

# INFLATION



## Price indices and inflation measurement: The devil is in the details

Índices de preços e medição de inflação: O diabo está nos detalhes

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# INFLATION

LET'S JUST  
BEND  
THE RULES...

ECB

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The Consumer Price Index (CPI) annual rate was **4,3%** in 2023 (7.8% in 2022).

In 2023, the Portuguese Harmonized Index of Consumer Prices annual rate was **5.3%** (8.1% in 2022)



*“The answer to the question what is the mean of a given set of magnitudes cannot in general be found, unless there is given also the object for the sake of which a mean value is required. There are as many kinds of average as there are purposes; and **we may almost say in the matter of prices as many purposes as writers.** Hence much vain controversy between persons who are literally at cross purposes.”*

(Edgeworth (1888, p. 347)).

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## Summary

**Main objective:** Examine a number of conceptual and operational issues related to the measurement of inflation based on price indices to be (seriously) taken into account by users

**Complementary objective:** Look at the particular case of the HICP and its central role in the monetary policy strategy of the European Central Bank (progresses and margins of improvement)

**Takeaway #1:** Uncertainties associated with the calculation of price indices suggest that the analysis of the inflation developments should have a **holistic approach**, based on alternative measures, particularly when the preferred index (HICP) for monitoring inflation is at one of the extremes of the spectrum of conceptual calculation possibilities.

**Takeaway #2:** The creation of a complementary inflation indicator close to a COLI - **an experimental COLI** - could be an important indicator to add to the ECB's analytical toolkit in assessing price developments

**Takeaway #3:** The COVID-19 crisis exposed statistical institutes to a greater measurement uncertainty, making the use of new data sources such as **scanner or web-scraped data** even more relevant



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# An illustrative example



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	Price $t_0$	Price $t_1$	Weight $t_0$	Weight $t_1$
Good A	100	100	50%	50%
Good B	100	102	50%	50%

**Question:** what is the inflation rate in this economy?

**Answer:** 1%.



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Assume price of good B increases but consumers switch away.

– Assumptions

- Price of A unchanged from base to reference period.
- Price of B increases 2% from base to reference period.
- **Consumers switch away from B and buy only A.**

	Price $t_0$	Price $t_1$	Weight $t_0$	Weight $t_1$
Good A	100	100	50%	<b>100%</b>
Good B	100	102	50%	<b>0%</b>

**Question:** what is the inflation rate in this economy?

**Answer:** it's complicated.



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	Price $t_0$	Price $t_1$	Weight $t_0$	Weight $t_1$
Good A	100	100	50%	100%
Good B	100	102	50%	0%

- Basic issue is: how to weight the price changes?
- **There is no “right” or “wrong” answer.** Rather, there is a variety of indicators/indices that capture the different aspects. 4 main possibilities:





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  1. Use the weights of the base year ( $t_0$ ).
  2. Use the weights of the reference period ( $t_1$ ).
  3. Use a “combination” of both weights ( $t_0$  and  $t_1$ ).



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  3. Use a “combination” of both weights ( $t_0$  and  $t_1$ ).
  4. **Extreme: unweighted indexes.**



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	Price $t_0$	Price $t_1$	Weight $t_0$	Weight $t_1$
Good A	100	100	50%	100%
Good B	100	102	50%	0%

Option #1: use the weights of the base period ( $t_0$ ).

Formula: Laspeyres index (Etienne Laspeyres (1871)).

$$P_L = \frac{\sum(p_t \cdot q_0)}{\sum(p_0 \cdot q_0)}$$

**Question:** what is the inflation rate in this economy?

**Answer:** from this point of view, it is 1%.



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	Price $t_0$	Price $t_1$	Weight $t_0$	Weight $t_1$
Good A	100	100	50%	100%
Good B	100	102	50%	0%

Option #2: use the weights of the reference period ( $t_1$ ).

Formula: Paasche index (Hermann Paasche (1874)).

$$P_P = \frac{\sum(p_t \cdot q_t)}{\sum(p_0 \cdot q_t)}$$

**Question:** what is the inflation rate in this economy?

**Answer:** from this point of view, it is 0%.



	Price $t_0$	Price $t_1$	Weight $t_0$	Weight $t_1$
Good A	100	100	50%	100%
Good B	100	102	50%	0%

Option #3: use both weights, base and reference period.

Formula: Fisher (1922) index (also called “ideal” price index).

$$P_F = \sqrt{P_L \cdot P_P} = \sqrt{\frac{\sum(p_t \cdot q_0)}{\sum(p_0 \cdot q_0)} \cdot \frac{\sum(p_t \cdot q_t)}{\sum(p_0 \cdot q_t)}}$$

**Question:** what is the inflation rate in this economy?

**Answer:** from this point of view, it is 0.5%.



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There is a large number of price indices:

- **Fixed weights indices:** Lowe index, Laspeyres index, Paasche index, Geometric means index.
- **Bilateral indices:**
  - Marshall-Edgeworth index.
  - Superlative indexes: Fisher index, Törnqvist index, Walsh index.
- **Unweighted indices:** Carli index, Dutot index, Jevons index, Coggeshall index, Carruthers-Sellwood-Ward-Dalén index, Ratio of harmonic means index.





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## PLAN OF MY TALK

1. The origins and conceptual frameworks of the CPI
2. The CPI coverage and classification structure
3. Information sources
4. Calculating consumer price indices in practice
5. Potential biases in measuring inflation based on a CPI
6. The HICP and its role in the ECB's monetary policy strategy
7. Conclusions



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## Two concepts: COGI vs COLI

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Consumer price indices are statistics that seek to measure variations over time in the prices of goods and services that households purchase. Originally, the purpose of constructing a CPI was to produce an indicator that could measure changes in workers' cost of living and, thus, be incorporated into the wage bargaining processes.

The first nationally-based CPI was calculated and released by the US Bureau of Labor Statistics in 1921, with a retrospective series going back to 1913.

Over the years, the CPI has increased in scope, and is currently a macroeconomic indicator of widespread use. They are used for indexation, deflation and as an indicator for monitoring price developments, particularly in central banks with explicit inflation targets.



## Two concepts: COGI vs COLI

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CPIs are considered one of the most important economic-social indicators compiled by national statistical institutes, which justifies the increasing emphasis placed on their quality, precision and comparability.

Price index theory distinguishes **two classes of CPI concepts**: cost of goods indices (**COGI**) and cost of living indices (**COLI**). Each of these concepts is designed with different objectives.

A COGI is designed for the purpose of measuring how the purchasing capacity varies over time (the amount needed to purchase a fixed basket of goods and services).

In turn, a COLI seeks to measure the cost of maintaining a fixed level of utility for consumers.



## Two concepts: COGI vs COLI

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A **COGI** includes the prices of goods and services that result from **monetary transactions** (acquisition approach). It is based on prices observed in the market and not on estimated or imputed prices, which reinforces transparency and credibility.

The scope of a **COLI** is not limited to products with a market price, **including non-market goods and services**, such as state-provided services (e.g. health or education) and, theoretically, even public goods, such as national defense or the level of air pollution, which requires price imputation for various goods and services.

An ideal COLI should instantly adjust to changes in consumption patterns

Difficulties: 1) Information about consumption structures is not available in real time 2) utility levels of individuals are unknown, which implies the establishment of hypotheses

Solution: Use of superlative indices, which only include those non-market goods that can be reasonably measured.



# Two concepts: COGI vs COLI

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## Differ in 3 main dimensions:

### 1. Substitution:

- **COGI** does not account for substitution (typically uses a Laspeyres/Lowe index).
- **COLI** takes into account substitution (typically using a Fisher index), at least upper level. For this reason, COLI typically run lower than their COGI counterparts.

### 2. Non-market prices:

- **COGI** does not include non-market prices.
- **COLI** includes estimates of non-market prices.

### 3. New products/outlets:

- **COGI**: included with a lag.
- **COLI**: in theory included as they become available. In practical implementations, not much different.

Most CPIs follow the COGI concept. However, some countries have sought to produce price indices close to a COLI, such as the Personal Consumption Expenditures Price Index (PCE) in the United States or the Swedish CPI



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## Classification system: the COICOP

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Choosing a **classification system** is one of the first steps in compiling a CPI

- Allows a correspondence between the coverage of each of the sub aggregates and the selected prices and weights.
- Draws the border between the products (and establishments) to be included and excluded from the index, as well as to define the hierarchy between the sub-aggregates.
- Products are organized into mutually exclusive categories and subcategories, which are as exhaustive as possible.

Currently, almost all countries follow the **COICOP classification system** (*Classification of Individual Consumption According to Purpose*).

Important advantage: **it allows for better international comparability**





## Geographical coverage: “national” vs “domestic” coverage

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**National coverage** means that the CPI should cover the expenditure made by resident households of the country, regardless of where the expenditure takes place.

The national concept is appropriate when the CPI is being used for indexation of incomes and cost of living measures. Collecting the prices of expenses incurred by residents abroad is the main difficulty of the national CPI concept. In Portugal, the CPI follows the national concept.

**Domestic coverage** means that the CPI would cover all the expenditure made within the economic territory of the country, including the household final consumption expenditure made by foreign tourists. These typically have a consumption structure different from that of residents, with relatively greater expenditure on accommodation and restaurants, categories that therefore have a higher weighting in the CPI that follows this concept.

The domestic concept is more appropriate for evaluating the evolution of inflation and as an indicator for monetary policy. The HICP follows the domestic concept.



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## Information sources: HBS, National Accounts and administrative data

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The recommendations of the International Labor Organization define that there are mainly two sources of information to do this: **household budget surveys (HBS) and national accounts**. It is also defined that the weights must be reviewed and updated at least every five years.

In a scenario where household budget surveys are typically conducted every five years, the use of national accounts allows for a more regular update of the weights

The exclusive use of national accounts has some disadvantages. They are generally only available at the national or regional level. To provide a finer level of detail or to produce regional expenditure weights is necessary using other available sources of information, namely including surveys of retail sales from establishments, point-of-sales surveys and aggregated scanner data, surveys of production, export and import data, and administrative data.



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**CPIs are typically calculated in two steps.**

**First**, price indices for **elementary aggregates are calculated**. Elementary aggregates constitute the lowest-level group of goods and services in the CPI aggregation hierarchy for which there is an explicit weight. Elementary aggregates are composed of groups of relatively homogeneous goods and services, with similar uses and price variations. They can refer to the entire country, a region or just a group of establishments, and must include a relatively large number of products and varieties.

In a **second** stage, the elementary price indices are averaged to obtain **higher-level indices** using the relative expenditure values of the elementary aggregates as weights.



## Calculating consumer price indices in practice

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Weights at the elementary aggregation level are generally derived from the HBS. The CPI aggregation structure is based on the COICOP. The global CPI can be subdivided into classes, such as “Food and beverage products”. Each class is divided into groups, such as “Food products”. In turn, the groups are divided into subgroups, such as “Cereals, bread and other cereal-based products”, and the subgroups into sub-subgroups, such as “Rice” (5-digit COICOP).

In some countries this subdivision is different, with the divisions being the initial level of disaggregation, which are subsequently disaggregated into groups, classes and subclasses.

Elementary indices are made up of several undisclosed varieties of a product, and the weights are generally not known. In the case of Portugal, they refer to a level below the 5-digit COICOP (for example, “Carolino rice”)



## Calculating consumer price indices in practice: the elementary aggregates

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Various methods and formulas may be used to calculate an average price based on the prices of the different varieties of a product and thus obtain an elementary index.

When weights are not available, the choice of the method for obtaining average prices can be quite relevant.

The three best-known price aggregation formulas for the elementary level are the **Carli, Dutot and Jevons indices**. All three are grounded on average prices or relative prices, based on some hypotheses that have a different impact on measured inflation.

The Carli (simple arithmetic average of relative prices) and Dutot (the ratio of arithmetic averages of prices) indices have some associated problems (ILO, 2020). The Jevons formula (the ratio of geometric averages of prices or the geometric average of relative prices) has been increasingly used, particularly when weights are not available, as it avoids many of the problems associated with arithmetic averages.

**Statistics Portugal uses the Jevons formula to obtain the elementary indices.**



**In a second stage, the more aggregated indices are calculated, which result from weighted averages of the elementary price indices.**

Typically, weights remain unchanged for at least 12 months. In some countries, weights are reviewed at the beginning of each year, aiming to approximate changes in consumption patterns as closely as possible, but in some they remain constant for some years.

Several types of formulas have been proposed over the last two centuries; **there is no single formula that would be preferred in all circumstances.**

**Superlative indices are considered as the best available index formula.** They treat prices and quantities in both periods being compared symmetrically.





## Calculating consumer price indices in practice: the calculation of the higher-level CPI aggregates

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When a monthly or quarterly CPI is first published, however, it is invariably the case that there is not sufficient information on the quantities and expenditures in the current period to make it possible to calculate a symmetric, or superlative, index.

This means that in practice alternative formulas are used. Most CPI calculation formulas (Laspeyres, Lowe, Young,...) have biases that are well known in the literature.

**A very popular class of price indices are the Lowe indices.**



Assuming that there are  $n$  products in the reference basket with prices  $p_i$  and quantities  $q_i$ , and that  $0$  and  $t$  are the two periods in comparison, the **Lowe index** is defined as :

$$P_{Lo} = \frac{\sum_{i=1}^n p_i^t q_i}{\sum_{i=1}^n p_i^0 q_i}$$

Any set of quantities could serve as the basket. The basket does not have to be restricted to the quantities purchased in one or other of the two periods compared, or indeed any actual period of time.

The quantities could, for example, be arithmetic or geometric averages of the quantities in the two periods.



### Most CPIs are calculated based on a version of the Lowe index.

The period for which quantities are actually used in the CPI, denoted by  $b$ , is called the weighting period and the period  $0$  is the price reference period. Period  $b$  most likely precedes the period  $0$ , at least when the index is first published, but  $b$  could be any period, including a period between  $0$  and  $t$ . The Lowe index using the quantities from the period  $b$  can be written as:

$$P_{Lo} = \frac{\sum_{i=1}^n p_i^t q_i^b}{\sum_{i=1}^n p_i^0 q_i^b} = \sum_{i=1}^n \left( \frac{p_i^t}{p_i^0} \right) s_i^{0b}$$

$$\text{where } s_i^{0b} = \frac{p_i^0 q_i^b}{\sum_{i=1}^n p_i^0 q_i^b}$$



## Calculating consumer price indices in practice: the calculation of the higher-level CPI aggregates

Any set of quantities could be used in a Lowe price index.

**Two special cases:** when the quantities are those of the price reference period  $b=0$ , the Laspeyres price index is obtained; when quantities are those of the other period  $b=t$ , the Paasche price index is obtained.

The **Laspeyres price** index is defined as:

$$P_{La} = \frac{\sum_{i=1}^n p_i^t q_i^0}{\sum_{i=1}^n p_i^0 q_i^0} = \sum_{i=1}^n \left( p_i^t / p_i^0 \right) s_i^0 \quad \text{with} \quad s_i^0 = \frac{p_i^0 q_i^0}{\sum_{i=1}^n p_i^0 q_i^0}$$

In turn, the **Paasche price index** is defined as:

$$P_{Pa} = \frac{\sum_{i=1}^n p_i^t q_i^t}{\sum_{i=1}^n p_i^0 q_i^t} = \left\{ \sum_{i=1}^n \left( p_i^t / p_i^0 \right)^{-1} s_i^t \right\}^{-1} \quad \text{with} \quad s_i^t = \frac{p_i^t q_i^t}{\sum_{i=1}^n p_i^t q_i^t}$$

$$Lowe \geq Laspeyres \geq Paasche$$



## Calculating consumer price indices in practice: the calculation of the higher-level CPI aggregates

From a practical point of view, it is important to have **a formula that allows the Lowe index to be calculated directly as a chain index**, where the index of  $t+1$  is obtained by updating the index of  $t$ . Since the Lowe index is transitive, the Lowe index for  $t+1$  with reference to 0 can be written as the product of the Lowe index of  $t$  with reference to 0 multiplied by the Lowe index of  $t+1$  with reference to  $t$ :

$$\frac{\sum_{i=1}^n p_i^{t+1} q_i^b}{\sum_{i=1}^n p_i^0 q_i^b} = \left[ \frac{\sum_{i=1}^n p_i^t q_i^b}{\sum_{i=1}^n p_i^0 q_i^b} \right] \left[ \frac{\sum_{i=1}^n p_i^{t+1} q_i^b}{\sum_{i=1}^n p_i^t q_i^b} \right] = \left[ \frac{\sum_{i=1}^n p_i^t q_i^b}{\sum_{i=1}^n p_i^0 q_i^b} \right] \left[ \sum_{i=1}^n \left( \frac{p_i^{t+1}}{p_i^t} \right) S_i^{tb} \right]$$

with

$$S_i^{tb} = \frac{p_i^t q_i^b}{\sum_{i=1}^n p_i^t q_i^b} \text{ are hybrid weights or "price update weights"}$$



## Calculating consumer price indices in practice: superlative indices

The **Fisher index** (like the US CPE) is defined as a geometric mean of the Laspeyres and Paasche indices:

$$P_F = \sqrt{P_{La}P_{Pa}}$$

The **Walsh index** (like the Swedish CPI), is a basket-based index whose quantities are geometric averages of the quantities of the two periods being compared:

$$P_W = \frac{\sum_{i=1}^n p_i^t \sqrt{q_i^t q_i^0}}{\sum_{i=1}^n p_i^0 \sqrt{q_i^t q_i^0}}$$

Finally, the **Törnqvist index** (like the US C-CPI) is defined as a weighted geometric average of relative prices, where the weights correspond to the average expenditure on each product in the two periods:

$$P_T = \prod_{i=1}^n \left( \frac{p_i^t}{p_i^0} \right)^{\sigma_i} \quad \text{with } \sigma_i = \frac{S_i^t + S_i^0}{2}$$



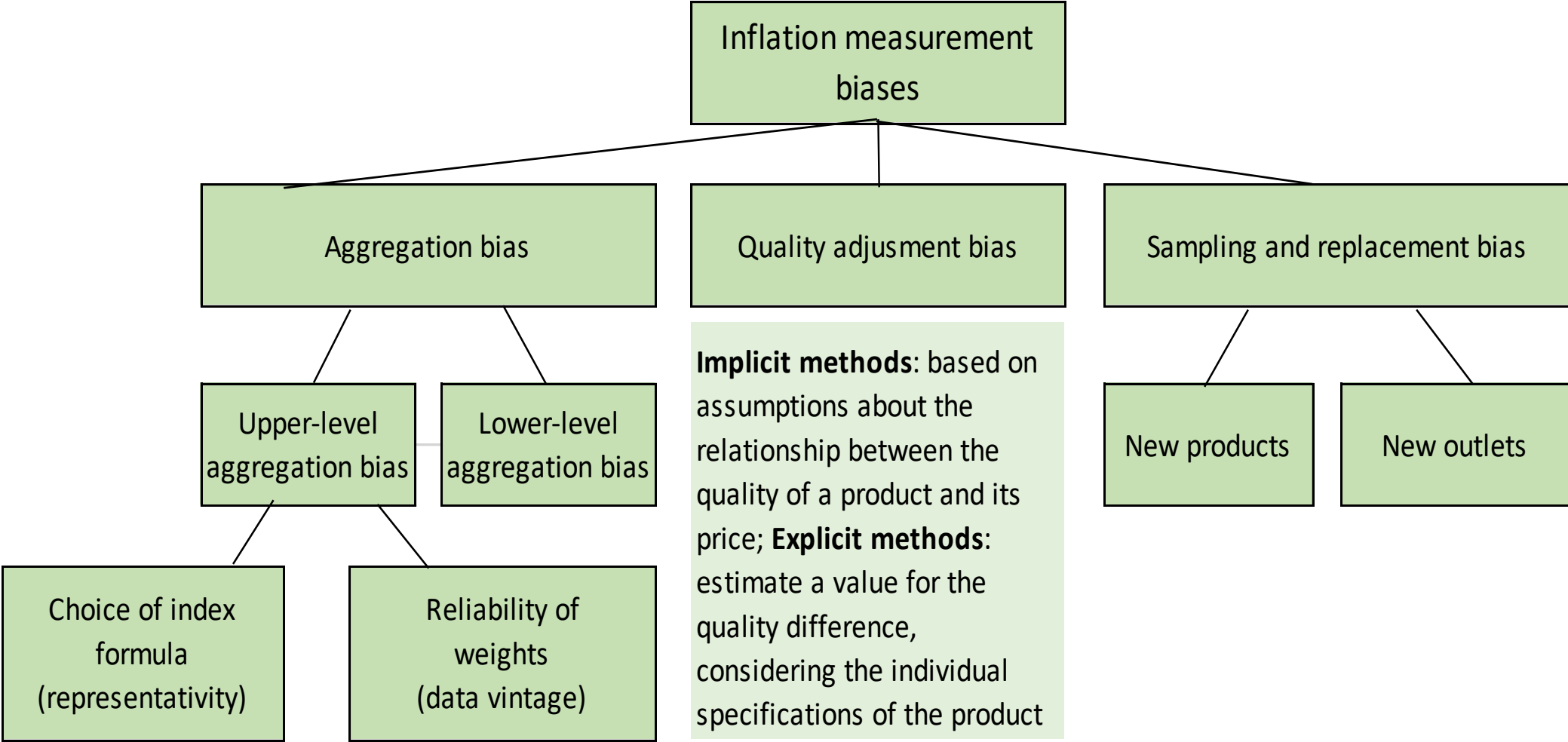
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# Potential biases in measuring inflation based on a CPI





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## The HICP and its role in the ECB's monetary policy strategy

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- The choice of a suitable framework for measuring inflation is a key element of any **price stability-oriented monetary policy strategy**.
- Since it was first established in 1998, the ECB has used the HICP to formulate its quantitative definition of price stability and to assess whether the outlook for inflation (in the medium term) is in line with this definition.
- The central criteria for the suitability of an inflation measure for monetary policy are its credibility, reliability, comparability over time and timeliness.



## The HICP and its role in the ECB's monetary policy strategy

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- The choice of the HICP as a measure of price stability was confirmed in the ECB monetary policy strategy reviews conducted in 2003 and 2021
- **The HICP is a Lowe index, formally considered as an annual chain-linked Laspeyres-type index.** It has the specificity of considering prices from December of the previous year and quantities for the entire year.
- It is compiled according to the “acquisition approach”, that is, it only includes prices that result from actual monetary transactions, thus excluding non-market goods and services.



# The HICP and its role in the ECB's monetary policy strategy

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## Important improvements:

- It has have become more representative of actual changes in prices: some prices are collected more than once per month
- Publication of flash estimates for headline inflation and main components
- Annual updates of HICP weights have become compulsory and national accounts data being used as the primary source to obtain HICP expenditure shares
- Introduction of explicit weights at a more granular level (5-digit COICOP)
- More harmonized procedures for sample design and product replacement



# The HICP and its role in the ECB's monetary policy strategy

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## Areas for potential improvement: **NOT CONSENSUAL!!**

- Inclusion of the costs of owner-occupied housing (OOH) in the HIPC. The creation of an official index complementary to the HICP that would combine the HICP basket with home ownership costs using the acquisitions approach (HICP-H) was advocated as part of the latest ECB's monetary policy strategy review
- Importance to quantify the measurement bias existing in current inflation indicators: despite de improvements it's not obvious that the bias has declined (new products, e-commerce, change in product life cycle,...)
- Greater harmonization in product replacement practices and quality adjustments



# My take



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**Takeaway #1:** Uncertainties associated with the calculation of price indices suggest that the analysis of the inflation developments should have a **holistic approach**, based on alternative measures, particularly when the preferred index for monitoring inflation is at one of the extremes of the spectrum of conceptual calculation possibilities.

**Takeaway #2:** The creation of a complementary inflation indicator close to a COLI - **an experimental COLI** - could be an important indicator to add to the ECB's analytical toolkit in assessing price developments

**Takeaway #3:** The COVID-19 crisis exposed statistical institutes to a greater measurement uncertainty, making the use of new data sources such as **scanner or web-scraped data** even more relevant



## Why did the FED decide to target PCE (COLI) rather than CPI (COGI)?

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*“The chain-type price index for PCE draws extensively on data from the consumer price index but, while not entirely free of measurement problems, has several advantages relative to the CPI. The PCE chain-type index is constructed from a formula that reflects the changing composition of spending and thereby avoids some of the upward bias associated with the fixed-weight nature of the CPI. In addition, the weights are based on a more comprehensive measure of expenditures. Finally, historical data used in the PCE price index can be revised to account for newly available information and for improvements in measurement techniques, including those that affect source data from the CPI; the result is a more consistent series over time. This switch in presentation notwithstanding, the FOMC will continue to rely on a variety of aggregate price measures, as well as other information on prices and costs, in assessing the path of inflation.*

Monetary Policy Report” (February 17<sup>th</sup>, 2000)





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Thank you!



Structure	CPI general	Class	Group	Subgroup	Subsubgroup	Regional breakdown	Type of outlet	Category	Varieties
COICOP	1 digit	2 digits	3 digits	4 digits	5 digits			6 digits	
<b>Examples</b>	Headline CPI	01-Food and non-alcoholic beverages	011-Food	0111-Cereals, bread and cereal products	01111-Rice	Sold in the North Region	Supermarkets North Region	011111-Simple rice	Carolino Rice: Brand A

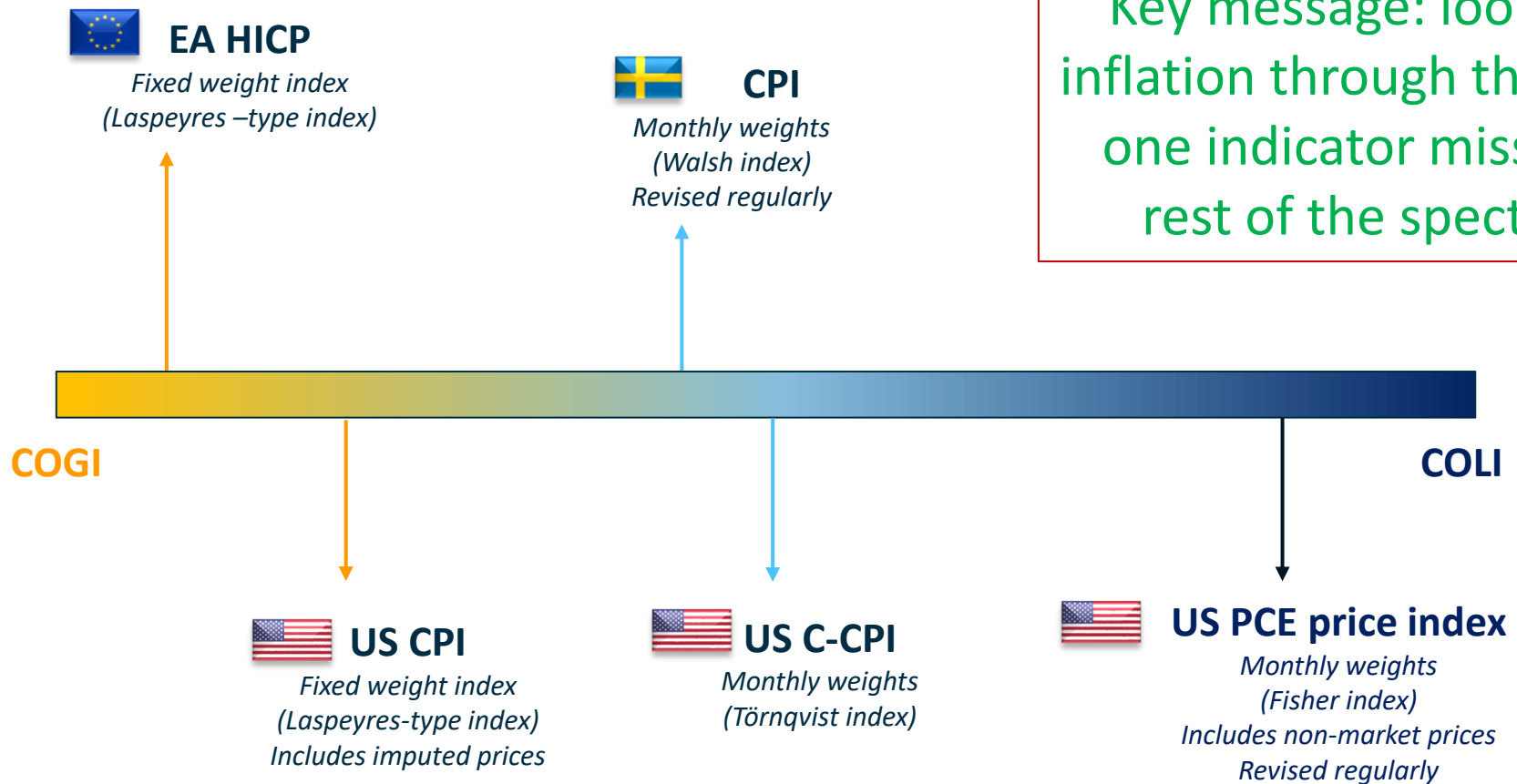
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## Prices in euros of seven varieties of a given product

	Base	Jan	Feb	Mar	Apr	May	Jun	Jul
v1	2,36	2,09	1,93	2,59	2,05	2,85	2,59	2,36
v2	5,02	5,38	5,12	5,52	4,08	4,08	5,52	5,02
v3	5,34	5,07	5,09	5,88	6,29	5,86	5,88	5,34
v4	6,00	5,73	4,27	6,00	4,75	5,27	6,60	6,00
v5	6,12	6,39	5,50	6,12	5,86	6,29	6,74	6,12
v6	2,80	2,72	2,82	3,08	2,85	2,05	3,08	2,80
v7	6,21	5,45	6,95	6,21	5,27	4,75	6,84	6,21
Geometric mean price	4,55	4,38	4,20	4,80	4,17	4,17	5,01	4,55
Arithmetic mean price	4,84	4,69	4,53	5,06	4,45	4,45	5,32	4,84
Jevons	100,0	96,3	92,4	105,6	91,7	91,7	110,0	100,0
Jevons chain-linked	100,0	96,3	95,9	114,3	86,8	100,0	120,0	90,9
Dutot	100,0	97,0	93,6	104,6	92,0	92,0	110,0	100,0





Key message: looking at inflation through the lens of one indicator misses the rest of the spectrum.

