.5% with the possibility of deviation to one percentage point up or down (Sławiński 2011). The adoption of the DIT strategy means that central banks assume an obligation to ensure a stable level of prices in the economy. The adoption of the DIT strategy means that central banks are not bound by any additional intermediate goals, such as the amount of interest rates, the amount of money in the economy or the exchange rate, but they are free to react to changes and make decisions relevant to the situation. It is worth noting that there may be numerous differences between CPI indices functioning at the level of individual countries, methodological and in terms of the content of the basket of goods. Therefore, they are not suitable for international comparisons. The Harmonised Index of Consumer Prices (HICP) was created on the initiative of the European Central Bank (ECB), dedicated to measuring inflation in the euro area countries. Each euro area country must use the same methodology imposed by the HICP standards, which guarantees comparability between countries (Pažický 2018). HICP values obtained from the Member States also form the basis for the global price dynamics index across the EU, i.e. the Monetary Union Index of Consumer Prices (MUICP). Let us add that the index formula here is the monthly chained Laspeyres-type index with the month December as the linking month. It should be noted that in some countries, when comparing the CPI and the HICP, differences in the composition of the inflation basket can be observed. For example, in Poland, games of chance (gambling) are included in the CPI but not in the HICP, while foreigners' expenditures normally included in the HICP calculation are not included in the Polish CPI basket. Finally, there are also countries where there is no difference in the composition of the CPI and HICP baskets

(these measures are the same)—such countries are e.g. the UK and Bulgaria. Guided by the credibility and international comparability of analyses conducted at the level of V4 countries, the authors decided to use Eurostat data, i.e. data on the HICP. It does not change the fact that the CPI is better embedded in the theory of the cost of living index (COLI), and the methodology for estimating the bias of inflation measurement is developed for the needs of CPI as a standard.

The main aim of the article, which consists of four specific objectives, is to assess diversity of inflation levels in the Visegrad countries at different levels of aggregation, with particular emphasis on the scale of the bias in measuring inflation due to substitution of goods.

Aim 1 Assessment of sensitivity of the bias to a change in the level of data aggregation within which inflation estimates were made.

Aim 2 Determining the size of differences arising from the change of the index formula used when determining the level of inflation.

Aim 3 Determining whether a change in the level of data aggregation within the adopted formula significantly affects the estimated value of inflation.

Aim 4 Presentation of the scale of differences in the measurement/rate of inflation at the COICOP 2 level measured by the CPI and HICP.

The following formulated research hypotheses correspond to the aims described above.

H1 Frequent updating of weights in the CPI basket in the V4 countries effectively reduces the bias of inflation estimates for substitution of goods.

H2 The level of bias in inflation measurement due to substitution of goods varies depending on the adopted level of data aggregation.

H3 The level of annual inflation, regardless of the adopted price index formula, significantly differs depending on the level of COICOP aggregation adopted for analysis.

H4 In the case of Poland, inflation measured by the HICP is lower than inflation measured by the CPI.

The paper consists of six sections, including the Introduction and Conclusions. The subsequent parts of the paper discuss sources and types of bias in inflation measurement, provide a review of index formulas broken down into weighted and unweighted ones, present statistical data on inflation in the Visegrad countries in a dynamic approach and the results of empirical research along with their discussion. A critical literature review was conducted to determine the impact of the formulas used on the emergence of the bias. In the paper, for the purpose of the empirical research, data from the Eurostat database and from the allegro.pl portal were used.

2 Sources and types of bias in inflation measurement: theoretical approach

In Poland, as in many other countries, the Laspeyres price index with baseline weights, which are calculated as the share of expenditures on particular goods in the total expenditure of all households in the previous year, is used to determine the CPI index (Hałka and Leszczyńska 2011). The choice of this kind of weights is determined, in part, by the ease of calculation and the availability of data. Statistical Office (Statistics Poland) updates the weights used in measuring inflation once a year. Such a practice leads to a reduction of the CPI index bias, at least for substitution of goods (CPI substitution bias), but it does not reduce it to zero. The obvious observation is that the index determined by the Laspeyres formula does not take into account changes in the consumption structure

which are caused by changes in prices in the examined time period (in this case, a year). Thus, in countries where the CPI index is determined on the basis of the Laspeyres index, there is a high probability of its bias, among others, due to substitution of goods, but not only. Most often the Laspeyres index overestimates the real inflation level (von der Lippe 2007), due to the fact that in the case of a negative price-quantity correlation (the most frequently observed situation in the basket of CPI goods and services), the value of this index is higher than the Fisher index value, treated as a very good approximation of COLI (White 1999; Pollak 1998). Most researchers dealing with the inflation measurement issue mention five potential sources of CPI index bias (White 1999; Consumer Price Index Manual. Theory and Practice 2004; Hałka and Leszczyńska 2011), or reduce this number to four (see the Boskin Commission Report (Boskin et al. 1996), examining the CPI index in the USA). Generally, every time the paper discusses the CPI bias, we understand this phenomenon as the difference between the CPI measurement result that we would obtain in the ideal measurement (i.e. assuming full access to price data and the volume of consumption of the entire inflation basket in any research period and with complete information about new goods, new outlets and consumer migration) and the result that we obtain in practice due to the reasons described in Fig. 1. In the literature, however, there is no universal and commonly accepted definition of CPI bias, just like there is no index formula that would be unanimously recognised by all statisticians and economists as the best.

Commodity substitution bias

- The reason for the emergence: changes in the prices of consumer goods or services to which consumers respond with the change of shopping preferences. Thus, they transfer their expenditure from relatively more expensive goods to relatively cheaper ones; weights from the base period in the index formula do not take into account these changes.

Outlet substitution bias

- The reason for the emergence: consumer migrations towards more attractive, more modern and newly emerging shopping markets (e.g.: resignation from traditional purchases in favour of purchases made on line).

New goods bias

- The reason for the emergence: launching new goods into the market which consumers started to use in the period of inflation measurement (e.g.: new technologies).

Quality adjustment bias

- The reason for the emergence: change in the quality of goods and services offered by the market and growing expectations of customers-consumers as to the utility of purchased goods.

Formula bias (also called elementary index bias)

- The reason for the emergence: application of a specific calculation method at the lowest level of aggregation.

Fig. 1 Types of CPI bias and the reasons for their formation. *Source:* Own elaboration based on: (Lloyd 1975; Ducharme 1997; White 1999; Hausman 2003; CPI Manual 2004; Boskin 2005; von der Lippe 2007; Hałka and Leszczyńska 2011; Consumer Price Index Manual 2020)

3 Index formulas

Pal Köves, in his work (1983), presented a proposal for classification of indices pointing to three so-called “generations of indices.” **The first** generation comprises simple, or unweighted, indices which include the Dutot, Carl or Jevons indices (von der Lippe 2007). The imperfection of unweighted index formulas resulted from the impossibility of their application to the assessment of price dynamics in an inhomogeneous basket of goods whose consumed quantities were expressed in different units. As a consequence, many economists have proposed their own ideas for weighing the price of goods in the basket, and thus many formulas have been created: the Laspeyres (1871), Drobisch (1871) or Sidgwick (1883), Paasche (1874), Palgrave (1886), Marshall (1887) and Edgeworth (1887), Walsh (1901), Fisher (1922), Törnqvist (1936), or Geary (1958) and Khamis (1970) formulas. **The second** index generation is a set of formulas that can be obtained by using weighted versions of the arithmetic, geometric or harmonic mean of the prices p_i^t or the price relations p_i^t/p_i^s . Fisher (1922) distinguished four basic methods of weighing. These are methods based on (a) the base period (weights take the form $p_i^s q_i^s$), (b) the period considered (weights take the form $p_i^t q_i^t$), or (c) mixed methods (weights take the form $p_i^s q_i^t$ or $p_i^t q_i^s$). This index group includes the Laspeyres and Paasche indices. **The third** and last generation of indices encompasses those indices that can be obtained, among others, by calculating the mean (without indicating a specific type of mean) or by using a combination of second generation indices. This group includes superlative indices, such as the Fisher index (1922) or the Törnqvist index (1936), as well as symmetrical indices, such as the Marshall-Edgeworth index or the Geary-Khamis index. Formulas of symmetrical indices have good axiomatic properties (Von der Lippe 2007). Further, the Marshall-Edgeworth (1887) and the Geary-Khamis (1958) price indices differ from the Walsh formula (1901) only with respect to the type of mean of quantities used. Nevertheless, the most recommended index formulas for the CPI measurement are *superlative* price indexes, firstly proposed by Diewert (1976). Superlative indices are symmetrical (conversion of quantity vectors from the base and studied periods does not affect the value of the index) and provide close approximations of cost of living indices (White 1999; von der Lippe 2007). A superlative index is defined technically as “an index that is exact for a flexible functional form that can provide a second-order approximation to other twice-differentiable functions around the same point” (Diewert 1976). All superlative indices produce similar results, i.e. they approximate each other under some quite natural conditions (Diewert 1976) and are generally the favoured formulas for calculating price indices (CPI Manual 2004). Please note that each superlative index is symmetrical but even symmetrical index does not have to be the superlative one (for instance, the Marshall-Edgeworth price index is “only” a symmetrical index formula but it is not superlative).

The table presents selected index formulas, with the list of weighted indices being limited to those used in the empirical part of this paper (Table 1).

It is also worth mentioning that in the axiomatic price index approach, a proper index should satisfy a group of “tests” (Fisher 1922; Balk 1995). Systems of minimum requirements of an index come from Martini (1992), Eichhorn and Voeller (1976) and Olt (1996). There is an agreement among statisticians that a good price index formula should satisfy the commensurability test which means that the index is not sensitive to change of the price unit. Therefore, from a methodological point of view, when using a well-constructed price index, it does not matter whether the components of the CPI

Table 1 Comparison of weighted index formulas. *Source:* own elaboration based on the publications listed in the table in the last column

Index name	Mathematical formula	Source
Non-symmetrical weighted price index formulas		
The Laspeyres price index	$P_{La}^{0,t} = \frac{\sum_{i \in G_{0,t}} p_i^t q_i^0}{\sum_{i \in G_{0,t}} p_i^0 q_i^0}$	Laspeyres (1871)
The Paasche price index	$P_{Pa}^{0,t} = \frac{\sum_{i \in G_{0,t}} p_i^t q_i^t}{\sum_{i \in G_{0,t}} p_i^0 q_i^t}$	Paasche (1874)
Symmetrical weighted price index formulas		
The Marshall-Edgeworth price index	$P_{ME}^{0,t} = \frac{\sum_{i \in G_{0,t}} p_i^t \left(\frac{q_i^0 + q_i^t}{2} \right)}{\sum_{i \in G_{0,t}} p_i^0 \left(\frac{q_i^0 + q_i^t}{2} \right)}$	Marshall (1887), Edgeworth 1887
The Geary Khamis price index	$P_{GK}^{0,t} = \frac{\sum_{i \in G_{0,t}} p_i^t \left(\frac{q_i^0 + q_i^t}{q_i^0 + q_i^t} \right)}{\sum_{i \in G_{0,t}} p_i^0 \left(\frac{q_i^0 + q_i^t}{q_i^0 + q_i^t} \right)}$	Geary (1958) – Khamis (1972)
Superlative weighted price index formulas		
The Fisher price index	$P_F^{0,t} = \sqrt{P_{La}^{0,t} \cdot P_{Pa}^{0,t}}$	Fisher (1922)
The Törnqvist price index	$P_T^{0,t} = \prod_{i \in G_{0,t}} \left(\frac{p_i^t}{p_i^0} \right)^{\frac{q_i^0 + q_i^t}{2}}$	Törnqvist (1936)
The Walsh price index	$P_W^{0,t} = \frac{\sum_{i \in G_{0,t}} p_i^t \sqrt{q_i^0 q_i^t}}{\sum_{i \in G_{0,t}} p_i^0 \sqrt{q_i^0 q_i^t}}$	Walsh (1901)

basket are expressed in PLN, EUR or other currency applicable on the territory of a given country. All price index formulas we consider meet the commensurability test (Von der Lippe 2007).

4 Statistical data

4.1 Data collection

The paper is based on data on the level of inflation expressed using the HICP available in the Eurostat database. Data on HICP values were collected for individual levels of aggregation—COICOP 2, COICOP 3 and COICOP 4—along with their corresponding weights. Thus, it was possible to compare substitution bias effects at different levels of aggregation using different index formulas and to formulate general conclusions from statistical analyses conducted. The choice of data also resulted from the fact that the HICP in all the Member States, including the V4 countries, is determined on the basis of the same methodology, which is a definite advantage from the point of view of international comparisons conducted in the paper. The analyses on the substitution bias effect were carried out on the basis of data for the period 2010–2018. The inflation dynamics in individual countries of the Visegrad group was presented at the aggregation level COICOP 2 based on data from the period 2005–2018. The choice of the period of analyses and aggregation levels was dictated by the availability of data in the Eurostat database.

In the context of the analyses, it should be added that CPI baskets from individual countries usually do not differ significantly from the accepted, obligatory HICP basket. For example, in Poland, when calculating the CPI, games of chance (COICOP 09.4.3) are taken into account, which the HICP does not do, while expenses of foreigners are included only in the HICP. However, these are really subtle differences. We should also add that despite their popularity, the CPI and HICP are not the only measures of inflation. Some countries categorise the standard CPI basket by modifying it. For example, the US Statistical Office (Bureau of Labor Statistics – BLS) uses also additional indices: the CPI-U (CPI for all Urban Consumers) or the CPI-W (CPI for Urban Wage Earners and Clerical Workers), i.e. consumers and employees in urban areas are treated separately. In the literature, one can also find a chain version of the CPI, i.e. the C-CPI-U (Chained Price Index for all Urban Consumers). Similarly to the United States, other countries used or continue to use their own local inflation measures. Another example is Great Britain, where until 2013 the Statistical Office officially used the RPI (Retail Price Index), which was supposed to apply to all retail trade. Currently, this index is still used, although on a much smaller scale (e.g. it is used to assess the dynamics of prices of rented dwellings), and it was replaced by the RPIJ. Both the RPI and RPIJ include prices in their baskets that are not included in the “standard” CPI, such as mortgage, home insurance and land rent costs. There exists also the CPIH, which additionally includes owner occupier’s housing costs (OOH), but it does not meet international standards, as is the case with the CPI, and thus is rather local and only applicable to Great Britain. Indicators such as core inflation or the GDP deflator are also considered measures of inflation. When determining core inflation, the “traditional” CPI basket is reduced, among others, by removing food and energy prices as well as administratively determined prices. In turn, the GDP deflator has a much broader basket of goods compared to the CPI basket, taking into account all categories of expenditure (consumption, investments, government expenditure, and net exports). A more detailed discussion of the differences between the HICP and CPI is provided in the next part of the paper.

4.2 Comparison of the HICP and the CPI

Both the Consumer Price Index (CPI) and the Harmonised Index of Consumer Prices (HICP) measure the change over time in the prices of a fixed basket of consumer goods and services acquired by households in a given country. The CPI is calculated as a weighted average of prices of goods and services contained in a statistical (representative) basket purchased by households in a given country. The disadvantage of this approach is the fact that in each country the basket has a different composition, which may affect the conducting of comparative analyses on an international basis. Statistical institutions deal with measuring inflation in most countries. In Poland, the Central Statistical Office (Statistics Poland) measures inflation every month, recording prices of PLN 240,000 products and services. CSO pollsters once a month register prices of products from the basket in shops, at marketplaces, in restaurants, hotels, or on the Internet. Prices of goods such as vegetables and fruits are recorded twice a month, and prices of fuel—every day. It should also be mentioned that the prices of shoes and books are collected via the Internet. In total, CSO pollsters observe prices of 1400 goods and services in 35,000 outlets throughout Poland.

The HICP is compiled by Eurostat in cooperation with national statistical institutes in accordance with harmonised statistical methods. The term “harmonised” denotes the fact that all the countries in the European Union follow the same methodology, which is the advantage that the HICP has over the CPI. Differences between the HICP and the

CPI come down primarily to the composition (content) of the statistical basket. The composition of the CPI basket is determined according to the methodology used by the Central Statistical Office (CSO – Statistics Poland) and is based on the results of analysis of household budgets conducted by the CSO. The guidelines for the construction of a basket of consumer goods and services forming the basis for the calculation of the HICP result from the unified Eurostat methodology. Such an approach eliminates discrepancies resulting from the application of various methodologies for creating a basket of goods and ensures that the data recorded for one country can be compared with the data obtained for another country. It should be emphasised, however, that there is no uniform basket which applies to all Member States. The HICP, apart from measuring consumer price inflation, is also used in assessing whether a country is ready to join the euro area.

The HICP is a measure of inflation in which the structure of consumption is determined on the basis of data from the System of National Accounts. It shows the change in consumption costs in the current year in relation to consumption costs (possibly with a different structure) in the base year. It is likely that the cost structure in consumption in the current year will not be the same as the cost structure in the audited year. Households monetary expenditures express their consumption patterns and determine weights attached to each category of goods and services covered by the Harmonised Index of Consumer Prices. determine. The relative importance of household monetary expenditures, expressed by their consumption patterns, determine weights attached to each category of goods and services covered by the Harmonised Index of Consumer Price.

The impact on the index of any price change is proportional to the corresponding weight. The structure of the weights may vary between the average weighting structure of the EU or the euro area and the HICP for an individual Member State. At the same time, considerable differences in weights might be recorded from country to country. HICP item weights are updated each year by the national statistical institutes using data from national accounts, household budget surveys and other administrative sources. Country weights for HICPs are derived from national accounts data for household final monetary consumption expenditure. For the euro area, they reflect household final monetary consumption expenditure, expressed in Euros, while for the other EU and European Economic Area countries, the amounts are expressed in purchasing power standard (PPS) (Table 2).

Comparison of the Consumer Price Index (CPI) and the Harmonised Index of Consumer Prices (HICP) regarding both the indices values and weights at the COICOP 2 level is presented in Tables 3 and 4. The conducted comparison shows that there are significant discrepancies between the CPI and HICP, both in terms of weights and in the level of inflation itself. It is worth noting that the comparison was carried out only at a two-stage level of aggregation, yet the differences are very clear. In the CPI methodology, food and non-alcoholic beverages have a much greater impact on the final level of inflation. The difference in weights between the CPI and HICP in 2018 was as much as 5.52 p.p. The situation was similar with regard to the use of housing, water, electricity, gas and other fuels as well as communications. In the HICP methodology, much more attention is given to other goods and services as well as transport. The values of CPI and HICP indices at the COICOP 2 level are also not the same. At the two-level level of aggregation, inflation expressed by the HICP is higher than that expressed by the CPI only for alcoholic beverages and tobacco products, clothing and footwear, the use of housing, water, electricity, gas and other fuels as well as furnishings, household equipment and routine household maintenance.

Table 2 Inflation measurement according to the COICOP levels of aggregation—the number of aggregates. *Source:* own elaboration based on Eurostat metadata

CODE	COICOP 2	COICOP 3	COICOP 4	COICOP 5
CP01	Food and non-alcoholic beverages	2 aggregates	11 aggregates	61 aggregates
CP02	Alcoholic beverages, tobacco and narcotics	3 aggregates	5 aggregates	14 aggregates
CP03	Clothing and footwear	2 aggregates	6 aggregates	12 aggregates
CP04	Housing, water, electricity, gas and other fuels	5 aggregates	15 aggregates	25 aggregates
CP05	Furnishings, household equipment and routine household maintenance	6 aggregates	12 aggregates	40 aggregates
CP06	Health	3 aggregates	7 aggregates	14 aggregates
CP07	Transport	3 aggregates	14 aggregates	28 aggregates
CP08	Communications	3 aggregates	3 aggregates	11 aggregates
CP09	Recreation and culture	6 aggregates	20 aggregates	54 aggregates
CP10	Education	5 aggregates	5 aggregates	6 aggregates
CP11	Restaurants and hotels	2 aggregates	3 aggregates	6 aggregates
CP12	Miscellaneous goods and services	7 aggregates	15 aggregates	33 aggregates

Table 3 Weights assigned to specific product groups at the COICOP 2 level—comparison of HICP and CPI in the year 2017 and 2018. *Source:* own elaboration based on Eurostat data and data of the Central Statistical office in Poland

Components – weights	2017			2018		
	HICP	CPI	Difference (p.p.)	HICP	CPI	Difference (p.p.)
Food and non-alcoholic beverages	18.38	24.28	−5.90	18.84	24.36	−5.52
Alcoholic beverages, tobacco and narcotics	6.41	6.38	0.03	6.40	6.19	0.21
Clothing and footwear	5.06	5.68	−0.62	5.18	5.37	−0.19
Housing, water, electricity, gas and other fuels	18.03	20.53	−2.50	17.87	20.35	−2.48
Furnishings, household equipment and routine household maintenance	5.89	5.14	0.75	5.87	5.25	0.62
Health	5.70	5.56	0.14	6.24	5.69	0.55
Transport	12.14	8.63	3.51	11.94	8.74	3.20
Communications	2.65	5.20	−2.55	2.62	4.87	−2.25
Recreation and culture	8.22	6.89	1.33	8.46	6.92	1.54
Education	1.12	0.97	0.15	1.10	1.00	0.10
Restaurants and hotels	3.54	5.23	−1.69	3.63	5.71	−2.08
Miscellaneous goods and services	12.85	5.51	7.34	11.86	5.55	6.31

4.3 Inflation in the Visegrad group: dynamic approach

Inflation is a nominal increase in the price level resulting from the fall in the purchasing power of money. Depending on the value of the indicator, it shows how much more or less the consumer had to spend in a given period compared to the previous period to purchase the same amount of the same or similar goods and services. In the years 2004–2018, the

Table 4 Inflation in particular product groups at the COICOP 2 level—comparison of HICP and CPI in the year 2017 and 2018. *Source:* own elaboration based on Eurostat data and data of the Central Statistical office in Poland

Components- index values	2017			2018		
	HICP	CPI	Difference (p.p.)	HICP	CPI	Difference (p.p.)
Food and non-alcoholic beverages	103.76	104.25	0.487	102.19	102.61	0.415
Alcoholic beverages, tobacco and narcotics	101.29	100.96	−0.323	101.66	101.51	−0.153
Clothing and footwear	94.99	94.80	−0.186	96.59	96.38	−0.215
Housing, water, electricity, gas and other fuels	101.91	101.93	0.024	102.36	102.09	−0.276
Furnishings, household equipment and routine household maintenance	100.50	100.30	−0.201	100.80	100.68	−0.119
Health	101.21	101.18	−0.031	102.00	102.05	0.049
Transport	102.17	103.78	1.615	103.33	104.21	0.879
Communications	100.30	100.69	0.386	98.10	98.15	0.053
Recreation and culture	100.52	101.40	0.887	100.82	101.31	0.484
Education	101.09	101.17	0.075	102.26	102.38	0.121
Restaurants and hotels	101.97	102.22	0.243	102.90	102.96	0.061
Miscellaneous goods and services	102.30	102.19	−0.113	97.37	99.50	2.129

inflation level in the Visegrad countries expressed by the HICP changed at a very similar rate to the average rate of change throughout the EU. The outlier here is Hungary, where a price increase of almost 60% has been observed over the past 15 years. This situation is reflected in the dynamics of inflation changes at the COICOP 2 level in individual countries of the Visegrad Group. Again, the highest dynamics of change in the years 2004–2018 was recorded in Hungary, where the price increase for alcoholic beverages and tobacco products exceeded 127%. The rate of change exceeding 100% was observed also in Slovakia in the case of education (Fig. 2).

Fig. 2 Changes in inflation levels in individual countries of the Visegrad Group (V4) in relation to the EU average (EU_28). *Source:* Own elaboration based on data from Eurostat HICP (2015 = 100)—annual data [prc_hicp_aind]

Fig. 3 Changes over time in the price level of individual groups of goods included in the HICP at the COICOP2 level of aggregation—EU_28. *Source:* Own elaboration based on data from Eurostat HICP (2015 = 100)—annual data [prc_hicp_aind]

Identification of groups of goods characterised by the highest price change dynamics

Fig. 4 Changes over time in the price level of individual groups of goods included in the HICP at the COICOP 2 level of aggregation—Czechia. *Source:* Own elaboration based on data from Eurostat HICP (2015 = 100)—annual data [prc_hicp_aind]

in the years 2005–2018 at the level of COICOP 2 in individual countries of the Visegrad Group (V4) (Figs. 3, 4, 5, 6, 7).

5 Results of empirical research

The study presented in the paper took into account three levels of aggregation used in measuring inflation: COICOP 2, COICOP 3 and COICOP 4. Although theoretically the COICOP 5 level data are available in Eurostat databases, in practice they contain too many missing pieces of data to be used in our comparative analysis of the V4 countries in the years 2010–2018. Observing the annual inflation in the V4 countries for 2018 determined by the index formulas discussed (Tables 5, 6, 7, 8), it can be seen that the level of data aggregation for which the differences between indices would always be the highest cannot be indicated, although the smallest differences always exist for the highest level of data aggregation (COICOP 2). Similarly, the substitution bias of inflation measurement, measured by the difference between the Laspeyres and Fisher indices (the last row of the tables indicated), is sometimes the highest at the COICOP 3 level (Poland, Table 5, Czechia,

Fig. 5 Changes over time in the price level of individual groups of goods included in the HICP at the COICOP 2 level of aggregation—Hungary. *Source:* Own elaboration based on data from Eurostat HICP (2015 = 100)—annual data [prc_hicp_aind]

Table 6) and other times at the COICOP 4 level (Slovakia, Table 7, Hungary, Table 8), but

Fig. 6 Changes over time in the price level of individual groups of goods included in the HICP at the COICOP 2 level of aggregation—Poland. *Source:* Own elaboration based on data from Eurostat HICP (2015 = 100)—annual data [prc_hicp_aind]

it is always the smallest at the COICOP 2 level. Interestingly, the inflation measurement itself, regardless of the choice of the index formula, is very sensitive to the selection of data aggregation level. In particular, differences between index values resulting from the adopted level of data aggregation exceeded in our study 0.75 p.p. for Poland (Table 5), 0.77 p.p. for Czechia (Table 6), 0.76 p.p. for Slovakia (Table 7), and as much as 0.82 p.p. for Hungary (Table 8).

Observing the behaviour of the price indices discussed in the years 2011–2018 (Figs. 8, 9, 10, 11, 12, 13, 14, 15), it can be seen that although in the case of annual changes, the effect of substitution of goods in inflation measurement is negligible, in the case of longer time periods, this effect accumulates, and there are noticeable differences between the Laspeyres and Fisher indices, and between their chain versions (Figs. 8, 10, 12, 14). Assuming as the reference base period the year 2010, we can see that the substitution bias increases to the level of about 1 p.p. (depending on the country and the level of aggregation, it may be smaller or larger) after only 3–4 years. Also, differences between the values of other price indices seem to increase with the passage of time and then do not have to be negligible even at the level of COICOP 2 (see Figs. 10, 11). We can also see that

Fig. 7 Changes over time in the price level of individual groups of goods included in the HICP at the COICOP 2 level of aggregation– Slovakia. *Source:* Own elaboration based on data from Eurostat HICP (2015 = 100)—annual data [prc_hicp_aind]

the positive and low CPI substitution bias dominates (usually does not exceed 0.15 p.p.),

Table 5 Yearly inflation rate [%] measured by different index formulas in Poland (year: 2018). *Source:* Own elaboration based on data from Eurostat HICP (2015 = 100)—annual data ([prc_hicp_aind])

Index formula used	COICOP 2	COICOP 3	COICOP 4
Laspeyres	1.1368	1.8889	1.3233
Paasche	1.1310	1.8287	1.2736
Fisher	1.1339	1.8588	1.2984
Walsh	1.1341	1.8588	1.2987
Marshall-Edgeworth	1.1339	1.8591	1.2986
Geary-Khamis	1.1342	1.8586	1.2988
Difference between the Laspeyres and the Fisher indices	0.0029	0.0301	0.0249

Table 6 Yearly inflation rate [%] measured by different index formulas in Czechia (year: 2018). *Source:* Own elaboration based on data from Eurostat HICP (2015 = 100)—annual data ([prc_hicp_aind])

Index formula used	COICOP 2	COICOP 3	COICOP 4
Laspeyres	1.9528	2.6163	1.8411
Paasche	1.9460	2.4235	1.7527
Fisher	1.9494	2.5198	1.7969
Walsh	1.9496	2.5196	1.7964
Marshall-Edgeworth	1.9494	2.5210	1.7973
Geary-Khamis	1.9498	2.5181	1.7957
Difference between the Laspeyres and the Fisher indices	0.0034	0.0964	0.0442

although this is not always the case, because we have also observed negative values of this bias (Slovakia, Fig. 12). Interestingly, the level of substitution bias is not only unstable over time (this applies to all V4 countries) but also very sensitive to changing the level of data aggregation. For example, in the case of Slovakia (Fig. 12), we can observe that in 2012

Table 7 Yearly inflation rate [%] measured by different index formulas in Slovakia (year: 2018). *Source:* Own elaboration based on data from Eurostat HICP (2015 = 100)—annual data [prc_hicp_aind]

Index formula used	COICOP 2	COICOP 3	COICOP 4
Laspeyres	2.4900	2.0373	2.8057
Paasche	2.4772	1.9229	2.6585
Fisher	2.4836	1.9801	2.7321
Walsh	2.4834	1.9805	2.7404
Marshall-Edgeworth	2.4837	1.9807	2.7331
Geary-Khamis	2.4831	1.9810	2.7424
Difference between the Laspeyres and the Fisher indices	0.0064	0.0573	0.0736

Table 8 Yearly inflation rate [%] measured by different index formulas in Hungary (year: 2018). *Source:* Own elaboration based on data from Eurostat HICP (2015 = 100)—annual data [prc_hicp_aind]

Index formula used	COICOP 2	COICOP 3	COICOP 4
Laspeyres	2.9205	2.1880	3.0110
Paasche	2.8373	2.0926	2.8045
Fisher	2.8789	2.1403	2.9077
Walsh	2.8793	2.1403	2.9106
Marshall-Edgeworth	2.8795	2.1408	2.9092
Geary-Khamis	2.8791	2.1398	2.9119
Difference between the Laspeyres and the Fisher indices	0.0416	0.0477	0.1033

the substitution bias was negative for the COICOP 2 and COICOP 3 levels but positive for the COICOP 4 level.

6 Discussion of the results obtained

The results of the analyses carried out are part of the current research on the CPI bias in different countries. A significant contribution to the development of this research was made by the report on the work of the Boskin Commission (1996). The conclusions of the Boskin Commission were based on a detailed review of research on the bias of individual CPI components in the USA. On that basis, the Commission estimated the inflation rate bias in the years 1995–1996. In the course of the work, the bias in the CPI in the United States was assessed at approx. 1.1 p.p., of which 0.5 p.p. was the bias resulting from substitution of goods –0.4 p.p. and of outlets –0.1 p.p., and the remaining 0.6 p.p. was the bias resulting from the change in the quality of goods and the introduction of new products. As a result of the publication of the report on the work of the Boskin Commission, the frequency of calculating weights in the USA has significantly increased. Noteworthy are also high estimates of the CPI index bias in Czechia (Filer and Hanousek 2003). The CPI revaluation in Czechia during the transformation (1990–1999) amounted to 4.4 and 4.8 p.p. per year depending on the sub-periods of the study. The difference was due to the different bias scale resulting from substitution of goods. The bias of new goods and change in quality did not change during the sub-periods and amounted to 3.9 p.p.. Among the many

A

Fig. 8 Comparison of substitution bias effects at different levels of aggregation. (HICP data for **Czechia**, Eurostat, COICOP-2, COICOP-3, COICOP-4, 2010–2018). *Source:* Own elaboration based on data from Eurostat HICP (2015 = 100)—annual data [prc_hicp_aind]

B

Fig. 9 Comparison of values of weighted price index formulas used. (HICP data for **Czechia**, Eurostat, COICOP-2, COICOP-3, COICOP-4, 2010–2018). *Source:* Own elaboration based on data from Eurostat HICP (2015 = 100)—annual data [prc_hicp_aind]

A

Fig. 10 Comparison of substitution bias effects at different levels of aggregation. (HICP data for **Poland**, Eurostat, COICOP-2, COICOP-3, COICOP-4, 2010–2018). *Source:* Own elaboration based on data from Eurostat HICP (2015 = 100)—annual data [prc_hicp_aind]

B

Fig. 11 Comparison of values of weighted price index formulas used. (HICP data for **Poland**, Eurostat, COICOP-2, COICOP-3, COICOP-4, 2010–2018). *Source:* Own elaboration based on data from Eurostat HICP (2015 = 100) – annual data [prc_hicp_aind]

A

Fig. 12 Comparison of substitution bias effects at different levels of aggregation. (HICP data for **Slovakia**, Eurostat, COICOP-2, COICOP-3, COICOP-4, 2010–2018). *Source:* Own elaboration based on data from Eurostat HICP (2015 = 100)—annual data [prc_hicp_aind]

B

Fig. 13 Comparison of values of weighted price index formulas used. (HICP data for **Slovakia**, Eurostat, COICOP-2, COICOP-3, COICOP-4, 2010–2018). *Source:* Own elaboration based on data from Eurostat HICP (2015 = 100)—annual data [prc_hicp_aind]

A

Fig. 14 Comparison of substitution bias effects at different levels of aggregation. (HICP data for **Hungary**, Eurostat, COICOP-2, COICOP-3, COICOP-4, 2010–2018). *Source:* Own elaboration based on data from Eurostat HICP (2015 = 100)—annual data [prc_hicp_aind]

B

Fig. 15 Comparison of values of weighted price index formulas used. (HICP data for **Hungary**, Eurostat, COICOP-2, COICOP-3, COICOP-4, 2010–2018). *Source:* Own elaboration based on data from Eurostat HICP (2015 = 100)—annual data [prc_hicp_aind]

reasons for the CPI bias, the authors point out, among others, the long periods of using invariant weights. Consumption structure studies rapidly lose their relevance, and as data show, the lags between the period from which the consumption structure originates and the period for which the data are used can reach up to 15 years (Crawford 1998; Boskin et al. 1996). This affects the deepening of the observed biases, especially due to goods substitution, which is based on dynamic changes in the structure of consumption. The studies cited so far have shown a positive CPI bias. The situation is different in studies using a method of estimating the bias on the basis of consumer perceived inflation (Nordhaus 1998) and estimates of the democratic price index (Prais 1959; Ruiz-Castillo et al. 2002). Nordhaus (1998) proposed a subjective method of testing the CPI bias. The study concerned the years 1968–1994 and consisted of comparing real household income, deflated CPI, with a subjective assessment of changes in the financial situation of a household. It is assumed that if real income changes at the same rate as the perceived financial situation, then the CPI is not biased. The Nordhaus method was often used in later studies (Marini et al. 2007; Giovane and Sabbatini 2008). In one of the studies, Giovane and Sabbatini (2008) point to the huge underestimation of HICP inflation in Italy in the years 2002–2004. This was related to the period when the country adopted the single EMU currency. Italy is an example of the exceptional escalation of this phenomenon, while in the other countries adopting the euro the gap between perceived and published inflation was small and short-lived. Bias estimates based on a subjective assessment of the financial situation of households are criticised due to distortion of perceived inflation caused by many factors independent of the CPI measurement method. One of the reasons for criticism is the fact that consumers perceive inflation through the prism of the goods and services they buy most often and those that get the most expensive (Łyziak and Stanisławska 2008; Pike et al. 2008). This leads to an overestimation of the perceived rate of price growth in relation to actual inflation. Therefore, the conclusions concerning the price index bias based on this research method should be formulated very carefully, due to the problems mentioned above with the subjective assessment of inflation by consumers. Estimates of the “plutocratic gap” are the other group of analyses that indicate a negative bias of inflation measurement. A study by Ruiz-Castillo et al. (2002) regarding the CPI bias in Spain pointed to the possibility of a slight underestimation of the CPI index due to the over-representation of luxury goods. The empirical study carried out for the Visegrad countries based on Eurostat data from the period 2011–2018 showed that the substitution bias was not captured at the level of COICOP 2 aggregation. The very fact of frequent update of the inflation basket weights in these countries means that the substitution bias is low regardless of the level of aggregation, but additionally the level of COICOP 2 is too aggregated to technically record differences between the Laspeyres index and Fisher indices. The effect of substitution, although to a small extent, is, however, visible at the COICOP 3 and COICOP 4 levels for selected years in the case of V4 countries. And so, in Czechia, the largest annual substitution bias was observed for 2012 (0.15 p.p. for COICOP 4 and over 0.12 p.p. for COICOP 3). In Poland, that was the year 2016, for which the measured annual substitution bias was almost 0.2 p.p. for the COICOP 4 level. Interestingly, in the case of COICOP 3 and COICOP 2 levels, the discussed bias in Poland was negligibly small almost throughout the entire research period, although its clear increase can be observed in 2015. In Slovakia, 2011 brought the largest annual substitution bias, which, however, had a clearly different value depending on the level of aggregation (0.16 p.p. and 0.07 p.p. respectively for the COICOP 4 and COICOP 3 levels). Observing the results for these aggregation levels, there is also the impression that the level of substitution bias worriedly increased in Slovakia in 2018. The situation in Hungary also resembles the situation in Slovakia: in 2011, the annual substitution bias

calculated at the COICOP 4 level was close to 0.12 p.p. and in 2018 it exceeded 0.1 p.p. To sum up, it can be stated that the measurement of substitution bias in the V4 countries does not differ from the results of global research—this bias is small and usually positive, it is in the range of 0.0–0.4 p.p. To compare individual countries in terms of the scale of this bias, however, it is necessary to go down to lower levels of aggregation (at least COICOP 4) and to determine the same level of COICOP for the compared countries. Confirmation of the importance of determining the level of aggregation for bias measurement may be illustrated by the example of Slovakia, where for 2012 a positive bias was obtained for the COICOP 4 level but a negative one for the COICOP 3 level.

7 Conclusions

The aim of the article has been achieved through a comprehensive comparative analysis of the V4 countries from the point of view of measuring inflation, with particular emphasis on the scale of the bias related to substitution of goods. All the hypotheses set out in the Introduction have been confirmed, and it has been demonstrated that a lower level of aggregation is not accompanied by a higher level of bias in measuring inflation due to substitution of goods. In addition, although the hypothesis that the level of annual inflation, regardless of the adopted price index formula, significantly differs depending on the level of COICOP aggregation adopted for analysis has been confirmed, it has not been indicated that the lower the level of data aggregation, the higher the level of determined annual inflation. It is worth noting that already at the two-level level of aggregation, there are significant differences in the level of inflation expressed by the CPI and HICP. In fact, at the COICOP 2 level, only for four of the twelve groups of HICP values are higher than CPI values.

The CPI and HICP Manuals provide a number of recommendations and regulations regarding the measurement of inflation, and the HICP methodology does not give EU countries the freedom to choose the price index formula at the data aggregate level. Thus the Member States are obliged to use the aggregate price index according to the Laspeyres formula. Also at the elementary level, in the case of HICP, there is a clear ban on the use of Carli index (Harmonised Index of Consumer Prices (HICP) 2018) and the simultaneous recommendation of the Jevons index (the Dutot index is accepted only in exceptional cases of goods). In the case of CPI Manual (Consumer Price Index Manual. Theory and Practice 2004), we have a number of recommendations in the field of price indices, both for the lowest and highest level of data aggregation, but the final choice remains in the hands of a given statistical office (within the framework of the recommendations). Superlative indices are known to have the greatest economic justification for calculating the Cost of Living Index and the CPI which approximates it. Superlative formulas such as the Fisher, Törnqvist or Walsh indices are very good also from the axiomatic point of view. The 2004 CPI Manual recommends these three indices as benchmarks for measuring CPI (Consumer Price Index Manual. Theory and practice 2004, p. 313). Nevertheless, please note that these indices have limited practical application because they use information on consumption (weights) from the current period. In fact, in measuring inflation, consumption information is out of date, lagged often a year or even a few years, and consequently the Laspeyres-type formula is used. As mentioned, this can lead to a bias in the CPI measurement due to the substitution of goods and, as a rule, the scale of this bias is estimated as the difference in the Laspeyres and Fisher indices. The paper compares the values of selected popular price indices based on inflation baskets of the V4 countries for different

COICOP levels. While it could be expected that at the most aggregate level (COICOP 2) these differences will be imperceptible, in the case of lower aggregation levels (COICOP3 and COICOP 4 were considered here) these differences may reach 0.2 p.p. (see Table 6 for Czechia). Such a difference, although it also seems to be slight, in practice, however, can lead to measurable financial consequences. This is due to the fact that the CPI is used, among others, for indexation of pensions, indexation of financial and credit agreements, as well as for determining measures of investment effectiveness. There is a consensus in the literature that real inflation is most often overestimated, due to the most frequently positive bias of substitution of goods. However, the analysis shows that in the case of countries that, similarly to the V4 countries, regularly (e.g. annually or even every 2 years) update their consumption knowledge, the bias in the CPI measurement in this respect is small. In the study conducted for 2018, it turns out that this bias was positive for each of the V4 countries and actually did not exceed 0.1 p.p. regardless of the COICOP level (the largest was recorded in Hungary at the COICOP 4 level). The scale of this bias varies depending on the COICOP level and there is no clear trend observed, e.g.: the higher the level of disaggregation, the larger the scale of the bias. However, it can be concluded that for the V4 countries this type of bias is satisfactorily reduced and almost eliminated. However, it is worrying that for the established index formula quite significant differences in estimating the annual inflation for different COICOP levels were obtained. For example, in the case of Slovakia and Hungary, the highest value of annual inflation was obtained for measurements at the COICOP 4 level, and the difference from the corresponding measurement at the COICOP 3 level amounted on average to approx. 0.8 p.p. (regardless of the price index formula used). In the case of Poland and Czechia, in turn, the highest annual inflation was obtained for the COICOP 3 level, and the difference in relation to the measurements at the other COICOP aggregation levels exceeded 0.5 p.p. Therefore, it seems that both the choice of the calculation formula and the level of data aggregation in the inflation analysis is significant in its estimates. Therefore, if future Eurostat regulations change the calculation formula (which is currently less likely in the case of traditional data collections but more likely in the case of new data sources, such as scanned data) or these regulations will force the implementation of even lower aggregation levels (lower than the lowest currently COICOP 5), then the time series of the determined inflation rates will encounter comparability problems. Each empirical analysis has various limitations, as is the case here. As mentioned in the *Introduction*, due to the international nature of the analyses, the authors decided to use in the empirical part the HICP data available in the Eurostat database. In the authors' opinion, the slight differences existing between the CPI and HICP in individual countries of the Visegrad group have not affected the validity of the considerations and derived conclusions. Therefore, the comparisons between index formulas made in the article can be successfully transferred to the case of local CPI in the V4 countries, where the CPI and HICP baskets differ only slightly. There is no doubt, however, that despite numerous methodological works on the HICP, the CPI is invariably better embedded in the theory of the cost of living index (COLI).

To sum up, it is worth noting that in measuring inflation, apart from the so-called traditional data collection, more and more countries are using alternative data sources, including scanner data. This kind of data, coming from supermarket chains, and more precisely from their electronic terminals, in addition to a number of advantages, has also a very important methodologically feature. Namely, scanner data contain information about the level of consumption of goods in any research period, including the current one, because they are complete transaction data. Consequently, there are no restrictions on the use of index formulas, hence we can also use superlative formulas here. It may be many years

before such data sources are used by statistical offices on a regular basis, but the availability of such data alone makes research on price index formulas (bilateral and multilateral) justified and valid.

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Compliance with ethical standards

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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References

- Balk, M.: Axiomatic price index theory: a survey. *Int. Stat. Rev.* **63**, 69–95 (1995). <https://doi.org/10.2307/1403778>
- Boskin, M.J., Dulberger, E.R., Gordon, R.J., Griliches, Z., Jorgenson, D.: Toward a More Accurate Measure of the Cost of Living. Final Report to the Senate Finance Committee from the Advisory Commission to Study the Consumer Price Index (1996)
- Boskin, M.J.: Causes and consequences of bias in the consumer price index as a measure of the cost of living. *Atl. Econ. J.* **33**(1), 1–13 (2005). <https://doi.org/10.1007/s11293-005-1631-6>
- Crawford, A.: Measurement biases in the Canadian CPI: an update. *Bank Can. Rev.* **4**, 38–56 (1998)
- Consumer Price Index Manual. Concepts and Methods. ILO/IMF/OECD/Eurostat/UNECE/The World Bank, International Labour Office (ILO), Geneva (2020)
- Consumer Price Index Manual. Theory and practice. ILO/IMF/OECD/UNECE/Eurostat/The World Bank, International Labour Office (ILO), Geneva (2004)
- Diewert, W.E.: Exact and superlative index numbers. *J. Econom.* **4**, 114–145 (1976). [https://doi.org/10.1016/0304-4076\(76\)90009-9](https://doi.org/10.1016/0304-4076(76)90009-9)
- Diewert, W.E.: Elementary Indices. In: Hill, P. (ed.) ILO, IMF, OECD, UNECE, Eurostat and World Bank, Consumer Price Index Manual: Theory and Practice. International Labour Organization, Geneva (2004)
- Drobisch, M.W.: Ueber einige Einwürfe gegen die in diesen Jahrbüchern veröffentlichte neue Methode, die Veränderungen der Waarenpreise und des Geldwerths zu berechnen. *Jahrbücher für Nationalökonomie und Statistik* **16**, 416–427 (1871)
- Ducharme, L.M. (ed.) Bias in the CPI: Experiences From Five OECD Countries. Analytical Series. Prices Division, Catalogue No. 62F0014MPB, No. 10, Statistics Canada (1997). <https://www150.statcan.gc.ca/n1/pub/62f0014m/62f0014m1997010-eng.pdf>
- Edgeworth, F.Y.: Measurement of Change in Value of Money I. The first Memorandum presented to the British Association for the Advancement of Science. Reprinted in *Papers Relating to Political Economy*, Vol. 1, New York, Burt Franklin, s. 1925 (1887)
- Eichhorn, W., Voeller, J.: Theory of the Price Index. Fisher's Test Approach and Generalizations. Springer, Berlin (1976)
- Fisher, I.: The Making of Index Numbers. Houghton Mifflin, Boston (1922)
- Filer, R.K., Hanousek, J.: Inflationary bias in middle to late transition Czech Republic. *Econ. Syst.* **27**, 367–376 (2003). <https://doi.org/10.1016/j.ecosys.2003.10.002>
- Geary, R.G.: A note on comparisons of exchange rates and purchasing power between countries. *J. R. Stat. Soc. Ser. A* **121**, 97–99 (1958). <https://doi.org/10.2307/2342991>

- Giovane, P., Sabbatini, R.: Perceived and measured inflation after the launch of the euro: explaining the gap in Italy. In: Del Giovane, P., Sabbatini, R. (eds.) *The Euro, Inflation and Consumer's Perceptions: Lessons from Italy*. Springer, Berlin (2008)
- Hałka, A., Leszczyńska, A.: Wady i zalety wskaźnika cen towarów i usług konsumpcyjnych – szacunki obciążenia dla Polski. *Gospodarka Narodowa* **9**, 51–75 (2011). <https://doi.org/10.33119/gn/101086>
- Harmonised Index of Consumer Prices (HICP). Methodological Manual. Publications Office of the European Union (2018). <https://doi.org/10.2785/68673>
- Hausman, J.: Sources of Bias and Solutions to Bias in the Consumer Price Index. *J. Econ. Perspect.* **17**(1), 23–44 (2003). <https://doi.org/10.1257/089533003321164930>
- Janus, J.: Real interest rate differentials between Central and Eastern European countries and the euro area. *Equilib. Q. J. Econ. Econ. Policy* **14**(4), 677–693 (2019). <https://doi.org/10.24136/eq.2019.031>
- Jędruchiewicz, A.: Monetary policy and investments in the Polish economy. *Oeconomia Copernic.* **6**(3), 7–22 (2015). <https://doi.org/10.12775/OeC.2015.018>
- Khamis, S.H.: Properties and conditions for the existence of a new type of index number. *Sankhya Ser. B* **32**, 81–98 (1970)
- Khamis, S.H.: A New System of Index Numbers for National and International Purposes. *J. R. Stat. Soc. Ser. A* **135**, 96–121 (1972). <https://doi.org/10.2307/2345041>
- Kwiatkowski, J.: Modele ze zmiennymi ukrytymi w analizie inflacji w Polsce. Wydawnictwo Naukowe Uniwersytetu Mikołaja Kopernika, Toruń (2019)
- Laspeyres, E.: Die Berechnung einer mittleren Waarenpreisteigerung. *Jahrbücher für Nationalökonomie und Statistik* **16**, 296–314 (1871)
- Lloyd, P.J.: Substitution effects and biases in non-true price indices. *Am. Econ. Rev.* **65**(3), 301–313 (1975)
- Łyziak, T., Stanisławska, E.: Consumer Inflation Expectations in Europe: some Cross-country Comparisons. *Bank i Kredyt* **39**(9), 14–28 (2008). <https://doi.org/10.2139/ssrn.897702>
- Martini, M.: A General Function of Axiomatic Index Numbers. *J. Ital. Stat. Soc.* **1**(3), 359–376 (1992). <https://doi.org/10.1007/bf02589086>
- Marini, G., Piergallini, A., Scaramozzino, P.: Inflation bias after the Euro: evidence from the UK and Italy. *Appl. Econ.* **39**(4), 461–470 (2007). <https://doi.org/10.1080/00036840500438962>
- Marshall, A.: Remedies for fluctuations of general prices. *Contemp. Rev.* **51**, 355–375 (1887)
- Nordhaus, W.D.: Quality change in price indexes. *J. Econ. Perspect.* **12**, 59–68 (1998). <https://doi.org/10.1257/jep.12.1.59>
- Olt, B.: *Axiom and Struktur in der statistischen Preisindextheorie*. Peter Lang, Frankfurt (1996)
- Paasche, H.: Über die Preisentwicklung der letzten Jahre nach den Hamburger Borsennotirungen. *Jahrbücher für Nationalökonomie und Statistik* **12**, 168–178 (1874)
- Palgrave, R. H. I.: Currency and Standard of Value in England, France and India and the Rates of Exchange Between these Countries. Memorandum submitted to the Royal Commission on Depression of trade and Industry, Third Report, Appendix B, pp. 312–390 (1886)
- Pażický, M.: The consequences of unconventional monetary policy in euro area in times of monetary easing. *Oeconomia Copernic.* **9**(4), 581–615 (2018). <https://doi.org/10.24136/oc.2018.029>
- Pike, R., Marks, C., Morgan, D.: Measuring UK inflation. *Econ. Labour Mark. Rev.* **2**(9), 18–25 (2008). <https://doi.org/10.1057/elmr.2008.135>
- Pollak, R.A.: The Consumer Price Index: a research agenda and three proposals. *J. Econ. Perspect.* **12**(1), 69–78 (1998). <https://doi.org/10.1257/jep.12.1.69>
- Prais, S.: Whose cost of living. *Rev. Econ. Stud.* **26**, 126–134 (1959). <https://doi.org/10.2307/2296170>
- Rosko-Wójtcowicz, E., Grzelak, M.M., Laskowska, I.: The impact of research and development activity on the TFP level in manufacturing in Poland. *Equilib. Q. J. Econ. Econ. Policy* **14**(4), 711–737 (2019). <https://doi.org/10.24136/eq.2019.033>
- Ruiz-Castillo, J., Ley, E., Izquierdo, M.: The Laspeyres bias in the Spanish consumer price index. *Appl. Econ.* **34**(18), 2267–2276 (2002). <https://doi.org/10.1080/00036840210138428>
- Sidgwick, H.: *The Principles of Political Economy*. Macmillan, London (1883)
- Sławiński, A.: *Polityka pieniężna (Monetary policy)*. C.H. Beck (2011)
- Szysko, M., Tura, K.: Can inflation forecast and monetary policy path be really useful? The case of the Czech Republic. *Equilib. Q. J. Econ. Econ. Policy* **10**(3), 9–26 (2015). <https://doi.org/10.12775/equl.2015.022>
- Törnqvist, L.: The Bank of Finland's Consumption Price Index. *Bank Finl. Mon. Bull.* **10**, 1–8 (1936)
- Walsh, C.E.: Inflation Targeting: What Have We Learned? *Int. Finance* **12**(2), 195–233 (2009). <https://doi.org/10.1111/j.1468-2362.2009.01236.x>
- Walsh, C.M.: *The Measurement of General Exchange Value*. The MacMillan Company, New York (1901)
- White, A.G.: Measurement biases in consumer price indexes. *Int. Stat. Rev.* **67**(3), 301–325 (1999). <https://doi.org/10.1111/j.1751-5823.1999.tb00451.x>

Von der Lippe, P.: Index Theory and Price Statistics. Peter Lang, Frankfurt (2007). <https://doi.org/10.3726/978-3-653-01120-3>

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