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ORIGINAL RESEARCH

Measuring Inflation During the Pandemic with the Benefit of Hindsight

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Abstract
This study has adopted the actual household expenditure data from the national accounts to construct 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 underestimate in 10 countries in the first wave of the COVID-19 pandemic. The result obtained for the countries where true inflation was higher than the official rate in this study matches the results obtained by Cavallo (Inflation with covid consumption baskets, 2020) and Reinsdorf (COVID-19 and the CPI: Is inflation underestimated?, 2020). However, a significant difference has been detected for the countries where the official inflation exceeds the true measure in this study. The core reason behind the discrepancies is in the use of appropriate expenditure weights. This suggests caution in using credit-card based expenditure data when spending behaviour has changed dramatically.

Keywords Coronavirus (COVID-19) · Pandemic · Inflation measurement · Household Final Consumption Expenditure (HHFCE) · Consumer Price Index (CPI)

JEL Classification C43 · E01 · E31 · I10

1 Introduction

The first documented case of Covid-19 was found in December 2019, and within three months the World Health Organization (WHO) declared Covid-19 as a Pandemic. Economies around the world experienced significant losses due to the disruption in global supply chains, temporary and permanent closures of businesses,

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temporary closures/limits of the production plants, restriction on international travel etc. It had a massive effect on the spending patterns within economies.

As was realized early on (see for example Dixon 2020b and Tenreyro 2020), this raised specific challenges for the measurement of CPI inflation, since the standard methods of constructing inflation statistics were not designed for periods when there were rapid and large changes in expenditure patterns. There were several attempts to use real time data such as credit card expenditures to try to understand exactly how expenditure patterns were evolving and how this might distort the official inflation figures. See for example Cavallo (2020) Chronopoulos et al. (2020), Dixon (2020a), Jaravel and O'Connell (2020b) in the UK; Chetty et al. (2020), Bachas et al. (2020), Dunn et al. (2020), Baker et al. (2020) in the US; Andersen et al. (2022) in the Denmark; Carvalho et al. (2021) in Spain; Seiler (2020) in Switzerland. As national account information was not available immediately, all the above-mentioned studies had to rely on the alternative sources of data, such as debit and credit card data, scanner data etc. Cavallo (2020) used US and Spanish card-based expenditure data, whilst Reinsdorf (2020) used US and Canada card-based expenditure data to measure the inflation in the Covid-19 pandemic across a range of countries. Both the studies found significant biases in the headline inflation rate during pandemic.[1] One of the strong assumptions of those papers was the use of US and Canada's expenditure share changes to other countries.[2] There might be no other options available for real-time measurement as the national account's information often has a considerable lag. However, since we now have the national accounts data for a most countries, we can look at the problem with the data from each country.[3]

The official headline inflation of most countries uses the "Lowe" price index which is a Laspeyres-type or fixed based weight index. Moreover, the advice offered by the international agencies[4] was to keep the pre-pandemic weights. Where goods and services were unavailable due to lockdowns the advice given was to impute the missing prices on the basis of the prices that were available.[5]

As is well known, using a base weighted Laspeyres index will tend to overstate inflation (since consumers are likely to consume less of items that become more expensive), whilst a current weighted Paasche index will tend to understate inflation. The true inflation will be between these two, and an alternative "ideal index" is the Fisher Index, which is the geometric average of the Laspeyres and Paasche indices (Fisher 1921). In this paper, we construct a Fisher index to evaluate the true inflation during the pandemic and compare to the official inflation figures with this

[1] Cavallo (2020) found that out of 17 countries 10 countries have higher inflation than that of the official CPI. Reinsdorf (2020) found that out of 83 economies where official CPI is underestimated in 65 countries during Feb-May 2020.

[2] Cavallo (2020) used Spanish card-based expenditure data to estimate the weight for the European countries in his sample.

[3] We review a detail some of the main papers published using real time data in Appendix B.

[4] Advice from Eurostat to European Union Countries, UNCE, IMF, US Bureau of Labor Statistics.

[5] Diewert and Fox (2020) argued that the implicit price of unavailable goods was in fact very high (the price that would have driven demand to zero in normal times), so that the imputation method recommended would likely understate the real inflation.

measure. Most statistical agencies have now published the actual expenditure shares for the period 2020–2021 which we can use to answer the question of how the official measures published in 2020–21 compare with the ex-post true inflation. Real time indicators used at the time were mostly based on a limited range of consumer expenditure (mostly using credit card data,[6] as in Cavallo 2020, Carvalho et al 2021, Reinsdorf 2020, and Sieler 2020) and the national statistical agencies have since published figures that are much more comprehensive and cover the whole range of consumer expenditure. We will also compare the actual data with some examples of the contemporary real time data. Hindsight is indeed an advantage when it comes to tracking what was going on in 2020–2021.

When we use the actual household expenditure data from the national accounts of the 33 OECD countries, that the official inflation figures were too high in 23 countries (including Belgium, Italy, Norway, and the UK) and too low in 10 (including the US, Australia, and Iceland).[7]

This paper is structured as follows. Section 2 is about the measurement issues of the official inflation rate during the pandemic. Section 3 explains the methodology and the data. Section 4 has measured the impact on the US and the UK inflation rates. Section 5 illustrates the impact on the other OECD countries' inflation rates and the differences between this study's outcome with some earlier studies. Finally, we conclude the paper by mentioning the importance of appropriate data set in measuring inflation.

2 Measurement Issues

During COVID-19 Pandemic, the nationwide lockdown has produced significant challenges to the inflation measurement by the national statistical offices (NSOs) as there were large and sudden changes in the consumers' expenditure patterns. The standard method of measuring inflation measure does not consider the possibility of sudden large changes in the expenditure patterns, but rather a gradual adjustment with most NSOs updating the expenditure weights used in the official CPI annually, with lagged expenditure data from previous calendar years (Jaravel and O'Connell 2020b). Therefore, sudden large changes in the expenditure shares across different sectors, products and outlets may all create biases in the official headline inflation rate.

There are of course other issues that made measurement more challenging during the pandemic. The physical collection of prices by agents was not possible, so collection moved online. Many goods and services became unavailable during the lockdown, and hence there were no prices to be collected. Some items were completely

[6] The main exception being Jaravel and O'Connell (2020b), which used store scanner data. This is best for capturing grocery expenditure and in particular food and beverage prices.

[7] However, the results were a little mixed for 23 out of 33 countries: the bias during the 2020 Q2 was the opposite to the whole period 2020–2021. See Table 3 below.

unavailable to buy, and even when items were available, consumers were less interested in purchasing the items during lockdown.

How did the UK calculate the official price index during the pandemic? If the item was unavailable, or with limited availability (with the sample of price quotes being less than 20% of its usual size), the Office for National Statistics (ONS) decided to impute the prices, based on the method that best reflects the price behavior of the missing item. For unavailable items,[8] the ONS followed the Eurostat guidelines to impute using one of three methods: firstly, imputing from the index immediately above it in the classification structure; secondly, imputing based in the price movement of a similar item; thirdly, carrying forward prices from earlier months. If the unavailable item is seasonal, the ONS will use aggregate annual growth of all available non-imputed items. However, if the unavailable item is not seasonal, the ONS will use aggregate monthly growth of all available non-imputed items.

Dixon (2020b) argued that the imputation of unavailable prices is equivalent to altering expenditure shares, since if we use the available prices to impute the unavailable prices, we are effectively increasing the weight of the available prices in the price index. Moreover, Diewert and Fox (2020) also presented that the advice from International Monetary Fund, Eurostat and the United Nations to the NSOs to implement carry-forward methodology for the items that are missing, will lead to a downward bias in estimating Cost of Living Index (COLI) and an upward bias in estimating the changes in the real consumption. As the headline inflation rate calculated by different NSOs is heavily biased due to the treatment of missing prices and use of out-of-date expenditure weights, Diewert and Fox (2020) has suggested to produce a new analytic CPI whenever new consumer information for the Covid-19 Pandemic periods becomes available. Therefore, we would like to say that this is key motivation for doing this study to calculate inflation rate during the Covid-19 Pandemic period with benefit of new consumer expenditure information.

3 Data and Methodology

3.1 Methodology

Generally, CPI uses a "Lowe" price index which is a Laspeyres-type or fixed based weight index. The Lowe price index measures the proportional change between reference period and the current t in the total value of a specific basket of goods and services.

In the UK and most NSOs, the expenditure weights come from previous years and are used to weight the price relatives across months within the current calendar

[8] ONS has identified 92 items as unavailable for April Index, where 90 items for CPIH (around 16.3% of CPIH basket), 90 items for CPI (around 20.2% of CPI basket) and 89 items for RPI (around 17.7% of RPI basket).

year. For example, in 2020 the expenditure weights used by the ONS were based on the household final consumption expenditure (HHFCE) data from 2018,[9] whilst the price relatives were between each month and January of 2020. Similarly, U.S. Bureau of Labor Statistics (BLS) calculate headline CPI (All Urban Consumers CPI-U) inflation rate in 2020 based on the expenditure share (relative importance) from 2017–2018 Consumer Expenditure Surveys (CE).[10] Before the outbreak of Covid-19 Pandemic, there is nothing significantly wrong with estimation method used by the several NSOs as the consumer expenditure patterns doesn't change dramatically in the most recent years where the current year inflation rate is calculated based on the two-year lag period of the expenditure share. However, the consumer expenditure has changed significantly in the Pandemic period as a result of lockdown measures and related changes in behaviour.[11] Diewert and Fox (2020) suggest using the Fisher Price Index because the substitution bias in Laspeyres (too high) and Paasche (too low) or any fixed basket index will be large during the period of exceptional changes in the consumer expenditure pattern. More studies are also advocating the use of various superlative price indices such as the Fisher and Törnqvist Index during pandemic period, including Fox et al. (2022), Jaravel and O'Connell (2020a), Kantur et al. (2021), and Alvarez and Lein (2020).

We will briefly revisit the standard formula of the simple fixed basket indexes and superlative price index.

Laspeyres price index:

$$I_L^{0,t} = \frac{\sum_{i=1}^{n} p_i^t q_i^0}{\sum_{i=1}^{n} p_i^0 q_i^0} = \sum_{\mathrm{i}=1}^{\mathrm{n}} R_i^{0,t}.w_i^0 \tag{1}$$

Paasche price index:

$$I_P^{0,t} = \frac{\sum_{i=1}^{n} p_i^t q_i^t}{\sum_{i=1}^{n} p_i^0 q_i^t} = \left[\sum_{\mathrm{i}=1}^{\mathrm{n}} \frac{1}{R_i^{0,t}}.w_i^t\right]^{-1} \tag{2}$$

Fisher price index:

[9] The major sources of data used to construct HHFCE estimates are the Retail Sales Inquiry (RSI) and the Living Costs and Food Survey (LCF). In LCF, annual and quarterly household sample size are 5000 and 1200 households respectively. While RSI is a monthly survey of 5,000 retail businesses including all 900 'large retailers' and 4100 'small and medium retailers' on a sampled basis.

[10] The U.S. Census Bureau collects CE data for BLS. The CE consists of two separate surveys, the Interview Survey and the Diary Survey. BLS designs the Interview Survey to collect data on large and/or recurring expenditures, such as rent, utilities, or insurance. On the other hand, BLS designed the Diary Survey to collect data on frequently purchased items, such as food and beverage expenditures at home and in eating places; housekeeping supplies and services; nonprescription drugs; and most personal care products and services. The sample size of Interview Survey and Diary Survey are 20,000 and 11,000 independent surveys completed annually respectively.

[11] The literature on the changes in the expenditure patterns during the Pandemic is reviewed in the online Appendix B.

$$I_F^{0,t} = (I_L{}^{0,t} \times I_P^{0,t})^0 .5 \tag{3}$$

where, $I^{0,t}$= Index value for period t based on period 0.

p_i^t= Price level of item i at period t

p_i^0 = Price level of item i at period 0 (base period)

q_i^t = Quantity on item i at period t

q_i^0 = Quantity on item i at period 0 (base period)

$R_i^{0,t} = \frac{p_i^t}{p_i^0}$, is the price relative

$w_i^0 = \frac{p_i^0 q_i^0}{\sum_i p_i^0 q_i^0}$, is the expenditure share of item i at base period 0

$w_i^t = \frac{p_i^t q_i^t}{\sum_i p_i^t q_i^t}$, is the expenditure share of item i at period t

The Laspeyres price index is thus the weighted arithmetic mean of price relatives. One of the notable strengths of the Laspeyres price index is CPI can be produced on a timely basis without knowing the current period quantity information (Diewert 2001). On the other hand, the Paasche price index is a weighted harmonic mean of price relatives which is based on the current period's quantities and expenditure shares. The Paasche price index can only be produced with a delay, as it requires current expenditure weights which are generated by the NSOs with a lag. However, both the indexes are easy to calculate and understand. From an economic perspective, the Laspeyres tends to overstate inflation, since it assumes the base quantities/expenditure-shares do not respond to price changes, where as the Paasche index understates inflation since it fixes the current quantities/expenditure-shares. The Fisher index takes the geometric mean on the two, and will be closer to the true value. Furthermore, the Fisher index is considered as a *superlative* or *ideal* price index because it passes a wide battery of desirable axiomatic tests (see Diewert 2001, 2021 for a detailed analysis of the indices in relation to a range of axiomatic tests). Crucially, the Fisher price index satisfies the important time-reversal test (which derives from the theory of rational choice), which means that if the prices and quantities in the two periods being compared are interchanged the resulting price index is the reciprocal of the original price index. Unlike the Fisher Index, both the Laspeyres and Paasche price index fail this fundamental test.

An alternative and popular index is the Törnqvist price index, which also passes the time reversal test. As Dumagan (2002) has shown analytically, the Fisher and Törnqvist indices are generally numerically approximate. As a check, we also applied the Törnqvist index to the US data and found the results very similar to the Fisher Index (see Appendix D).

We now have the consumer expenditure information for the Pandemic period (the benefit of hindsight), so we are able to use the Fisher method to measure the "true" inflation rate during the pandemic, which we call the Pandemic inflation rate, and compare this with the official rate published by the NSO. The key difference between official inflation and the Pandemic inflation rates are that the Official inflation rate used a Laspeyres (or Lowe) price index usually based on one or two-year old consumer expenditure information,[12] whereas the

[12] For example, in the UK, the 2020 CPI figures were based on 2018 expenditure data, whilst the 2021 CPI data was based on 2020 expenditures and 2022 CPI on 2021 expenditures.

Pandemic inflation rate uses both current and base expenditures for each period. While calculating Pandemic price index, we have used the weights for 2019 as our pre-pandemic base, needed for constructing the Laspeyres part of the Fisher index. For the Paasche part of the Fisher index, we will be using the "current month" expenditure weights based on the frequency of expenditure share data in each country.

Our method is the "direct" Fisher price index approach (see Australian Bureau of Statistics (2022)). The "chained" Fisher index is obtained by comparing each "current" period with using the previous period as the "base": this gives a sequence of two-monthly indices which can then be joined together by chaining. We also calculate the chained Fisher index measure for the US data in Sect. 4 to check whether choosing this methodology yields different results. Chaining of course has its own problems: one-off outliers in the time series can become permanently embedded in the index (chain drift), which is a potential issue even without the pandemic due to the seasonality of expenditure data. However, we found that the chained Fisher was little different to the direct Fisher index when we compare them using the US data.

Finally, we will compare our Pandemic inflation rate with Cavallo (2020) and Reinsdorf (2020) Covid inflation rates in detail. The methodology and consumer expenditure information used in both the studies are different from this study. Cavallo (2020) uses a chained index and Reinsdorf (2020) uses the Paasche index. They also use different expenditure data. We are able to show that what drives the differences in our estimates is the expenditure share data used.

3.2 Data

In this study, we use (depending on availability) the annual and quarterly/monthly household final consumption expenditure (HHFCE) data from the national accounts of 33 OECD countries to directly measure the changes in spending pattern during the pandemic. In the UK, the HHFCE data is contained in Consumer Trends published by the Office for National Statistics (ONS). Statistics Canada and Statistics Korea also published quarterly consumer expenditure data for the Canada and the South Korea, which we also converted into monthly data as in the UK (see Appendix E). For the US, we have collected monthly personal consumption expenditure (PCE) data from the U.S. Bureau of Economic Analysis (BEA), which is proxied by the consumer expenditure survey (CEX) from the U.S. Bureau of Labor Statistics (BLS) due to the significant error in collecting data directly from consumers during the pandemic period (Curtin 2022). PCE collected data from several statistical reports, such as reports come from various government agencies, administrative and regulatory agencies, and other private organizations. The HHFCE data for the rest of the countries in the list are collected mostly from Eurostat, OECD Stat, and other statistical agencies, including Australian Bureau of Statistics, Statistics of Japan. In Appendix-A, we will find the full list of countries along with the frequency of the data and collecting institution.

4 Impact on the US and the UK Inflation

In this section we will look in detail at the US and UK experience to illustrate the main issues involved in measuring the effect of the pandemic on inflation. Each country has a slightly different set up for its CPI and indeed how it dealt with the pandemic.

4.1 Impact on US Inflation

The first COVID-19 case was found in the US on the 20th of January 2020. Since then, more than one-million people have died and the US remains the top country in the world in terms of total cases and deaths. Table 1 gives us information regarding the change in the expenditure pattern by consumers during the period of the Pandemic. The expenditure pattern changed dramatically in the first wave, i.e., from March to May 2020.

On 13th March 2020, the president of the United States (POTUS) declares the Covid-19 outbreak as a national emergency (Department of Defense, n.d.). The declaration significantly affected consumer behaviour in March 2020 as people started to stocking food and beverage at home which is reflected in Table 1. In addition, U.S. State Department issues Global Level 3 Health Advisory: Do Not Travel on the 15th of March 2020 which is reflected in the expenditure share in transportation. As the consumer started to cook at home, the expenditure share for the food away from home has significantly declined from March 2020. Moreover, Centers for Disease Control and Prevention (CDC) recommends that travelers defer all cruise travel worldwide and avoid all nonessential travel to China (Department of Defense, n.d.) that significantly reflect in the consumer expenditure share in recreation (see Table 1). On August 6, 2020, the U.S. State Department in coordination with the CDC lifted the Global Level 4 Health Advisory and returning to its previous system of country-specific levels of travel advice. That announcement has significantly affected people's movement along with increase in the expenditure share in the third quarter of 2020 in compared to the second quarter in several categories, such as Food and beverages purchased for off-premises consumption; Clothing, footwear, and related services; Transportation; Recreation; Food services and accommodations (see Table 1). In December, U.S. Food and Drug Administration has started to issue authorization to emergency use for Pfizer and Moderna's Covid-19 vaccine (Department of Defense, n.d.). This declaration has brought mass people's confidence as well as in their consumption behaviour.

Figure 1 depicts the official inflation rate and the Pandemic inflation rate, as well as the corresponding indices. Significant differences have been detected in the US inflation during the Pandemic period in these two measures. In 2020 the Pandemic inflation rate was higher, reflecting large price changes and the increased consumer expenditure in food and non-alcoholic beverage, alcoholic beverage, housing, and household services. In 2021, the situation was reversed. This is partly a result of the base effect (higher pandemic prices in 2020 tend to reduce inflation implied by prices in 2021), but also the differences in expenditure shares (the Fisher price index price levels are below the official levels).

Table 1 Personal Consumption Expenditure in the US

	Personal Consumption Expenditure (PCE)											
	2020M1	2020M2	2020M3	2020M4	2020M5	2020M6	2020M7	2020M8	2020M9	2020 M10	2020 M11	2020 M12
Food and beverages purchased for off-premises consumption	76	77	99	101	95	89	88	86	85	84	85	84
Clothing, footwear, and related services	30	30	24	19	24	29	29	28	30	30	29	29
Housing, utilities, and fuels	183	184	200	231	210	198	196	194	192	192	192	193
Furnishings, household equipment, and routine household maintenance	42	42	44	44	47	47	47	47	47	46	46	46
Health	218	219	211	199	210	214	214	214	215	217	219	218
Transportation	95	94	77	67	78	80	83	84	85	84	84	86
Communication	20	20	22	25	23	21	21	21	21	21	21	21
Recreation	93	93	90	88	91	96	95	95	95	95	95	95
Education	22	22	23	24	22	21	21	21	21	20	20	20
Food services and accommodations	73	73	57	43	50	57	59	62	62	62	60	58
Financial services and insurance	80	80	87	96	87	83	82	82	82	82	82	83
Other goods and services	68	68	67	64	64	65	66	65	65	66	67	67
Total	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000

Source: U.S. Bureau of Economic Analysis (BEA)

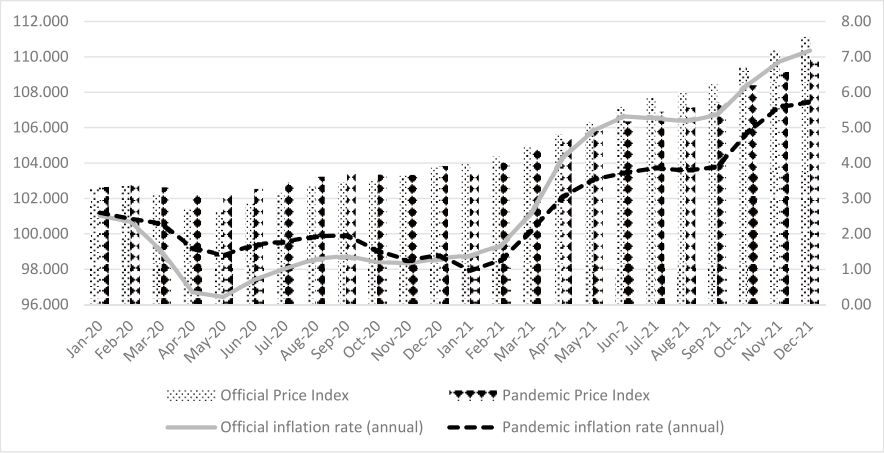

Fig. 1. US Official and Pandemic Inflation Source: Author calculation

The U.S. Bureau of Economic Analysis also calculates an alternative price index known as the Personal Consumption Expenditure (PCE) Price Index, which is calculated using the Fisher index.[13] This is the measure primarily used by the FED in formulating its policy. Curtin (2022) has also confirmed that during pandemic the data quality in the CE Survey by the BLS is poor in comparison to the PCE by BEA. In Fig. 2 we show the PCE inflation measure in addition to the Official and Pandemic inflation rates. Both PCE and Pandemic inflation rates has used the Fisher price index and the identical consumer expenditure share, but in this study,

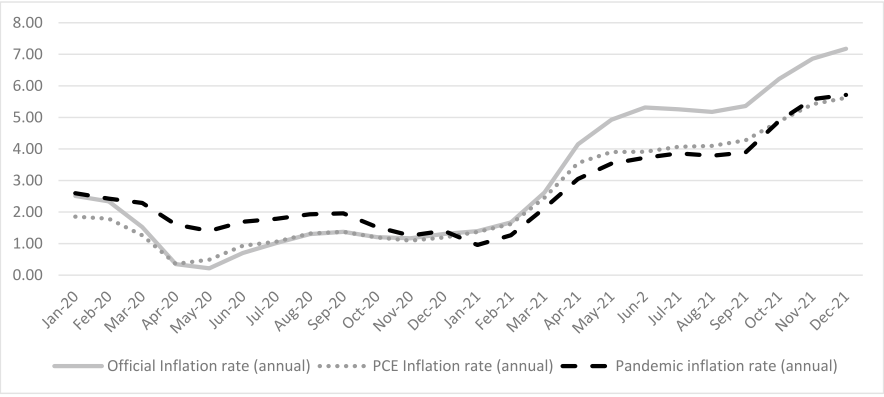

Fig. 2 US Official, PCE and COVID Inflation Source: Author calculation

[13] The relative weights used in the PCE index are derived from business surveys—for example, the Census Bureau's annual and monthly retail trade surveys, the Service Annual Survey, and the Quarterly Services Survey.

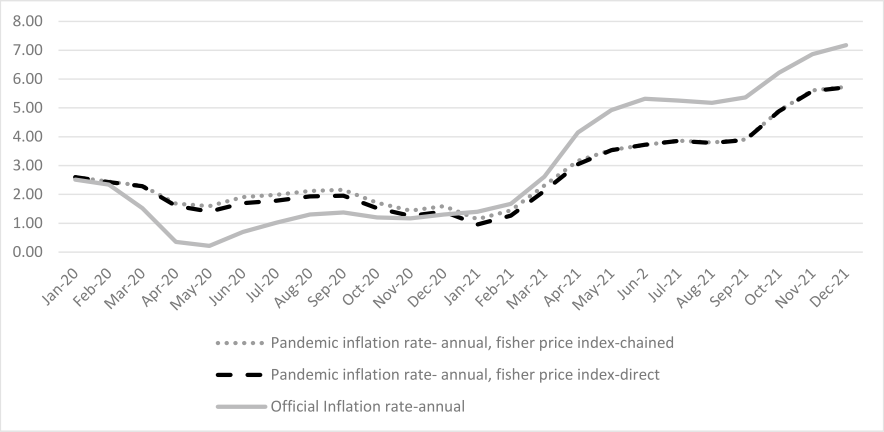

Fig. 3 Fisher Price Index US: Chain Vs Direct Source: Author calculation

we calculate Pandemic price index as the weighted average of the PCE share and the Consumer Price Index for All Urban Consumers (CPI-U). That's why PCE inflation rate is closer to the Pandemic inflation rate. In 2020, the PCE followed the Official figure more closely (both below the pandemic measure), whilst in 2021 the PCE follows the Pandemic measure more closely (both below the official measure).

4.1.1 Pandemic inflation and Cavallo (2020) Covid inflation

Figure 4 highlights the differences between the Pandemic inflation rate and the Covid inflation rate calculated in this study and the Cavallo (2020) respectively. Before comparing these two approaches of calculating annual inflation rate of US during the Pandemic period (2020 to 2021), it is worth to mention the methodological differences between these two measurements.

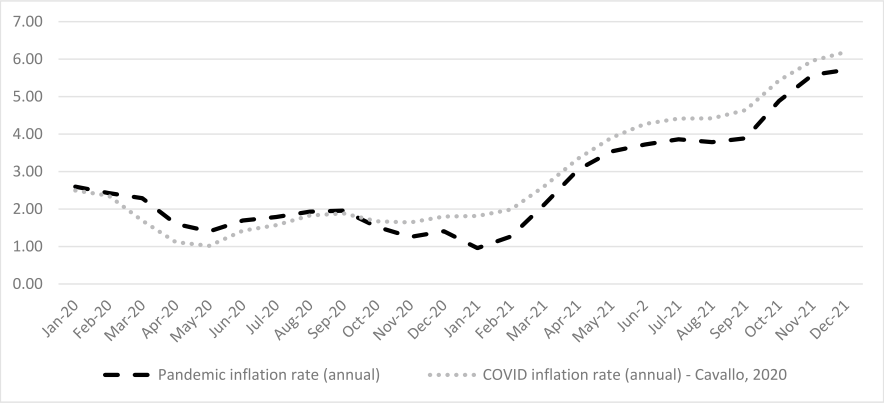

Fig. 4 Pandemic inflation rate (annual) and COVID inflation rate (annual)- Source: Author calculation

First, Cavallo (2020) used a chained price index to calculate Covid inflation rate. With chaining, prices in each month are compared to the previous month using the expenditure weights in the two consecutive months, where in our approach we use the current month and base month weights (the "direct" method). Our method is more comparable to the official methodology, which uses fixed weights within the year. In Fig. 3 we compare the annual Pandemic inflation using both the direct and chained method to calculate the price index for the US, and they are very close (it appears chain drift was not an issue). Therefore, the difference between the inflation measurement during the Pandemic in this study and Cavallo (2020) isn't driven by the use of chained or direct Fisher methods.

Second, expenditure share/weights used in this paper are updated from Personal Consumption Expenditure (PCE) by The U.S. Bureau of Economic Analysis (BEA), whereas Cavallo (2020) updated the weight from data collected by Opportunity Insights (based at Harvard University). PCE collected data from several statistical reports, such as reports come from various government agencies, administrative and regulatory agencies, and other private organizations. On the other hand, Opportunity Insights (OI) collected data from credit and debit card spending collected by Affinity Solutions Inc. Therefore, whilst neither dataset wasn't collected from consumer-based sample like Consumer Expenditure Survey (CE) by the U.S. Bureau of Labor Statistic (BLS).

The key reason that our measure differs from Cavallo is the changes in weights for different categories of products in the CPI basket during pandemic (see Appendix C for a full breakdown). The source of the lower inflation rate estimated by Cavallo from March'20 to July'20 are:

1. The changes in Cavallo weights in the health category are more, being -13%, -39%, -19% in March, April and May 2020 as compared to January 2020. The comparative changes in weights from PCE where only -3%, -10% and -4%…
2. For recreation activity the Cavallo expenditure weight fell significantly across all months in 2020 compared to January. For example, changes in the Cavallo (2020) weights were -25%, -60%, -48%, -32%, and -34% for March, April, May, June and July 2020 respectively. The corresponding changes in PCE weights were only -6%, -12%, -8%, -2%, and -3%.
3. The expenditure share changes in the food away from home (food services) in Cavallo were also very large -50% and -37% respectively in April and May 2020. The corresponding changes in PCE weights are -41% and -32%.

Lower weights in these sectors (and higher ones in other sectors) combined with the price changes led to the differences in the inflation rate Fig. 4.

The pandemic inflation rate calculated in this study from November 2020 to December 2021 was lower than Cavallo.

The main reasons behind these discrepancies in these two approaches again reflects differences in the changes in expenditure shares relative to January 2020:

1. In food, the weight changes in Cavallo (2020) are consistently higher than the PCE weight changes. For example, the weight changes in Cavallo (2020) are 32% and 34% in January and February 2021 compared to 14% and 13% in PCE expenditure weights. Since food had significantly high inflation this raised the Cavallo measure more than our estimate.
2. For apparel, there is a base effect as negative annual inflation rate prevails till March'21 and returned to positive until the end of 2021. The weight changes in Cavallo uare higher than the PCE weight changes from October'20 to December'21. Again, higher inflation rate along with the higher weight led higher inflation rate calculated in Cavallo (2020).
3. Similar to apparel, a base effect was also seen in transportation category where official inflation rate increased significantly from March 2021. The weight change in Cavallo was negative but significantly increased from January 2021 as compared to PCE. This also lead to higher covid inflation rate for Cavallo in comparison to this study's pandemic inflation rate.

As we can see, there are significantly different expenditures weights in Cavallo (2020) as compared to the PCE weights. This probably reflects the partial coverage of the predominantly credit card data underlying Cavallo, which excludes cash payments and direct bank transfers which are more important is some sectors than others.

4.2 Impact on UK Inflation

The first nationwide lockdown was enforced on the 23rd of March 2020, and it continued until the relaxing of restrictions and social distancing rules on the 23rd of June 2020. The subsequent lockdowns were the Second Lockdown (5th November 2020 to 2nd December 2020) and Third Lockdown (6th January 2021 to 12th April 2021).[14] From the literature, we have already identified that the consumers' expenditure pattern has changed significantly during the lockdown period. Table 2 has well demonstrated this concern with the help of actual household final consumption expenditure during the COVID-19 pandemic period. Major changes took place during the first lockdown. Among the 12 divisions in the COICOP category, significant changes happened in the Food and non-alcoholic beverages; Alcoholic beverages and tobacco; Housing, water, electricity, gas, and other fuels; Transport; Education; Restaurants and hotels division. However, the expenditure patterns were moving to their previous track after the end of the third lockdown in the UK.

Figure 5 shows how far the official headline inflation rate is from the pandemic inflation rate (the Fisher index). The figure depicts both the price-index level (in bars) and the Pandemic inflation rate. The two measures diverge in two periods: the official inflation rate is slightly higher than the pandemic inflation in the first lockdown period (i.e., second quarter of 2020) and lower after the third lockdown period (i.e., second quarter of 2021) till at end of 2021. The major contributors accounting

[14] For details see Institute for Government Analysis, UK.

Table 2 Official expenditure weight and HHFCE in the UK

COICOP Divisions	Official Expenditure Weight		Household Final Consumption Expenditure (HHFCE)							
	2020	2021	2020Q1	2020Q2	2020Q3	2020Q4	2021Q1	2021Q2	2021Q3	2021Q4
Food and non-alcoholic beverages	79	89	89	116	93	94	100	89	85	85
Alcoholic beverages and tobacco	32	35	34	50	41	42	42	37	34	33
Clothing and footwear	51	59	44	46	48	50	45	49	47	48
Housing, water, electricity, gas and other fuels	296	328	267	342	289	295	305	276	265	267
Furniture, household equipment and maintenance	50	49	51	59	59	59	58	59	53	54
Health	22	20	21	17	17	20	21	21	22	22
Transport	120	107	129	67	108	99	99	106	114	125
Communication	17	19	22	28	25	25	23	21	20	20
Recreation and culture	136	112	100	96	92	101	104	103	99	101
Education	24	30	23	28	24	25	27	24	24	24
Restaurants and hotels	96	69	104	28	84	70	52	94	119	101
Miscellaneous goods and services	77	83	118	123	120	120	124	121	117	120
Total	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000

Source: ONS

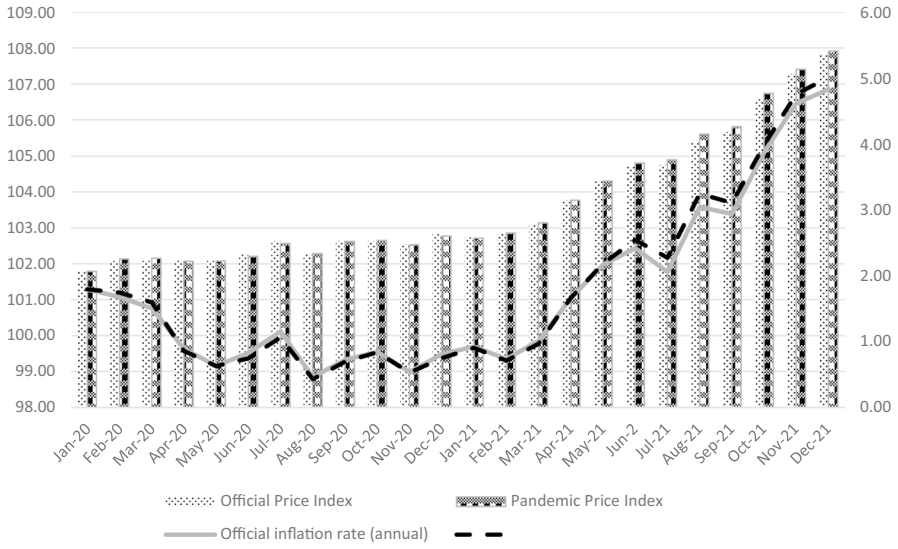

Fig. 5 UK Official and COVID Inflation Source: Author calculation

for the differences in the second quarter of 2020 inflation were restaurant and hotels, recreation and culture, housing and household services, food and non-alcoholic beverage, clothing and footwear, and transport. As the official inflation used the earlier expenditure weight, the higher inflation in the restaurant and hotels, recreation and culture divisions have positively contributed to the overall inflation. However, the increased expenditure in the food and non-alcoholic, housing and household services divisions has also positively contributed to higher pandemic inflation but remaining below the official headline inflation rate because of the sharp decline in the expenditure on transport where inflation rate was largely negative.

In 2021, the ONS updated its expenditure weight significantly considering the dramatic change in the expenditure behaviour in 2020. The major contributor to the inflation in the second quarter of 2021 are housing and household services, transport, recreation and culture, other goods, and services divisions. As the actual expenditure pattern has started to return to the earlier track, the increase in transport, restaurants and hotels expenditure weight in the pandemic inflation calculation is the main factor behind the difference with the official inflation rate. However, the official inflation rate and the pandemic inflation rate look quite similar after the third quarter of 2021 because the increased inflation rate in the housing and household services and the transport division were cancelled out due to the expenditure weight in these two different inflation rate calculations. The official expenditure weight of the housing and household services is higher than the actual expenditure and the vice-versa for the transport after the second quarter of 2021. These are the main divisions where the change took place in the form of the inflation rate as well as the expenditure weight in the two methods of calculating the inflation rate.

The UK experience shows how the comparison of the official inflation figures with the pandemic measure depends on a detailed comparison of often offsetting effects across the expenditure categories with offsetting trends.

5 Impact on the other OECD Countries

The US and UK provide contrasting experiences of how the pandemic inflation and official figures can differ. In the UK there is a small difference, with pandemic inflation being slightly lower than the official figures, whilst there is a more substantial difference in the US with pandemic inflation being higher in 2020 and lower in 2021. We now go on to explore the differences across the remaining OECD countries using the same methodology, as shown in Table 3. The third and fourth columns give us the difference between the official and pandemic inflation: in the third column we see the difference in 2020 Q2 and in the fourth column we see the difference over the two years 2020–2021.

Among the rest of the OECD countries, the official inflation rate is mostly higher than the pandemic measure in the second quarter of 2020 and less over the whole COVID period of 2020–21. A common pattern in those countries is that the bias is greater in the second quarter of 2020 compared to the whole year as a result of the large change in the expenditure patterns in that quarter. An identical pattern observed in almost all the countries with a higher official rate: (i) pandemic weight is higher where the price level is decreasing; (ii) official weight is higher where the price level is increasing.

In two countries out of the sample (Iceland and Poland), the official inflation rate was lower than the pandemic inflation in both the second quarter of 2020 and the whole COVID period of 2020–21. Among these two, the changes in the expenditure pattern were quite similar. In these countries, pandemic weights have increased in food and non-alcoholic beverage, alcoholic beverage, housing and household services, furniture, health, communication, and education. In addition, the price level has increased in food and non-alcoholic beverage, alcoholic beverage, housing and household services, furniture, health, recreation and culture, education, restaurant, and hotels; and the price level has decreased in clothing and footwear, transport, and communication. Again, a similar pattern has also been observed in those countries where the official inflation rate is higher, they are: (i) pandemic weight is higher where the price level is increasing; (ii) official weight is higher where the price level is decreasing.

For most countries, there are mixed results, meaning the bias during 2020 Q2 was the opposite to the whole period 2020–2021. In Norway, the official inflation rate was significantly higher than the pandemic in 2020 and lower over the whole period. The opposite scenario was seen the Czech Republic where the official inflation rate was lower in the second quarter of 2020 and higher for the whole. Clearly, the differences can be very small (smaller than 0.1 pp in absolute terms) ranging to over 1 pp in absolute terms in 2020 Q2 (Norway and the US). There is great heterogeneity in how the pandemic impacted om the inflation experience in different countries, reflecting different expenditure patterns, government policies and the behavior of households and firms.

Table 3 CPI and Pandemic CPI in OECD countries

(1)	OECD Countries (2)	Annual Official inflation rate minus Pandemic inflation rate for **2020Q2** (3)	Annual Official inflation rate minus Pandemic inflation rate for the **Pandemic Period (2020–2021)** (4)	Cavallo (2020) (CPI-Pandemic CPI, YoY, Sept 2020) (5)	Reinsdorf (2020) (CPI-Pandemic CPI, 3-month growth, March–May, 2020)	
					Canada Weight (6)	US Weight (7)
Official Inflation > Pandemic Inflation	Canada	0.03	0.08	-0.15	-0.36	-0.36
	Hungary	0.21	0.41	…	-0.72	-0.95
	Israel	0.20	0.09	…	-0.14	-0.27
	Japan	0.09	0.03	-0.24	-0.08	-0.17
	Latvia	0.02	0.09	…	-0.08	-0.54
	Lithuania	0.42	0.05	…	-0.09	-0.52
	Netherlands	0.49	0.00	0.34	-0.01	-0.1
	Turkey	0.20	0.02	0.44	-0.08	-0.27
Mixed result in 2020Q2 and Pandemic Period	Australia	-0.09	0.18	…	…	…
	Austria	-0.16	0.03	…	-0.09	-0.33
	Belgium	0.65	-0.07	…	-0.39	-0.45
	Czech Republic	-0.01	0.29	…	-0.59	-0.64
	Denmark	0.09	-0.09	…	-0.17	-0.25
	Estonia	0.08	-0.13	…	-0.38	-0.51
	Finland	-0.17	0.02	…	-0.2	-0.19
	France	0.06	-0.07	-0.46	…	…

Table 3 (continued)

(1)	OECD Countries (2)	Annual Official inflation rate minus Pandemic inflation rate for **2020Q2** (3)	Annual Official inflation rate minus Pandemic inflation rate for the **Pandemic Period (2020–2021)** (4)	Cavallo (2020) (CPI-Pandemic CPI, YoY, Sept 2020) (5)	Reinsdorf (2020) (CPI-Pandemic CPI, 3-month growth, March–May, 2020)	
					Canada Weight (6)	US Weight (7)
	Germany	-0.04	0.00	0.58	0.17	-0.03
	Greece	0.67	-0.07	-0.06	1.28	0.34
	Ireland	0.68	-0.06	0.32	0.22	0.18
	Italy	0.74	-0.08	0.15	…	…
	Luxembourg	-0.16	-0.05	…	-0.16	-0.33
	Mexico	0.22	-0.02	…	-0.63	-0.69
	Norway	1.61	-0.46	…	0.47	0.42
	Portugal	0.16	-0.03	…	0.64	-0.04
	South Korea	0.02	-0.02	-0.52	-0.38	-0.5
	Slovakia	-0.37	0.25	…	-0.26	-0.38
	Slovenia	0.66	-0.09	…	0.32	0
	Spain	0.78	-0.14	-0.32	0.26	-0.36
	Sweden	0.31	-0.08	…	-0.2	-0.3
	United Kingdom	0.04	-0.04	0.06	-0.09	-0.14
	United States	-1.14	0.29	-0.48	-0.68	-0.77

Table 3 (continued)

(1)	OECD Countries (2)	Annual Official inflation rate minus Pandemic inflation rate for **2020Q2** (3)	Annual Official inflation rate minus Pandemic inflation rate for the **Pandemic Period (2020–2021)** (4)	Cavallo (2020) (CPI-Pandemic CPI, YoY, Sept 2020) (5)	Reinsdorf (2020) (CPI-Pandemic CPI, 3-month growth, March–May, 2020)	
					Canada Weight (6)	US Weight (7)
Official Inflation < Pandemic Inflation	Iceland	-1.08	-0.36	…	-0.17	-0.18
	Poland	-0.06	-0.05	…	-0.57	-0.77

All the result shows in this table are in percentage point. Those percentage points obtained by deducting Pandemic inflation rate from the Official inflation rate. Column 1 describe the classification of output into three categories: 1) Official Inflation is higher than Pandemic Inflation; 2) Different output in the second quarter of 2020 and the whole pandemic period (2020–2021); 3) Official Inflation is lower than Pandemic Inflation. Column 2 list the name of the OECD countries. In column 3, the positive output means Official inflation rate is higher than the Pandemic inflation rate in the second quarter of 2020 and vice-versa. In column 4, the positive output means Official inflation rate is higher than the Pandemic inflation rate in the whole pandemic period (2020–2021) and vice-versa. Column 5 gives us the information from Cavallo (2020) up to the September 2020. Columns 6 and 7 provide output from Reinsdorf (2020) only for May 2020 considering February 2020 as base. Column 6 results are based on the debit and credit cards data on Canada, whereas Column 7 results are based on the debit and credit cards data on the US

Source: Author calculation

In columns 5, 6 and 7 we show the earlier results obtained by Cavallo (2020) and Reinsdorf (2020) using real time debit and credit card-based expenditure data. Whereas this study is based on the actual data from the national accounts with the benefit of hindsight, these studies were attempts to measure the effects as they were happening. Both Cavallo and Reinsdorf used credit card data from one country and applied it to several other countries: Cavallo used US card data, Reinsdorf Canadian and US data. Even when applied to the US or Canadian data, the credit card data can be misleading. For example, Reinsdorf (2020) and Cavallo (2020) use 37.12 and 35.80 respectively for the COICOP category 04 housing and household services in Canada, but the actual data from Statistics Canada gives us 32.59 for this COICOP category. In the case of the UK, the official expenditure share for the COICOP category 01 food and non-alcoholic beverage in the second quarter of 2020 is 11.3 whereas the expenditure share for the similar category in Cavallo (2020) is estimated as 29.5 in April 2020.[15] The difference is quite high and the potential source of bias in the inflation measurement. Whilst using card data provides real time information, it can be significantly different to the real expenditure behavior since it only captures a part of expenditure.

6 Conclusion

During the coronavirus pandemic, specifically the first wave (second quarter of 2020) of the pandemic, the official Consumer Price Index (CPI) inflation figure wasn't as informative as usual about the balance of supply and demand in the economy. The reason behind that is the conceptual challenges that have affected price measurement during the lockdown period. The major change were the large shifts in spending patterns due to the stringent lockdown policies adopted by the government across the world, which changed the representative household consumption basket.

The aim of this study is to identify whether the official inflation rate was higher or lower than the true inflation rate (using the Fisher index) during the COVID-19 pandemic. Adopting the actual household expenditure data from the national accounts, this study found that the official inflation rate in the 33 OECD countries was an overestimate of true inflation for 23 and underestimate in 10 countries in the

[15] Cavallo (2020) used Spanish card-based expenditure data to estimate the weight for the European countries in his sample.

first wave of the COVID-19 pandemic. The result obtained for the underestimating countries in this study has matched the result obtained by Cavallo (2020) and Reinsdorf (2020). However, a significant difference has been detected for the countries where the official inflation rate was higher than the true inflation rate in this study. The core reason behind the discrepancies in the use of appropriate expenditure weight. Finally, this study suggests caution while adopting card-based expenditure data in calculating any superlative price indexes for measuring general price levels when spending behaviour has changed dramatically.

One of the limitations of this study is time aggregation. As Ivancic et al. (2011) showed, time aggregation choices lead to the differences in price estimates of the chained index for both the superlative index (though relatively lower) and the non-superlative indices. As this study is based on the national account's expenditure share data, there is a possibility of potential time aggregation bias for the countries which have generally published expenditure share data only on an annual or quarterly basis.

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Data Availability In this study, we recalculate the official CPI of 33 OECD countries based on the true household expenditure share from the national account during the period of the COVID-19 Pandemic. The monthly official CPI/CPIH/HICP index and the Household Final Consumption Expenditure (HHFCE) are the key data used in this study. All the data used in this study are publicly available and collected from the following sources:

OECD Countries	Frequency of Official CPI/HICP Index	Sources of Official CPI/HICP Index	Frequency of HHFCE Data	Source of HHFCE
United Kingdom	Monthly	Office for National Statistics (ONS). Consumer price inflation tables. Table 56. CPIH: Detailed indices to 3 dp: 1988 to 2023. Link: https://www-ons-gov-uk.abc.cardiff.ac.uk/economy/inflationandpriceindices/datasets/consumerpriceinflation	Quarterly	Office For National Statistics (ONS). Consumer trends, UK: October to December 2021 (current price, seasonally adjusted). Link: https://www-ons-gov-uk.abc.cardiff.ac.uk/economy/nationalaccounts/satelliteaccounts/datasets/consumertrendscurrentpriceseasonallyadjusted
United States	Monthly	U.S. Bureau of Labor Statistics (BLS). Databases, Tables & Calculators by Subject. Inflation & Prices. All Urban Consumers (Current Series). Link: https://www.bls.gov/data/	Monthly	Bureau of Economic Analysis (BEA). National Data. National Income and Product Accounts. Table 2.3.5U. Personal Consumption Expenditures by Major Type of Product and by Major Function. Link: https://apps.bea.gov/iTable/?1921=underlying&isuri=1&reqid=19&step=2#eyJhcHBpZCI6MTksInN0ZXBzIjpbMSwyLDMsM10sImRhdGEiOltbIkNhdGVnb3JpZXMiLCJTdXJ2ZXkiXSxbIk5JUEFfVGFibGVfTGlzdCIsIjIwMTQiXSxbIkZpcnN0X1llYXIiLCIyMDE4Il0sWyJMYXN0X1llYXIiLCIyMDIxIl0sWyJTY2FsZSIsIi02Il0sWyJTZXJpZXMiLCJNIl1dfQ==
Australia	Monthly	Australian Bureau of Statistics. Consumer Price Index, Australia. Table 9. CPI: Group, Sub-group and Expenditure Class, Index Numbers by Capital City. Link: https://www.abs.gov.au/statistics/economy/price-indexes-and-inflation/consumer-price-index-australia/dec-2021	Quarterly	Australian Bureau of Statistics. Australian National Accounts: National Income, Expenditure and Product. Table 8. Household Final Consumption Expenditure (HFCE). Link: https://www.abs.gov.au/statistics/economy/national-accounts/australian-national-accounts-national-income-expenditure-and-product/mar-2023#data-downloads

OECD Countries	Frequency of Official CPI/HICP Index	Sources of Official CPI/HICP Index	Frequency of HHFCE Data	Source of HHFCE
Canada	Monthly	OECD.Stat. Prices and Purchasing Power Parities. Consumer Prices Indices. CPIs and Weights by COICOP by country. Link: https://stats.oecd.org	Quarterly	Statistics Canada. Household final consumption expenditure, quarterly, Canada. Current Prices, seasonally adjusted at annual rates. Link: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3610010701&pickMembers%5B0%5D=2.2&pickMembers%5B1%5D=3.1&cubeTimeFrame.startMonth=01&cubeTimeFrame.startYear=2018&cubeTimeFrame.endMonth=10&cubeTimeFrame.endYear=2021&referencePeriods=20180101%2C20211001
Israel Mexico	Monthly	OECD.Stat. Prices and Purchasing Power Parities. Consumer Prices Indices. CPIs and Weights by COICOP by country. Link: https://stats.oecd.org	Annually	OECD.Stat. Annual National Account. 5. Final consumption expenditure of households. Link: https://stats.oecd.org
South Korea	Monthly	OECD.Stat. Prices and Purchasing Power Parities. Consumer Prices Indices. CPIs and Weights by COICOP by country. Link: https://stats.oecd.org	Quarterly	Statistics Korea. Household Income and Expenditure. Link: https://kostat.go.kr/board.es?mid=a20106020000&bid=11736

OECD Countries	Frequency of Official CPI/HICP Index	Sources of Official CPI/HICP Index	Frequency of HHFCE Data	Source of HHFCE
Austria Belgium Czech Republic Denmark Estonia Finland France Germany Greece Hungary Iceland Ireland Italy Latvia Lithuania Luxembourg Netherlands Norway Poland Portugal Slovakia Slovenia Spain Sweden Turkey	Monthly	Eurostat. Database. Economy and Finances. Prices. HICP—monthly data (index). Link: https://ec.europa.eu/eurostat/databrowser/view/PRC_HICP_MIDX/default/table?lang=en	Annually	Eurostat. Database. Economy and Finance. Annual National Account. Detailed Breakdown of main GDP aggregates. Final consumption expenditure of households by consumption purpose (COICOP 3 digit). Link: https://ec.europa.eu/eurostat/databrowser/view/NAMA_10_CO3_P3/default/table?lang=en
Japan	Monthly	Statistics Bureau of Japan (e-Stat). Consumer Price Index. Table 18. Monthly COICOP Group Index for Japan. Link: https://www.stat.go.jp/english/data/cpi/1588.html#mon	Annually	Statistics of Japan (e-Stat). Family Income and Expenditure Survey. Link: https://www.e-stat.go.jp/en/stat-search/files?page=1&layout=datalist&toukei=00200561&tstat=000000330001&cycle=7&month=0&tclass1=000000330001&tclass2=000000330019&tclass3=000000330021&cycle_facet=tclass1%3Atclass2%3Atclass3%3Acycle&tclass4val=0

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