Energy Economics 145 (2025) 108482

Contents lists available at ScienceDirect

Energy Economics

journal homepage: www.elsevier.com/locate/eneeco

Energy expenditures and CPI inflation in 2022: Inflation was even higher than we thought

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ARTICLE INFO

JEL codes:
C43|
C67
D10
E01
E31
Q41

Keywords:
Energy price
Inflation measurement
Household final consumption expenditure (HHFCE)
Consumer Price index (CPI)

ABSTRACT

Following the sudden increase in the energy price in the second quarter of 2022 caused by the Russia-Ukraine war, inelastic demand generated significant changes in household expenditure shares for energy (particularly in electricity, gas, and other fuels and in fuels and lubricants). These produced a significant downward bias in the official CPI inflation rate for energy and in the official CPI inflation rate for all items in the UK. The downward bias was significantly higher in the European Union in 2022, specifically in Belgium, Estonia, Ireland, Greece, Italy, Cyprus, Lithuania, the Netherlands, Romania, and Slovenia.

1. Introduction

The Office for National Statistics (henceforth referred to as ONS) calculates the CPI index and inflation using past expenditure shares, as has been common practice across most statistical offices across the world since inflation statistics started to be published after World War 2. Since expenditure shares usually evolve very slowly, with little change from year to year, this raised little debate. However, with the onset of the Covid-19 pandemic in 2020, this issue was brought to the fore as there were rapid shifts in expenditure patterns, especially during periods of lockdowns. The question naturally arose as to whether the published inflation figures were accurate as they were based on pre-pandemic expenditure shares that were significantly different from the reality of 2020 (see for example Cavallo, 2024, Dixon, 2020, Giles, 2020). Therefore, considering actual household expenditure data from the national accounts, Chowdhury and Dixon (2024) constructed a true inflation rate (using the Fisher index) and found that the official inflation rate in the 33 OECD countries was an overestimate of true inflation for 23 and an underestimate in 10 countries in the first wave of the pandemic.

In the current paper, we show that a similar situation arose in 2022. There was a massive increase in energy prices during the year as a result of the Russo-Ukrainian war and ensuing sanctions imposed on Russian energy exports by Western nations.[1] Since energy demand is inelastic, rising energy prices will lead to larger expenditure shares for energy. This raises the question of whether the published CPI inflation captures fully the inflation when it is based on the pre-war expenditure shares. This paper aims to address this issue.

The current method of using past expenditure shares is often called a "modified Laspeyres Index". Each January the CPI weights are changed, currently using the weights from a previous year. Hence the 2022 inflation figures are calculated using the 2021 expenditure weights (see ONS 2024a and Eurostat, 2023 for details).[2] As we move through the

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[1] The main countries to impose sanctions were the EU, Norway, Iceland, the UK, the USA, Canada, and Australia. New Zealand, Japan, South Korea, and Singapore also imposed more limited sanctions.

[2] Prior to 2021, the expenditure weights used were two years old. Hence, the weights in 2020 were from 2018. The pandemic led to a review of this and a shift to the most recent year prior to the current one. As a result, the UK and other European Union countries adopted a new methodology for updating expenditures for 2021, 2022, and 2023 based on the most recent year expenditure data (t-1). However, they have reverted to the standard methodology of t-2 for measuring expenditure shares.

https://doi.org/10.1016/j.eneco.2025.108482
Received 18 October 2024; Received in revised form 28 March 2025; Accepted 30 March 2025
Available online 9 April 2025

year, the prices of goods and services are measured as "price relatives", ratios of the current months price relative to its January level. For each of the 800 or so items in the CPI basket, a geometric average of the price relatives is taken and then each of the items is given the expenditure weights to compute the overall CPI inflation figure. This use of base weights is similar to the famous Laspeyres' formula, except that rather than using the January or first quarter expenditure shares, the average over a previous year is used.[3] The use of base weights is primarily a practical issue. Expenditure data is gathered from a large household survey and the results take time to process, so that it only becomes available with a significant lag. Also, the ONS and other statistical offices do not want to revise the inflation figures (since they are used for many purposes, including indexation of benefits, pensions, and so on), so they are reluctant to update the expenditure shares after the event.

Why is it crucial to measure an accurate inflation rate? The CPI inflation rate is an important metric for policymakers, particularly the government and the central bank. We have already mentioned that the CPI inflation rate is the basis of indexation for several benefits programs, pensions, regulated prices, minimum wages and affects many other policy areas in the UK. Similarly, Lebow and Rudd (2003) also mentioned the importance of CPI and its use as an index for many public programs in the US. Furthermore, they emphasized the significance of precise inflation figures in accurately measuring real output and productivity, as inaccurate or overestimated inflation figures can lead to erroneous information about real economic growth.

In this paper, we adopt the methodology of Chowdhury and Dixon (2024). We use the published expenditure weights from national accounts for each quarter of 2022. This means we are able to measure the current weighted Paasche Index, which weights changes of a particular month relative to January using the expenditure weights of that month (or at the quarter in which it occurred if the monthly data is unavailable). We can use this to find that the "true" CPI inflation rate in the UK. As is well known, due to consumer substitution, the Laspeyres index tends to overestimate inflation, while the Paasche index tends to underestimate it. We will use the Fisher Index, which takes the geometric mean of the Laspeyres and Paasche indices, as our "true" measure of inflation, which we can then compare with the published figures. The Fisher index passes most of the important axiomatic tests of price indices, and is hence is known as one of the *superlative* or *ideal* indices.

We find that the true CPI inflation rate in the UK is significantly higher than the official rate in the second quarter onwards of 2022. The downward bias[4] in the official CPI inflation rate was mainly generated from the expenditure Classification of Individual Consumption According to Purpose (henceforth referred to as COICOP) 04 housing, water, electricity, gas, and other fuels and the COICOP 07 transport due to the "sky-high" energy price.[5] Moreover, the input-output matrix of the national accounts has also helped us find the indirect effect of the rise in the energy price in the other COICOP divisions, such as COICOP 02 Alcoholic Beverages and Tobacco, COICOP 05 Manufacture of Furniture, and COICOP 06 Health, hence on the overall CPI inflation rate.

Similarly, we find that the true CPI inflation rate in the European Union (henceforth referred to as EU) in 2022 was 10.34 %, while the official inflation rate was 9.16 %, indicating a downward bias of approximately 1.18 % in the official rate. However, the bias is significantly higher for Belgium, Estonia, Ireland, Greece, Italy, Cyprus, Lithuania, the Netherlands, Romania, and Slovenia. Similar to the UK, COICOP 04 and 07 primarily generated the bias, as the energy expenditure share significantly changed in 2022 for most European Union countries.

This paper is structured as follows. Section 2 is about the scenario of increasing energy prices in the UK, EU, and globally. Section 3 illustrates a brief review of inflation measurement errors due to the changes in the consumption basket. Section 4 explains the methodology and the data used in this study. Section 5 describes the detailed results and findings of the study. Section 6 concludes.

2. Background: Increasing energy prices in the UK, EU and global economies

After the end of the third lockdown in April 2021 in the United Kingdom, the social distance restrictions were significantly relaxed, and the economy started to rebound with a 7.3 % real GDP growth rate (quarter-on-quarter) in the second quarter of 2021. Similarly, the quarterly GDP growth rate in the G7 and EU countries also increased notably to 1.9 % and 2.1 %, respectively, in the second quarter of 2021.[6] However, the CPI inflation rate also started increasing from the low level in the pandemic in the United Kingdom as well as the G7 and EU countries (see Fig. 1). In the United Kingdom, the increasing inflation rate was mainly driven by contributions from the following COICP categories: transport, housing and household services, restaurants and hotels, food and non-alcoholic beverages, furniture, and household goods (ONS, 2023).

The reasons behind the increasing nature of inflation in 2021 in the aftermath of the pandemic were several, including global supply-chain disruption following on from the pandemic, expansionary monetary programmes and fiscal stimulus packages, changes in general consumer expenditure patterns from services towards goods, and the "base effect" following on from low inflation during 2020 (Santacreu and LaBelle, 2022; Chakraborty, 2023; Bernstein and Tedeschi, 2021; Chowdhury and Dixon, 2024). Santacreu and LaBelle (2022) identified that both domestic and foreign exposure to supply chain disruption had a positive effect on the industry PPI inflation in the United States for the period January 2021 to November 2021. Moreover, they also mentioned that the shift in demand for durable goods and the excessive reliance on foreign suppliers to produce those goods had increased the price level due to the mismatch between demand and supply. However, by the end of 2021, it was expected that inflation would start to fall in early 2022.

However, the Russian invasion of Ukraine in February 2022 added upward pressure on the price level through energy and food, with the inflation rate reaching its highest levels not seen for decades in the United Kingdom, G7, and EU countries (see Fig. 1). The energy component of CPI hit its highest point since 2001 in the United Kingdom, EU, and G7 countries at the end of the second quarter of 2022 (see Fig. 1). The Brent crude oil spot price jumped to $133.18 per barrel (31 % increase) in March 8, 2022, from $101.29 per barrel on February 24, 2022 (see Fig. 2). On the other hand, the National Grid UK System average gas price has jumped to 17.11p per kilowatt hour (around 95 % increase) in March 8, 2022, from 8.77p per kilowatt hour on February 24, 2022 (see Fig. 2). Butler (2022) mentioned that the reason behind the rapid increase in the natural gas price compared to crude oil is that natural gas relies on the dedicated pipelines and liquefaction facilities, which makes it quite difficult to adjust supply in the wake of the Russian-Ukraine war. Yagi and Managi (2023) identified that the global increase in energy prices has a significant impact on the three energy-

[3] More accurately, the method used is called a "Lowe" index in the UK, named after the Scottish statistician Joseph Lowe.

[4] Downward bias occurs when the estimate is lower than the true parameter.

[5] According to the United Nations Classification of Individual Consumption According to Purpose (COICOP) 2018, items are classified as divisions, groups, classes, and sub-classes. However, those classifications are also known as two digits for divisions, three digits for groups, four digits for classes, and five digits for sub-classes. In the UK, the CPI is categorized as 12 divisions, 47 groups, and 117 classes according to COICOP 1999. However, this will be changed to 13 divisions, 52 groups, 188 classes, and 334 sub-classes upon the implementation of the COICOP 2018 classification.

[6] All the statistics are taken from OECD Data. The growth rate is calculated based on "Gross domestic product at market prices: Chained linked volume indices".

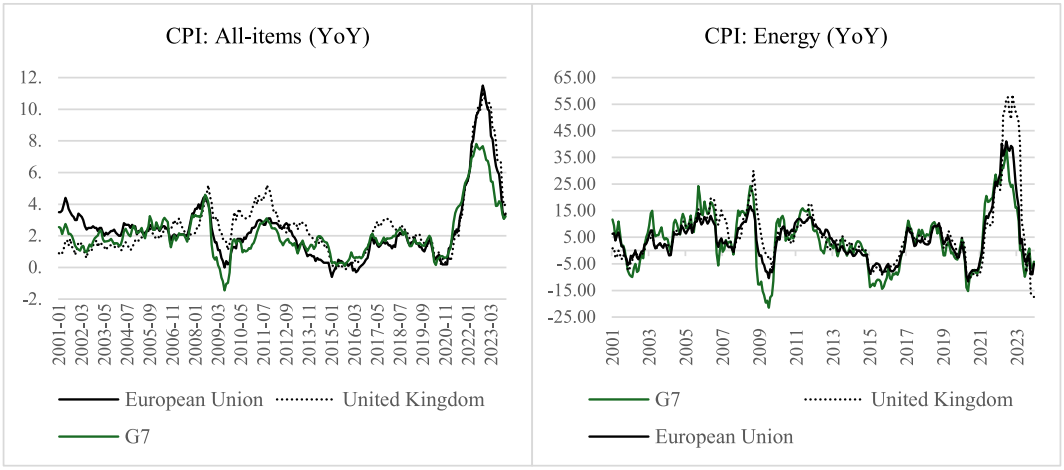

Fig. 1. Annual growth of CPI All items and energy in the UK, G7, and EU countries. *Source:* Data obtained from Eurostat and FRED Economic Data.

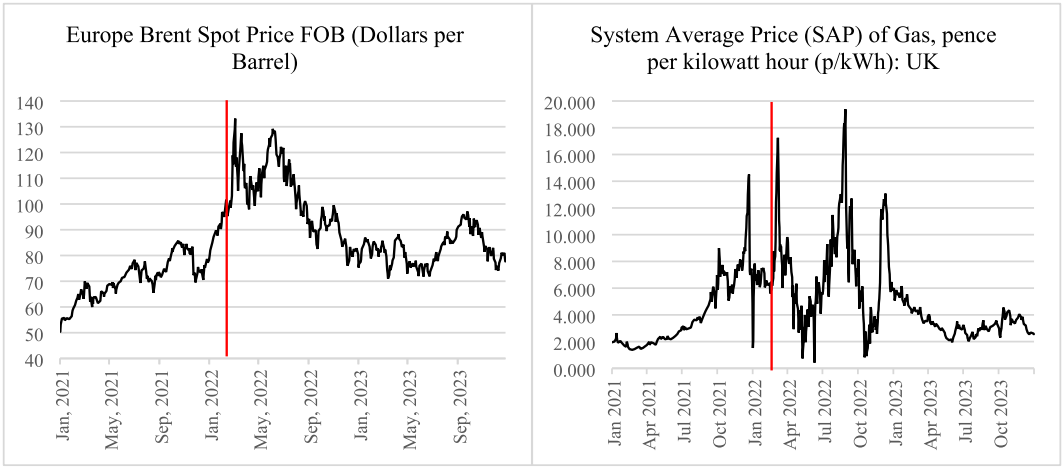

Fig. 2. Daily Europe Brent crude oil spot price and Daily National Grid Gas UK System Average price. *Note:* Oil spot price is in $ per barrel, and gas price is in p per kilowatt hour. The red line indicates the start of the Russian invasion of Ukraine (24th February 2022). *Source:* Data obtained from the U.S. Energy Information Administration (eia.gov) and ONS. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

related sectors (mining & quarrying, coke & petroleum products, electricity & gas supply), manufacturer of metal, mineral products, electrical equipment, chemical products, air transport, and construction.

The EU energy crisis was significantly amplified as pipeline gas supplies to Europe from Russia were reduced by 80 billion cubic meters (bcm) in 2022. Prior to 2022, Russian supply met around 40 % of the EU's gas demand (IEA, 2024). Liquefied natural gas (henceforth referred to as LNG) from the United States rose to meet around half this gas supply deficit, with the EU becoming the largest importer of LNG (ACER, 2024). Among the 27 EU countries, France, Spain, the Netherlands, Italy, Belgium, Germany, Poland, and Portugal became the top importers of LNG. In the second half of 2022, the Asian and EU spot LNG prices jumped from 80 to 90 EUR/MWh to 250–300 EUR/MWh (ACER, 2024). This had a significant impact on the gas price for households in EU countries in 2022. The natural gas price for the EU, Belgium, Germany, Ireland, Italy, and the Netherlands increased by around 32 %, 45 %, 17 %, 82 %, 33 %, and 55 %, respectively, in the second half of 2022 compared to the first half of 2022 (see Fig. 3).

Moreover, the high natural gas price significantly affected the electricity price for UK households. Historically, the UK has produced around 40 % of its electricity using gas (Digest of UK Energy Statistics, 2023a). The UK primarily relies on net imports for its total gas supply, which has been approximately 50 % in recent years (Digest of UK Energy Statistics, 2023b). Therefore, the increase in the global gas price in 2022 had a significant impact on both the electricity and gas price for households. The high domestic gas price has had a significant impact on consumer behaviour, resulting in a significant decrease in demand in 2022. However, the high gas price increased households' average overall energy expenditure since household energy demand is inelastic.

In the EU, households' electricity prices increased by 12.5 % in the second half of 2022, compared to the first half of 2022. This increase is significantly higher in the Netherlands, Belgium, Ireland, and Italy by around 199 %, 31 %, 39 %, and 17 %, respectively (Eurostat, 2024). Despite the significant increase in renewable energy's share of electricity production in EU countries since 2004 (to nearly 40 % in 2022), fossil fuels continue to hold a significant share, with gas usage reaching no less than 20 % in 2022. The EU countries that are still significantly relying on fossil fuels, specifically gas, are Malta, Cyprus, Poland, Estonia, Italy, Ireland, the Netherlands, Spain, Greece, and Germany (European Council, 2024).

3. A brief review of inflation measurement error due to the changes in the consumption basket

National statistical agencies across the world generally adopt the "fixed basket" approach to calculate the price index. Hausman (2003) identifies four main measurement biases in the fixed basket approach that can produce an inaccurate cost-of-living index: substitution bias,

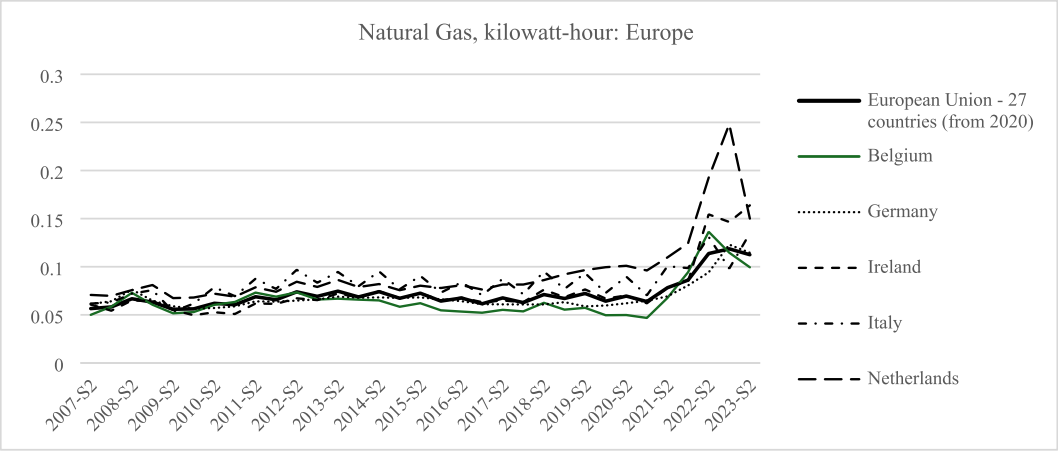

Fig. 3. Bi-annual gas price for household consumers in kilowatt hour in euro. *Source:* This data is collected from Eurostat.

new goods bias, quality bias, and outlet bias. Substitution bias is the inability of a constant basket approach to account for consumers substituting cheaper alternatives when prices change. New-goods bias is defined as the delayed incorporation of new products into the basket, thereby failing to capture the consumer welfare benefits they bring. Quality change bias overlooks the enhancements in the quality of goods and services, resulting in exaggerated inflation. Finally, outlet bias arises due to neglecting the shift in consumer shopping patterns to lower-priced stores (and nowadays to online shopping). However, statistical agencies have moved to address some of these issues, such as the use of scanner data (which includes price and quantity data) and hedonic quality measures.

Despite numerous advancements in the price index calculation, the static nature of consumer expenditure weights has limited significant research on weighting bias in the inflation measurement literature. Moreover, Lebow and Rudd (2003) identified several common biases in the literature on CPI measurement, such as upper-level and lower-level substitution bias, new-outlet bias, quality change, and new-item bias, which includes weighting bias. They identified that the consumer expenditure data in the national income and product accounts (NIPAs) in the United States are more accurate than the corresponding CPI weights. Similarly, Curtin (2022) confirmed that during the pandemic, the data quality in the Consumer Expenditure Survey by the U.S. BLS was poorer than the Personal Consumption Expenditure (PCE) price index by the U.S. Bureau of Economic Analysis. This was due to the difficulties in collecting data in person during the stringent lockdown period. In this study, we are the first to identify the issue of weighting bias in the inflation measurement literature, which arises from significant changes in household expenditure due to high energy prices.

In recent years, the weighting bias has earned significant focus in the study of CPI inflation due to the massive changes in the expenditure pattern during the pandemic. Using real-time expenditure data, such as debit and credit card expenditure, several studies have found significant bias in the CPI inflation figure during the pandemic.[7] Moreover, Chowdhury and Dixon (2024) have also found CPI inflation bias in the 33 OECD countries based on the actual household expenditure data from the national accounts. They found that the official inflation rate was overestimated and underestimated for 23 and 10 countries, respectively, in the first wave of the pandemic.

Most of the national statistical offices use a Laspeyres-type or fixed-base weight index where the expenditure weights come from previous years and are used to weight the price relatives across months within the current calendar year. In the UK, the expenditure weights were from two years prior to the current year (t-2). During the pandemic, most countries had to apply stringent lockdowns to reduce the spread of the virus, which brought sudden and enormous changes in the consumer spending pattern. This meant that the basket based on the pre-pandemic consumption expenditure pattern was not a good approximation of expenditure weights during the pandemic.

In response to the significant changes in household consumption patterns during the pandemic, the ONS and Eurostat modified the traditional t-2 rule to a t-1 rule using the previous year to calculate household expenditure share for the years 2021, 2022, and 2023 (see ONS 2024a and Eurostat, 2023 for details). However, in 2024 the ONS has reverted the standard methodology for calculating expenditure weight to t-2. However, Eurostat (2024) recommends continued use of the t-1 methodology for calculating CPI weights in 2024, citing the continued impact of Covid-19 and high energy prices due to the Russia-Ukraine conflict sine 2022.

As in the pandemic period, we would expecting a similar measurement bias to occur in 2022, with significant changes in consumer spending due to the rapid rise in energy prices. As the statistical agencies in the UK and EU adopted the t-1 methodology for calculating CPI weight in 2022, the real expenditure share was significantly different from the official expenditure weight. Therefore, we are expecting a downward bias in the CPI inflation rate in the UK and EU countries. Furthermore, the reverse bias may have occurred in the UK in 2024, when 2022 expenditure shares were used for the CPIH and CPI weights. This may not be such a problem for the EU, which used t-1 expenditure shares (i.e. 2023) to calculate 2024 CPI.

4. Methodology and data

We measure the true CPI inflation rate based on actual household expenditure data from the National Accounts. In brief, this is a retrospective analysis of the impact of the changes in expenditure weight on CPI, calculated by applying the actual household expenditure shares in a particular period. We use the Fisher price index, a superlative price index to calculate the CPI inflation rate because it minimizes the substitution bias in Laspeyres (too high) or Paasche (too low) by taking the geometric average of the two. Several studies have also advocated the use of a superlative index (e.g., the Fisher price index, the Törnqvist price index) during the period of the pandemic, for example Diewert and Fox (2020); Diewert and Fox (2022); Jaravel and O'Connell (2020a); Kantur et al. (2021); and Alvarez and Lein (2020). Moreover, Chowdhury and Dixon (2024) showed that the direct measure of the Fisher index is not significantly different from the chained Fisher index as well

[7] Chronopoulos et al. (2020), Dixon (2020), Jaravel and O'Connell (2020b) in the UK; Cavallo (2020), Chetty et al. (2020), Bachas et al. (2020), Dunn et al. (2020), Baker et al. (2020) in the US; Andersen et al. (2022) in Denmark; Carvalho et al. (2021) in Spain; Seiler (2020) in Switzerland.

as the Törnqvist price index. As a superlative price index, the Fisher price index has fulfilled all the desirable axiomatic tests of price indexing. Therefore, we will be applying the direct Fisher price index to calculate the true CPI inflation rate in the UK and EU for the year 2022.[8] More detailed methodology will be found in Chowdhury and Dixon (2024).

Actual household expenditure is the core data required for the study, which is publicly available on the ONS website and the Eurostat Database. Consumer Trends, a quarterly statistical bulletin, provides information on household final consumption expenditure (HHFCE), which encompasses all spending on goods and services by UK household members. We have access to this data for all quarters in 2022. As the actual household expenditure data in the UK is available in four-digits (which means different COICOP classes), we will be able to construct a true CPI inflation rate from a quite low level. However, the actual household expenditure for the EU aggregate and individual countries is only available in three-digits (which means different COICOP groups). Therefore, the true CPI inflation rate for the EU will be at a high level in 2022.

Table 1 gives us the true picture of UK household expenditure for goods and services in 2022. The difference between the official CPI weights and the actual household expenditure is obvious at different division levels. However, the two specific COICOP divisions, COICOP 04 Housing, water, electricity, gas, and other fuels, and COICOP 07 Transports, capture our particular interest in the energy expenditures of the UK consumer. If we look at COICOP 04, the actual household expenditure is below the official weight, but it's on an increasing trend during 2022. Therefore, we need to further dissect this division to understand the actual household energy expenditure situation. On the other hand, the actual household expenditure in COICOP 07 exceeds the official weight and is also on the rise in 2022.

Table 1
UK's CPI Official Weights and HHFCE for the year 2022: According to COICOP Divisions.

COICOP divisions	CPI official weights	HHFCE share from consumer trends			
	2022	2022 Q1	2022 Q2	2022 Q3	2022 Q4
01 Food and non-alcoholic beverages	116	99	99	101	102
02 Alcoholic beverages and tobacco	50	36	35	35	34
03 Clothing and footwear	60	58	56	56	56
04 Housing, water, electricity, gas and other fuels	138	116	124	127	128
05 Furniture, household equipment and maintenance	76	65	62	61	60
06 Health	21	25	24	24	24
07 Transport	139	156	154	154	154
08 Communication	25	24	22	22	21
09 Recreation and culture	134	121	117	116	113
10 Education	33	29	29	29	28
11 Restaurants and hotels	114	132	138	134	133
12 Miscellaneous goods and services	94	140	140	142	148

Source: We collected both data sets from the ONS website.

[8] The Fisher price index is the geometric average of the Laspeyres and the Paasche Price Indexes, which is also known as the superlative price index. The Laspeyres price index is the weighted arithmetic mean of price relatives which is based on the base period's quantity. On the other hand, the Paasche price index is a weighted harmonic mean of price relative which is based on the current period's quantity.

As the UK's actual household expenditure data is publicly available up to four-digits, this further helps us to breakdown details of household expenditure on energy in Table 2. From COICOP 04.5 and 07.2, we observed that the expenditure has increased significantly in the category of electricity, gas, and fuels and lubricants from the second quarter of 2022, and they are all above the CPI official weights. The official weights of electricity and gas were 20 and 14 (out of 1000) in 2022, but the actual household expenditure moved to 24 and 19 for electricity and gas, respectively, in the third quarter of 2022. Similarly, actual household spending on fuel and lubricant for personal transportation has increased significantly in 2022 compared to the official CPI weights.

The pattern of changes in expenditure share at the COICOP divisional level in EU countries bears a striking resemblance to that of the UK. However, our key concern is household spending on energy components. Table 3 provides us with the details of household expenditure in COICOP 04.5 (electricity, gas, and other fuels) and COICOP 07.2 (operation of personal transport equipment) in 2021 and 2022. In 2022, the overall expenditure in both categories have significantly increased for the 27 EU countries compared to the previous year. All the numbers in Table 3 are out of 100. In terms of household electricity and gas use, Belgium, Denmark, Estonia, Ireland, Italy, Latvia, and Finland showed significant changes in 2022 compared to 2021. From COICOP 07.2, we have the idea of household spending on fuels and lubricants. In this category, Czechia, Germany, Estonia, Ireland, Spain, Lithuania, Luxembourg, and Slovenia marked a significant difference in 2022 compared to the previous years. All that information has hinted at the notable differences between actual household spending and official CPI weights. Table 3 may provide insight into the likely bias in official CPI inflation in EU countries in 2022, primarily due to the high inflation in the energy sector.

5. Results and analysis

5.1. United Kingdom

Fig. 4 shows a large difference between the official CPI inflation rate and the inflation rate based on the Fisher price index. The CPI inflation bias started in the second quarter of 2022 and continues until the end of 2022. The official inflation rate in 2022 had a downward bias of 0.70 percentage points on average. However, the downward bias was higher in the third quarter of 2022, when it was around 1 percentage point.

Table 2
UK's CPI Official Weights and HHFCE for the year 2022: According to COICOP 04.5 and 07.2.

COICOP Groups/ Classes	CPI official weights	HHFCE share from consumer trends			
	2022	2022 Q1	2022 Q2	2022 Q3	2022 Q4
04.5 Electricity, gas and other fuels	36	31	41	44	47
04.5.1 Electricity	20	18	23	24	25
04.5.2 Gas	14	11	16	19	20
04.5.3 Liquid fuels	1	1	2	1	1
04.5.4 Solid fuels	1	0	0	0	0
07.2 Operation of personal transport equipment	72	68	69	68	65
07.2.1 Spare parts and accessories	4	4	4	4	4
07.2.2 Fuels and lubricants	31	37	38	39	37
07.2.3 Maintenance and repairs	21	16	14	14	13
07.2.4 Other services	16	12	12	11	11

Source: We collected both data sets from the ONS website.

Table 3
EU's actual household expenditure share: According to COICOP 04.5 and 07.2.

	04.5 Electricity, gas and other fuels		07.2 Operation of personal transport equipment	
	2021	2022	2021	2022
Belgium	5.2	7.6 (p)	6.6	6.6 (p)
Bulgaria	5.3	5.9	7.7	8.1
Czechia	6.1	6.1	4.5	5.2
Denmark	5.0	6.3	5.8	6.1
Germany	4.5 (p)	4.9 (p)	6.6 (p)	7.2 (p)
Estonia	5.0	7.1	6.7	7.4
Ireland	3.9	5.2	4.3	5.1
Greece	4.6 (p)	5.1 (p)	4.2 (p)	4.7 (p)
Spain	4.0	4.1	6.9	7.3
France	4.7 (p)	4.5 (p)	8.2 (p)	8.6 (p)
Croatia	5.0	4.7 (p)	4.7	5.1 (p)
Italy	3.6	5.6	7.7	8.2
Cyprus	3.2	3.9 (p)	6.9	7.2 (p)
Latvia	5.3	6.6	7.0	7.3
Lithuania	3.6	4.6	10.4	11.5
Luxembourg	2.2	2.5	10.0	10.7
Hungary	4.0	3.8	7.7	8.1
Malta	2.5	2.2	5.5	4.7
Netherlands	3.3 (p)	3.2 (p)	7 (p)	7.1 (p)
Austria	4.3	4.7	6.7	6.9
Poland	7.4	7.8	7.3	7.1
Portugal	3.1	3 (p)	6.7	6.4 (p)
Romania	3.9 (p)	3.4 (p)	5.1 (p)	5.1 (p)
Slovenia	5.4	5.5	10.7	11.6
Slovakia	8.5	7.9	3.2	3.4
Finland	4.9	5.6	6.5	6.8
Sweden	5.9	6.6	6.3	6.4
European Union - 27 countries (from 2020)	4.5	5.1	6.9	7.4

Note: p means provisional.
Source: We obtained this data from the Eurostat database.

The Russian-Ukraine conflict affected Europe in particular, as Russia was the largest energy supplier to the European countries prior to 2022. In comparison to EU countries, the United Kingdom was less reliant on Russian natural gas supplies as it imported around only around 5–6 % gas from Russia in the form of LNG (Ralston, 2022). But the energy crisis in EU countries caused the international market prices of natural gas to increase, which affected domestic prices in the UK. This led to electricity price increases as natural gas is used to generate around 40 % of UK electricity (Ralston, 2022). Moreover, most UK residential heating systems rely on gas rather than electricity, which led to the sharp increase in household expenditures on energy at the end of 2022.

However, the bias has narrowed significantly in the first three quarters of 2023. The two main reasons are the decline in the energy price cap (see Table 4) and the CPI weight update. We mentioned earlier that the ONS has updated its CPI weight in 2021, 2022, and 2023 based on the t-1 methodology. The increase in energy-related expenditure shares caused by the rise in energy price in 2022 was applied to the official CPI weights for household energy consumption in 2023. As the energy price significantly decreased in the final quarter of 2023 compared to previous quarters, the official CPI weights were again considerably different (higher) from actual household energy consumption. Therefore, the fourth quarter of 2023 experienced an upward bias, as the declines in energy prices were given a bigger weight than consistent with the current expenditure shares.

We can break down the analysis according to the main household energy expenses in the COICOP classification. As energy is price inelastic, the high inflation in the energy sector after February 2022 has certainly caused an increase in household expenditure on electricity, gas, and fuels & lubricants (see Table 2). The increased household expenditure in the energy sector along with the high inflation rate caused a downward bias in the official CPI inflation rate in the last three quarters of 2022. However, the downward bias is much more evident in COICOP 04 and COICOP 07, where the high inflation in the energy sector has a direct impact on the household expenditure share, in the last three quarters of 2022 (Figs. 5 and 6). Fig. 5 suggests that the bias has increased significantly in the last quarter of 2022. The reason behind the high inflation bias is the winter, when the weather is comparatively cold, and people are compelled to use heating in their home, which is mostly operated by gas. However, the bias might have been more without the Energy Bills Support Scheme (EBSS) of a £400 discount to all households from October 2022 to March 2023.[9] Moreover, the Energy Price Guarantee (EPG) has also helped to limit the further price increase in October 2022 by setting a price cap for the energy sector in the United Kingdom (Appendix-A, Fig. A1).

In addition, the high inflation rate in the energy sector has also a direct impact on the COICOP 07 Transports expenditure share (see Table 2). The inflation rate in fuels and lubricants started increasing in the last quarter of 2021 and jumped enormously from the second quarter of 2022. Kuik et al. (2022) mentioned that the rebound of economic activity after the pandemic, supply-side issues after the pandemic, and declining investment in oil and gas production after 2014 are the key reasons behind the increasing oil price in the last quarter of 2021. The gradual reduction in lockdown restrictions and increased travel raised the demand for oil after the second quarter of 2021. The supply-side effect has derived from the continuous failure of the OPEC+ countries to produce the target level of oil after the pandemic. Moreover, the gradual reduction in investment in oil and gas production after 2014 provoked tension in the international oil market in the last quarter of 2021 (Appendix-A, Fig. A2). However, the sudden increase in the oil price in the global market in the second quarter of 2022 is simply derived from the Russia-Ukraine conflict that began on 24 February 2022 (Appendix-A, Fig. A3). The increase in oil price has also led to a rise in the other components of the transport division, such as household expenditure for passenger transport by railway, road, and air. Therefore, the increased household expenditure on fuels and lubricants and other transport services has generated a significant deviation from the official CPI weights, which produced a downward bias in the official CPI inflation figure in 2022.

However, we can further investigate the indirect impact of high inflation in the energy sector on the other COICOP divisions with the help of the "combined use" matrix.[10] Input-output supply-and-use tables from ONS can be used to get the required data. The latest table gives us information up to 2020. Therefore, we have used the pre-pandemic table (i.e., Industries' intermediate consumption in 2018) to understand the intermediate demand for energy-related products (i.e., electricity, gas, oil, transport) in a normal period. The table gives us information that the intermediate demand for gas is around 40 % in the electric power generation, transmission, and distribution sector, which is visible in Fig. 5.

Other than electricity and gas, we have found that transport services as an intermediate product have an impact on the production of COICOP 02 Alcoholic Beverages and Tobacco. Around 8 % of the total intermediate consumption of manufacturing alcoholic beverages and tobacco products is made up of land transport services and transport services via pipelines, excluding rail transport. Therefore, high inflation in transport services has a significant impact on household expenditure on alcoholic beverages and tobacco, hence a downward bias in the official CPI inflation (Appendix-A, Fig. A4).

Similarly, transport services as an intermediate product have an impact on the manufacture of furniture (COICOP 05). This is mostly taken in the form of land transportation of furniture or furniture-related

[9] The discount has applied to all the household electricity bill for 6 months starting in October 2022. All the household received £66 in October and November and £67 in December, January, February, and March.

[10] Combine Use matrix helps to understand the industries intermediate consumption. This is also known as input-output matrix or Leontief Matrix.

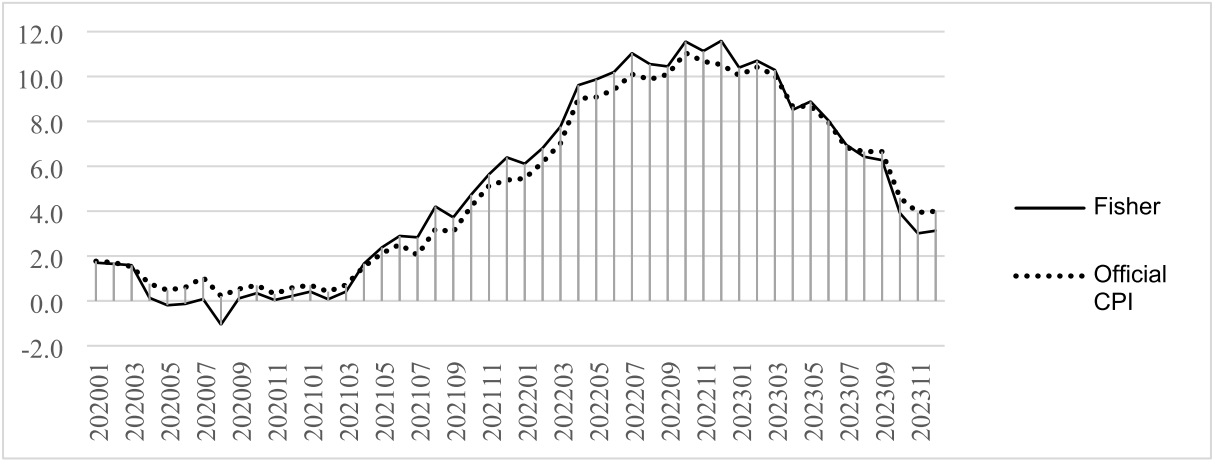

Fig. 4. UK's Official CPI inflation rate and inflation rate based on Fisher price index: All items. *Source:* author calculation.

Table 4
Ofgem's Energy Price Cap History.

	Jul to Sept 2024	April to Jun 2024	Jan to Mar 2024	Oct to Dec 2023	Jul to Sept 2023	April to Jun 2023	Jan to Mar 2023	Oct to Dec 2022	Summer 2022	Winter 2021/22	Summer 2021
Energy Price Cap, payment by Direct Debit (£)	1568	1690	1928	1834	1976	3116	4059	3371	1877	1216	1084
Energy Price Cap change vs Previous Price cap (%)	−7 %	−12 %	5%	−7 %	−37 %	−23 %	20 %	80 %	54 %	12 %	9 %

Source: Ofgem data, May 2024.

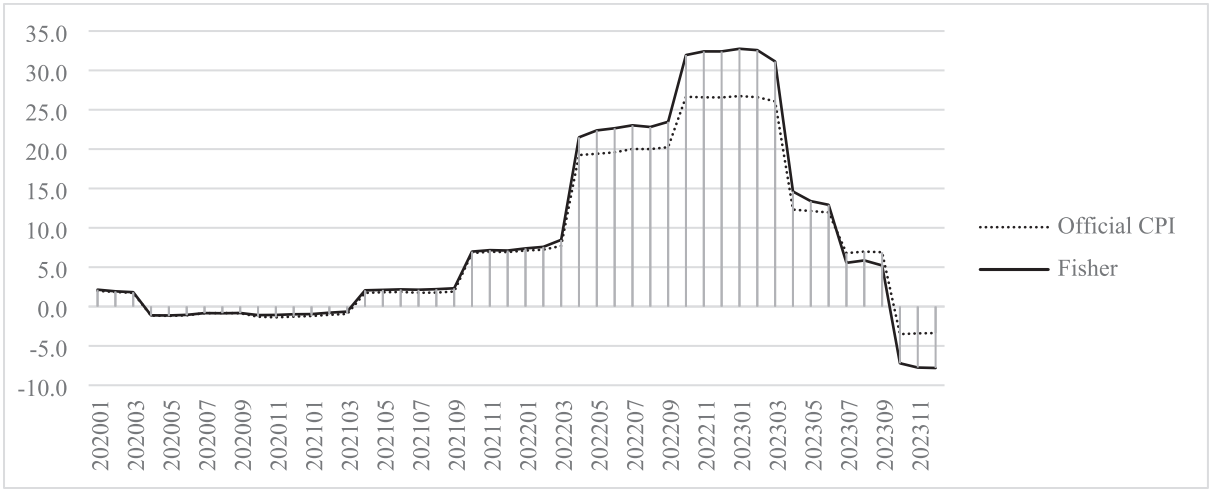

Fig. 5. UK's Official CPI inflation rate and inflation rate based on Fisher price index: COICOP 04. *Source:* author calculation.

equipment. According to the 2018 combined use matrix, around 3 % of the total intermediate consumption of manufacturing furniture and furniture-related products is made up of land transport services and transport services via pipelines, excluding rail transport. So, increased inflation in transport services has an impact on household expenditure on furniture or furniture-related products. This might be the potential reason for a slight downward bias in the official CPI inflation in COICOP 05 (Appendix-A, Fig. A5).

Finally, transport services as an intermediate product have an impact on the production of human health activities (COICOP 06). In this category, around 3 % of the total intermediate consumption of human health activities is made up of land transport services and transport services via pipelines, excluding rail transport. Therefore, high inflation in transport services in 2022 has an impact on the expenditure share in the COICOP 06 health category in a similar fashion. Hence, this might lead to a downward bias in the official CPI inflation in COICOP 06 (Appendix-A, Fig. A6).

5.1.1. Contribution of sub-categories to the overall bias

We can calculate the contribution of different COICOP divisions/groups to the aggregate bias in the official inflation figure. We may apply the re-weighting decomposition framework to ensure that the

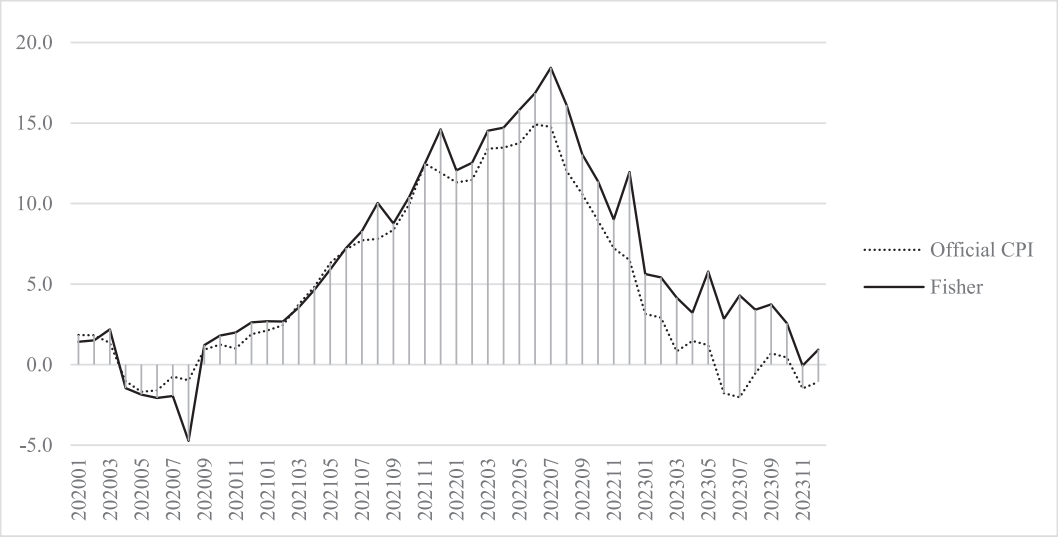

Fig. 6. UK's Official CPI inflation rate and inflation rate based on Fisher price index: COICOP 07. *Source:* author calculation.

divisional-level contributions sum up to the overall bias. Therefore, we can decompose the overall inflation bias as follows:

$$\text{Aggregate bias} = \text{Within} - \text{division bias} + \text{Between} - \text{division bias} \quad (1)$$

Within-division bias will capture the inflation bias due to the differences in inflation rates within each division. The between-division bias integrates the inflation bias resulting from variations in weights among divisions.

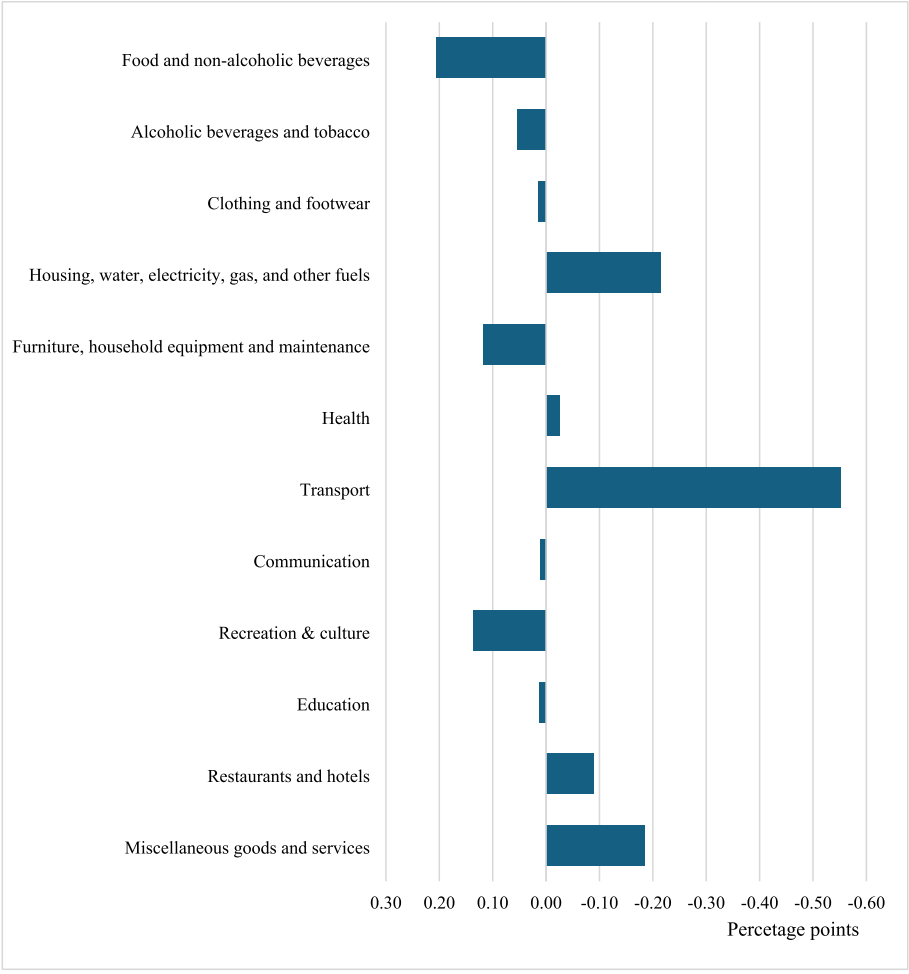

Fig. 7. Contribution of Divisions to aggregate bias: 2022Q2 - 2023Q2. Source: author calculation.

$$\text{Within} - \text{division bias} = \sum_i w_i^{HHFCE} . \left(\pi_i^{Official} - \pi_i^{Fisher} \right) \quad (2)$$

$$\text{Between} - \text{division bias} = \sum_i (\Delta w_i) . \pi_i^{Official} \quad (3)$$

whereas w_i^{HHFCE} is the household final consumption expenditure share, $\pi_i^{Official}$ is the annual official inflation rate, π_i^{Fisher} is the inflation rate based on the Fisher Price Index, and Δw_i as the difference between official weight and HHFCE weight for the different COICOP divisions.

One of the major sources of data for this calculation is obviously the HHFCE weight data. The ONS has published this dataset from the four-digit, i.e., classes of the COICOP categories. This will allow us to calculate the Fisher Price index, adopting the updated actual household expenditure from the three-digit data points, i.e., groups of the COICOP categories. Fig. 7 presents the contributions of different COICOP divisions to the overall inflation bias for the most downward-biased period from the second quarter of 2022 to the second quarter of 2023.

The negative bias indicates a downward bias in the official inflation rate; the inflation rate based on the Fisher Price index is higher than the CPI inflation rate. Fig. 7 depicts the average aggregate bias in the official inflation rate over a period of five consecutive quarters, commencing with the second quarter of 2022 and concluding with the second quarter of 2023. The major contributions come from COICOP 04: Housing, water, electricity, gas, and other fuels; and COICOP 07: Transport.

Table 5 gives us the contribution to aggregate bias based on all the quarters from 2022 to 2023. The highest downward bias in the official CPI inflation rate is in the fourth quarter of 2022. Out of the −0.83 % aggregate bias, the contribution from COICOP 04: Housing, water, electricity, gas, and other fuels is −0.52 %, while COICOP 07: Transport contributes −0.62 %. Moreover, a few more downward biases also generate from COICOP 11: Restaurants and hotels and COICOP 12: Miscellaneous goods and services.

The major contribution to COICOP 04: Housing comes from COICOP 04.5: Electricity, gas, and other fuels. It contributed around −0.71 % to the downward bias in the official CPI inflation rate in the last quarter of 2022. In COICOP 07: Transport, the major contribution comes from COICOP 07.3 Transport services, accounting for approximately −0.56 % of the downward bias in the official CPI inflation rate in the fourth quarter of 2022. We are unable to directly determine the contribution from COICOP 07.2.2 Fuels and Lubricants, as it falls under the four-digit COICOP categories. However, the three-digit COICOP 07.2: Operation of Personal Transport Equipment, which also exacerbated the overall downward bias in the CPI inflation rate, provides us with an indirect understanding of how the share of fuel spending influences the overall bias.

As we previously discussed the use of the "Combined Use" matrix to investigate the indirect impact of the energy sector on the other COICOP categories, Table 5 clearly illustrates the contribution of COICOP 06: Health to the downward aggregate bias in the official CPI inflation rate. Within these COICOP categories, COICOP 06.2: Outpatient services and COICOP 06.3: Hospital services primarily generate the negative downward contribution.

5.1.2. Distributional aspects of the bias

Cavallo (2024) found that during the pandemic, the inflationary bias in the headline inflation rate in the US is significantly higher for low-income households. Therefore, it could be interesting to examine the impact of weighting bias across the income distribution, considering the hypothesis that the expenditure share for energy is higher at lower income levels. The HHFCE data we have used previously does not give the shares for the individual income groups, a key data point for this measurement. However, we can approximate it with ONS expenditure weights for different income deciles published in the Household Cost Indices (hereafter HCIs). Since December 2017, the ONS has been publishing experimental HCIs for different household groups, including the income deciles (ONS 2017).[11] The HCI provides expenditure shares by decile for each year, and by applying these in an analogous way to our analysis of the CPI data, we can obtain a Fisher index for each decile in each quarter of 2022–2023. The Paasche index for the quarters of 2022 uses the shares for the whole year 2022, and the Laspeyres index uses the share for 2021, with the Fisher index taking the geometric average. The price data for each type of expenditure uses the standard CPI index for the relevant quarter. We can then compare these to the official CPI inflation.

Table 6 reveals the inflationary bias in the official CPI inflation rate across various household income groups. The data supports our hypothesis that high energy prices primarily impact the lower household income group. If we consider decile 5 to be the median income household, the lower deciles can be considered the lowest income groups, and the higher deciles will be the higher income groups. The downward bias in the official CPI inflation figure is clearly higher in the lower household income group. Even decile-5 also gives us a clear indication of the downward bias in the official CPI inflation during the affected periods. In the higher income deciles, the inflationary bias is significantly lower in compared to the lower income deciles, as anticipated. For the lowest decile, the official CPI was 4 percentage points too low in 2023 Q1, as compared to less than 2 percentage points for deciles 6 to 10. Similarly, in 2023 Q4 when the official CPI inflation is "too high", the effect is much larger for the lower deciles.

However, we would like to identify the limitations of this investigation. The HCIs adopt a different methodology for some categories of expenditure. For example, unlike CPI it includes mortgage interest rates, stamp duty, and other costs related to the purchase of a dwelling in COICOP 04. HCI also adopts a slightly different method for assessing the cost of insurance in COICOP 12. Furthermore, we do not have quarterly expenditure shares for the HCI, which makes the figures more approximate. However, despite these limitations, it is clear that there is a substantial difference across the income distribution as we would expect.

5.2. The European Union

In this section, we apply the same methodology across EU countries but are able to do this consistently on an annual basis across 2020 to 2022. The downward bias in the CPI inflation was significantly higher in the European Union in 2022, specifically in Belgium, Estonia, Ireland, Greece, Italy, Cyprus, Lithuania, the Netherlands, and Romania (see Table 7). The inflation measurement issue in EU countries during the energy crisis in 2022 was more substantial than the COIV-19 period in 2020–21, where sudden changes in household consumption expenditures were also significant. There was a downward bias of around 1.2 percentage points in the aggregate official CPI inflation rate across the 27 EU countries. However, this bias was even greater than 2 percentage points in some EU nations.

Before the Russia-Ukraine conflict, Europe was considerably dependent on the Russian energy supply. In the first quarter of 2022, the total EU's import from Russia was 30 % of petroleum oil, 19 % of LNG, and 41 % of natural gas (Eurostat). After the EU imposed massive sanctions against Russia, Europe had to reduce its dependence on Russian energy and seek an immediate alternative, albeit at a high price,

[11] The HCIs offer valuable insights into the inflationary experiences of various household groups, serving as a complementary measure to the CPI inflation. Like CPI, HCIs also follow the similar "fixed basket" approach to measure the price change statistics. However, the "fixed basket" measure in HCIs differs from that in CPI, as HCIs utilize democratic weights, whereas CPI employs plutocratic weights for calculating the price index. Democratic weights are based on the average across each household's share of expenditure, whereas plutocratic weights reflect the total share of expenditure across all households (ONS, 2024).

Table 5
Contribution of Divisions to aggregate bias (2022Q1 to 2023Q2).

COICOP divisions		2022Q1	2022Q2	2022Q3	2022Q4	2023Q1	2023Q2	2023Q3	2023Q4
1	Food and non-alcoholic beverages	0.06	0.11	0.17	0.20	0.28	0.26	0.20	0.14
2	Alcoholic beverages and tobacco	0.00	0.01	0.03	0.05	0.07	0.11	0.12	0.12
3	Clothing and footwear	0.00	0.01	0.02	0.02	0.01	0.01	0.01	0.00
4	Housing, water, electricity, gas, and other fuels	0.09	−0.05	−0.11	−0.52	−0.41	0.02	0.29	0.44
5	Furniture, household equipment and maintenance	0.05	0.11	0.14	0.17	0.10	0.07	0.05	0.03
6	Health	−0.01	−0.03	−0.03	−0.03	−0.03	−0.02	−0.01	−0.02
7	Transport	−0.29	−0.46	−0.70	−0.62	−0.44	−0.55	−0.67	−0.27
8	Communication	0.00	0.01	0.01	0.01	0.01	0.02	0.01	0.01
9	Recreation & culture	−0.10	0.02	0.15	0.16	0.14	0.20	0.21	0.23
10	Education	0.02	0.02	0.02	0.02	0.00	0.00	0.00	0.00
11	Restaurants and hotels	−0.13	−0.20	−0.20	−0.18	0.08	0.06	0.05	0.04
12	Miscellaneous goods and services	−0.04	−0.02	−0.10	−0.12	−0.27	−0.41	−0.40	−0.41
0	**Aggregate Bias**	**−0.35**	**−0.47**	**−0.59**	**−0.83**	**−0.45**	**−0.24**	**−0.14**	**0.30**

Note: The aggregate bias is expressed in percentage points. We calculated it by subtracting the inflation rate based on the Fisher Price index from the official CPI inflation rate.
Source: Author calculation.

Table 6
Official CPI inflation minus Fisher Price Index inflation (2022Q1 to 2023Q4).

Income Decile	2022Q1	2022Q2	2022Q3	2022Q4	2023Q1	2023Q2	2023Q3	2023Q4
Decile 1	0.23	−1.81	−2.02	−3.58	−4.00	−1.58	−0.54	1.45
Decile 2	0.16	−1.40	−1.59	−2.83	−3.17	−1.58	−0.47	1.45
Decile 3	0.16	−1.34	−1.48	−2.63	−2.90	−1.32	−0.33	1.11
Decile 4	0.04	−1.37	−1.45	−2.48	−2.67	−1.14	−0.23	1.13
Decile 5	0.03	−1.19	−1.25	−2.12	−2.23	−0.98	−0.14	1.14
Decile 6	0.02	−0.97	−0.98	−1.65	−1.70	−0.78	0.02	1.02
Decile 7	0.05	−0.88	−0.84	−1.45	−1.59	−0.52	0.06	0.93
Decile 8	−0.01	−0.86	−0.81	−1.30	−1.29	−0.44	0.17	0.92
Decile 9	0.04	−0.85	−0.68	−1.17	−1.33	−0.25	0.28	0.88
Decile 10	−0.14	−0.80	−0.60	−0.88	−0.82	−0.14	0.42	1.03

Note: We express the above data in percentage points. Decile 1 represents the household with the lowest income, while decile 10 represents the household with the highest income.
Source: Author calculation.

to import essential energy from other parts of the world. Out of all the energy components, gas is the most important for Europeans, as households, industry, power, and heating generation require gas at around 26 %, 24 %, and 33 %, respectively. This high dependency on a specific energy source, increasing demand for alternative sources, and extremely high price levels have caused significant changes in household consumption of energy components (see Table 3). Therefore, the true inflation rate in Europe differs significantly from the official inflation rate. We can look in more detail at the experiences of Belgium, Estonia, Ireland, Greece, Italy, Lithuania, and the Netherlands.

5.2.1. Belgium

In 2022, total domestic energy production was in the form of 70.6 % nuclear, 17.3 % biofuels and waste, 10.3 % wind, solar, etc. However, apart from nuclear, biofuels, wind, and solar PV, around 23 % of electricity generation comes from natural gas. As a result, they had to heavily rely on imports, ranking 8th among all European countries in 2021 (IEA, 2025a). This leads the Commission for the Regulation of Electricity and Gas (CREG) to raise the new energy contract to €5988.95 per year in October 2022, which was around 95 % higher than the previous year at €3066.60 per year (Taylor, 2022). The downward bias of the official CPI inflation rate was 1.5 percentage points in 2022, which was significantly higher compared to the pandemic period. Therefore, the energy crisis has caused more measurement errors in the CPI inflation calculation in Belgium.

5.2.2. Estonia

Coal is the largest domestic energy source in Estonia, comprising around 60 % of total energy production in 2022. Moreover, coal will capture around 63 % of the total energy supply in 2022. Coal generated around 66 % of total electricity in 2022. However, other important energies, such as petroleum oil and natural gas, also played a vital role in the total energy supply. Estonia was totally dependent on imports for petroleum oil and natural gas supplies. Oil imports have increased by around 101 % in 2022 compared to 2000. However, natural gas imports will decline by around 47 % in 2022 compared to 2000, as the share of renewable energy consumption has increased significantly in the last decade (IEA, 2025b). Since 2000, industrial prices and residential prices for gas have increased 5.7-fold and 4.3-fold, respectively. This led to a significant change in household energy spending in 2022. Hence, there is a big downward bias in the official CPI inflation rate of 1.2 percentage points, which is considerably higher compared to the pandemic period.

5.2.3. Ireland

The inflation measurement error in 2022 is notably higher compared to during the pandemic. The downward bias in the official CPI inflation rate was around 2.1 percentage points in 2022. The average electricity price per household has increased to 31.72 cents per KWh in the second half of 2022 from 22.83 cents per KWh in the first half of 2022, which represents a 40 % rise in the electricity price and is higher than any EU nation for that period. The other key energy component, the price of gas

Table 7
Official CPI inflation and true CPI inflation based on Fisher price index.

	2020			2021			2022		
	Official CPI	Fisher CPI	Difference	Official CPI	Fisher CPI	Difference	Official CPI	Fisher CPI	Difference
Belgium	0.431	−0.067	0.498	3.222	3.849	−0.627	10.319	11.800	−1.481
Bulgaria	1.228	1.138	0.090	2.847	3.109	−0.262	12.986	13.469	−0.483
Czechia	3.279	3.221	0.058	3.305	2.785	0.521	14.788	15.392	−0.604
Denmark	0.334	0.276	0.058	1.943	2.163	−0.219	8.513	9.111	−0.598
Germany	0.378	0.386	−0.009	3.216	3.203	0.013	8.644	8.349	0.295
Estonia	−0.620	−0.735	0.115	4.490	4.861	−0.371	19.375	20.555	−1.180
Ireland	−0.455	−0.903	0.448	2.430	2.982	−0.552	8.049	10.160	−2.111
Greece	−1.255	−1.690	0.435	0.587	1.162	−0.575	9.290	10.243	−0.953
Spain	−0.332	−0.879	0.548	3.005	3.846	−0.841	8.333	8.433	−0.100
France	0.527	0.472	0.055	2.066	2.268	−0.202	5.896	6.134	−0.238
Croatia	0.024	−0.115	0.139	2.672	2.753	−0.081	10.632	10.658	−0.027
Italy	−0.143	−0.680	0.537	1.940	2.638	−0.698	8.702	11.297	−2.594
Cyprus	−1.091	−1.616	0.524	2.258	2.806	−0.548	8.077	8.883	−0.807
Latvia	0.090	−0.047	0.137	3.248	3.206	0.042	17.143	16.976	0.167
Lithuania	1.069	0.650	0.419	4.628	4.949	−0.321	18.781	20.052	−1.272
Luxembourg	0.011	0.076	−0.064	3.478	3.509	−0.031	8.155	7.945	0.210
Hungary	3.381	3.047	0.335	5.199	4.722	0.476	15.160	14.998	0.162
Malta	0.791	0.022	0.768	0.712	1.520	−0.808	6.105	6.354	−0.249
Netherlands	1.115	0.737	0.378	2.824	3.208	−0.384	11.607	12.881	−1.274
Austria	1.391	1.426	−0.035	2.756	2.653	0.102	8.591	9.026	−0.434
Poland	3.658	3.636	0.022	5.215	5.298	−0.083	13.153	13.155	−0.002
Portugal	−0.118	−0.217	0.099	0.944	1.135	−0.190	8.080	8.438	−0.358
Romania	2.332	2.304	0.028	4.100	4.582	−0.482	11.986	12.739	−0.753
Slovenia	−0.265	−0.504	0.239	2.051	2.459	−0.408	9.294	9.835	−0.542
Slovakia	2.018	2.341	−0.323	2.818	1.986	0.832	12.091	12.016	0.075
Finland	0.385	0.434	−0.050	2.066	1.962	0.104	7.160	7.283	−0.122
Sweden	0.659	0.294	0.365	2.649	3.151	−0.502	8.037	8.422	−0.384
European Union – 27 countries	0.692	0.599	0.092	2.897	3.091	−0.194	9.164	10.329	−1.164

Note: Since most countries have not yet updated their actual household expenditure data for 2023, this calculation only covers 2022. The difference indicates annual official CPI inflation minus Fisher CPI inflation.
Source: author calculation.

to households, has increased to 15.48 cents per KWh in the second half of 2022 from 8.5 cents per KWh in the first half of 2022. This represents an 82 % increase in the household gas price and significantly higher than any other EU country (SEAI, 2024). Hence, this sudden change in energy consumption expenditure led to a significant measurement error in the official CPI calculation in 2022.

5.2.4. Greece

Total energy supply in Greece was mostly reliant on oil and gas, which were approximately 52 % and 22 %, respectively, in 2022. However, both energy components were heavily reliant on imports. The import share of crude oil was around 73 % of total energy imports in 2022. In 2022, gas imports accounted for only 13 % of total energy imports, but they have increased by around 189 % in the last two decades. Furthermore, gas accounted for approximately 38 % of total electricity generation in 2022 (IEA, 2025c). As a result, increased gas prices have caused a significant shift in household energy spending. Therefore, the official CPI inflation in 2022 had a downward bias. In 2022, the downward bias was around 1 percentage point, which was significantly greater than the pandemic period.

5.2.5. Italy

The downward bias in the official CPI inflation was around 2.6 percentage points in 2022, which was significantly higher than any of the EU countries. The CPI inflation measurement error due to energy is considerably higher than the pandemic period. The key reason was the high dependency on oil and gas in the total supply of energy. In 2022, the supply of oil and gas accounted for approximately 35 % and 41 % of the total energy supply, respectively. However, the net gas import was around 99.2 % of the total gas supply in 2022. Moreover, natural gas was responsible for producing around 48 % of total electricity production in 2022. Therefore, the higher global market price for gas has caused both the gas and electricity prices to rise for households. In Greece, crude oil is another important energy component, accounting for around 34.3 % of the total energy supply in 2022. Again, crude oil is also import-based energy for Greece, where net crude oil imports were around 93.5 % of total crude oil supply (IEA, 2025d). As a result, high household energy expenditures in 2022 caused the greatest inflation measurement error in Greece.

5.2.6. Lithuania

Oil and gas are the country's primary energy sources, accounting for around 46 % and 22 %, respectively, of the total energy supply in 2022. Both energy sources heavily rely on imports. In 2022, crude oil and gas accounted for 60 % and 21 % of total energy imports in Lithuania (IEA, 2025e). It demonstrated Lithuania's high reliance on specific energy resources, typically imported from other countries. As a result, the price of domestic energy is highly dependent on the international market. That's why a significant measurement error in the official CPI inflation was observed in 2022. The downward bias was around 1.3 percentage points in 2022, and it was considerably higher than the biases generated during the pandemic.

5.2.7. Netherlands

The downward bias of CPI inflation was significantly higher in 2022 compared to the pandemic period in 2020–21. In 2022, the true CPI inflation rate was approximately 1.3 percentage points higher than the official inflation rate. The key reason was the difference between the

official CPI weights and actual household spending due to the energy crisis in 2022. If we look at the Netherlands' energy composition, we find that oil and gas will account for around 75 % of the total energy supply in 2022. The supply of crude oil was fully dependent on imports, which constituted around 34 % of total energy imports in 2022. Gas, another essential energy component, formerly underwent significant internal production. However, a recent trend says that net imports of gas have increased significantly in the last couple of years (IEA, 2025f). As the global market trends for oil and gas in 2022 have significantly affected households' spending on the energy component, the official CPI inflation rate in 2022 experienced a higher downward bias.

Other EU countries in Table 5 also show the same trend of significant downward bias in the official CPI inflation rate in 2022. The scenario for other EU nations is also identical to the cases explained for the above-mentioned countries. If we examine the demand and supply of key energy components in the EU, we find a significant gap, with most EU countries heavily relying on Russian energy supplies as well as those from the rest of the world. As a result, the sudden surge in the global energy market has had a significant impact on household energy expenditure. Hence, actual household spending significantly deviated from the official CPI weight and generated a large downward bias in the official CPI inflation rate in 2022.

6. Conclusion

Rapid changes in household expenditure may cause bias in the official CPI inflation from the Fisher Index (true inflation). The degree and direction of the bias depends on how official expenditure weights deviate from the actual household expenditure share. Our initial hypothesis is that the changes (increases) in the actual household expenditure for energy consumption in 2022 could potentially lead to a downward bias in the official CPI inflation rate. Given that this problem bears resemblance to the official CPI inflation bias during the pandemic period, which was also caused by sudden changes in the expenditure share, we have utilized the Chowdhury and Dixon (2024) methodology to analyse the hypothesis. Using the actual household expenditure data for 2022, we have found a significant downward bias in the official UK CPI inflation rate (all items) in 2022.

The main sources of this bias were household expenditure shares for COICOP 04 housing, water, electricity, gas, and other fuels, as well as the COICOP 07 transport categories, which increased in 2022 due to the high inflation in the energy sector. We also found that the downward bias in the official CPI inflation figure was highest in the lower household income deciles and indeed for all households below the median income.

In the European Union, the downward bias in CPI inflation was significantly higher in 2022, especially in Belgium, Estonia, Ireland, Greece, Italy, Cyprus, Lithuania, the Netherlands, and Romania. The larger size of the bias reflected the more direct impact of the restriction of Russian energy from 2022 onwards.

CRediT authorship contribution statement

Aftab Chowdhury: Writing – review & editing. **Huw Dixon:** Writing – review & editing, Conceptualization.

Declaration of competing interest

None.

Appendix

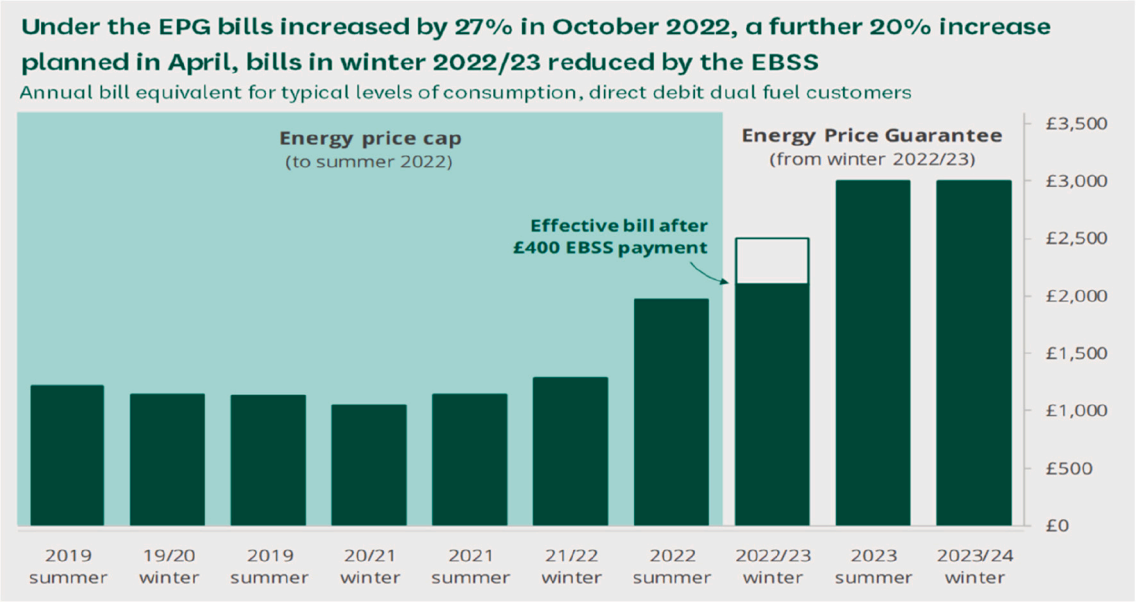

Fig. A1. Energy Price Guarantee (EPG) and Energy Bills Support Scheme (EBSS) in the UK.
(Source: Bolton and Stewart (2023)*)*

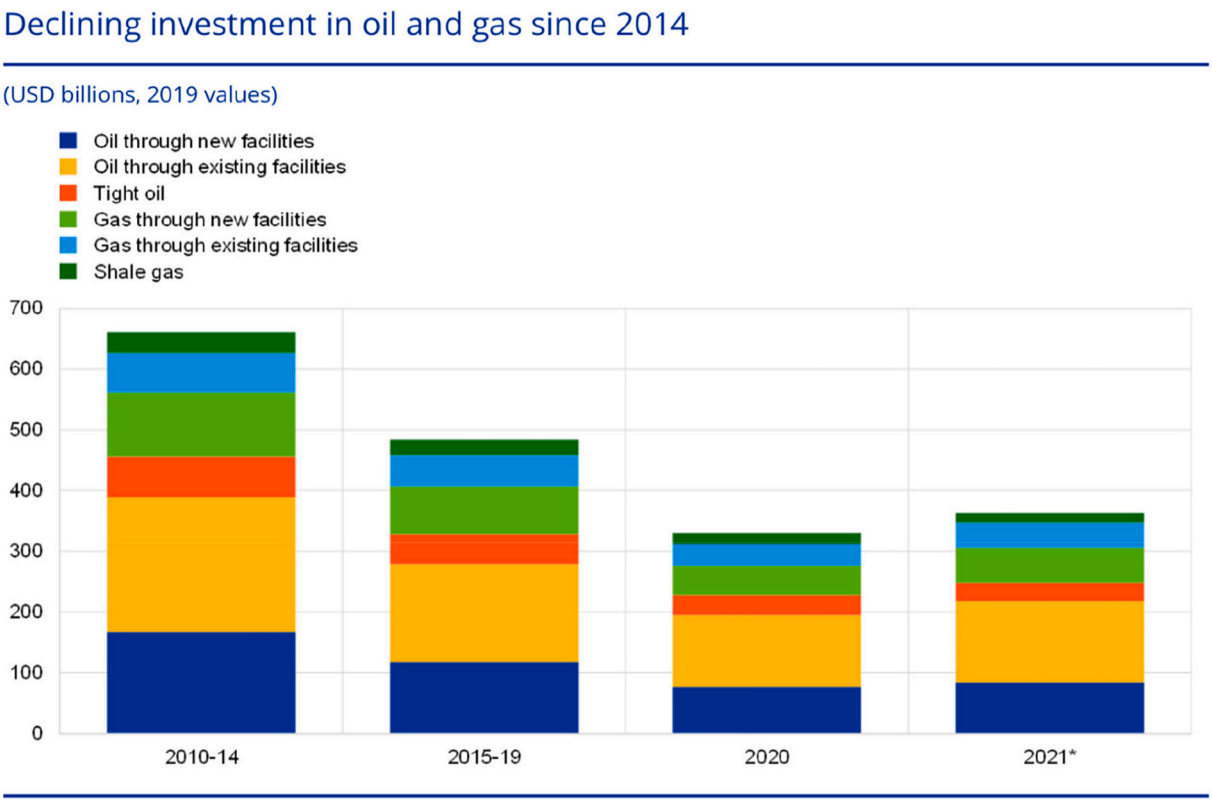

Fig. A2. Global investment in oil and gas production.
(Source: Kuik et al. *(2022))*

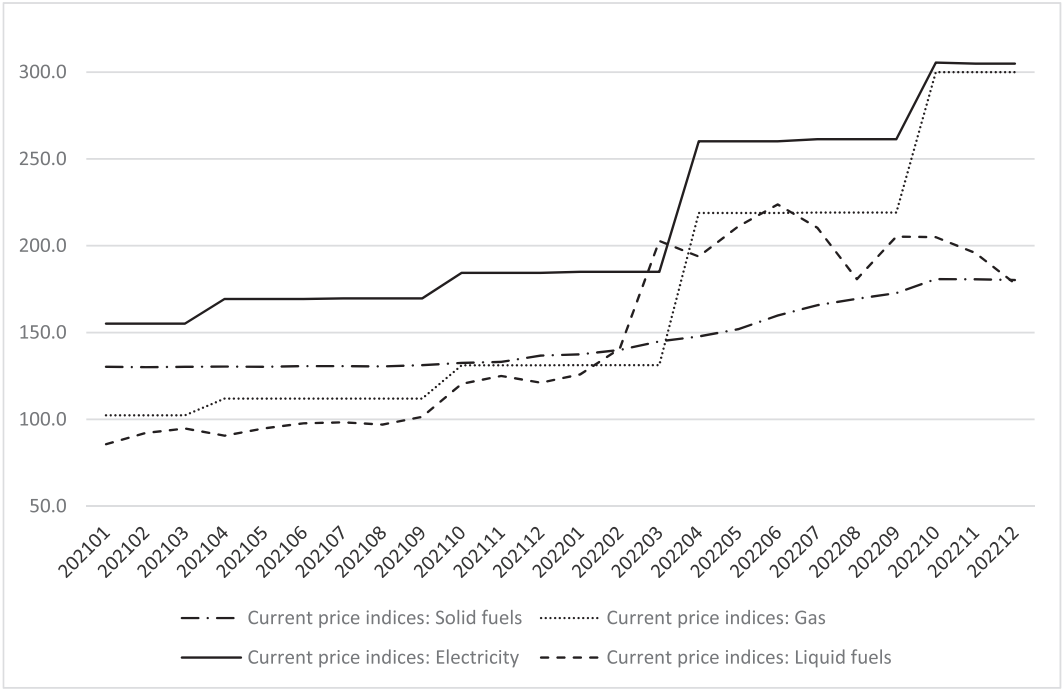

Fig. A3. Consumer Price Index, UK: Fuel Components.
(Source: Department for Energy Security and Net Zero)

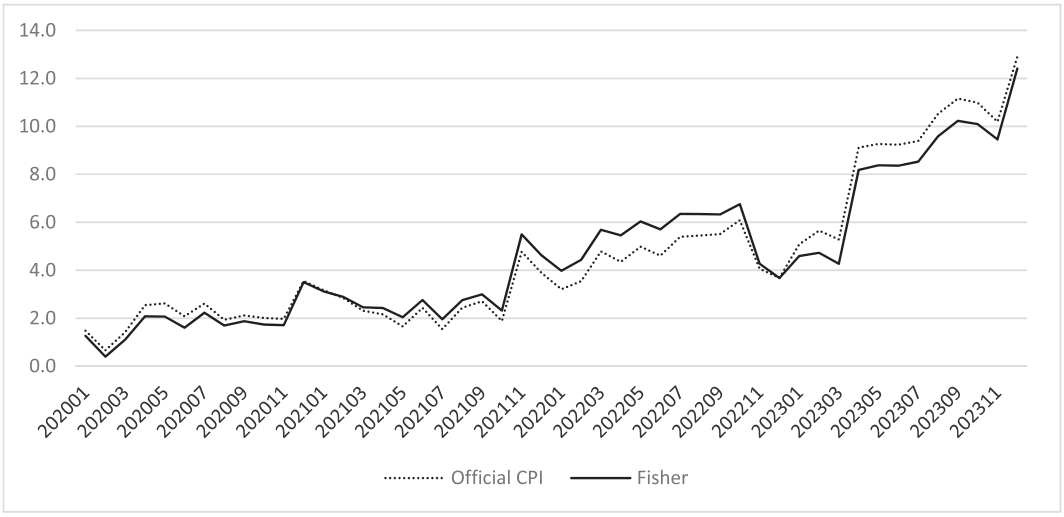

Fig. A4. CPI inflation rate: COICOP 02 Alcoholic Beverages and Tobacco.
(Source: Author calculation)

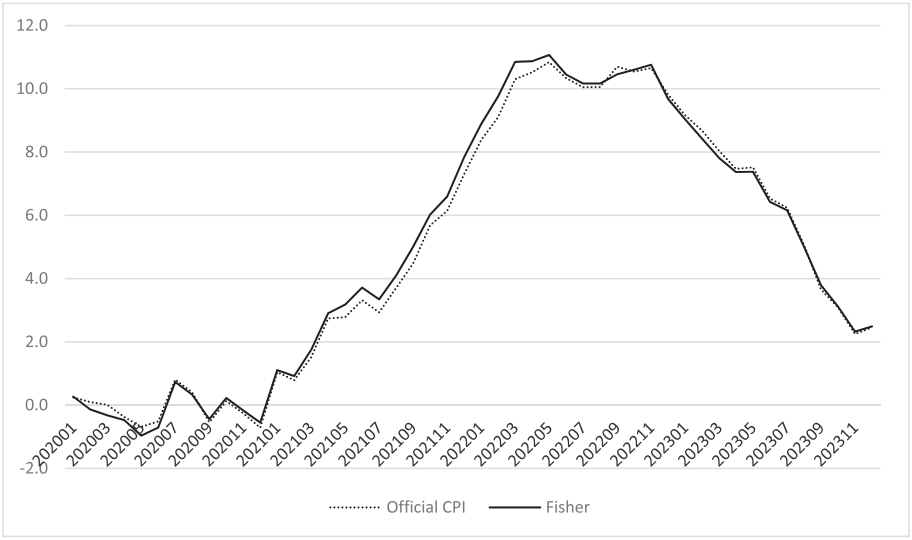

Fig. A5. CPI inflation rate: COICOP 05 Furniture, Household Equipment and Maintenance.
(Source: Author calculation)

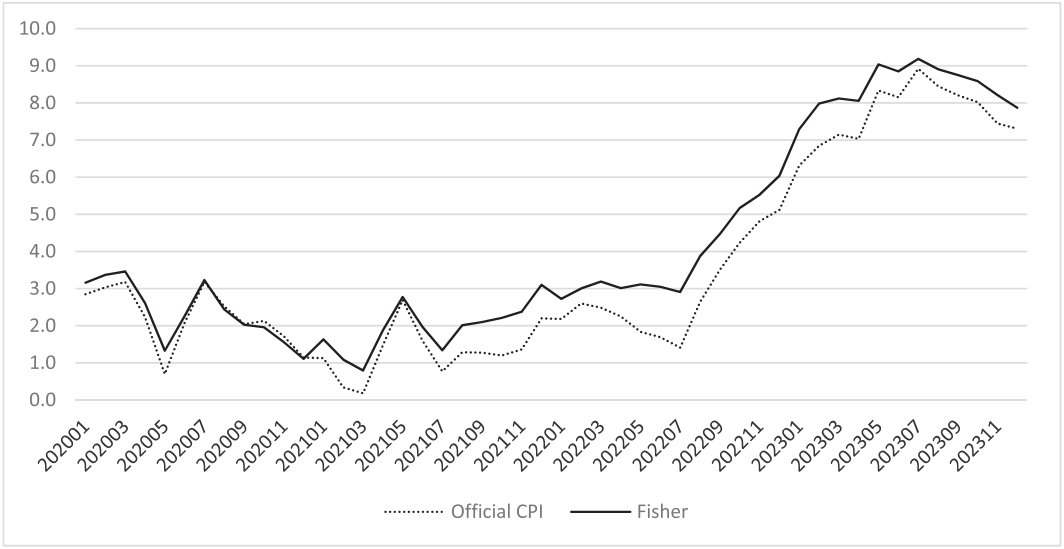

Fig. A6. CPI inflation rate: COICOP 06 Health.
(Source: Author calculation)

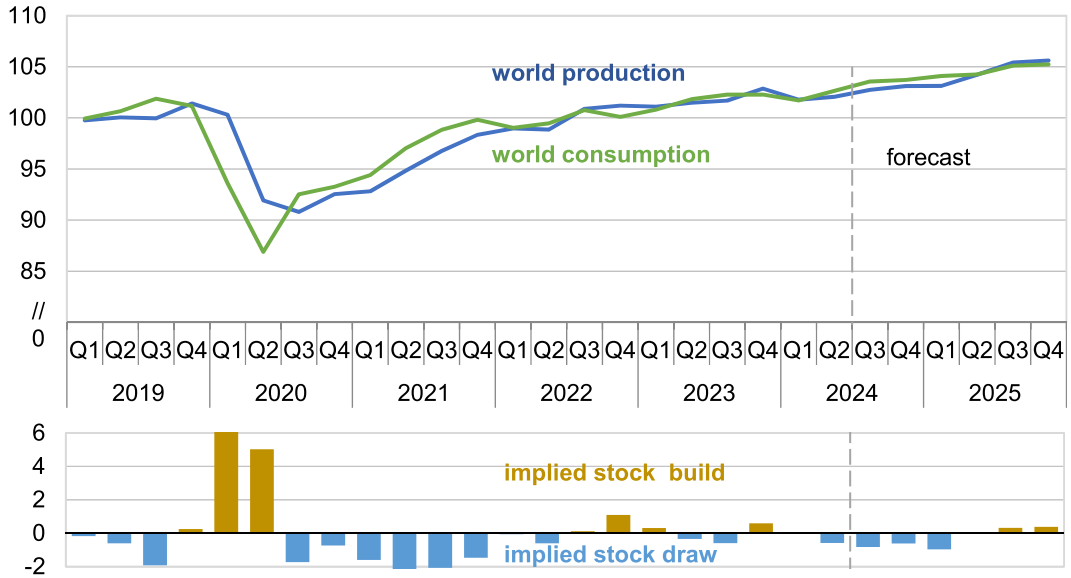

Fig. A7. Global Oil Market.
(Source: U.S. Energy Information Administration, Short-Term Energy Outlook, July 2024)

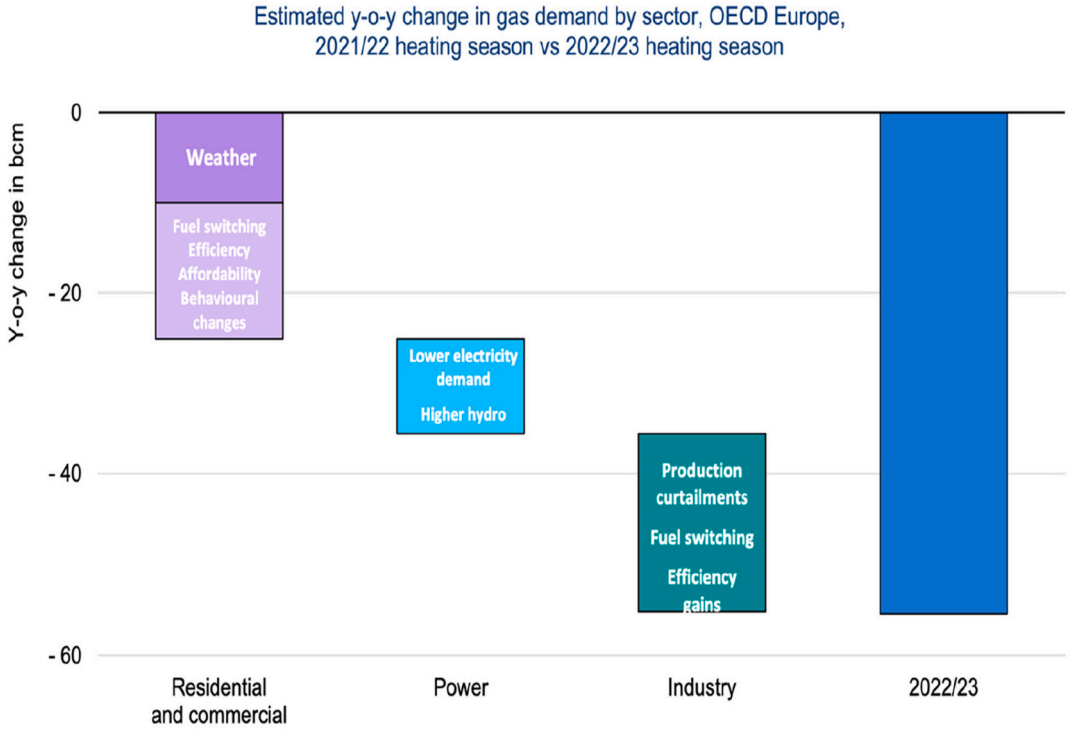

Fig. A8. Gas Demand by sector, OECD Europe.
(Source: IEA *(2023))*

Table A1
World natural gas consumption and production by region and key country (bcm).

	Consumption					Production				
	2020	2021	2022	2023	2024	2020	2021	2022	2023	2024
Africa	161	169	170	176	181	240	260	251	253	260
Asia Pacific	834	891	877	902	942	622	648	660	670	685
of which China	325	367	364	391	417	189	205	216	230	240
Central and South America	142	153	150	149	152	150	148	151	149	153
Eurasia	585	649	622	631	646	866	961	865	830	860
of which Russia	461	516	487	495	507	692	762	672	638	670
Europe	576	609	524	488	497	230	222	230	215	219

(continued on next page)

Table A1 (*continued*)

	Consumption					Production				
	2020	2021	2022	2023	2024	2020	2021	2022	2023	2024
Middle East	546	562	580	592	607	670	692	715	725	745
North America	1079	1091	1144	1157	1166	1145	1172	1240	1285	1270
of which United States	868	874	919	928	935	954	984	1021	1061	1055
World	3923	4124	4067	4095	4191	3923	4105	4112	4127	4192

Source: IEA, Global Market Report, Q2–2024.

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