FACULTY OF ECONOMICS AND BUSINESS ADMINISTRATION

COVID-19 EFFECTS ON THE MEASUREMENT OF INFLATION

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Preface

We present you our master's dissertation: 'COVID-19 effects on the measurement of inflation', written to obtain the degree of 'Master in Economics'. Our dissertation analyses how inflation is measured, inflation during the COVID-19 pandemic and the potential measurement bias. From September to June, we worked closely together and supported one another throughout the process. By writing this dissertation, we learned valuable skills such as processing large amounts of data, writing academically and teamwork.

First of all, we would like to thank Prof. Dr. De Schryder for making this dissertation possible. We especially would like to thank Lara Coulier for her guidance throughout the writing of our dissertation. She was always available and ready to answer our questions. She motivated and supported us and provided valuable feedback.

Furthermore, we would like to thank our family and friends for the support and encouragement throughout this year. They all helped to make this degree possible.

We hope you will enjoy reading our master's dissertation.

Amber Meganck en Melita Van Steenberghe

Ghent, June 7, 2022

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List of abbreviations

ARPA	American Rescue Plan Act
BLS	Bureau of Labor Statistics
COGI	Cost-of-goods index
COICOP	Classification of Individual consumption by Purpose
COLI	Cost-of-living index
CPI	Consumer Price Index
CPI-U	Consumer Price Index for All Urban Consumers
ECB	European Central Bank
ECOICOP	European Classification of Individual Consumption by Purpose
EU	European Union
GDP	Gross Domestic Product
HBS	Household Budget Survey
HFEN	High-Frequency Expenditure Network
HICP	Harmonized Index of Consumer Prices
IMF	International Monetary Fund
mom	month-over-month
n.e.c.	not elsewhere classified
NSI	National Statistical Institute
OECD	Organization for Economic Cooperation and Development
OI	Opportunity Insights
OOH	Owner occupiers' housing
PCE	Personal Consumption Expenditures Price Index
PPI	Producer Price Indices
US	United States
VAT	value added tax
WHO	World Health Organization
yoy	year-over-year

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1. Introduction

1.1 The COVID-19 Pandemic and its Influence on Inflation

On 11 March 2020, the World Health Organization (WHO) declared the COVID-19 situation officially a pandemic (World Health Organization, 2020). The negative economic consequences of this pandemic were the largest since the great financial crisis in 2008. The GDP level of all advanced economies in the world plunged. The US economy suffered a 10% drop in GDP in the second quarter of 2020, just as the coronavirus broke out, compared to 2019. The European countries experienced an even greater fall in GDP, namely a 15% decrease (Milesi-Ferretti, 2021).

The economic consequences are caused by the restrictions on mobility and social-distancing and the stay-at-home measures. These rules dramatically changed consumers' behavior. The consumption of transportation, hotels and recreation diminished and the consumption of food increased. By consequence, this might lead to a bias in the inflation rates because the weights for these categories are no longer representative. Therefore, we study, as Cavallo (2020) did, the impact of these changing expenditures on the measurement of inflation, both for the United States (US) and the European Union (EU).

1.2 Objectives

The objective of our master's dissertation consists of the following three parts. First of all, the aim to clarify the concept of inflation by giving an overview of the different measures and methods of inflation. Secondly, to provide an outline of the inflation rates and of the consumption patterns during the pandemic because consumers all over the world changed their behavior due to the COVID-19 virus. Furthermore, it is also our purpose to specify the impact of the pandemic on the measurement of inflation.

Finally, the existing literature will be expanded by extending the COVID CPI of Cavallo (2020) for the US. Moreover, the main contribution will be to construct a COVID index for inflation for the EU. Our aim is to make an analysis of the possible incorrect measurement of inflation and to find out the reasons behind this measurement error.

1.3 Outline

The dissertation is structured as follows: in section 2, an overview is given about the inflation measurement in normal times. Important concepts, such as the CPI, the HICP, and methods to measure inflation will be explained in detail. Additionally, an answer to the question of why it is important to measure inflation correctly will be provided. Further, section 3 will focus on inflation during the pandemic. The impact of the pandemic on, on the one hand consumer behavior and on the other hand the measurement of inflation will be discussed.

Section 4, the econometric analysis concerning the construction of a COVID index of inflation for the US and the EU is illustrated. Further, the numbers regarding the COVID infections are integrated in order to draw some conclusions. Finally, section 5 summarizes the main findings of the dissertation.

2. Inflation Measurement in Normal Times

The focus of section 2 will be on how inflation is measured in normal times. We will start with explaining the Consumer Price Index (CPI) and the Harmonized Index of Consumer Prices (HICP), as these are the most used measures for inflation worldwide. Nevertheless, other versions of inflation measures will also be defined. Next, we will explain the statistical methods as these are used to compose the inflation measure. In addition, we discuss core inflation, because it focusses more on the long-term trend of future inflation. Finally, we will summarize the main reasons why it is important to measure inflation correctly.

2.1 Cost-of-goods Index or Cost-of-living Index?

The measurement of inflation is the process in which changes in prices of goods and services are combined to create a measure of general price change. This definition brings three main stages to attention. First, one must decide which goods and services we want to include to collect price changes; second, price changes need to be correctly measured; and finally, a method is needed to combine those changes into a measure of aggregate inflation (Lebow & Rudd, 2006).

Before exploring these three stages, one should decide whether the CPI should be a *cost-of-goods index* (COGI) or a *cost-of-living index* (COLI).

The simplest way to set up a measure of overall inflation is via a COGI (also referred to as a *fixed-basket index*). The COGI determines the overall price level of the cost of a fixed basket of goods and services (European Central Bank, 2022). A disadvantage of the COGI is that when new goods come to the market or characteristics of existing goods change and by consequence goods are consumed or produced in different quantities, the basket becomes less representative (Lebow & Rudd, 2006).

Another way to construct a measurement for inflation is the COLI, which is a special case of a COGI. The COLI measures the change in expenditure necessary to maintain a specific level of utility as prices change (European Central Bank, 2022). An advantage of the COLI is that it can deal with changes in expenditure patterns and the creation of new goods (Lebow & Rudd, 2006).

When the purpose of the CPI is indexation, countries use methods to approximate a COLI, as it is not possible to construct a true COLI. On the other hand, when the purpose is to measure inflation, countries use the COGI as the target index. Selecting a COLI or a COGI has consequences for the scope of the index and how goods and service are included. In practice, most national statistics institutes (NSIs) produce a CPI that makes a combination of a COLI and a COGI (International Labour Office, 2020).

2.2 The Consumer Price Index

The most widely used inflation measure is the CPI, which measures the rate of price changes that households experience. Changes in prices affect the real purchasing power of a consumers' income and thus everyday decision-making. However, different goods and services can have different rates of price changes, which is why the CPI reflects only the average movement (International Labour Office, 2004). As the CPI is built to represent an average household, it also represents price change in normal economic times (Zimmer & Jonckheere, 2020).

As already noted, there are three main stages in calculating a CPI. The first is which goods and services should be included. The CPI tracks the evolution of the prices of goods and services which are collected in a consumption basket relative to a base year. That basket aims to be representative for consumption patterns of all types of households. Goods and services of the consumption basket can be everyday items such as food, clothing, beverages and gas, durable goods such as household appliances and services such as insurance, health care, restaurants and hotels (International Labour Office, 2004). Most of the time, the basket is kept constant for consistency, but occasionally it is amended to reflect changes in consumption patterns – for example, including new goods on the market and replacing products which are no longer purchased (Oner, n.d.). Most countries use the internationally agreed Classification of Individual Consumption by Purpose (COICOP), in which the disintegration at the highest level is by purpose, as shown in table 2.1, and the lower levels by product type (see appendix A) (International Labour Office, 2004).

Table 2.1 Classification of Individual Consumption by Purpose (COICOP) Main Headings

01	Food and non-alcoholic beverages
02	Alcoholic beverages, tobacco and narcotics
03	Clothing and footwear
04	Housing, water, electricity, gas and other fuels
05	Furnishings, household equipment and routine household maintenance
06	Health
07	Transport
08	Information and communication
09	Recreation, sport and culture
10	Education services
11	Restaurants and accommodation services
12	Insurance and financial services
13	Personal care, social protection and miscellaneous goods and services
14	Individual consumption expenditure of non-profit institutions serving households (NPISH)
15	Individual consumption expenditure of general government

Note: This table represents the main headings of the COICOP, obtained from the United Nations (2018).

The second stage is concerned with the collection of price data and correct measuring of price changes. Collecting every single transaction price is impossible, consequently, agencies collect only a sample of representative prices from shops and outlets for each of the chosen product groups. Some prices can also be collected from catalogues, by telephone, fax, emails, from internet sites etc. (International Labour Office, 2004).

Measuring price changes correctly can be difficult as new goods appear, old goods disappear, and the quality of existing ones can change (International Labour Office, 2004). Several techniques exist for handling changes in characteristics (or quality) of existing items. All these techniques have a procedure for dividing the price change into a component that reflects the quality change and a component for the 'pure' price change – only the latter component can be included in the measurement of the CPI. For example, when the original item and the improved item exist in the same period, the difference in the items' characteristics reflects the difference in their price. On the other hand, when an item exists in the original form in period t and in the improved form in period $t+1$, the 'pure' price change is calculated by taking the observed average price change of a similar group of goods. Finally, additional information may be used. Data from manufacturers on the cost

of modifying the characteristics of the item is sometimes used to compute the price change due to these modifications. However, the so-called ‘hedonic’ methods can only be used when detailed information about the item’s characteristics is available. The hedonic method associates the item’s observed price to its characteristics. When there is a change in the characteristics of an item, it can be controlled for and removed from the total price change of the item (Lebow & Rudd, 2006).

A more difficult variant of the quality adjustment problem is the ‘new goods’ problem. New goods have characteristics that never existed before such as the introduction of the mobile telephone, broadcasting services and electronic storage of data (Lebow & Rudd, 2006). When it comes to the CPI, the focus is on keeping the consumption basket relevant and up to date. Especially with new goods is it critical to the accuracy of the CPI because there is a greater chance for introduction bias if these new goods are ignored. However, in practice, they are often only introduced when there is a CPI revision. If these CPI revisions are only done infrequently, this could lead to a CPI basket that is unrepresentative. On the other hand, new goods come with a lot of uncertainty; some new goods will be successful, while others will only be popular for a short amount of time. A solution that reduces these potential problems is frequently updating the CPI basket (International Labour Office, 2020).

A final problem that will be discussed is that of identical goods that can be sold at different prices across different sellers. The price difference can reflect true price differences, for example, a certain outlet might be able to sell at a lower price. However, the price difference might also reflect characteristics of the outlet such as customer service. In the latter case, the identical goods should be treated as two individual goods (Lebow & Rudd, 2006).

The relative importance of a good or service for households is represented by a given weight, these weights are collected by consumer expenditure surveys and national accounts (Patel & Villar, 2016). At the beginning of each year, the consumption basket is adjusted to account for changes in consumption patterns during the year before (Claeys & Guetta-Jeanrenaud, 2021). The most used method for calculating a CPI is to take an average of the period-to-period price changes for the different goods and services, using weights that represent the average amounts that households spend on them (International Labour Office, 2004). This concept is also known as a Laspeyres index, which will be further explained in section 2.3.1.

The US releases three CPI series. First, the Consumer Price Index for All Urban Consumers (CPI-U), which is most used by the Bureau of Labor Statistics (BLS). The CPI-U[1] is based on the spending of consumers that live in urban areas. Furthermore, Consumer Price Index for Urban Wage Earners and Clerical Workers (CPI-W)[2] is also available, which is mostly used for wage escalation agreements and focusses on the population of wage earners and clerical workers in urban areas. The CPI-W is a subset of the CPI-U and can also be referred to as the 'blue-collar-measure'. The only difference between both indices is the used weights (Bureau of Labor Statistics, 2020). Additionally, the US also uses the Chained Consumer Price Index (C-CPI-U). They prefer this measure because it is a better approximation to a cost-of-living index (Bureau of Labor Statistics, 2016). The difference between CPI-U and the C-CPI-U is that the CPI-U is not revisable, and the C-CPI-U can be revised. For the C-CPI-U the expenditure weights vary each month, contrary to the CPI-U and the CPI-W for which the weights are only updated every two years. In other words, the C-CPI-U addresses the CPI-U substitution bias problem (see section 2.3). However, due to a lag in data availability of consumer expenditure behavior, the Bureau of Labor Statistics (BLS) of the US can only publish the C-CPI-U with a two-year lag. (Cage et al., 2003).

The CPI has a variety of purposes such as monetary policy; for calculating changes in living standards or national consumption; or as a tool for the indexation of commercial contracts, financial instruments, wages, pensions or social protection benefits (Eurostat, 2008). This will be explained in section 2.5.

2.2.1 Harmonized Index of Consumer Prices

In the euro area preference is given to the HICP to measure inflation. This because an important prerequisite to form a monetary union is the convergence of inflation in the Member States. To do this, a precisely defined measure of inflation and a common methodology was required to ensure that the Member States' price indices are comparable. All the NSIs of the EU Member States together with Eurostat, the Statistical Office of the EU, reviewed all aspects of the compilation of the CPIs. The end result was the HICP as a new EU standard for the Member States (International Labour Office, 2004).

[1] The CPI-U was introduced in 1978 to have a more representative index for the urban, non-institutional population of the US. The index covers approximately 93% of the total US population (Bureau of Labor Statistics, 2020).
[2] The CPI-W covers approximately 29% of the US population (Bureau of Labor Statistics, 2020).

The HICP serves two main purposes. First, it is used by the European Central Bank (ECB) to quantity the definition of price stability; second, when a country wants to join the monetary union, it is used to evaluate price convergence. Additionally, the HICP can be used for economic analysis and for indexing contract prices, just like other CPIs (Eurostat, 2018).

The HICP measures the price change of goods and services based on final monetary consumption expenditure of households. It is essential for the HICP that it contains monetary transactions only, e.g. goods and services produced by households themselves, such as household chores or vegetables from a homemade vegetable garden, are not included. The HICP is a COGI, as it measures the price change of a fixed basket of goods and services (Eurostat, 2018). Even though the categories of the HICP are fixed, the HICP is not a strict fixed-basket price index, this because the goods and services included in the basket can fluctuate over time (European Central Bank, 2022). To keep the basket representative, it is reviewed each year in December (Claeys & Guetta-Jeanrenaud, 2021). The classification system used by the HICP, is the European Classification of Individual Consumption by purpose (ECOICOP), which divides the basket into divisions (2-digit), groups (3-digit), classes (4-digit) and sub-classes (5-digit). The main headings of the ECOICOP are displayed in table 2.2 (a 3-digit table can be found in appendix A). The data for constructing the weights comes from different sources, such as national accounts data, household budget surveys (HBSs), retail trade data and more recently scanner data. The country specific HICP is calculated by the NSI, while the country-group aggregates are calculated by Eurostat (Eurostat, 2018).

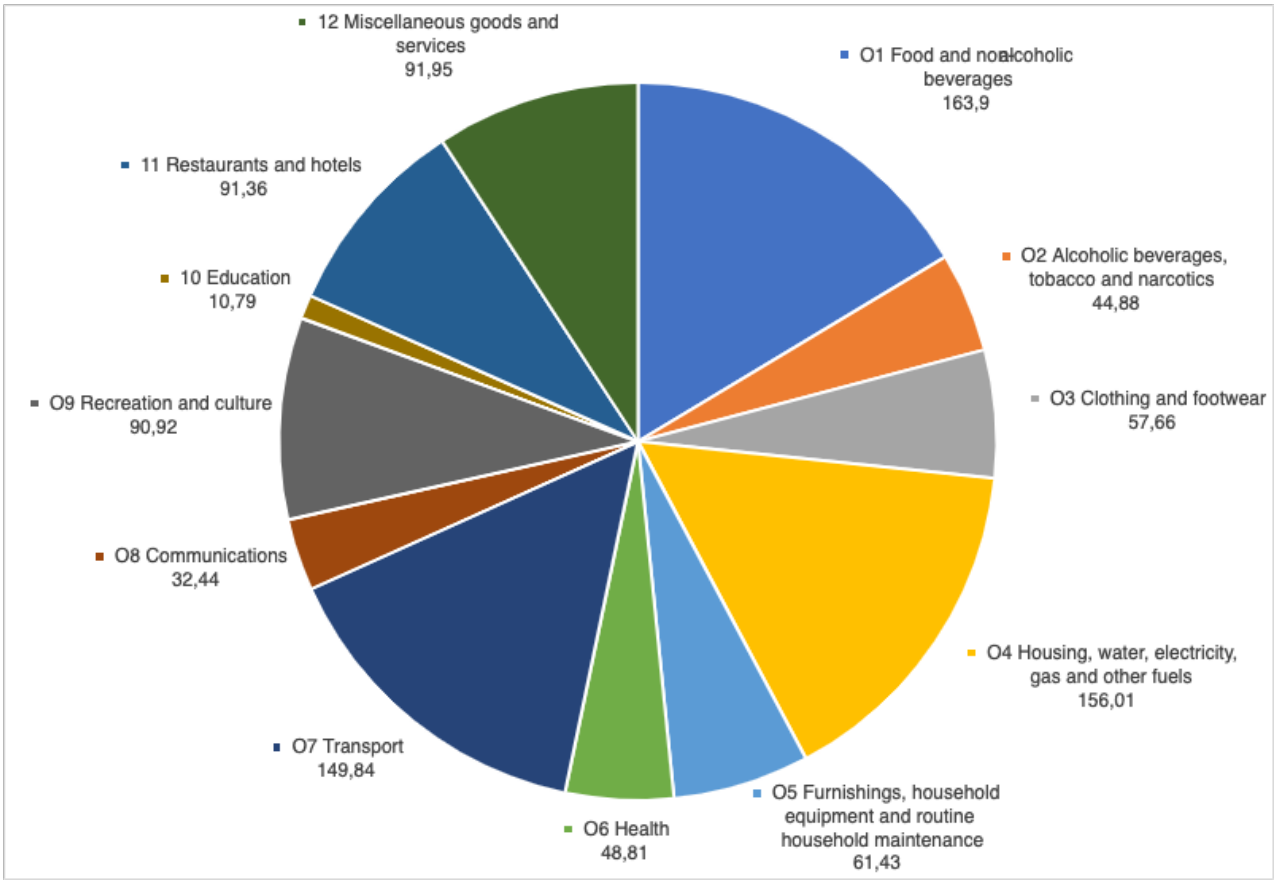
Table 2.2 European Classification of Individual Consumption by Purpose (ECOICOP) Main Headings

00	All items (total or all-items index)
01	Food and non-alcoholic beverages
02	Alcoholic beverages, tobacco and narcotics
03	Clothing and footwear
04	Housing, water, electricity, gas and other fuels
05	Furnishings, household equipment and routine household maintenance
06	Health
07	Transport
08	Communication
09	Recreation and culture
10	Education
11	Restaurants and hotels
12	Miscellaneous goods and services

Note: This table represents the division of the European Classification of Individual Consumption according to Purpose adapted to the needs of the Harmonized Indices of Consumer Prices obtained from Eurostat (n.d.) (RAMON – Reference And Management of Nomenclatures).

Figure 2.1 provides an example of how the weights are distributed in normal times (before COVID-19). We focus on the main headings of the EU-27 in 2018. The most important categories that have the largest influence on the level of the HICP are category 01 ‘Food and non-alcoholic beverages’, category 04 ‘Housing, water, electricity, gas and other fuels’ and category 07 ‘Transport’.

Figure 2.1 Item Weights according to the ECOICOP Main Headings, EU-27, 2018



Note: This figure represents the item weights according to the ECOICOP main headings for the EU-27 in 2018. Reproduced from Eurostat (2022).

2.2.1.1 Comparison of the National CPIs with the HICP

Both the CPI and the HICP measure the change in the average level of prices paid for consumer goods and services. However, both measures have different aims and can therefore use different methods or concepts. As the HICP is mainly used for monetary policy aims but also for economic analyses and indexation, the CPIs can have a wider range of uses, such as the indexation of wages, financial instruments and social protection benefits (Eurostat, 2008).

Some countries often wish to produce a national CPI as they want to cover goods and services which differ from the HICP consumption basket. The national CPI can be adapted to the countries' objectives because they do not need to follow Eurostat regulations (Eidukas, 2016). In the euro area, the used method to calculate the CPI and the HICP is the same, namely the Laspeyres chain

index. However, there are some differences between the national CPIs and HICPs across a number of countries (Zuzana, 2010).

First of all, the geographic and population coverage difference (Zuzana, 2010). The HICP applies a domestic approach, this means that the HICP includes all consumption expenditure in the country concerned, which is purchases of goods and services of domestic residents and non-residents. By contrast, most of the CPIs apply a residence concept, which covers only the expenditure of domestic residents, including their purchases abroad. Due to this difference in expenditure coverage, different weights could be used in the national CPIs and the HICP (Eidukas, 2016).

The second divergence from the HICP is in the number and the coverage of items in the consumption basket. The HICP has a fixed consumption basket, Member States of the EU cannot deviate from these goods and services. On the contrary, a country is free to include or exclude certain goods or services from its CPI. For example, France excludes healthy services from the CPI and Germany includes lottery tax and motor vehicle tax in their CPI (Zuzana, 2010). However, the treatment of owner occupiers' housing cost (OOH) makes the comparability between countries CPI most difficult. According to Zuzana (2010), 11 out of 27 countries in the EU include OOH in their calculation of the CPI. OOH is included in the CPI for example in Sweden, Germany, Austria and the Netherlands (Eiglsperger, 2022; OECD, 2020). However, different approaches to cover OOH are used between these countries. In the HICP, OOH is excluded, nevertheless, in the 2021 Strategy Review the Governing Council recommended to include OOH but implementing this will take time (European Central Bank, 2022).

The difference is also in the choice of using net versus gross expenditure for compiling weights. For some goods or services, such as education, provision by the state is used. When one uses net weights, only the fee payed by the consumer is included, whereas the gross weight approach takes the total expenditure. As regulated by Eurostat, the HICP makes use of the net approach. However, some countries use gross weights in their national CPI, such as Ireland or the Netherlands[3] (Eidukas, 2016).

Sources used to collect expenditure data is another area where in some cases the CPIs differ from the HICP regulations. Some countries use HBS for calculating the national CPI, while the weights

[3] To the best of our knowledge, this is the most recent source.

of the HICP are computed using the national account's expenditure data. In practice, however, most countries' national CPIs use a mix of both data sources for quality and accuracy reasons (Eidukas, 2016). There may be also differences in the frequency of updating the consumption basket and the expenditure shares of the items covered in the HICP and the national CPIs. The methods used for quality changes can differ and also different classification systems can be used for the CPI and the HICP (Zuzana, 2010). An example of the difference in the classification systems can be seen in table 2.1 in section 2.2 and table 2.2 in section 2.2.1 or in appendix A.

2.2.2 Alternative Measures of Inflation

In addition to the CPI and the HICP there are many other instruments for measuring inflation. In this section we will explain the most common indices in the literature.

2.2.2.1 The Personal Consumption Expenditures Price Index

First, the PCE or Personal Consumption Expenditures Price Index, which is often used by the Federal Reserve in the US. As the CPI, the PCE measures price changes of a basket of goods and services bought by consumers. The biggest differences between both indices are the differences in their baskets. First, the two indices estimate the appropriate basket differently. Different from the CPI, which is based on a household expenditure survey, the PCE is based on business selling surveys. Another aspect is that the PCE includes expenditures that are not directly paid for such as medical care paid for by the employer-provided insurance. These are not included in the CPI, as the CPI only covers out-of-pocket expenditures (Haubrich & Millington, 2014). A final difference is in how both indices account for changes in the basket. The indices are calculated using a different formula. In contrast to the CPI, which is based on the Laspeyres formula as mentioned before, the PCE is based on the Fisher-Ideal formula, which will be explained in section 2.3 (Bureau of Economic Analysis, n.d.). Furthermore, there are a few more minor differences between the CPI and the PCE. These consist of seasonal-adjustment differences, residual differences[4] and price differences (difference in aggregation procedure) (Mccully et al., 2007).

[4] For example, the CPI for airline fares is based on prices that are charged for air travel for sampled routed, while the PCE index is based on passenger revenues and the passengers' traveled miles (Mccully et al., 2007).

2.2.2.2 The GDP Deflator

A second alternative is the GDP deflator, which is an index with a broad coverage. It calculates an overall inflation rate for a country, this contrasts with the CPI which only focusses on consumers (Oner, n.d.). The GDP deflator indicates on average how prices change for everything that is produced in an economy, the index includes exports to other countries but excludes prices of imports (Bureau of Economic Analysis, n.d.). As the CPI basket is mostly fixed, the GPD deflator contents vary every year and are more current. However, the GDP deflator is not a good measure for the cost of living as it includes nonconsumer items such as military spending (Oner, n.d.).

2.2.2.3 The Producer Price Index

A last indicator that we want to mention is the Producer Price Index (PPI, also referred to as the output price index). This index measures changes in the selling prices received by producers. Taxes, transport or other costs that the purchaser may have, are not included in this index (OECD, n.d.-a). Comparing the PPI with a CPI, one could say that the PPI measures changes in price of a product from the producers/manufacturers point of view, while the CPI has a consumer's point of view. The PPI reflects basic prices, which means that it excludes value added tax (VAT) and other deductible taxes that are linked to turnover. However, all product subsidies that the producer receives should be included.

There are two sets of the PPI; the domestic PPI, which measures the average price development of goods sold on the domestic market; and the non-domestic PPI, which measures the average price development of goods that are sold outside the domestic market (Eurostat, n.d.-b). Furthermore, the PPI has three uses. In the first place, the index can be used as an economic indicator, price movements prior to the retail level can already be captured by the PPI. This is convenient for consumers and businesses, as the index may foreshadow upcoming price changes. The PPI can also be used as a deflator of other economic series. And lastly, as the basis for contract price adjustments (escalation) (Eurostat, 2008).

For economies that are vulnerable to terms-of-trade shocks, the PPI or the GDP deflator provide an alternative to the CPI. When a central bank targets the PPI or GDP deflator, it might help to safeguard their mandate of price stability, as fluctuations in the nominal exchange rate can counter

movements in the terms of trade. A central bank then needs to react when there are changes in producer prices that are not absorbed by exchange rate fluctuations (Patel & Villar, 2016).

2.3 Methods

Constructing a measure for inflation involves the weighting of the individual price changes for the goods and services in the consumption basket by their shares in overall expenditures (Lebow & Rudd, 2006). In this section, we will give a summary of the most important methods in the literature.

2.3.1 The Laspeyres Index

When the expenditure weights that are used are those of the baseline *(t-1*), one talks about the Laspeyres index (European Central Bank, 2022). Hence, inflation between two periods of time is measured with the basket of the previous period. In other words, when one wants to measure the evolution in prices between *t* and *t-1*, by using a Laspeyres index, we make use of the quantities in *t-1*.

$$I^{L}_{t-1\rightarrow t} = \frac{\sum_i p_{i,t} \times q_{i,t-1}}{\sum_i p_{i,t-1} \times q_{i,t-1}} \quad (1)$$

The Laspeyres index answers to the question of how much a basket bought by consumers in the base period would cost in the current period. Because the Laspeyres index makes use of the base period basket, the basket can also be defined as a fixed-weight, or fixed-basket index (Eurostat, 2008).

2.3.2 The Paasche Index

Another method that can be used is the Paasche index, which works with the current basket. The index measures the price changes between *t-1* and *t* by using the basket that is consumed in the current period (*t*). The Paasche index is also known as a 'current-weight index' (Eurostat, 2008).

$$I^{P}_{t-1\rightarrow t} = \frac{\sum_i p_{i,t} \times q_{i,t}}{\sum_i p_{i,t-1} \times q_{i,t}} \quad (2)$$

If consumption patterns evolve slowly, the Paasche index and Laspeyres index lead to very similar results. This being said, a disadvantage of the Laspeyres index is that it cannot capture substitution towards cheaper goods because most statistical offices update the CPI weights once a year. In other words, it ignores the fact that consumers change the quantities they buy due to price changes, so monthly fluctuations in consumption expenditure are never considered. This makes that the Laspeyres index tends to overestimate inflation. In contrast to the Paasche index, which understates inflation because it allows cheaper goods to replace more expensive ones (Claeys & Guetta-Jeanrenaud, 2021).

The Laspeyres index and the Paasche index are known as Lowe indices because they make use of a fixed basket of goods and services (International Labour Office, 2020).

2.3.3 The Superlative Indices

Hence, alternative methods that capture substitution can be more appropriate. Such methods are called 'superlative' indices and they make us of both the basket of the base period and the current period. Examples are the Törnqvist index, the Walsh index or the Fisher price index (the Fisher ideal) (International Labour Office, 2020).

The Fisher price index is a geometric average of the Laspeyres index and the Paasche index, shown in equation 3 (Eurostat, 2008).

$$I^{F}_{t-1\to t} = \sqrt{I^{L}_{t-1\to t} \times I^{P}_{t-1\to t}} \qquad (3)$$

The Walsh index takes a geometric average of the quantities in both periods. The Törnqvist index is a geometric average of the price relatives with as weights the average expenditure share in two periods (International Labour Office., 2004). However, the details of these indices are beyond the scope of the paper.

The choice on which index depends on the availability of the data. As the Paasche index, Törnqvist index, the Walsh index and the Fisher price index work with the current consumption basket, the preference goes to the Laspeyres index. The main reason for this is that collecting consumption data in real time is rather difficult (Claeys & Guetta-Jeanrenaud, 2021). In the euro zone, the NSIs

collect the data on consumption behavior and thus are responsible for compiling the inflation weights (European Central Bank, 2022). However, because of the delay in consumption data, the statistics for a given year are only available in September the following year. And because the deadline for the publication of inflation weights is already in February, the weights that are meant to be representative of the consumption patterns of the previous year (*t-1*) are partly[5] based on statistics of the year before that (t-2) (Claeys & Guetta-Jeanrenaud, 2021). In normal times, *t-2* data can be used to estimate *t-1* because structural changes between the two years are limited (Eurostat, 2020b).

2.3.4 Fixed-base Indices and Chain Indices

In the subsections above the base period and the current period were compared. Now two ways of calculating the indices when considering a series of periods will be discussed.

Fist, the fixed-base method, to calculate the price changes between any of the periods, the method uses a fixed set of quantities of the base period. A disadvantage is that the difference between the current basket and the base period basket will become larger over time. That is why it is necessary to rebase the series by starting with a new base period (Eurostat, 2008).

The second method is the chaining method. This method compares each period with the preceding period. This means that for each period the weight and price reference periods are being moved forward by one (International Labour Office, 2004). For example, if one wants to calculate the change between t_4 and t_0, one needs to multiply the annual changes between these years (Eurostat, 2008).

2.4 Core Inflation

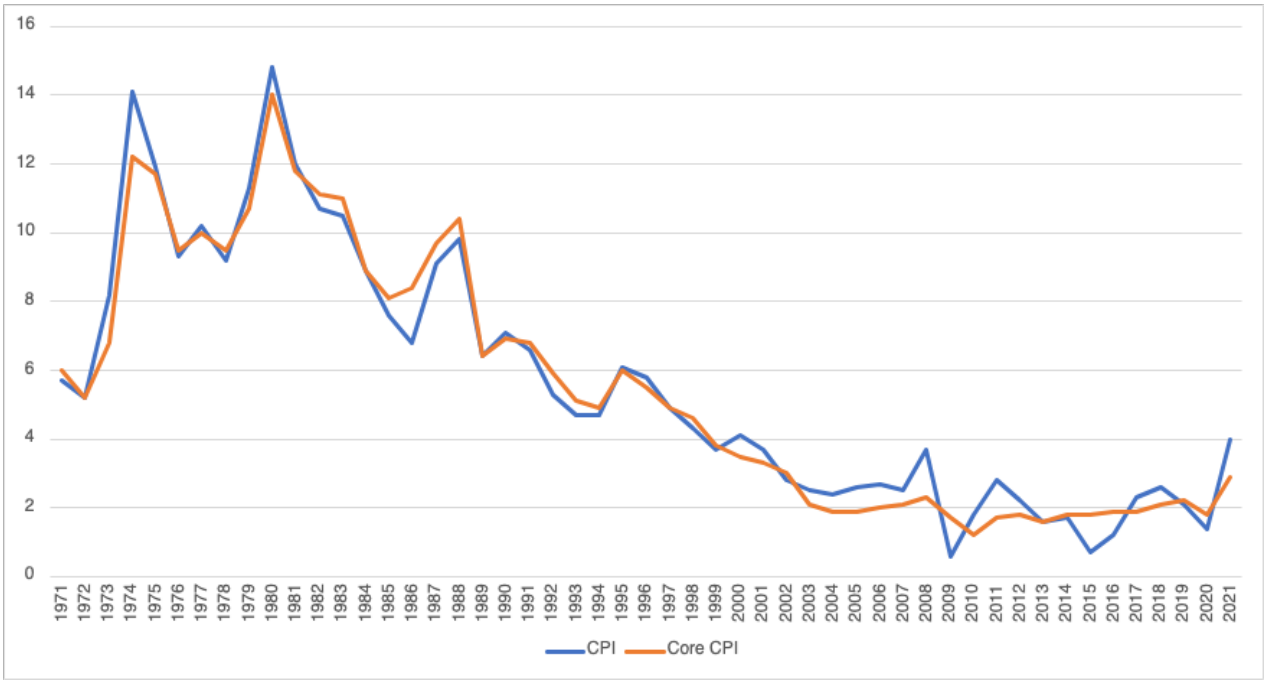
Many central banks make use of the measure ‘core inflation’. This because they have an inflation mandate in reference to a medium or long-term horizon. For example, the ECB’s objective is to maintain price stability defined as a year-on-year (yoy) increase in the HICP of 2% over the medium term (Bilke & Stracca, 2007).

[5] Item-level weights are taken from most recent sources. The weights for subclasses and higher levels of aggregation in the CPI are derived from the national accounts, which include the household consumption expenditures and are from year *t-2* (Blundell et al., 2020).

More specifically, a problem that may occur is fluctuations in the CPI because of transitory shocks, such as seasonality, that causes prices to increase or decrease. Focusing on core inflation, which eliminates the most erratic or volatile components, is based on the idea that monetary authorities are not concerned with every price fluctuation. Transitory shocks are of temporary nature and are not of primary interest to policy makers as they will not become permanently incorporated into the inflation rate. Therefore, monetary authorities focus on the persistent or underlying trends in inflation (Johnson, 1999) Core inflation is often used to look at the long-term trend of inflation or future inflation (BSP, 2020).

Figure 2.2 provides an example of the difference between the CPI and the core CPI for the OECD-Total[6] countries from 1971 until 2021. One can see that the CPI fluctuates more than the core CPI and that the CPI fluctuates around the long-term trend that core inflation represents. This complies with the literature described above.

Figure 2.2 Annual CPI and Core CPI for OECD-Total Countries, in Percentage, 1971-2021



Note: This figure represents the annual CPI and core CPI, measured in percentage change on the same period of the previous year. Core CPI is defined as CPI: all items less food and energy. Data retrieved from (OECD, 2022b).

[6] Austria, Australia, Belgium, Canada, Chile, Colombia, Costa Rica, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Latvia, Lithuania, Luxemburg, Mexico, the Netherlands, New Zeeland, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the US (OECD, n.d.-b).

There are several methods that can be used to calculate core inflation. The most prevalent method is the 'exclusion' method, which excludes the prices of a fixed set of items from the CPI basket. Items that are excluded are considered to be volatile or sensitive to supply disturbances, for example food and energy (BSP, 2020). However, different countries can eliminate different components. It may exclude volatile or erratic prices (e.g. fuel and food), non-monetary expenditures (e.g. OOH costs or rents) or the effects of changes in taxes (Patel & Villar, 2016). A variant for the exclusion method is adjusting the weights of erratic items in inverse proportion to their variability. Thus, instead of omitting them completely, the volatile items are downweighted (Lebow & Rudd, 2006).

Other methods that can be used to compute core inflation are statistical-based methods such as medians or trimmed means. These methods remove for each period a certain proportion of the smallest and largest price changes. In this it differs from the exclusion method as the omitted items vary every period, depending on which items experience extreme price fluctuations. Furthermore, it is also a possibility to use econometric techniques to compute core inflation. An example is the econometric reduced-form Phillips curve, where when one controls for aggregate demand and supply shocks, the lagged inflation terms can proxy for the persistent component of inflation (Lebow & Rudd, 2006).

2.5 Why is it Important to Measure Inflation Correctly?

Measuring inflation correctly matters for a couple of reasons. First and most obviously, a central bank has the objective to maintain prices stable. For example, the objective of the ECB (see section 2.4). To achieve their mandate, it is essential to track price changes in the economy. Moreover, timely and accurate measurement of inflation is key for implementing policies (Jaravel & O'Connell, 2020).

The level of inflation influences the inflation expectations. For example, if consumers are used to inflation being very high, they will expect that inflation will continue to be that high. Inflation expectations are very important as people use them to make everyday decisions such as how much to spend, borrow or invest. Besides people, also businesses take expectations into account when setting their goods or services prices. When inflation expectations move away from the central bank's inflation target, it may become difficult to steer the prices in the economy back to the target (European Central Bank, 2021a).

Further, Lebow and Rudd (2006) point out that economic decisions often depend directly on publicly available inflation measures. Government programs are often indexed to inflation and account for changes in the CPI. For example, income tax schedules, social security benefits and coupon payments on inflation-indexed government debt in the US are linked to changes in the CPI. Also, private contracts, such as wage schemes, are indexed to inflation (Lebow & Rudd, 2006).

Measuring inflation correctly is also important because inflation affects economic welfare. When there are problems with measuring inflation, measurement errors could vary over time in unknown ways. This could lead to inappropriate responses to movements in inflation rates (Lebow & Rudd, 2006).

In addition to the previous reasons why correct inflation is important, inflation is an index that is often used to construct other economic statistics such as real GDP and productivity. Therefore, not only the published inflation rates but also other important indices may be biased and give rise to wrong decisions and policy measures. If inflation is measured incorrectly and by consequence also other crucial economic variables, growth comparisons could also be affected and should be interpreted with caution (Lebow & Rudd, 2006).

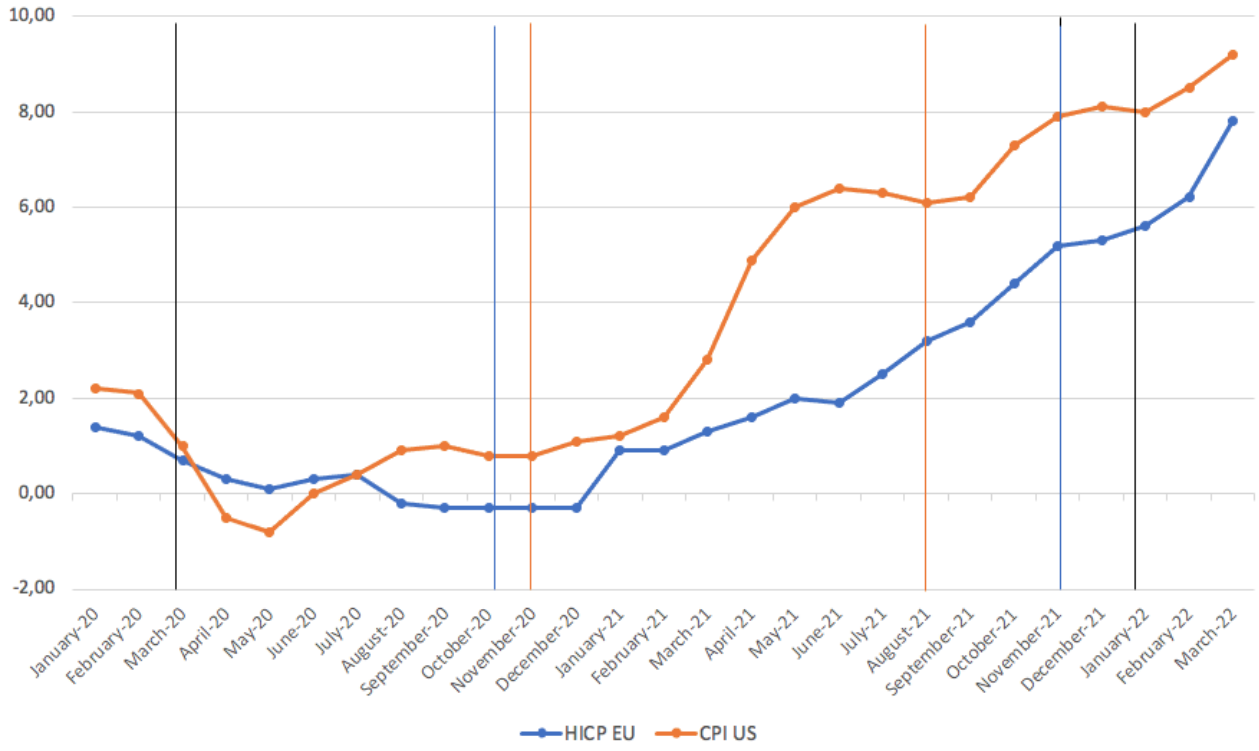
3. Inflation Since the Pandemic

This section starts with an overview of the inflation rates during the COVID-19 pandemic. Next, we explain the underlying trends of the evolution of inflation, focusing on the EU and the US. Insights from existing literature give a better understanding of the changes in consumption patterns. Further, we discuss the implications and problems posed by these changes in consumption behavior. Finally, some alternative measures from the literature are discussed.

3.1 Overview of Inflation Numbers

3.1.1 CPI and HICP

Figure 3.1 HICP of the EU and CPI of the US (Annual Inflation Rates, Percentage Change), 2020 – March 2022



Note: Data retrieved from (Eurostat, n.d.). The graph shows the HICP and CPI from January 2020 until February 2022 of the EU and the US respectively. The vertical lines indicate the start of a COVID wave. The vertical black line on the left indicates the outbreak of the global COVID pandemic and thus the first wave, both in the EU and the US. The first line in blue indicates the start of the second wave in the US in October 2020 and the first line in orange indicates the second wave in the EU in November 2020. The second line in orange and blue indicate the third wave in the US in August 2021 and November 2021 EU respectively. The last black line indicates the fourth wave in both the US and the EU starting in December 2021.

Figure 3.1 shows the HICP for the EU and the CPI for the US in the period of January 2020 until the beginning of 2022 based on the monthly data of Eurostat (n.d.). Before the pandemic, the inflation rate in the US was slightly higher than in the EU. This is probably due to the European countries that were more struggling to push inflation up because of the euro crisis and sovereign debt crisis (Jordà et al., 2022). After the outbreak, the CPI of the US declined sharply and became negative from April 2020 onwards until it came out of deflationary territory in June 2020. In comparison, the decline in the EU was less sharp, and the inflation rates stayed positive until the second wave of COVID-19 cases around August and September 2020 (Winkleman et al., 2021)

From August 2020 onwards both the CPI and the HICP remained relatively constant until the end of that year. Remarkably, the CPI of the US was positive and the HICP of the EU was negative during that period. From 2021 onwards, both inflation indices soared. The positive inflation numbers are caused by a resurgence and reopening of the economy after a year of economic downturn. The US reached their pre-COVID GDP level by the end of the third quarter. This was faster than all other advanced economies due to the large and rapid recovery of domestic consumer spending and enormous fiscal stimulus. For example, in the third quarter of 2021 the GDP level of France was substantially below its pre-pandemic level. Furthermore, especially South-European countries were struggling to increases their GDP as for these countries sectors such as tourism are of great importance. In addition, the labor market in the US is more flexible than the labor market in the EU and in the US, the labor demand stayed strong. By consequence, this recovery has strongly pushed up the inflation (Milesi-Ferretti, 2021).

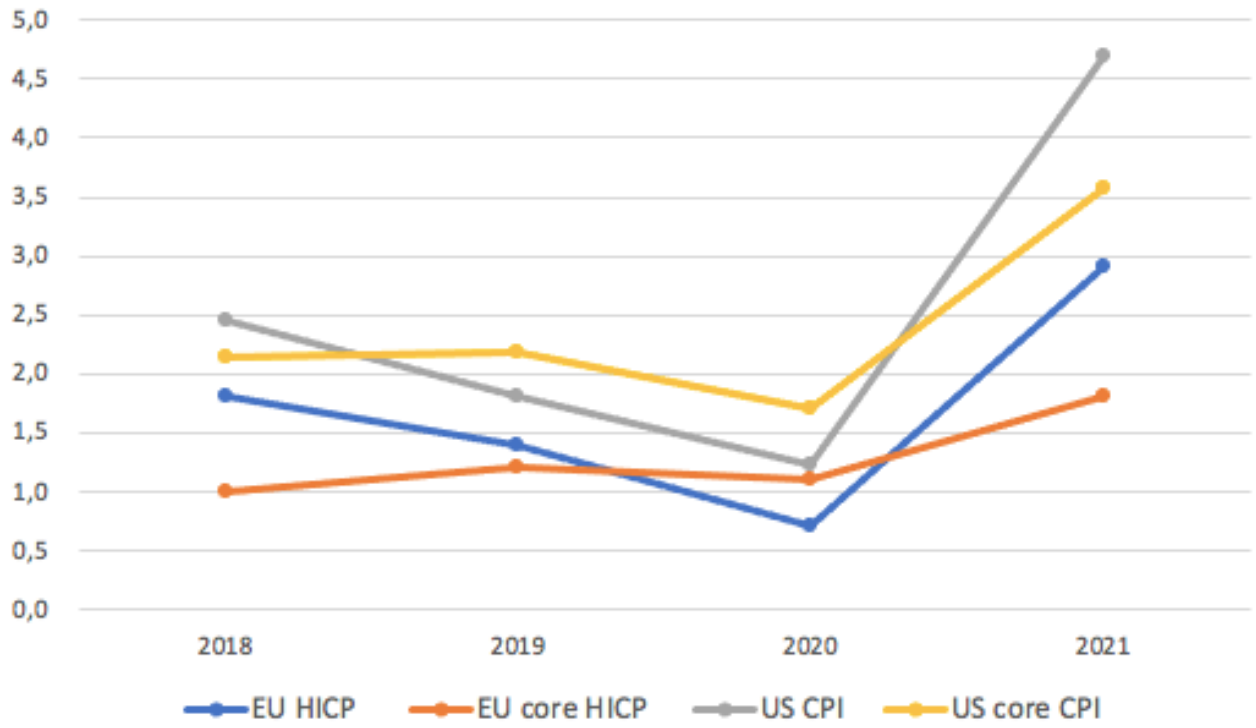
The huge rise slowed down one more time for both the EU and the US, but the inflation was still at a very high level. First it happened in the US, in the summer months of 2021 and a few months later it happened in the EU, this time in the autumn. In both cases, this delay is due to a new outbreak of the coronavirus in the respective periods (Winkleman et al., 2021).

Finally, the high inflation numbers in 2021 and 2022 are also caused by global supply factors. First, supply chain disruptions, such as shipping and production bottlenecks, are related to the high inflation rates (Akinci et al., 2022). This can be explained by a fall in labor force due to lockdowns and restrictions. Also, the imbalance of the COVID situation across big regions of the world caused problems. Furthermore, changes in consumer behavior strongly increased demand for some goods, e.g. consumer electronics, and companies were not prepared for that (eClear, 2022). These

supply chain disruptions together with high input prices and energy prices are pushing up inflation rates (Akinci et al., 2022).

3.1.2 Core CPI and Core HICP

Figure 3.2 CPI and Core CPI US and HICP and Core HICP euro area, Percentage Change on the Same Period of the Previous Year, 2018-2022



Note: Core CPI of the US is defined as the CPI all items non-food, non-energy. Core HICP of the EU is defined as the HICP excluding food, energy, alcohol and tobacco. Data retrieved from (OECD, 2022a).

A comparison between the core and all-items inflation numbers is shown in figure 3.2. As explained in section 2.4, core inflation measures prices change while excluding volatile components such as energy and food. As mentioned before and clearly illustrated in the graph, both for the US and the EU the core CPI and core HICP are less volatile than the CPI and the HICP. Therefore, the core inflation gives a better insight in long-term trends of inflation and the real development of the economic cycles. This is the reason why we look at the period of 2018 until 2021.

As mentioned earlier, the CPI and HICP for the US and the EU respectively, reached a minimum in March 2020 as this was the center of gravity of the pandemic with severe economic consequences. This pulled core inflation down in both parts of the world, which is also clearly

illustrated in figure 3.2. A severe decrease of the core inflation indicates that the real economy was going into a recession and that not only volatile components such as energy and food had a negative impact on the economy.

In 2021, inflation rose to unprecedented levels, which is very clear in figure 3.1. Inflation reached 4.7% in the US and 2.9% in the EU. These high levels pulled core inflation upwards. The increase in the CPI and the HICP can be partly explained by energy prices, supply bottlenecks… that went to unseen levels (discussed in section 3.1.1). To illustrate this, the average price of electricity in the US has never been higher in the last decade than in 2020 (U.S. Energy Information Administration, 2022). Due to such a relative price shock of energy, not only the headline inflation but also the underlying trend of inflation, namely the core inflation, was affected with a lag. These effects are called second-round effects because the relative price shocks push up prices and wages set by firms and in turn, they cause a rise in general prices (de Plessis et al., 2016).

In the period under investigation, it is not only the pandemic that made this period exceptional. On February 22nd, Russian troops crossed the Ukrainian border and this was the beginning of a war (van Muylem, 2022). This conflict has enormous military, diplomatic and economic consequences. Oil, gas and metals are products of which Russia is a major supplier and wheat and corn of which Ukraine is a major supplier. By consequence, the war has seriously reduced the supply of these products, which has significantly pushed up prices. With the region of Russia and Ukraine being such an important player in the food industry, further price increases are expected (Ellyatt, 2022). Furthermore, this conflict caused some extra risks. First, a threat of high inflation on the long-term occurs because of rising commodity prices. This may cause social unrest and stagflation[7]. Secondly, there are some sectors that are more likely to suffer, namely automotive, transport and chemicals (Coface, 2022).

The enormous inflation numbers in February and March 2022 were already shown in figure 3.1. The possible consequences of the war for European countries and the world should not be underestimated. There might be an additional inflation of 1,5 percentage points to the EU inflation of 2022 and the GDP of the EU could be 1 percentage point lower. To conclude, the longer the conflicts drag on, the more prices of products such as energy and commodity will rise and the greater the negative impact on European economies (Coface, 2022).

[7] Stagflation is known as the combination of high inflation rates and stagnating growth and employment, which should be avoided (Coface, 2022).

3.1.3 Fiscal and Regulatory Factors

In section 3.3 the implications of the pandemic on the actual measurement of inflation, e.g. the problem of over- and underestimation of the inflation rates, will be discussed in detail. Of course, there are other factors (fiscal and regulatory) that appeared during the COVID-19 period that affected inflation levels both directly and indirectly (O'Brien et al., 2021).

To tackle the economic downturn many governments in the EU reduced their indirect tax rate(s) massively. For example, the Bulgarian government reduced the VAT for restaurants from 1 July 2020 to increase the profit of restaurants, which have been hit hard by the virus (Demitrova, 2020). These fiscal policy decisions had a negative impact on the core HICP in the second half of 2020, assuming that firms did an immediate and full pass-through of the tax reductions (O'Brien et al., 2021). However, the pass-through of the tax adjustments is probably incomplete and depends on the sectors. The energy sector and retail sector are assumed to pass through these adaptions in a large amount to their clients. By contrast, service sectors or other sectors that experienced substantial revenue losses are less likely to pass through the tax reductions. Therefore, the impact on the HICP, including energy and food inflation, can be much larger than the impact on the core HICP. Furthermore, the basket of the HICP includes goods and services that are not subjected to indirect taxes (Koester et al., 2020).

Another fiscal measure applied by the governments are fiscal stimulus plans including wage and income supplements. The US government created the American Rescue Plan Act (ARPA). This plan together with the COVID-19 vaccine program pushed up the disposable incomes of American household (Hanlon et al., 2022).

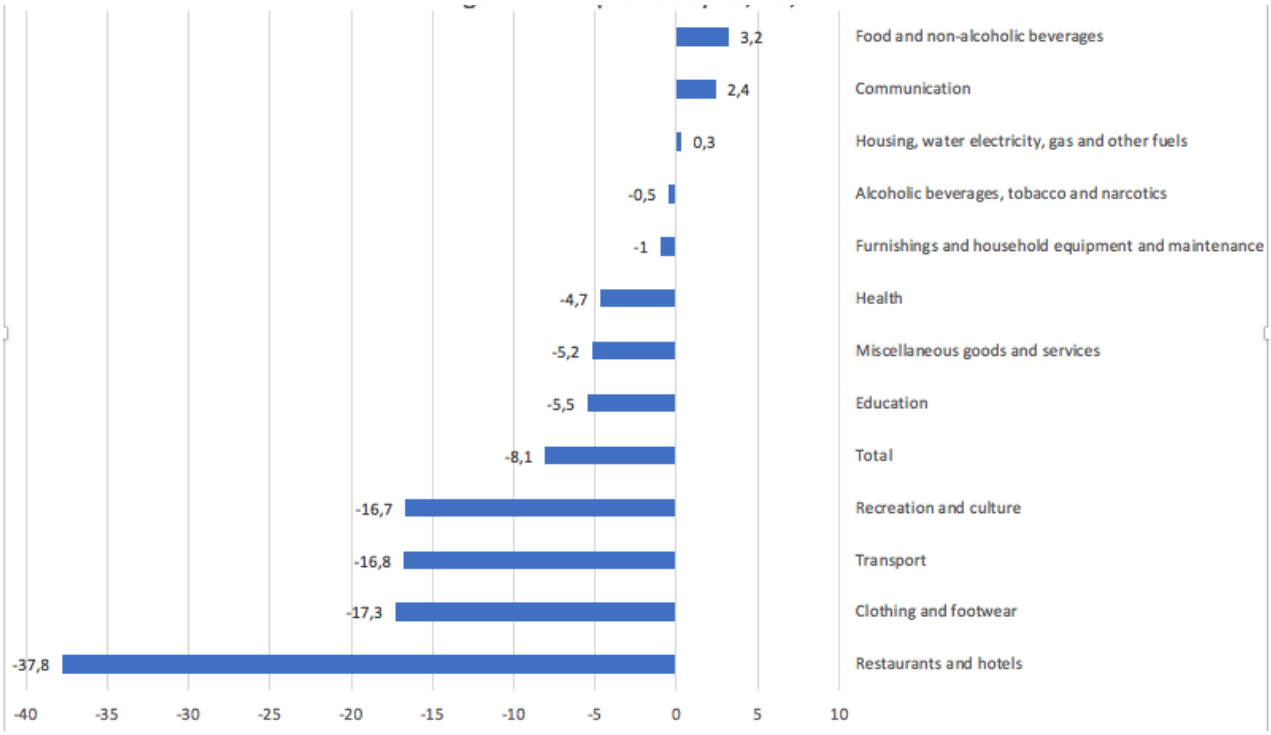
Next to the effect on inflation levels, some measures also affected the volatility of inflation. Regulatory measures affected the inflation numbers which made it more difficult to estimate and correctly analyze the underlying price trends. A concrete example is the postponement of the sale season in European countries from July to August and September. These policies increased the volatility in the annual inflation rates (O'Brien et al., 2021).

3.2 Changes in Consumption Trends

An enormous shock such as a worldwide pandemic can lead to a radical adaptation of the consumer behavior of households. The consumption patterns of people all over the world has completely changed with the outbreak of the COVID-19 pandemic in the spring of 2020. During that period, the great uncertainty and social restrictions dominated the behavior of consumers. This section goes into explaining the inflation numbers presented in section 3.1 and gives an overview of the changes in consumption trends by focusing on household of the EU.

On the one hand, several sectors were closed and services were unavailable. Flights were cancelled, tourism suffered a major setback and restaurants and hairdressers were closed. By consequence, money was no longer spent on these activities. On the other hand, the demand of items that households consume at home exploded. Therefore, the weights that are implemented in the inflation measurement are no longer representative and by consequence, the published inflation numbers as discussed in section 3.1 might be biased. In normal times, consumption weights are slowly adapted to represent the consumption patterns at that time but a radical change cannot be implemented quickly in the measurement of the headline inflation numbers.

Figure 3.3 Household Consumption Expenditure by Consumption Purpose – ECOICOP, % Change over the Rrevious Year, EU, 2020



Note: Reproduced from Eurostat (nama_10_co3_p3). The percentage change in every COICOP category used to construct the HICP in the EU is shown in this figure and constructed as the annual percentage change of 2020 compared to 2019.

Figure 3.3 gives an overview of all categories and their increase or decrease of the household consumption expenditure in 2020 compared to 2019. The consumption of the ECOICOP category ‘Restaurants and hotels’ for European aggregates decreased by 37,8% in 2020 compared to 2019. There is no other category for which European households changed their consuming behavior so much. Also, the categories ‘Recreation and culture’, ‘Clothing and footwear’ and ‘Transport’ experienced a major decrease in consumption. However, some categories experienced an increase in consumption in 2020 compared to 2019, e.g. the largest increase in household consumption was found in the category ‘Food and non-alcoholic beverages’ which rose by 3,2% (Eurostat, 2021). Furthermore, figure 3.3 indicates an increase of ‘Communication’ by 2,4% and ‘Housing, water, electricity, gas and other fuels’ by 0,3%.

Due to the pandemic and its economic consequences such as decreases in disposable incomes in the EU, households tend to switch consumption from more expensive to less expensive goods and services. To illustrate this, households shifted their consumption pattern away from energy, semi-durable and durable goods and increased the amount of non-durable goods and food items

(Kouvavas, Trezzi, Goldhammer, et al., 2020). Another consequence of the reduction in disposable income is the decrease in consumption of non-essential items and the rising relative importance of food and housing (Reinsdorf, 2020).

As the COVID-19 virus is a global pandemic, not only European consumers but households all over the world adjusted their consuming behavior. Table 3.1 indicates the average percentage change in each category of the COICOP classification system. These changes are an average of all 83 countries for which the IMF has data. The two most important categories during this pandemic are 'Food and non-alcoholic beverages' and 'Transport', in the table they are indicated in bold (Reinsdorf, 2020).

Table 3.1 Average Change in each COICOP Category as an Average of 83 countries in 2020

	COICOP Division	12-Month % Change to May 2020	3-Month % Change to May 2020
01	**Food and non-alcoholic beverages**	**4,7**	**1,58**
02	Alcoholic beverages, tobacco and narcotics	4,9	1,03
03	Clothing and footwear	0,2	2,48
04	Housing, water, electricity, gas and other fuels	1,0	-1,11
05	Furnishings and household equipment and maintenance	1,9	0,64
06	Health	2,5	0,74
07	**Transport**	**-2,9**	**-3,18**
08	Communication	-0,1	-0,12
09	Recreation and culture	1,0	-0,07
10	Education	1,8	-0,20
11	Restaurants and hotels	2,3	0,39
12	Miscellaneous goods and services	3,3	0,53
	All-items	**1,9**	**0,16**

Note: Calculation of Reinsdorf (2020), based on the IMF CPI database. Table 3.1 indicates the average annual percentage change of May 2020 compared to May 2019 for all COICOP categories. Next, to the annual percentage change also the three-month average percentage change is shown in the figure. The IMF included 83 countries is these average numbers.

The IMF uses data from 83 countries all over the world so logically these changes are more nuanced than the percentages of the EU-countries as showed in figure 3.3. Nevertheless, the conclusions are approximately the same, namely 'Food and non-alcoholic beverages' and

‘Alcoholic beverages, tobacco and narcotics’ experienced the largest annual increases in consumption. Furthermore, the category ‘Transport’ is worth mentioning with an annual decrease of 2,9%. By contrast, the category ‘Restaurants and hotels’ increased by 2,3%. To conclude, the all-items CPI change of three months ending in May 2020 is 0,16 percent which indicates a relatively low inflation in the beginning of the pandemic although there may be still a bias (Reinsdorf, 2020).

There is evidence that some changes in demand during the lockdown for some categories will be temporary and maybe involuntary, which is the case by shifting away consumption from restaurants and bars. When the economy is reopening again, households tend to immediately consume as before the pandemic because old habits die hard (Kantur & Özcan, 2021). By contrast, a share of the consuming behavior during the pandemic is likely to be permanent and thus will not go back to their pre-pandemic levels of consumption. Intuitively, as more persons worked from home when the COVID-19 virus was circulating, they did not have to move to their workplace. By consequence it is likely that the category ‘Transport’ decreased during that period and will not return to its pre-pandemic level because many people continue to work at home. This can be demonstrated by the following numbers. For example, in Belgium, the traffic jam level in 2022 is still 62% lower compared to 2019 (ANWB Verkeersinformatie, 2022). Further, tele-working and education from home gave people an incentive to shop online instead of going to physical shops (Leering & Nijboer, 2021). For example, a survey done over 7500 households in 5 European countries to examine why consumption was shifting, indicates that there are signs that long-term changes in demand occurred. Respondents were asked which goods and services they did ‘not miss’ after not consuming them during the lockdown. The main categories that emerged from the results were the service sectors and the hospitality sector (Hodbod et al., 2021).

3.3 Implications for Inflation Measurement

3.3.1 Problems

In this section, three main problems that appear when measuring inflation during the pandemic are discussed. First of all, we give insights from the existing literature about the under- and overestimation of the inflation rates in the beginning and later on in the pandemic. In the second part, the implication for the fixed basket is discussed and in the last part the focus is on data collection and the difficulties that the pandemic caused.

3.3.1.1 Under- and Overestimation

The change in the consumption patterns due to the pandemic, as discussed in section 3.2, reduced the credibility of the published inflation numbers. The expenditure weights per category need to reflect the consumption pattern of the households. However, changes in consumer behavior and changes in consumption patterns cause the weights used in the HICP to be in danger of no longer reflecting reality. More specifically, there may be a measurement bias because the weights determined at the beginning of a year are used for the whole year. Therefore, the weights of the HICP cannot be adapted to reflect the continuing and drastic changing COVID-19 situation and consuming behavior. To conclude this paragraph, in times of economic stress, the inflation rates should be interpreted with caution.

In the beginning of every year Eurostat and the BLS announce the expenditure weights of the EU and the US respectively. In other words, in January 2020 the weights for 2020 were published and kept constant until December of that year. Important to notice is the concept of the weights and the fact that the weights of 2020 are based on the consumption patterns of the previous year (Gonçalves et al., 2021). Therefore, the consumption behavior of households in 2019 are reflected in the weights of 2020 and by consequence these weights do not indicate the patterns of consumers during the pandemic (Eurostat, 2020a). The shifts in the spending patterns would only be included in the weights of 2021 and also in the measured numbers of inflation in 2021. Furthermore, as consumption patterns have changed dramatically in 2020 compared to 2019, using the published weights to calculate the inflation of 2020 would be inaccurate and bias the inflation numbers (Gonçalves et al., 2021).

In the literature we find a growing consensus about the underestimation of inflation in the period of April 2020 until April 2021 caused by this measurement bias. As mentioned in the previous section ‘Transport’ was given too much weight and ‘Food at home’ was given too little (Cavallo, 2021). In the early months of the pandemic the inflation rate was underestimated, so the prices that household actually paid were in fact higher than what the published numbers indicated. Furthermore, this underestimation did not only occur in developed countries, but was found in almost all countries of the world (Reinsdorf, 2020). Many studies came to this conclusion of underestimation after constructing a new and adjusted CPI, namely a COVID index. These alternatives of the CPI will be explained in detail in section 3.3.2.

After the shock in spending of households in April and May 2020, consumption patterns for some categories returned to previous levels fairly quickly. These changes were therefore very temporary and were mainly seen in semi-durable goods such as clothing and books. The spending level of other categories remained somewhat constant and did not immediately return to its old level in the second half of the pandemic. Especially food and recreation are categories that underwent a more persistent change (Kouvavas, Trezzi, Eiglsperger, et al., 2020).

After about one year of underestimation a turning point was reached around April 2021, after which a period of overestimation began. In the US, inflation in the second half of 2021 was overestimated by 0,7 percentage points (Cavallo, 2021). Contrary to underestimation, the prices paid by consumers are in reality lower than indicated by the inflation rates. This overestimation can be primarily explained by large base effects because inflation rates are measured compared to 12 months ago. The annual inflation rates in the second half of 2020, the period when the coronavirus regained strength, were low. Because annual inflation rates in 2021 are compared to these low rates of 2020 base effects appear and the inflation rate in 2021 seems higher than it truly is (Cavallo, 2021).

The last concern is that due to the pandemic the gap between the actual rise in prices of goods and services, the published inflation numbers, and the additional cost for households to keep their standard of living, because the purchasing power decreased following the economic downturn, will become bigger. The CPI only measures the overall price change but impacts on consumers' welfare are not reflected (Blundell et al., 2020).

3.3.1.2 Fixed Basket and Product Shortages

The second problem that occurs is the fixed basket, which becomes almost irrelevant because many goods and services were no longer available and could no longer be bought. Since the composition of the official consumption basket of both the CPI and the HICP no longer responds to the real basket that households consume, the change that the inflation numbers are biased is high (Diewert & Fox, 2020). However, households are likely to keep on buying necessities despite the fact that relative prices rise (Kantur & Özcan, 2021).

Another issue that appears and might lead to a measurement bias in the period after the pandemic is the fact that the CPI basket for 2021 and 2022 is based on household spending that took place

in 2020 and 2021 respectively. By consequence, not only the inflation rates in 2020 are biased but also published numbers of 2021 and 2022 should be interpreted with caution. In conclusion, the implications of this pandemic may cause difficulties even in the following years (Blundell et al., 2020).

Further, cost increases for households are not always included in the measurement of the CPI. Due to supply disruptions, household may have to buy smaller quantities of their products and services of choice or buy products of other brands. As the CPI basket contains fixed items and fixed locations, these extra costs might not be reflected in the published CPI. Discounts, which can be finished abruptly due to the pandemic, are also not included in the measurement of the CPI (Blundell et al., 2020).

In addition, the consumption weights are not the only reason of the high inflation but also supply disruptions explain the high inflation rates in 2021. Supply disruptions during the pandemic become apparent as there is an increase in product shortages (Cavallo, 2021). Both out-of-stocks and a higher extent of discontinued goods are considered as product shortages. Especially in the beginning of the pandemic these shortages were widespread and mainly temporary stockouts caused these disruptions in supply (Cavallo, 2021). Furthermore, the impact of product shortages on inflation rates are found to be gradual, transitory and significant. Therefore, there seems a causal effect of supply disruptions on inflation rates (Cavallo & Kryvtsov, 2021). Following supply disruptions prices and quantities are typically negatively correlated. After a negative supply shock e.g., during the pandemic there was a lack in demand due to closure of some sectors, prices and quantities tend to go in the opposite direction (Sheremirov et al., 2021).

3.3.1.3 Data Collection

A third problem that occurs is the following. The circulation of the COVID-19 virus and the restrictions on everyone's life made data collection more difficult. The impact of the COVID-19 pandemic on official statistics has been an important topic for central banks. This because a central bank, often in corporation with statistical offices such as Eurostat, is both the producer and user of economic and financial data (de Beer & Tissot, 2021).

First of all, the pandemic made the collection of data necessary to measure inflation difficult or even impossible due to the imposed restrictions (de Beer & Tissot, 2021). To collect prices for services

and commodities in the US in normal times, the BLS issues a survey. In this survey about two-thirds of the prices are collected by personal visits to brick-and-mortar stores. The other part is collected either by phone calls or on the website of outlets. In addition, sometimes some secondary sources are used such as the US Department of Transportation to collect prices of airline fares (Consumer Price Index: Data Sources, 2020). Since the start of the pandemic in the US on March 16th in 2020, price collection by personals visits were no longer possible and so, when possible, prices were obtained online or by phone (de Beer & Tissot, 2021).

Second, due to this statistical data gap, pursuing their monetary and financial stability policy objectives became problematic (de Beer & Tissot, 2021). Both roles of the central bank require constant attention to the evolution of statistics, economic environment and analytic tools and products. As a result of the pandemic, the economic environment is changing drastically, requiring an adaptation of the statistical framework (Rosolia et al., 2021). This paragraph once again shows the importance to measure inflation correctly as discussed in section 2.5.

Missing prices needed to be imputed in the ordinary calculation. There are two ways to do an imputation. First, other price indices from the same or higher product category can be referred to. Another option is forwarding prices that were actually collected in a previous month (Kouvavas, Trezzi, Goldhammer, et al., 2020). When the prices of a good or services are assumed to be fairly stable the first option should be the preferred one. By contrast, when the prices are characterized by a seasonal pattern, forwarding seems the best option (Zimmer & Jonckheere, 2020). Prices that were based on patterns of previous years were typically found in goods and services that experienced low persistence (Prices & Inflation, 2021).

In April, 30 percent of the European prices included in the HICP were not sampled and therefore were imputed. It was especially in the sector of recreation that the closure of the sector reduced the collection of actual prices (Kouvavas, Trezzi, Eiglsperger et al., 2020). Mainly due to abolition of tourism and holidays and the ban on concerts and other events that the recreation sector was most affected by imputations prices (Kouvavas, Trezzi, Eiglsperger, et al., 2020). Due to those high numbers of prices that needed to be imputed the price indices that were published should be interpreted with caution. The official rates did not fully express the impact of the economic downturn due to the COVID-19 pandemic but actually they reflected economic development from the period just before the outbreak of the virus (Prices & Inflation, 2021).

Once the first and worst period of the pandemic was over and the restrictions were gradually lifted, the problem of properly collecting data became smaller and smaller and the share had fallen to 1 percent in July 2020 prices (Kouvavas, Trezzi, Eiglsperger, et al., 2020).

Because of the reduced reliability of imputed indices, the relative importance of actually correct price indices increased. This once again highlights the importance of good and credible data collection, especially in times of economic distress. When estimating conventional models, one should be aware of these difficulties when conducting empirical analysis (Bobeica & Hartwig, 2022).

3.3.2 Alternative Methods to Measure Inflation since COVID-19

In the literature, we see an emergence of researchers who do not longer stick to the original CPI methods but look for alternatives that may approach reality more closely, especially since the COVID-19 crisis. In this section we give a short overview of some alternative methods to measure inflation rates that are discussed in the literature.

First of all, researchers more often use high-frequency data and alternative data to develop more realistic indices for inflation. Therefore, the adjusted CPI or HICP that will be used in the future will become more robust and more informative (Seiler, 2020). Further, the use of high-frequency data ensures that the expenditures shares vary over time. As a result, these expenditures shares clearly show the difference between the published CPI, calculated with the unadjusted weights, and the actual inflation of goods and services purchased by consumers prices (Kouvavas, Trezzi, Eiglsperger, et al., 2020). A particular type of high frequency-data is the use of High Frequency Expenditure Network (HFEN) data for estimating changes in individual spending categories. In Canada, The Bank of Canada can consult HFEN datasets from payment service providers and they give weekly statistics on the values of transactions. These datasets contain 75 percent of the value of all purchases in Canada made through payment cards (Huynh et al., 2020).

Contrary, other researchers such as Diewert and Fox (2022) suggest a continuous consumer expenditure survey to collect data more frequently and they are not in favor of the use of high frequency data via payment transactions. These authors conclude that a consumer survey is the only way to construct a correct CPI. They think it is not likely that price patterns will go back to their

levels of the period before the pandemic. Therefore, a CPI that indicates inflation adjusted carry forward pricing does not seem to be accurate according to the researchers (Diewert & Fox, 2022).

As discussed in the first problem for inflation measurement during the pandemic, the weights are no longer realistic and create a measurement bias. As a result, there is increasing focus on how the weights can be adjusted so that they are relevant and reflect inflation more accurately. The weights are updated with the expenditure data and in the literature these weights are now often called COVID weights.

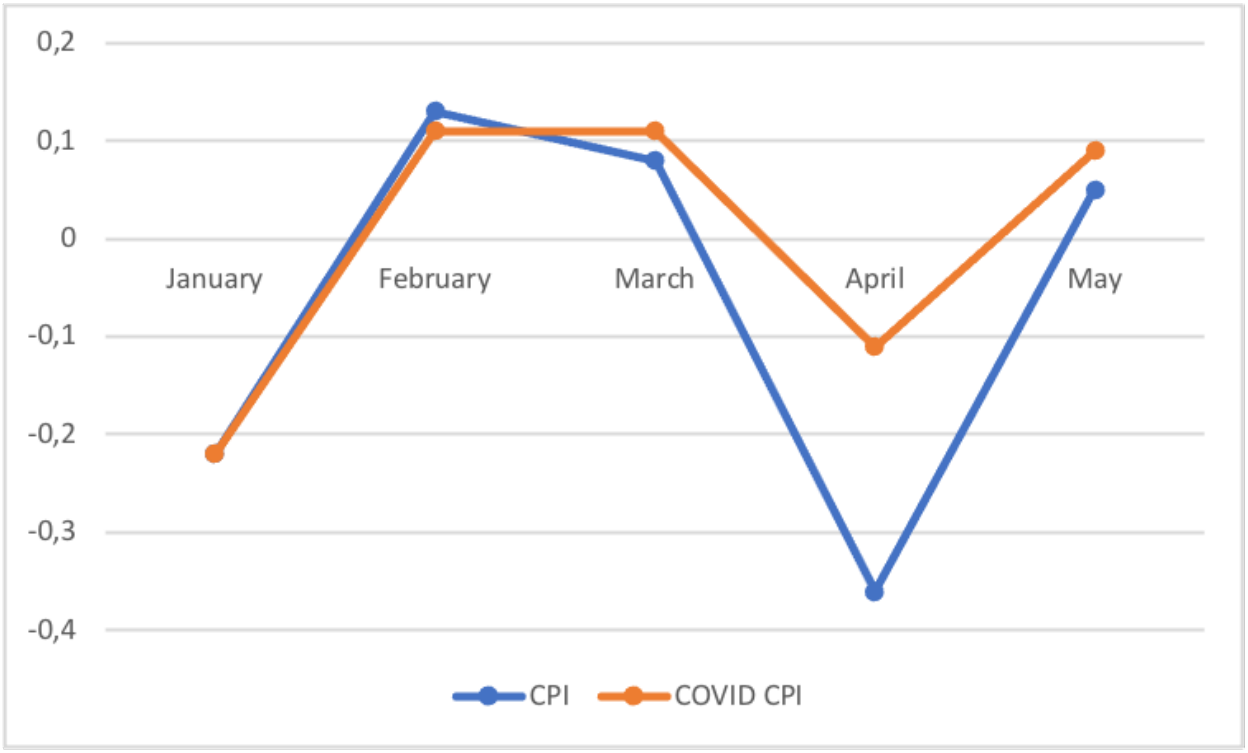
A study that constructed COVID weights to develop an adjusted CPI for Switzerland collected weekly data on Swiss debit card expenditure (Seiler, 2020). The formula of the COVID weights is:

$$s'_{i,t} = \frac{w_{i,0}\Delta e_{i,t}}{\sum_i w_{i,0}\Delta e_{i,t}} \qquad with \qquad \Delta e_{i,t} = \frac{P_{i,t}Q_{i,t}}{P_{i,0}Q_{i,O}} \tag{4}$$

These estimates of the expenditure shares in the new basket, namely the COVID basket are calculated by the latest official CPI weight $w_{i,0}$ that is multiplied by the average percentage change in each category each month. Finally, this multiplication is divided by the sum of this multiplication over all categories. The base month in this study is January 2020. Further, the importance of a category in the COVID basket might change because these are relative weights. This can be the case even when the expenditure does not change (Seiler, 2020).

Next, the COVID price index is computed as the weighted sum of the sectoral CPI indices. More details about the calculation of this adjusted index are in Appendix C. More important are the results and conclusion of this study.

Figure 3.4 Swiss Monthly Inflation Rates (%), CPI and COVID CPI, 2020



Note: Data retrieved from (Seiler, 2020). This graph gives the monthly not seasonally adjusted CPI and COVID CPI of Switzerland. The index uses expenditure weights of consumption during the COVID pandemic.

As shown in figure 3.4, the CPI and the COVID CPI seem very similar in the months before the pandemic. However, when the pandemic breaks out in March 2020, the divergence becomes very clear on the graph, with the COVID CPI considerably higher than the normal CPI. This confirms the conclusions as mentioned before, namely an underestimation of the inflation rates in the first period of the pandemic.

The ECB also constructed a monthly reweighted index for the euro area in which changes in expenditures of consumers during the pandemic are included. The ECB's conclusion is that their adjusted index is consistently higher than the HICP from March 2020 to June 2020. In April, the difference was at its highest and amounted to 0.2 percentage points prices (Kouvavas, Trezzi, Eiglsperger, et al., 2020).

4. Econometric Analysis

The COVID-19 pandemic and the associated restrictions, such as social-distancing and lockdowns, induced changes in consumption patterns in many countries (as described in section 3.2). Due to these changes, significant biases in measuring inflation could be possible. Because CPI expenditure weights are only updated once a year (most of the time with lagged expenditure data), interpreting the CPI during the COVID-19 pandemic can be much harder, as noted in section 3.3.

In this section of the paper, we will empirically study the impact of these changes in expenditure patterns on the measurement of inflation. To do so, we will use the methodology of Cavallo (2020). First, the goal and research question of our analysis is noted. Next, the used data and methodology are discussed in detail. Further, all our results will be analyzed for both the US and the EU. Finally, a comparison between the most important conclusions of the EU and the US is made.

4.1 Goal and Research Question

The goal of our analysis is to update the official CPI weights since the start of the pandemic by computing an alternative 'COVID Basket'. We will use this COVID Basket to calculate a COVID CPI and compare it with the CPI in normal times. The differences between the COVID CPI and the official CPI will be explained based on the COVID waves and the state of the economy. Furthermore, we will draw conclusions based on our results. To limit our research, we will focus on the EU and the US. This choice is based both on the fact that the relevance of these countries as major advanced economies and on a lack of available data for other countries.

Our research contributes to the literature by extending Cavallo's (2020) research to more recent data. We will describe, like Cavallo (2020), what happened during the beginning of the COVID-19 pandemic. What distinguishes us, is that we will describe more recent evolutions, make conclusions based on these evolutions and we will also focus on the EU. In conclusion, the US, the EU and core inflation will be our main focus.

4.2 Methodology and Data

To make the CPI representative during the COVID-19 pandemic, we will update the official CPI on a monthly basis for the US and the EU. We will do this by taking the official CPI weights per category and multiply them by the real-time changes in consumption patterns. By doing this, we obtain a 'COVID Basket' that contains the new COVID weights per category, which will be used to compute the COVID CPI. This COVID CPI will be an inflation rate that represents the true expenditures during the pandemic.

The daily credit and debit card-based expenditure data of the US[8], which is publicly available on the Opportunity Insights (OI) Economic Tracker website[9], will be used to measure the real change in US consumption patterns since January 2020. The credit and debit card transactional data should be a good representative of consumption patterns for the reason that it is daily data that represents consumer expenditure in real-time opposed to official CPI weights which are based on expenditure data that is typically only available at low frequencies and comes with a time lag. In other words, the OI data gives a more representative picture of the consumption patterns during the pandemic. Details of the OI data are described in section 4.2.1.

The categories obtained from the OI data do not align one to one with the US CPI categories (and the EU HICP categories), therefore, we will match these categories according to the latter principle, as done by Cavallo (2020). To accomplish this, Cavallo (2020) makes some assumptions, which we will follow for the most part and are displayed in table 4.1. We split the CPI category 'Food and Beverages' into three subcategories: namely 'Food at Home', 'Alcoholic Beverages' and 'Food Away from Home'. For 'Food at Home' and 'Alcoholic Beverages', we use the OI 'Grocery' category. For 'Food Away from Home' we use the OI category 'Restaurants and Hotels'. For the category 'Other Goods and Services', we assume, as Cavallo (2020), that the expenditure change is equal to the expenditure change of the whole OI basket (aggregate spending). For the categories 'Housing' and 'Education and Communication', we deviate from Cavallo's (2020) assumption that the expenditures do not change. Cavallo's (2020) assumption may be reasonable during the first months of the pandemic, we do not agree with this assumption for a longer period. In the beginning of the lockdown consumers could not visit houses on the real estate market. However, after the first months of experiencing COVID-19, the economy reopened and so did the real estate market

[8] A full description of the dataset is provided by Chetty et al. (2020).
[9] https://tracktherecovery.org

and by consequence prices started changing again. In addition, Cavallo assumed that education did not change because schools and universities were closed in 2020. After the worst period of the pandemic, schools were never fully closed again. Further, persistent tele-working caused a lot of communication to be consumed. By consequence, we assume that these categories do experience changes in expenditure and that the change is equal to the change in aggregate spending. Furthermore, we choose to assign aggregate spending to the categories of Cavallo (2020) that experience zero change because no other specific OI category is suited to assume an equal expenditure change.

Table 4.1 Matching of US CPI Categories and OI Expenditure Categories

CPI Category US	OI Expenditure Category
Food at home	Grocery
Alcoholic beverages	Grocery
Apparel	Apparel and general merchandise
Housing	Total
Medical care	Health care
Transportation	Transportation
Recreation	Entertainment and recreation
Education and communication	Total
Food away from home	Restaurants and hotels
Other goods and services	Total

Note: The categories 'Housing', 'Education and communication' and 'Other goods and services' assume the same change as the total expenditure.

The OI data will be used for both the COVID CPI of the US and the COVID HICP of the EU (this will be further explained in section 4.5). Important to mention is the expansion of the data. As indicated in the previous section, Cavallo (2020) used data up to May 2020 while for our calculations and subsequent conclusion we use data up to March 2022. These additional data will allow us to make more long-term conclusions and focus on the evolutions during the different phases of the pandemic.

To create the COVID basket, COVID expenditure shares are needed. As mentioned before, these are obtained by multiplying the official CPI weights by the average percentage change in the corresponding expenditure category each month (from the OI data). The new weights are divided

by the share of the total, to account for the fact that total expenditure is changing. The COVID weights are given by the following equation:

$$s_t^i = \frac{P_t^i Q_t^i}{\sum_i P_t^i Q_t^i} = \frac{s_0^i \Delta e^i}{\sum_i s_0^i \Delta e^i} \quad (5)$$

where P_t^i is the price of the CPI category *i* at time *t*, Q_t^i represents the corresponding quantity and $\Delta e^i = \frac{P_t^i Q_t^i}{P_0^i Q_0^i}$ indicates the change in expenditure. Note that these are relative weights in equation 5, so even when expenditure is not affected, the importance of a category in the consumption basket can change. Finally, by using the weights s_t^i, and the changes in the official sectoral CPI, the COVID CPI can be calculated (Cavallo, 2020). This is done from January 2020 until March 2022, with CPI sectoral data obtained from OECD (2022b) for the EU and the Bureau of Labor Statistics (n.d.) (BLS) for the US. This gives us the COVID CPI for the EU and the US respectively. As Cavallo (2020), we use the CPI sector series of the first level of disaggregation of the headline CPI. For the official weights, we use the weights of 2019 to calculate the CPI of 2020 and the weights of 2020 and 2021 for the CPI of 2021 and 2022 respectively. This is done to closely follow the calculation of the official CPI numbers. To calculate the COVID CPI, the official weights of 2019, 2020 and 2021 are every time updated with the OI data.

As mentioned in section 2.4, the core CPI is also relevant to take a look at because it will give a more precise view of the long-term trend in inflation. To calculate the core inflation of the US, we exclude the most volatile components, namely food and energy. We drop all categories that are related to food, which are ‘Food at home’ and ‘Food away from home’. To exclude the energy components, we split the category ‘Housing’ into ‘Shelter’, ‘Household furnishings and operations’ and ‘Water and sewer and trash collection services’ and we also split the category ‘Transportation’ into ‘Motor vehicle fees’, ‘Motor vehicle insurance’, ‘Motor vehicle maintenance and repair’, ‘Motor vehicle parts and equipment’, ‘New and used motor vehicles’ and ‘Public transportation’. For the consumer spending patterns, we make similar assumptions as the all-items CPI (see appendix B).

To compile core inflation for the EU, we follow the same method that was used to calculate the core CPI of the US. More precisely, we exclude the volatile components out of the HICP, namely food and energy. The category ‘Food and non-alcoholic beverages’ will no longer be used due to its food component. However non-alcoholic beverages are not related to food, so we add the

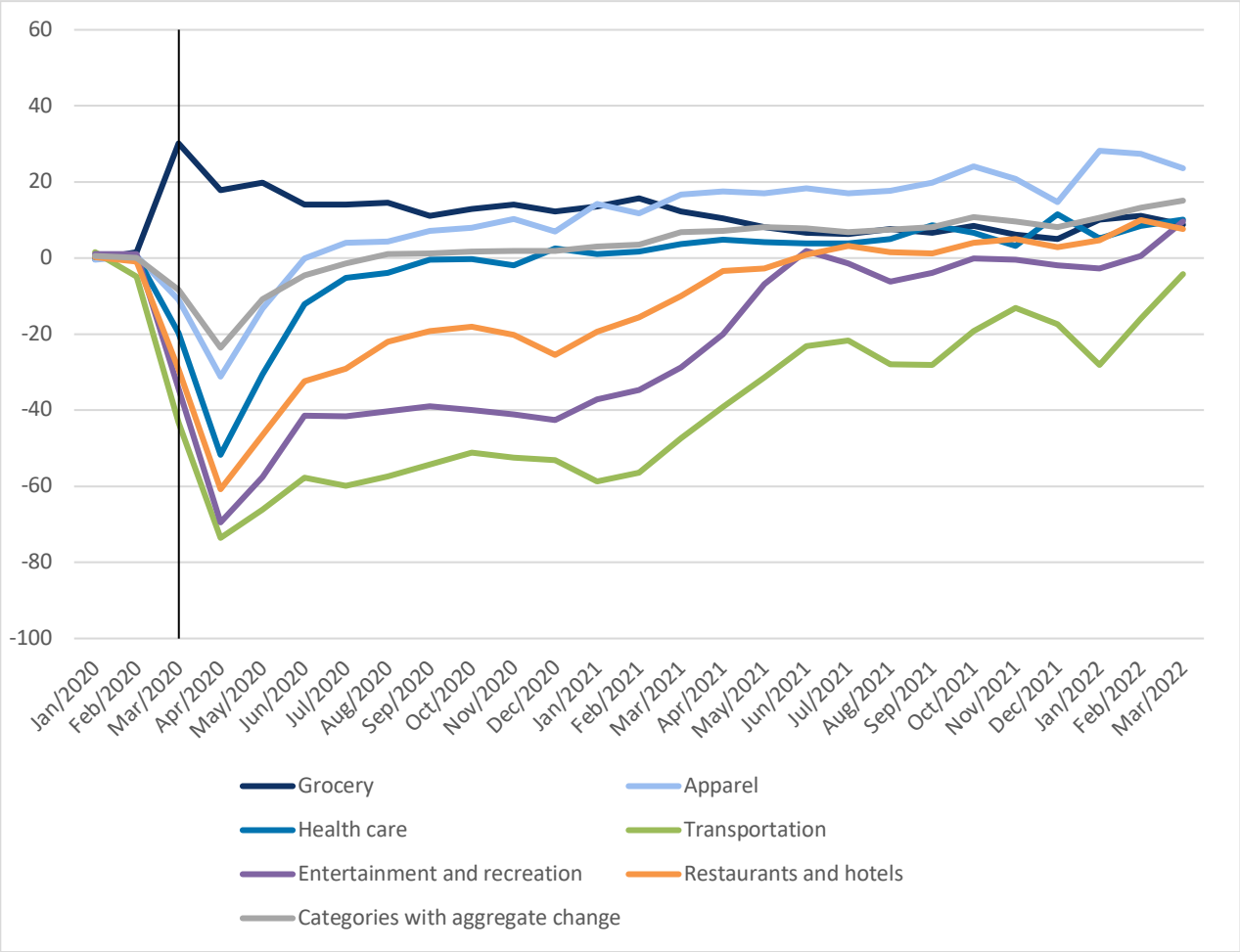
subcategory ‘Non-alcoholic beverages’. To exclude the energy components, we split the category ‘Housing, water, electricity, gas and other fuels’ into ‘Actual rents for housing’, ‘Maintenance and repair of the dwelling’ and ‘Water supply and miscellaneous services relating to the dwelling’. Furthermore, the category ‘Transportation’ is split into ‘Purchase of vehicles’ and ‘Transport services’ to also exclude the energy components. Similar assumptions as the all-items HICP are followed for the consumer spending patterns (see appendix B).

Furthermore, we divide our analysis for the US and the EU into two subsections, namely one for 2020 and one for 2021-2022. This choice was made to give a better overview for the reader and to make a better comparison between the first phase and the second phase of the pandemic.

4.2.1 Details of the OI Data

The US OI data, which is used to update the official CPI weights, is plotted in figure 4.1. It illustrates the change in the US consumer spending per category based on credit and debit card transactions compared to December 2019. The represented categories are ‘Grocery’, ‘Apparel’, ‘Health care’, ‘Transportation’, ‘Entertainment and recreation’ and ‘Categories with aggregate change’ from January 2020 until March 2022. The category ‘Categories with aggregate change’ stands for the categories ‘Housing, water, gas, electricity and other fuels’, ‘Furnishings, household equipment and Routine maintenance of the house’, ‘Communications’, ‘Education’ and ‘Miscellaneous goods and services’.

Figure 4.1 Percent changes in US Consumer Spending (January 2020 – March 2022)



Note: This graph shows the changes in US consumer spending since January 2020 based on daily data collected from credit and debit card transactions (weekly data for the months January, February and March of 2022). The vertical line represents the start of the COVID-19 Pandemic in March 2020. The categories with expenditure changes equal to the aggregate change are 'Housing, water, gas, electricity and other fuels', 'Furnishing, household equipment and routine maintenance of the house', 'Communications', 'Education', 'Miscellaneous goods and services'. These estimates are retrieved from Chetty et al. (2020) which are publicly available on the Opportunity Insights (OI) Economic Tracker website (https://tracktherecovery.org).

When the COVID-19 pandemic hit in March 2020, consumption patterns changed drastically as described in section 3.2. Some sectors such as 'Restaurants and hotels' needed to close their doors due to the pandemic restrictions. The consequence was that some goods and services were no longer available and people could not buy these anymore. This can be seen in figure 4.1 for the categories 'Entertainment and recreation', 'Restaurants and hotels', 'Apparel' and the categories with aggregate change. These categories experienced a sharp decrease in consumption with their lowest point in April 2020. Comparing these changes to the changes in the EU gives the same

patterns. Similar to the US, the categories ‘Restaurants and hotels’, ‘Clothing and footwear’, ‘Transport’ and ‘Recreation and culture’ experienced significant decreases. However, the category ‘Restaurants and hotels’ had the largest decline in the EU, while this was the category ‘Transport’ in the US OI data.

Because going to restaurants, hotels, holidays or the cinema and theatre was no longer possible, people started to buy more food to consume at home. This phenomenon is reflected by the category ‘Grocery’. A sharp increase can be seen starting one month before the start of the COVID-19 pandemic and reaches its peak in March 2020. As mentioned in section 3.2 and figure 3.3 the category ‘Food and non-alcoholic beverages’ experienced in the EU the largest increase in consumption expenditure in 2020. To conclude, in general the changes in consumption patterns in the US are very similar to those in the EU. These figures motivate why we use the US data in our analysis of the EU.

Looking at the longer horizon, all the categories experience a long-stretched V shape, except the category ‘Grocery’, which experiences an inverted long-stretched V shape. In April 2020, the categories already start to recover slowly. The categories ‘Apparel’, ‘Health care’ and the ones that follow the aggregate change had the fastest recovery and were already fully recovered in July 2020, August 2020 and September 2020. This seems very normal as clothing could be ordered online instead of going to the stores. People spent more time in their homes because working from home became obligated if possible, so consumption related to the household increased. Moreover, a reasonable assumption is that when people needed to stay longer at home, consumption in communication, education and miscellaneous goods and services augmented. For the other categories, the recovery back to their pre-pandemic levels takes a longer time. The same trends for the categories ‘Communication’ and ‘Housing, water, electricity, gas and other fuels’ for the EU households were described in section 3.2.

During the winter months of 2020, most of the consumption expenditures went back down because people traveled and gathered to celebrate the holidays, which led to a second wave of COVID-19 infections in the US. December 2020, vaccines arrived and vaccinations started from January 2021 onwards. The result was that COVID-19 infections went down during spring 2021 (Maragakis, 2021; Worldometer, 2022). This is also visible in figure 4.1, with a decrease for most of the categories during the winter months of 2020 and a remarkable increase during spring 2021 for the categories ‘Transportation’, ‘Entertainment and Recreation’ and ‘Restaurants and hotels’. Infections began to

surge again in the US during July 2021 due to the circulation of the delta variant and the relaxation of public policies. The categories 'Transportation', 'Entertainment and recreation' and 'Restaurants and hotels' experienced a small drop. During October 2021 more and more people became vaccinated, however due to the winter months a small decrease in some categories occurred (Maragakis, 2021). From February 2022 onwards, all categories except 'Transportation' experienced positive changes in consumer spending.

The category 'Grocery' remains the category with the highest positive change in spending until March 2021. After that 'Apparel' takes the lead, followed by the 'Categories with aggregate change' and 'Health care'. In conclusion, almost all categories went back to their pre-pandemic levels or went even above it. According to section 3.2, changes in demand could remain permanent, such as the decrease in transport due to tele-working or shopping online. Looking at figure 4.1, the category 'Transport' remains indeed below its pre-pandemic level, however, it is on its way back. Another possible explanation for the fact that 'Transportation' is not at its pre-pandemic level might be the enormous high level of energy prices.

4.3 US Inflation 2020

In this section, we present the results of our analysis for the US in 2020. Fist, we will look at the impact on the all-items CPI. Next, we will take a closer look at the core CPI. Until May 2020, the same conclusions appear as Cavallo (2020). However, the COVID rate slightly differs from Cavallo (2020) for some months, this could be due to the update of the used datasets and because the categories 'Housing', 'Education and communication' and 'Other goods and services' have aggregate change in consumption unlike the zero assumption of Cavallo (2020). However, the difference is small. We also follow the structure of the tables made by Cavallo (2020) throughout our whole analysis.

4.3.1 All-items CPI

Table 4.2 represents the monthly and annual inflation rate for the US in 2020. The first column shows the months of 2020, the second and third column show the monthly inflation rate (compared to the previous month) for the official CPI and the COVID CPI. The last two columns show the annual inflation rate (compared to 12 months ago) for both indices. By comparing the CPI and the COVID CPI, the impact of the updated weights with the changes in expenditure shares across the

categories since the pandemic started becomes clear. Because the COVID-19 pandemic started in March 2020, the CPI and COVID CPI have nearly identical inflation rates in January and February for the reason that the updated weights with the expenditures shares did not significantly differ from the official weights, as also found by Cavallo (2020).

Table 4.2 Monthly and Annual US Inflation Rates During COVID-19, 2020

	Monthly Inflation Rate (1-month change, %)		Annual Inflation Rate (12-month change, %)	
	CPI	COVID CPI	CPI	COVID CPI
January	0,39	0,39	2,50	2,49
February	0,27	0,28	2,35	2,35
March	-0,22	-0,11	1,56	1,68
April	-0,69	-0,07	0,35	1,10
May	-0,02	0,10	0,13	0,99
June	0,57	0,44	0,66	1,40
July	0,53	0,32	1,03	1,55
August	0,32	0,26	1,35	1,81
September	0,14	0,14	1,41	1,87
October	0,04	0,02	1,22	1,66
November	-0,06	-0,08	1,21	1,62
December	0,09	0,07	1,38	1,78

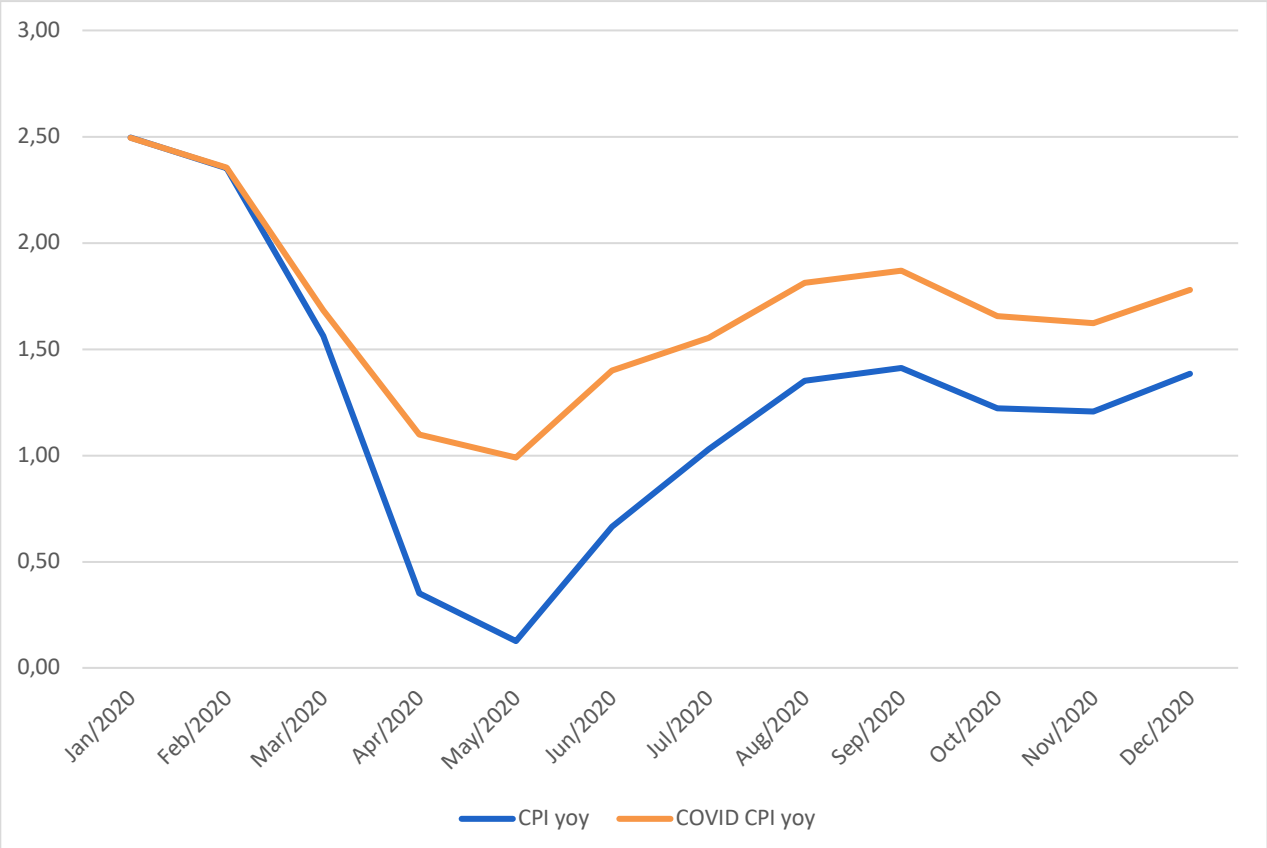
Note: This table shows the monthly and annual inflation rate for all-items in 2020, not seasonally adjusted, US city average CPI, and the COVID-19 CPI using consumption expenditure during COVID-19.

When the COVID-19 pandemic hit the US in March 2020, the inflation indices started to deviate. Both monthly inflation rates went into deflationary territory, as shown in the second and third column of table 4.2. This could possibly be explained by the strict stay-at-home measures, the according change in consumer behavior and the slowdown of the economy (Leatherby, 2021; Milesi-Ferretti, 2022). Furthermore, the COVID CPI experienced only half the deflation of the CPI in March, which was mostly due to weights that were not representing the real consumption behavior. Some goods and services were not available in the beginning of the pandemic due to the restrictions and the lockdown, others were consumed even more to substitute the loss of products (as described in section 3.2). In the following months, the difference between the indices became larger. In April, when the first COVID wave reached its peak in the US, the CPI had a monthly inflation rate of -0,69% and the COVID CPI had only an inflation rate of -0,07%. This was mainly due to categories such as ‘Transportation’ receiving too much weight and categories such as ‘Food at

home' receiving too little weight (this will be explained in more detail later on). The following month, the COVID CPI was already back in positive territory while the rebound of the CPI only happened one month later in June. From June onwards, the monthly inflation rate of the CPI rises above the COVID CPI (which will be explained later). During October, the monthly inflation indices went down again as the daily new COVID cases started to rise and the next COVID wave started (Worldometer, 2022). However, the difference between the two indices becomes smaller going further to the end of 2020. In December, the CPI had a monthly inflation rate equal to 0,09% compared to 0,07% in the COVID index.

Figure 4.2 shows the official annual CPI and the annual COVID CPI of the US. We look at the yoy instead of month-over-month (mom) because it includes a year's worth of data compared to the previous year. Yoy will also give a better long-term picture of the underlying trend.

Figure 4.2 US All-items Annual Inflation rates (12-month change, %), 2020



Note: The CPI and COVID CPI from table 4.2 (column 4 and 5) are shown in this figure. The COVID CPI yoy is built by updating the official CPI weights with the OI data.

Unlike the monthly inflation rate, the annual inflation rate of the COVID CPI remains above the official CPI rate throughout 2020[10], shown in the last two columns of table 4.2 and in figure 4.2. This means that the official inflation underestimated the real inflation. Before the start of the pandemic, both annual indices are identical and around 2,50%. From March 2020 onwards, the CPI and COVID CPI differ but the trend of both indices stays the same throughout the year. Both indices decline sharply during the months March, April and May. This can be explained by the falling economy due to the severe restrictions and the lockdown, as mentioned before (Leatherby, 2021). Both indices reach their lowest point in May 2020, which is also the month with the biggest difference between the annual indices with inflation rates of 0,13% and 0,99% respectively. During the summer months, both the CPI and the COVID CPI show an upward trend until August. Despite the rising COVID cases during the summer, the relaxation of the restrictions in most of the states led to the revival of the economy (Leatherby, 2021; Milesi-Ferretti, 2022). Another reason for the rising inflation indices could be supply disruptions due to product shortages, as explained in section 3.3.1.2. From August onwards, both indices stay around the same inflation level, namely 1,50%. However, just like the monthly inflation rates, the difference between the two indices becomes smaller when reaching December. In December 2020, the official CPI had an annual inflation rate of 1,38%, while the COVID CPI shows an inflation rate of 1,78%.

To understand why the official CPI and COVID CPI differ, consider table 4.3, that shows the monthly CPI and its weights. We focus on April 2020 because it is the month with the largest difference between both indices and the first full month influenced by the COVID-19 pandemic. The first column represents the CPI categories that form the all-item CPI. The second column shows the monthly sector inflation rate for April 2020. The third and fourth columns represent the weights associated with both indices. The last two columns represent the incidence that each CPI category has on the total inflation rate for that month. The incidence in composed by multiplying the monthly inflation rate with the corresponding weight. The sum[11] of the incidence of each category in the last two columns equals the monthly inflation rate in April 2020 for the CPI and COVID CPI, namely -0,69% and -0,07%.

[10] This is possible because the annual inflation rate abstracts the monthly inflation rates, which are more effected by one-time events and tend to be more volatile.
[11] This may deviate from the inflation numbers due to rounding.

Table 4.3 CPI Weights US and Incidence – April 2020

CPI Category	Monthly CPI Inflation	Expenditure Change (vs December 2019, %)	Weight		Incidence	
			CPI	COVID CPI	CPI	COVID CPI
Food at home	2,67	17,81	7,58	13,85	0,20	0,37
Alcoholic beverages	0,30	17,81	1,02	1,87	0,00	0,01
Apparel	-4,38	-31,17	2,81	3,00	-0,12	-0,13
Housing	-0,03	-23,56	42,11	49,94	-0,01	-0,02
Medical care	0,28	-51,72	8,83	6,62	0,02	0,02
Transportation	-4,97	-73,57	15,74	6,45	-0,78	-0,32
Recreation	-0,27	-69,49	5,82	2,76	-0,02	-0,01
Education and communication	0,13	-23,56	6,77	8,03	0,01	0,01
Food away from home	0,15	-60,77	6,19	3,77	0,01	0,01
Other goods and services	-0,04	-23,56	3,13	3,71	0,00	0,00

Note: This table shows the CPI category, monthly inflation, weights and incidence with and without the use of the COVID basket in April 2020. The CPI weight for a given category is the share of the expenditure over total expenditure. The incidence is the monthly CPI inflation rate multiplied by the weight. The sum of the incidence numbers equals the monthly inflation rate.

The main reason why the COVID CPI was so much higher than the official CPI in April 2020 was because the COVID CPI gave more weight to categories which experienced a positive inflation rate and less weight to categories which experienced deflation. For example, the weight for the category 'Food at home' increased from 7,58% to 13,85%, which let the incidence rise from 0,20% to 0,37%. Which could be explained due to the rising demand when consumers stockpiled. Furthermore, the higher inflation for food could also be due to food shortages at grocery stores as retailers needed to compete for goods to sell due to supply disruptions (CaixaBank Research, 2020; McCracken, 2021). For the category 'Transportation' the weight went down from 15,74% to 6,45% and the incidence rose from -0,78% to -0,32%. This phenomenon is very normal during the beginning of the COVID-19 pandemic as the expenditures changed due to the COVID restrictions, such as working from home and social-distancing. Other categories experienced also significant increases in their weight such as the category 'Housing'. However, this category does not influence the monthly inflation rate that much because the categories' inflation rate is low. Table 4.3 gives us the same conclusions as Cavallo (2020).

Table 4.4 explains why the COVID CPI goes below the official CPI from June 2020 onwards. We look at July 2020 because it is the month with the biggest difference in magnitude between both indices, also COVID cases diminished and restrictions were eased. The reason why the COVID CPI is lower than the official CPI was because categories such as 'Food at home' had more spending weight while experiencing deflation, while categories such as 'Transportation' had less spending weight combined with inflation. In particular, the weight for the category 'Food at home' rose from 7,58% to 10% respectively. The incidence decreased from -0,07% to -0,10%. While the CPI weight for the category 'Transportation' was 15,74% compared to the COVID CPI weight which was only 7,29%. This led the incidence on the total monthly inflation rate decrease from 0,41% to 0,19%. These changes in inflation per category could be due to the relaxation of the restrictions during summer (Leatherby, 2021).

Table 4.4 CPI Weights US and Incidence – July 2020

CPI Category	Monthly CPI Inflation	Expenditure Change (vs December 2019, %)	Weight		Incidence	
			CPI	COVID CPI	CPI	COVID CPI
Food at home	-0,97	14,09	7,58	10,00	-0,07	-0,10
Alcoholic beverages	-0,42	14,09	1,02	1,35	0,00	-0,01
Apparel	-0,41	3,95	2,81	3,38	-0,01	-0,01
Housing	0,23	-1,45	42,11	47,99	0,10	0,11
Medical care	0,37	-5,13	8,83	9,69	0,03	0,04
Transportation	2,64	-59,93	15,74	7,29	0,41	0,19
Recreation	-0,58	-41,56	5,82	3,93	-0,03	-0,02
Education and communication	1,10	-1,45	6,77	7,72	0,07	0,09
Food away from home	0,47	-29,10	6,19	5,08	0,03	0,02
Other goods and services	0,34	-1,45	3,13	3,56	0,01	0,01

Note: This table shows the CPI category, monthly inflation, weights and incidence with and without the use of the COVID basket in July 2020. The CPI weight for a given category is the share of the expenditure over total expenditure. The incidence is the monthly CPI inflation rate multiplied by the weight. The sum of the incidence numbers equals the monthly inflation rate.

4.3.2 Core CPI

In this section, we will analyze our results for the core CPI of the US in 2020. As described in section 2.4, core inflation eliminates the most volatile components and will say something about the long-term trend. The tables in this section follow the same structure as the ones in section 4.3.1.

Table 4.5 Monthly and Annual US Core Inflation Rates During COVID-19, 2020

	Monthly Inflation Rate (1-month change, %)		Annual Inflation Rate (12-month change, %)	
	Core CPI	COVID Core CPI	Core CPI	COVID Core CPI
January	0,40	0,40	2,27	2,27
February	0,47	0,47	2,37	2,36
March	0,02	0,04	2,10	2,12
April	-0,46	-0,27	1,43	1,65
May	-0,13	-0,02	1,20	1,52
June	0,21	0,19	1,18	1,48
July	0,55	0,41	1,58	1,74
August	0,39	0,33	1,74	1,84
September	0,12	0,13	1,74	1,85
October	0,11	0,05	1,64	1,70
November	0,06	0,00	1,67	1,68
December	-0,10	-0,07	1,65	1,67

Note: This table shows the monthly and annual core inflation rate for all-items less food and energy in 2020, not seasonally adjusted, US city average CPI, and the COVID-19 core CPI using consumption expenditure during COVID-19.

Despite excluding the food and energy components out of the CPI, a similar bias can still be seen in the core inflation indices, displayed in table 4.5. The core indices follow the same trend as the all-items CPI indices (table 4.2). Namely, for the months April and May both indices also become negative. This change from positive inflation to negative inflation can be explained by the severe restrictions, such as the stay-at-home measures, that were taken in the beginning of the pandemic as mentioned before (Leatherby, 2021). Afterwards, both monthly core indices become positive until December.

Until May, the monthly core COVID CPI remains above the official core CPI, which means that the official core CPI underestimated the real core inflation. Afterwards, we have a period of overestimation by the core CPI of the real core inflation rate as the COVID core CPI falls below the

official core CPI[12]. This was also the case for the monthly all-items CPI. Why the COVID core CPI was first higher than the core CPI and later on lower was because categories received the wrong weights in the official core CPI as they did not account for the change in expenditure patterns during the pandemic. In April, when the first COVID wave hit its peak, both monthly indices reached their lowest inflation number of 2020, namely -0,46% and -0,27%. Afterwards, restrictions became looser, and the economy improved despite the rising COVID cases (Worldometer, 2022). In July, both the monthly core CPI and the monthly COVID core CPI reached their highest level of 2020, with inflation rates of 0,55% and 0,41% respectively. However, as mentioned before, these high inflation numbers could also be due to the supply disruptions. The difference between both becomes smaller when reaching the end of the year. By December, the official core CPI was -0,10%, while the COVID core CPI was -0,07%.

Looking at the annual inflation rates in table 4.5 and figure 4.3, both indices are the same in the beginning of the year and are around 2,30%. After March, the COVID core inflation rate stays throughout the whole year above the official core CPI. This indicates an underestimation of the real core inflation rate by the core CPI. From March until June, both indices decrease to an inflation level of approximate 1,20%. This could possibly be explained by the deterioration of the economy due to the covid restrictions, which was also the case for the all-items indices (Milesi-Ferretti, 2022). The annual core inflation had its lowest number, namely 1,18% in June, and reaches its peak in August with a core inflation rate of 1,74%. The COVID core inflation rate's lowest number was also in June, with a COVID core CPI of 1,48%, while its peak was in September (1,85%). From June onwards, both indices increase again to an inflation number of approximate 1,70%. This could be due to the revival of the economy and the relaxation of COVID restrictions (Milesi-Ferretti, 2022; National Law Review, 2020). The difference between both core indices becomes also smaller over time. In November the divergence is almost fully gone, with an official core CPI of 1,65% and a COVID core CPI of 1,68%. Comparing with figure 4.2, both the annual all-items CPI and core CPI demonstrate the same trend but the magnitude of the bias in the all-items CPI is larger. This could point out the importance of the categories related to food and energy in the bias of the all-items CPI during the last months of 2020. Furthermore, the annual core indices are almost always higher than the annual all-items indices[13]. This is due to the exclusion of the categories 'Food at home' and the subcategories that are energy related.

[12] For the months September and December, the core COVID CPI comes slightly above the official core CPI but the difference between both indices is rather small.
[13] In September and December, the annual COVID core CPI is higher than the annual COVID CPI.

Figure 4.3 US Annual Core Inflation rates (12-month change, %), 2020

Note: The core CPI and COVID core CPI from table 4.5 (column 4 and 5) are shown in this figure. The COVID CPI yoy is built by updating the official CPI weights with the OI data.

The reason why the COVID core CPI has still higher inflation than the official core CPI during March to May, is that subcategories that experienced deflation, such as 'Apparel', 'Motor vehicle fees', 'Public transportation' or 'Motor vehicle insurance', received less weight, as also concluded by Cavallo (2020). While categories with inflation, such as 'Household furnishing and operations', received higher weights. For example, in April 2020 the monthly core CPI weight for the category 'Motor vehicle insurance' was 1,70%, while the weight of the COVID core CPI was only 0,90%. The incidence increased from -0,16% to -0,07%. This phenomenon can be seen in table 4.6.

Table 4.6 US Core CPI – April 2020

CPI Category	Monthly CPI Inflation	Expenditure Change (vs December 2019, %)	Weight		Incidence	
			Core CPI	COVID Core CPI	Core CPI	COVID Core CPI
Alcoholic beverages	0,30	17,81	1,02	2,43	0,00	0,01
Apparel	-4,38	-31,17	2,81	3,89	-0,15	-0,17
Household furnishing and operations	0,40	-23,56	4,60	7,08	0,02	0,03
Shelter	-0,03	-23,56	33,16	51,01	-0,01	-0,01
Water and sewer and trash collection services	0,13	-23,56	1,08	1,67	0,00	0,00
Medical care	0,28	-51,72	8,83	8,58	0,03	0,02
Motor vehicle fees	-1,06	-73,57	0,57	0,30	-0,01	0,00
Motor vehicle insurance	-7,70	-73,57	1,70	0,90	-0,16	-0,07
Motor vehicle maintenance and repair	0,08	-73,57	1,08	0,57	0,00	0,00
Motor vehicle parts and equipment	-0,53	-73,57	0,40	0,21	0,00	0,00
New and used motor vehicles	-0,54	-73,57	7,28	3,87	-0,05	-0,02
Public transportation	-7,39	-73,57	1,27	0,68	-0,12	-0,05
Recreation	-0,27	-69,49	5,82	3,57	-0,02	-0,01
Education and communication	0,13	-23,56	6,77	10,42	0,01	0,01
Other goods and services	-0,04	-23,56	3,13	4,81	0,00	0,00

Note: This table shows the following core inflation rates for the US in April 2020 for all-items less food and energy. The expenditure change in percentage of April 2020 compared to December 2019. The CPI monthly core inflation, the core CPI weight and the COVID core CPI weight. And the core CPI incidence, the COVID core CPI incidence and the difference between these two rates. The incidence is the monthly core CPI inflation rate multiplied by the weight.

4.4 US Inflation 2021-2022

By December 2020, after 10 months of COVID the initial phase of the pandemic came to an end. As mentioned in section 4.1 Cavallo (2020) calculated and analyzed his COVID index until May 2020. Our contribution will be an expansion of the new index and an analysis of the middle and end of the COVID-19 period. During the first year of the pandemic there were fewer COVID-cases compared to the second year. However, when someone got infected in the second year of the pandemic, the risk of hospitalization and fatality was lower (Hoogenboom et al., 2021). In addition, the role out of the vaccine program started in January 2021. In this section the focus is on inflation in the US in 2021 and 2022.

4.4.1 All-items CPI

Table 4.7 CPI Monthly and Annual US Inflation Rates During COVID-19, 2021-2022

	Monthly Inflation Rate (1-month change, %)		Annual Inflation Rate (12-month change, %)	
	CPI	COVID CPI	CPI	COVID CPI
January 2021	0,43	0,40	1,46	1,82
February 2021	0,54	0,44	1,74	1,98
March 2021	0,70	0,50	2,66	2,59
April 2021	0,80	0,64	4,16	3,28
May 2021	0,77	0,64	4,97	3,82
June 2021	0,89	0,77	5,31	4,17
July 2021	0,47	0,45	5,26	4,32
August 2021	0,22	0,27	5,16	4,33
September 2021	0,29	0,36	5,32	4,56
October 2021	0,81	0,76	6,13	5,33
November 2021	0,46	0,42	6,69	5,85
December 2021	0,30	0,30	6,91	6,09
January 2022	0,84	0,85	7,83	6,92
February 2022	0,91	0,87	8,19	7,36
March 2022	1,33	1,23	8,76	8,09

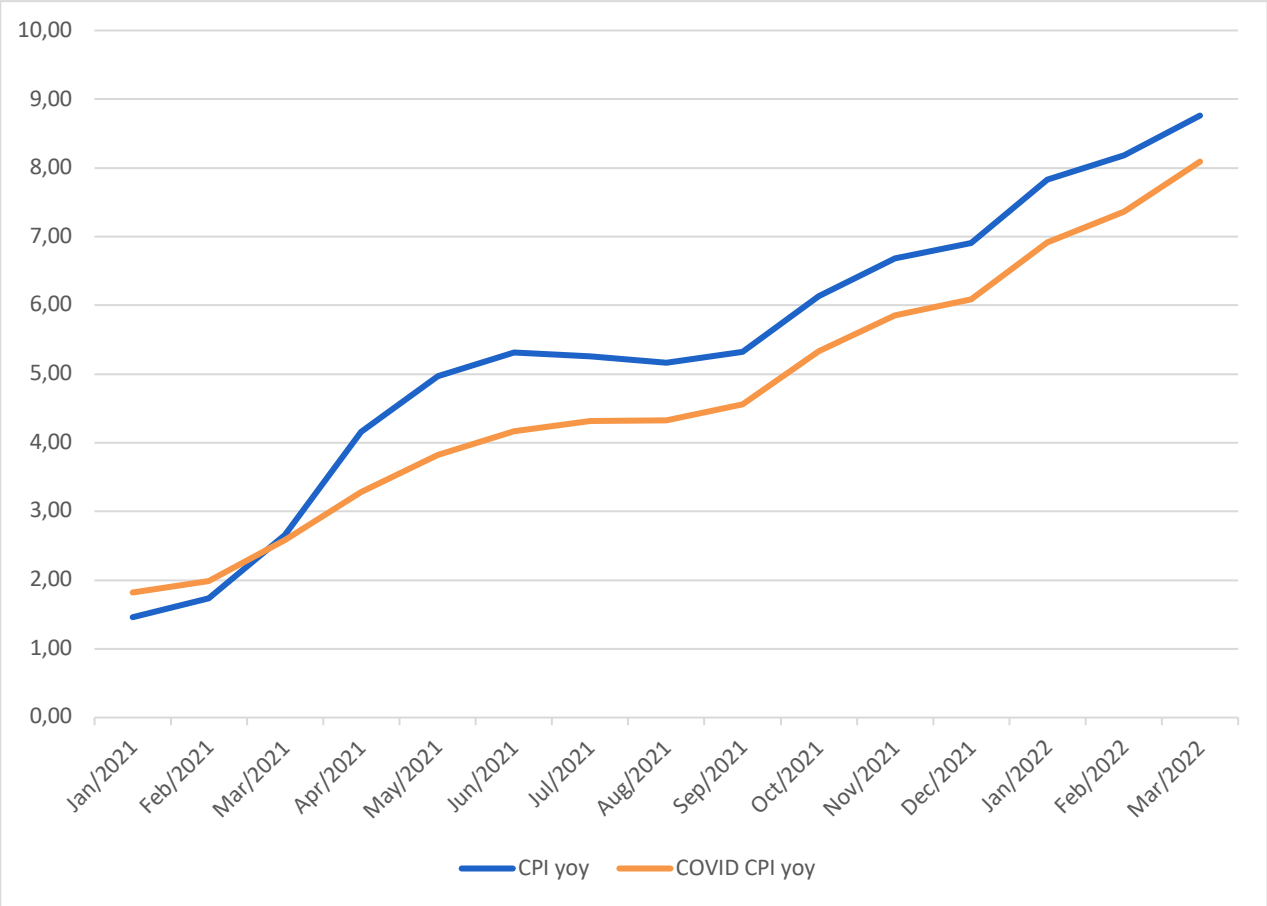
Note: This table shows the monthly and annual inflation rate for all-items in 2021-2022, not seasonally adjusted, US city average CPI, and the COVID-19 CPI using consumption expenditure during COVID-19.

Table 4.7 once again shows the monthly and annual inflation rates of the CPI and the COVID CPI for our selected period. Contrary to the indices of 2020, both the CPI and COVID CPI are never experiencing deflation. As mentioned in section 3.1.1, the positive inflation numbers are caused by the resurgence and reopening of the economy after a year of serious economic downturn. Our rates confirm this.

When looking at the monthly inflation rates, it becomes clear that for the first half of 2021 the CPI is remarkably higher than the COVID CPI, which indicates that the real inflation is overestimated. In addition, both the CPI and COVID CPI are rising in this period because the third wave in the US, peaking at the end of December 2020, diminished. During the first five months of 2021 the US recovered from its severe winter surge and the corona measures eased, as did the behavior of people. In addition, by the end of May 2021 at least one shot had been given to roughly half of the US population. As restrictions to contain the virus were relaxed so much and the delta variant emerged, a new wave started in early summer. The peak took place in August. The CPI was underestimated and the inflation rates fell again (Leatherby, 2021).

After this wave, a new period of very slight overestimation started in October 2021, which could be linked to the fourth wave that came to an end. It should be mentioned that the difference between the two indices becomes smaller at the end of 2021. Finally, from the time the omicron variant appeared, in November 2021, the monthly inflation rates fell again. After peaking at the beginning of 2022, the number of corona cases fell rapidly and inflation rates shot up again (Leatherby, 2021).

Figure 4.4 US All-items Annual Inflation rates (12-month change, %), 2021-2022



Note: The CPI and COVID CPI from table 4.7 (column 4 and 5) are shown in this figure. The COVID CPI yoy is built by updating the official CPI weights with the OI data.

As mentioned before, the annual inflation rates give another view concerning the CPI and the COVID CPI as these numbers are more nuanced and indicate a longer-term trend. During January 2021 the COVID CPI of 1,82% is much larger than the CPI of 1,46% and also in February the COVID CPI is considerably larger than the CPI. Next, in March 2021 a turning point occurs and 12 months follow in which the CPI is larger than the COVID CPI. Figure 4.4 gives a clear picture of this turning point and the year of overestimation of the real CPI. In section 3.3.1 the existing literature was discussed and many researchers came to the same conclusion of overestimation of the official inflation numbers from March 2021 onwards. Furthermore, there is a small period in the summer of 2021 where the inflation rates are constant. Due to the fourth wave of COVID cases in the US, the economy slowed down slightly, but remained strong. Therefore, the inflation rates, still at high levels, were not rising anymore (Milesi-Ferretti, 2021).

Important to mention are the climbing annual inflation rates during 2021 and 2022. Column three and four in table 4.7 and especially the graph indicates the enormous inflation rates during that period. With inflation numbers reaching 7-8% in the beginning of 2022, it is clear that the economy is booming. As mentioned in section 3.1 it is due to factors such as the enormous fiscal stimulus of the US government. Furthermore, as noted in section 3.1.1 mainly supply-side factors, such as supply chain bottlenecks and energy prices, are pushing up inflation. As also discussed in section 3.1.1 with the outbreak of the war between Russia and Ukraine and its economic consequences the inflation rates of March 2022 should be compared to previous months and years with caution.

Next, there will be more detail on what has driven these rates. Going into detail for each month separately would be too extensive for our analysis, so the focus will be on just one month from this period. The choice for March 2021 is twofold. First, the largest difference between the CPI and COVID CPI for the monthly inflation rate is found in March 2021. Secondly, when looking at the annual inflation rates this month is the turning point from a long period of underestimation to a long period of overestimation. The specific inflation rates for March 2021 are shown in table 4.8.

Table 4.8 CPI Weights US and Incidence – March 2021

CPI Category	Monthly CPI Inflation	Expenditure change (vs December 2019, %)	Weight		Incidence	
			CPI	COVID CPI	CPI	COVID CPI
Food at home	0,20	12,22	7,77	9,09	0,02	0,02
Alcoholic beverages	0,25	12,22	1,04	1,21	0,00	0,00
Apparel	0,62	16,77	2,66	3,24	0,02	0,02
Housing	0,32	6,78	42,39	47,19	0,14	0,15
Medical care	0,10	3,66	8,87	9,59	0,01	0,01
Transportation	3,21	-47,43	15,16	8,31	0,49	0,27
Recreation	0,44	-28,75	5,80	4,31	0,03	0,02
Education and communication	-0,28	6,78	6,81	7,58	-0,02	-0,02
Food away from home	0,12	-10,03	6,35	5,95	0,01	0,01
Other goods and services	0,58	6,78	3,16	3,52	0,02	0,02

Note: This table shows the CPI category, monthly inflation, weights and incidence with and without the use of the COVID basket in 2021-2022. The CPI weight for a given category is the share of the expenditure over total expenditure. The incidence is the monthly CPI inflation rate multiplied by the weight. The sum of the incidence numbers equals the monthly inflation rate.

As mentioned in the section 3.2 the category that experienced the most radical change in consuming behavior in 2021 is ‘Transportation’. When focusing on March 2021 and going into detail it is immediately clear that such categories contribute to the measurement bias and by consequence the overestimated inflation. In March 2021 the expenditure of the category ‘Transportation’ almost dropped to half compared to December 2019 but the monthly CPI inflation is positive because compared to February 2021 the economy is recovering from the third wave of COVID cases. However, with the incidence decreasing from 0,49% to 0,27% the category ‘Transportation’ pulls down the COVID CPI. Further, the difference for this category between the normal CPI weight and the new COVID weight is the largest of all categories. The weight going from 15,16% to 8,31% indicates that the initial weight was too high and thus this category was given too much weight in the calculation of the CPI. There are two other categories that had a lower COVID weight than the normal CPI weight, namely ‘Recreation’ and ‘Food away from home’. This is not surprising as these categories were still hit hard in 2021 and to a smaller extend in 2022 by the ongoing COVID pandemic. All other categories, except ‘Education and Communication’, experienced a positive monthly CPI, which can be due to the recovery of the economy and relaxation of COVID measures after the winter surge.

4.4.2 Core CPI

In this section, as in the case of the year 2020, the core CPI will also be analyzed. Table 4.9 gives the monthly and annual inflation rates for both the core CPI and COVID CPI of the US in the same period, namely January 2021 until March 2022.

Table 4.9 CPI Monthly and annual US core Inflation rates during COVID-19, 2021-2022

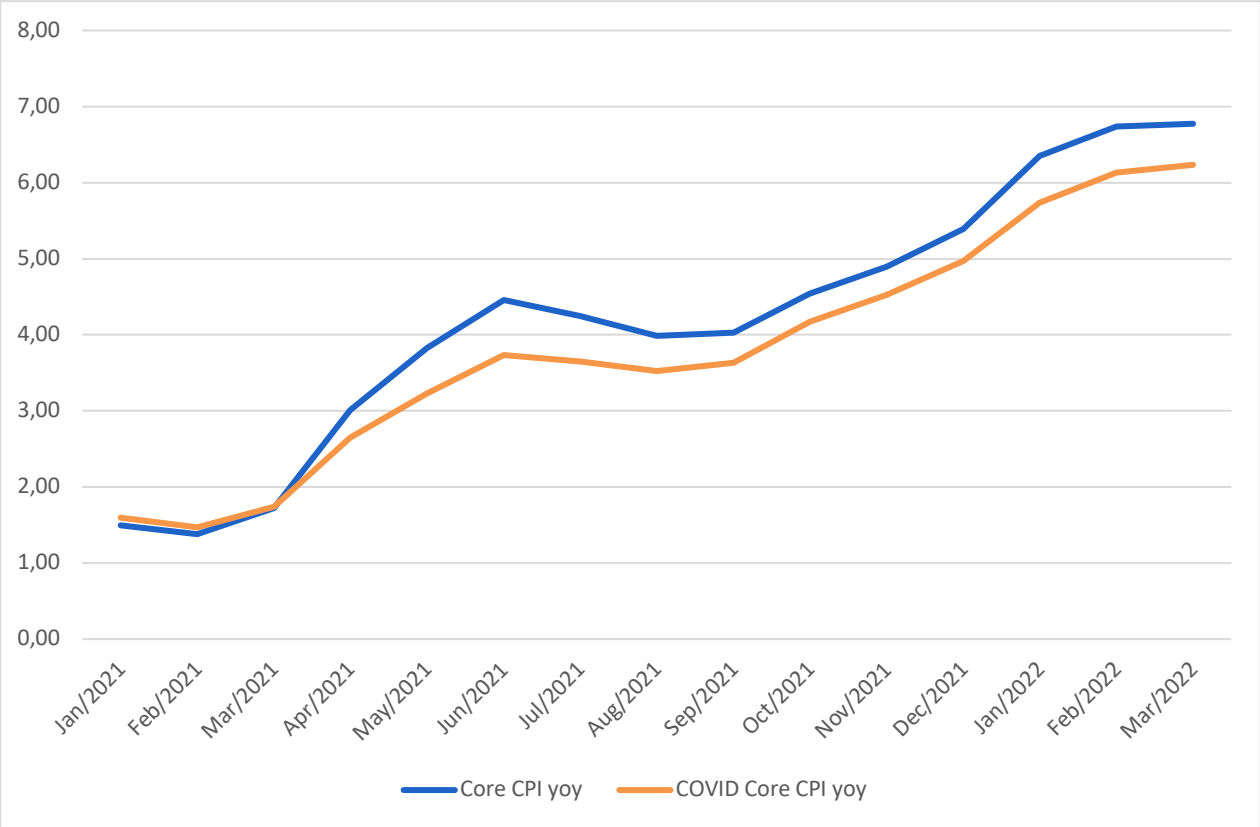
	Monthly Inflation Rate (1-month change, %)		Annual Inflation Rate (12-month change, %)	
	Core CPI	COVID Core CPI	Core CPI	COVID Core CPI
January 2021	0,20	0,28	1,50	1,60
February 2021	0,35	0,34	1,38	1,47
March 2021	0,38	0,33	1,72	1,74
April 2021	0,83	0,64	3,01	2,65
May 2021	0,69	0,56	3,83	3,23
June 2021	0,81	0,67	4,46	3,73
July 2021	0,33	0,33	4,24	3,65
August 2021	0,15	0,21	3,98	3,53
September 2021	0,15	0,23	4,02	3,63
October 2021	0,60	0,57	4,54	4,17
November 2021	0,39	0,35	4,89	4,53
December 2021	0,39	0,36	5,39	4,97
January 2022	0,74	0,73	6,35	5,73
February 2022	0,72	0,72	6,74	6,13
March 2022	0,43	0,44	6,77	6,23

Note: This table shows the monthly and annual core inflation rate for all-items less food and energy, not seasonally adjusted, US city average core CPI, and the COVID core CPI using consumption expenditure during COVID-19.

Immediately noticeable is that the differences between the core CPI and COVID core CPI are significantly smaller than the differences between the all-items CPI and the all-items COVID CPI from table 4.7. By consequence, the measurement bias of the core CPI is smaller than the bias of the all-items CPI. The most volatile categories, food and energy, which received quite a large weight in the all-items CPI and experienced a large change in consumer behavior, are excluded.

As opposed to the period of 2020, the core CPI rates are smaller than the all-items rates. When energy prices started to increase in 2021, the energy component became more important in the CPI compared to 2020. If the energy categories are excluded from the CPI, the core CPI will drop below the official CPI (as shown in figure 3.2). Further, table 4.9 and the monthly inflation rates shows that the COVID core CPI is more nuanced than the Core CPI. The core CPI has higher peaks and lower troughs.

Figure 4.5 US Annual Core CPI Inflation Rates (12-month change, %), 2021-2022



Note: The Core CPI and COVID Core CPI from table 4.9 (column 4 and 5) are shown in this figure. The COVID CPI yoy is built by updating the official CPI weights with the OI data.

The annual inflation rates and especially the difference between the core CPI and COVID core CPI has a similar evolution to the difference between the all-items CPI and all-items COVID CPI in table 4.7. As can be clearly seen from the graph and similar to the all-items rates, the core inflation rates will start to rise from March 2021 because the third COVID surge came to an end. During the summer months, a fourth wave starts and the delta variant emerges. By consequence, this might be the reason why the inflation rates are constant from June 2021 until September 2021. After that surge, the inflations rates are rising again until the end of that year. In addition, the exceptionally high inflation numbers in the beginning of 2022 also appear in the core inflation rates. The reasons why also the core inflation is high, such as second round effects, supply side factors and the Russian-Ukrainian war were mentioned in section 3.1.2. In contrast to the all-items rates, there is a levelling off in the beginning of 2022 as a consequence of the omicron variant and the associated sixth wave. This can possibly be explained by the fact that energy (sub)categories are taken out of the index and these huge energy price increases were excluded.

For the same reasons as in the previous section of the CPI, April 2021 will be discussed in detail to analyze the reasons why there is over- or underestimation of the US core CPI. Table 4.10 gives a more detailed insight in the inflation rates of April 2021. The largest contributions to the monthly COVID core CPI of 0,65% are the categories ‘New and used motor vehicles’ and ‘Shelter’ with an incidence of 0,26% and 0,17%. In April 2021, COVID cases are still falling after peaking in December 2020. In addition, the vaccination campaign is running at full capacity (Leatherby, 2021). Further, the measurement bias of the core CPI can be explained when looking at the weights in more detail. The weight of the category ‘Shelter’ rises from 33,32% to 45,61%. The demand on the real estate market in the spring of 2021 was incredibly high (Voyles, 2022). This indicates that this category was given too little weight in the calculation of the core CPI and this category, among others, caused the core CPI to be overestimated.

Table 4.10 US Core CPI – April 2021

CPI Category	Monthly CPI Inflation	Expenditure Change (vs December 2019, %)	Weight		Incidence	
			Core CPI	COVID Core CPI	Core CPI	COVID Core CPI
Alcoholic beverage	0,24	12,22	1,04	1,47	0,00	0,00
Apparel	-0,07	16,77	2,66	4,00	0,00	0,00
Household furnishing and operations	0,76	6,78	4,68	6,41	0,04	0,05
Shelter	0,37	6,78	33,32	45,61	0,16	0,17
Water and sewer and trash collection services	0,15	6,78	1,11	1,52	0,00	0,00
Medical care	-0,03	3,66	8,87	11,88	0,00	0,00
Motor vehicle fees	0,02	-47,43	0,57	0,44	0,00	0,00
Motor vehicle insurance	0,41	-47,43	1,60	1,24	0,01	0,01
Motor vehicle maintenance and repair	0,16	-47,43	1,10	0,85	0,00	0,00
Motor vehicle parts and equipment	0,88	-47,43	0,39	0,31	0,00	0,00
New and used motor vehicles	4,40	-47,43	7,53	5,85	0,41	0,26
Public transportation	7,96	-47,43	1,11	0,86	0,11	0,07
Recreation	0,79	-28,75	5,80	5,93	0,06	0,05
Education and communication	0,32	6,78	6,81	9,32	0,03	0,03
Other goods and services	0,22	6,78	3,16	4,32	0,01	0,01

Note: This table shows the following inflation variables for the US in April 2021 for all categories. The expenditure change in percentage of April 2021 compared to December 2019. Further, the core CPI monthly inflation, the core CPI weight and the COVID cord CPI weight. The core CPI incidence, the COVID core CPI incidence and the difference between these two rates. The incidence is the monthly core CPI inflation rate multiplied by the weight.

4.5 EU Inflation 2020

In this section, we will present the results of the impact of COVID-19 on the all-items HICP and the core HICP for the EU in 2020. Due to a lack of high-frequency consumption expenditure data in the EU, the consumption expenditure changes of the US from the OI data are used to update the official weights. In other words, we assume that the change in expenditure for the EU during the pandemic is the same as in the US. This is a reasonable assumption, when comparing the OI data with the expenditure pattern of the EU (described in section 4.2.1), a lot of similarities between both expenditure patterns arise. Following this, we only provide an approximation of the COVID-19 impact for the EU.

Furthermore, the EU uses the ECOICOP classification system (see section 2.2.1, table 2.2), which differs from the one used by the BLS in the US (see section 2.2, table 2.1). The matching of the OI categories and the ECOICOP categories, and the associated assumptions are shown in appendix B and do not differ substantially of those for the US categories and OI categories. There will still be a difference between the US and the EU because we use the official HICP weights and the sectoral inflation of the EU.

4.5.1 All-items HICP

Table 4.11 represents the monthly and annual inflation rates, both with and without COVID basket, for the EU in 2020. The first two months of 2020 have almost identical monthly and annual inflation rates for the HICP and the COVID HICP. The difference between the official and updated weights was not significant before the outbreak of the pandemic due to almost no difference in expenditure patterns, which was also found for the US (section 4.3.1). However, the increase from January to February was the biggest monthly increase seen since 2016. Even though the lockdown was not in place in the European countries yet, supply disruptions due to the lockdown in China made the monthly inflation rise (CaixaBank Research, 2020). From March 2020 onwards, with the outbreak of the COVID-19 pandemic in the EU and the related lockdown, the two indices start to differ. The monthly inflation rates for the HICP and the COVID HICP stay for the most part positive, except for the months May, July, August and November. In contrary to the annual inflation rate, which stays positive throughout the whole year, shown in the last two columns of table 4.11.

Table 4.11 Monthly and Annual EU Inflation Rates During COVID-19, 2020

	Monthly Inflation Rate (1-month change, %)		Annual Inflation Rate (12-month change, %)	
	HICP	COVID HICP	HICP	COVID HICP
January	-0,81	-0,80	1,90	1,91
February	0,20	0,21	1,75	1,76
March	0,57	0,70	1,28	1,43
April	0,21	0,38	0,73	1,05
May	-0,07	0,04	0,47	0,90
June	0,39	0,19	0,74	0,97
July	-0,26	-0,57	0,85	0,77
August	-0,42	-0,48	0,34	0,20
September	0,16	0,47	0,22	0,39
October	0,19	0,27	0,23	0,48
November	-0,30	-0,16	0,19	0,58
December	0,35	0,13	0,19	0,36

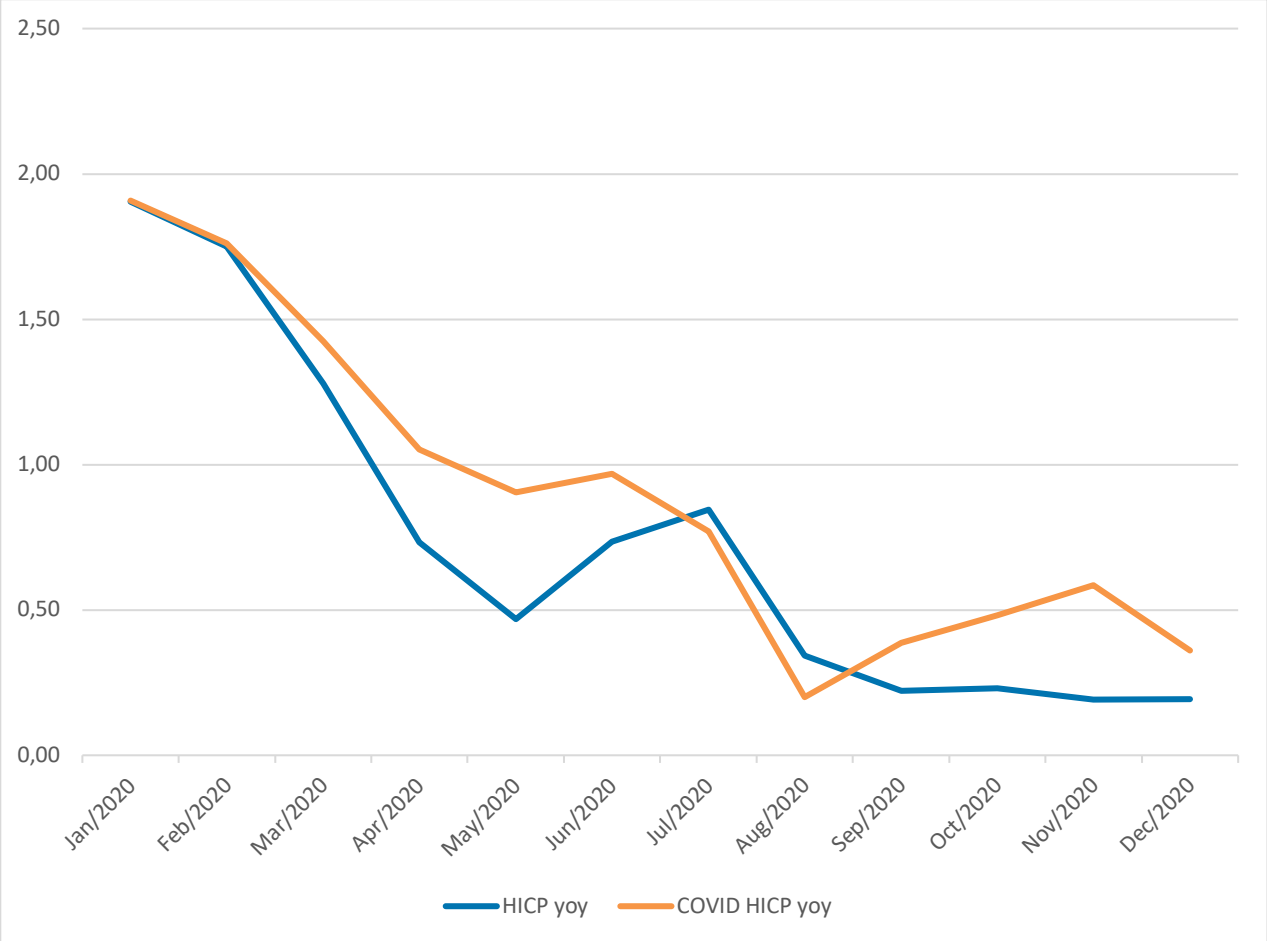
Note: This table shows the monthly and annual inflation rate for all-items in 2020, not seasonally adjusted, EU HICP, and the COVID-19 HICP using consumption expenditure during COVID-19.

The monthly COVID HICP, for the months March, April and May, is higher than the official HICP, which means that the official HICP underestimates the real inflation rate. Categories such as 'Food and non-alcoholic beverages' and 'Furnishings, household equipment and routine household maintenance' received weights that were too low in the official HICP, while categories such as 'Transportation' received weights that were too high. In addition, demand for energy sources collapsed, which led to a drop in energy prices. This is very normal, because due to COVID restrictions such as the lockdown, going out was impossible and that is why these categories are over- or underrepresented in the official HICP (Chadwick, 2020). Furthermore, both monthly indices show a clear downwards trend during these months. Which could again be explained by the severe restrictions (Chadwick, 2020).

During the next three months, the number of new COVID cases goes down (Statista, 2022). The monthly COVID HICP becomes lower than the official inflation rate, which indicates a period of overestimation. This could be explained by categories, such as 'Transportation' and 'Food and non-alcoholic beverages' that received the wrong weights in the official HICP (this will be further explained later on). Despite the increase of the monthly inflation numbers in June, both indices reach their lowest inflation number in August. This could be explained by the start of again increasing COVID-19 cases and the start of the second COVID wave (Chadwick, 2020; Statista,

2022). For the months September, October and November, the COVID HICP reaches again a higher inflation level than the official HICP, which again shows the underestimating of the HICP. During these months, the EU experienced its second COVID wave as the number of the new COVID cases increased heavily (Statista, 2022). Both monthly inflation rates decrease during this period. This phenomenon is very different from the US, where the monthly COVID inflation rate stays below the official CPI from June onwards (see table 4.2). This could possibly be explained by a difference in restrictions between the US and the EU. Overall, the monthly all-items EU indices show a clear downwards trend from March to December. The official monthly inflation rate in December was 0,35%, while the COVID rate was 0,13%.

Figure 4.6 EU Annual Inflation rates (12-month change, %), 2020



Note: The HICP and COVID HICP from table 4.11 (column 4 and 5) are shown in this figure. The COVID HICP yoy is built by updating the official CPI weights with the OI data.

Looking at the annual inflation rates in the last two columns of table 4.11 and figure 4.6, both indices start from the same inflation number in January and February and the inflation rates are close to 2%. Overall, there is a remarkable decline in both the HICP and the COVID HICP from March onwards. Consumer expenditures changed as some goods were not available anymore due to supply shortages or due to restrictions such as closing certain sectors and the lockdown (as described in section 3.2). This had a severe negative impact on the economy. Until June, the COVID HICP is higher than the HICP. This clearly indicates an underestimation by the HICP of the real inflation rate and the difference between the HICP and the COVID HICP becomes only larger. For example, in April the annual HICP rate was 0,73%, while at the same time the COVID HICP already reached 1,05%. From May onwards, most lockdowns in the EU countries ended and restrictions eased as the number of new infections went down. This can also be seen in figure 4.6, both indices increase again. In June and August, the COVID HICP went under the HICP rate, however, the difference between both indices is rather small. Overall, both indices keep on declining from June/July onwards. This could be explained by the second COVID wave that hit the EU during the late months of the summer. This second wave was due to the circulation of the COVID variants due to the relaxation of restrictions and traveling internationally (Bollen, 2021). During the last months of 2020, the difference between the HICP and COVID HICP becomes again larger with an annual inflation rate of 0,19% for the HICP and 0,58% for the COVID HICP in November. The HICP remains around the same inflation level from September onwards while the COVID HICP starts to increase. By December, the COVID HICP declines again to 0,36%.

Next, we will go into more detail. Table 4.12 provides an example of the month July. This month is chosen because the monthly COVID HICP goes below the official HICP. The reason why the COVID inflation is lower, is that there is more spending weight in categories such as ‘Clothing and footwear’, ‘Food and non-alcoholic beverages’ and ‘Communications’, which experienced deflation. The categories ‘Clothing and footwear’, ‘Food and non-alcoholic beverages’ and ‘Communications’, had weights of 5,91%, 15,92% and 3,07% for the official HICP, while the COVID weights are 7,52%, 22,74% and 7,69%, respectively. Furthermore, there is less spending in categories which experienced inflation, such as ‘Transportation’, ‘Restaurants and hotels’ and ‘Recreation and culture’. The HICP weights for the category ‘Transportation’, ‘Restaurants and hotels’ and ‘Recreation and culture’ were 15,02%, 9,32% and 8,77%, while the weights for the COVID HICP were 7,54%, 8,28% and 6,42%, respectively. However, these COVID weights are rising compared to previous months. The deflation and inflation in the categories could be explained by the

relaxation of restrictions, such as the reopening of restaurants, and the decreasing COVID cases during summer (Chadwick, 2020).

Table 4.12 HICP Weights EU and Incidence – July 2020

HICP Category	Monthly HICP Inflation	Expenditure Change (vs December, %)	Weight		Incidence	
			HICP	COVID HICP	HICP	COVID HICP
Food and non-alcoholic beverages	-1,18	14,09	15,92	22,74	-0,19	-0,27
Alcoholic beverages, tobacco and narcotics	0,13	14,09	4,43	6,33	0,01	0,01
Clothing and footwear	-5,96	3,95	5,91	7,69	-0,35	-0,46
Housing, water, electricity, gas and other fuels	-0,16	-1,45	16,34	20,16	-0,03	-0,03
Furnishings, household equipment and routine household maintenance	-0,39	-1,45	6,19	7,64	-0,02	-0,03
Health	-0,12	-5,13	4,90	5,82	-0,01	-0,01
Transportation	0,85	-59,93	15,02	7,54	0,13	0,06
Communication	-0,71	-1,45	3,07	3,79	-0,02	-0,03
Recreation and culture	2,17	-41,56	8,77	6,42	0,19	0,14
Education	0,05	-1,45	1,02	1,25	0,00	0,00
Restaurants and hotels	0,51	-29,10	9,32	8,28	0,05	0,04
Miscellaneous goods and services	-0,01	-1,45	1,90	2,35	0,00	0,00

Note: This table shows the HICP category, monthly inflation, weights and incidence with and without the use of the COVID basket in 2020. The HICP weight for a given category is the share of the expenditure over total expenditure. The incidence is the monthly HICP inflation rate multiplied by the weight. The sum of the incidence numbers equals the monthly inflation rate.

4.5.2 Core HICP

Table 4.13 shows the monthly and annual core HICP and COVID core HICP for the EU in 2020. We focus on the months from March onwards because from then on, the expenditure shares started to differ due to the start of the pandemic. Despite excluding the food and energy components out of the HICP categories, a similar bias is still observed in the core HICP.

Table 4.13 Monthly and Annual EU Core Inflation Rates During COVID-19, 2020

	Monthly Inflation Rate (1-month change, %)		Annual Inflation Rate (12-month change, %)	
	Core HICP	COVID Core HICP	Core HICP	COVID Core HICP
January	-1,52	-1,51	1,66	1,66
February	0,38	0,38	1,78	1,78
March	1,24	1,35	1,61	1,73
April	0,77	0,56	1,46	1,37
May	0,05	0,11	1,52	1,50
June	0,36	0,23	1,51	1,35
July	-0,21	-0,46	1,80	1,39
August	-0,57	-0,65	1,04	0,54
September	0,35	0,79	0,88	0,83
October	0,15	0,24	0,89	0,93
November	-0,45	-0,28	0,91	1,13
December	0,35	0,11	0,88	0,86

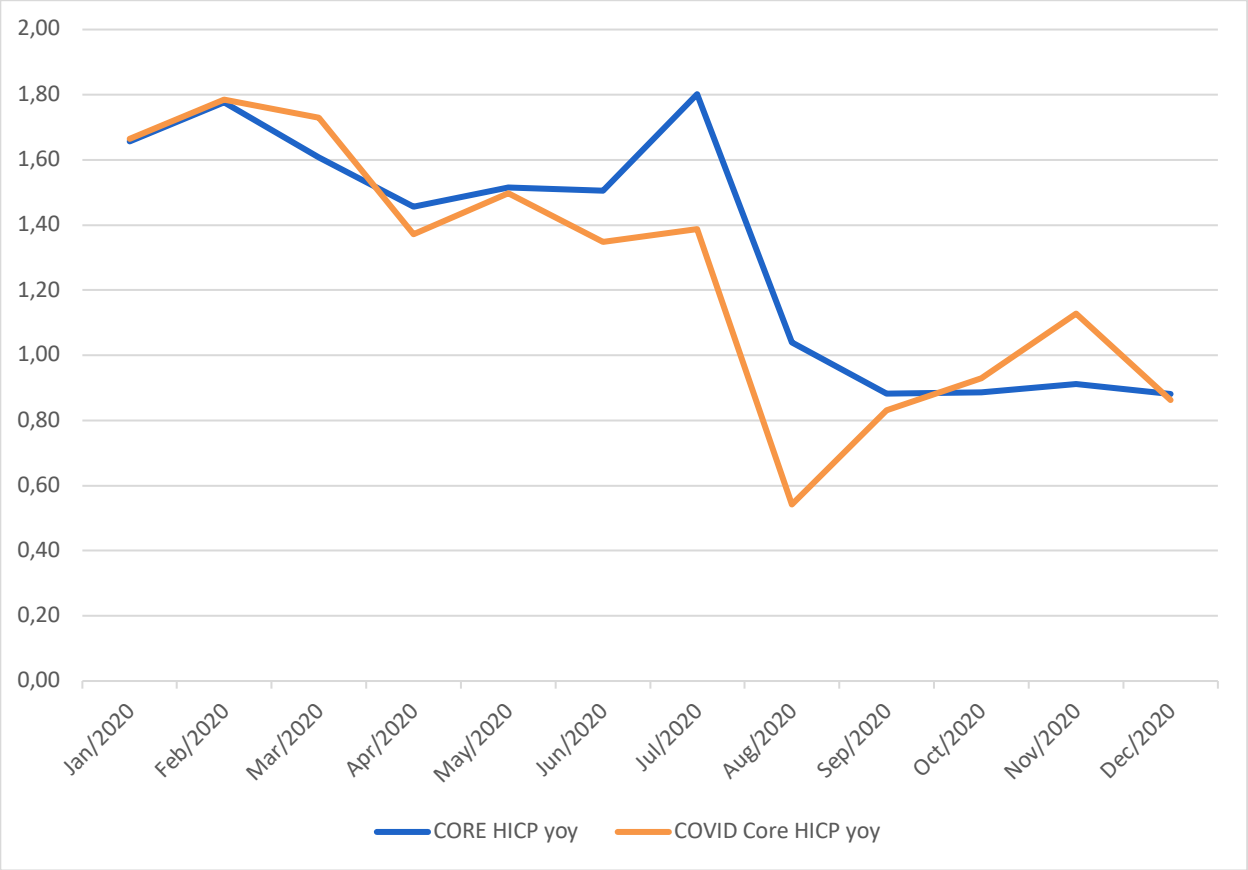
Note: This table shows the monthly and annual core inflation rate for all-items less food and energy of the EU, and the COVID-19 core HICP using consumption expenditure during COVID-19.

From March until June, both monthly indices stayed in positive territory. During these months, over- and underestimation by the official core HICP of the real core HICP occur randomly. In July and August, both indices go into deflationary territory. Namely, the COVID core HICP experienced in July twice as much deflation than the core HICP, with rates of -0,46% and -0,21% respectively. This was mainly due to categories such as ‘Clothing and footwear’ and ‘Communications’, which experienced deflation and had a larger weight in the COVID basket. These negative inflation rates during the summer could be linked to the start of the second COVID wave in the EU, as described in section 4.5.1 (Chadwick, 2020).

From September onwards, both inflation rates are back in positive territory, except in November. The inflation rate is again underestimated as the COVID core HICP is higher than the core HICP, except for December. This will be explained in more detail later on. When looking at the difference

in magnitude, the largest difference was in September of 2020. The core inflation rate was 0,35% while the COVID core inflation rate was 0,79%. By the end of the year, there is still a remarkable difference between both monthly indices. Namely, in December the core inflation rate and the COVID core inflation rate were 0,35% and 0,11% respectively.

Figure 4.7 EU Annual Core Inflation rates (12-month change, %), 2020



Note: The core HICP and COVID core HICP from table 4.13 (column 4 and 5) are shown in this figure. The COVID core HICP yoy is built by updating the official CPI weights with the OI data.

By comparing the annual core inflation rates in the last two columns of table 4.13 and in figure 4.7, the bias between both indices becomes even more clear. Both indices start with an inflation rate of approximate 1,70%. Furthermore, three periods can be distinguished; first, a period of underestimation by the official core HICP of the real core HICP from March until April; second, during the months April until September a period of overestimation; and lastly, the core HICP from October onwards again underestimates the real inflation rate. After July, a remarkably sharp decline can be seen in both indices, which could be linked to the start of the second COVID wave in the EU. COVID restrictions tightened and infections rose (Chadwick, 2020).

The biggest difference between both indices was in August, with an annual core inflation rate of 1,04%, while the COVID core inflation rate was only 0,54%. While the core HICP was still around 1,70% at the beginning of the year, it is only around 0,90% at the end of 2020. Overall, there is a clear downwards trend in both annual core inflation rates. Compared to figure 4.6, the bias between the core indices is always smaller than the bias between the all-item indices, except in July and August. Furthermore, the annual COVID core HICP remains above the annual all-items COVID core HICP throughout the whole year. Both the smaller bias and higher core inflation rate are mainly due to the exclusion of the subcategories that are related to food or energy.

Next, we will look in more detail at the monthly inflation rates. From September onwards, the COVID core HICP becomes larger than the core HICP. Furthermore, September is also the month with the largest difference in magnitude between both monthly indices, with core inflation rates of 0,35% and 0,79% respectively. The reason for this phenomenon, is that categories such as ‘Transportation services’ had less spending weight combined with deflation and categories such as ‘Clothing and footwear’ had more spending weight combined with inflation, shown in table 4.14. The weights in September for the category ‘Transportation services’ were 2,59% for the official core HICP and 2,11% for the COVID core HICP, increasing the incidence from -0,26% to -0,14%. For the category ‘Clothing and footwear’ the weight was 5,91% for the core HICP, while the weight for the COVID core HICP was 11,28%, which let the incidence increase from 1,05% to 1,27%.

Table 4.14 EU Core HICP – September 2020

HICP Categories	Monthly HICP Inflation	Expenditure Change (vs December 2019, %)	Weight		Incidence	
			Core HICP	COVID Core HICP	Core HICP	COVID Core HICP
Alcoholic beverages, tobacco and narcotics	-0,03	11,05	4,43	8,78	0,00	0,00
Non-alcoholic beverages	-0,53	11,05	1,44	2,85	-0,01	-0,02
Clothing and footwear	11,27	7,15	5,91	11,28	1,05	1,27
Actual rentals for housing	0,07	1,16	5,78	10,42	0,01	0,01
Maintenance and repair of the dwelling	0,11	1,16	1,54	2,78	0,00	0,00
Water supply and miscellaneous services relating to the dwelling	0,06	1,16	2,69	4,85	0,00	0,00
Furnishings, household equipment and routine household maintenance	0,20	1,16	6,19	11,16	0,02	0,02
Health	-0,07	-0,50	4,90	8,69	-0,01	-0,01
Purchase of vehicles	0,19	-54,26	4,04	3,46	0,01	0,01
Transport services	-6,43	-54,26	2,59	2,11	-0,26	-0,14
Communications	0,07	1,16	3,07	5,54	0,00	0,00
Recreation and culture	-1,92	-38,90	8,77	9,55	-0,26	-0,18
Education	0,80	1,16	1,02	1,83	0,01	0,01
Restaurants and hotels	-1,45	-19,13	9,32	13,44	-0,21	-0,20
Miscellaneous goods and services	0,00	1,16	1,90	2,33	0,00	0,00

Note: This table shows the HICP category, monthly core inflation, weights and incidence with and without the use of the COVID basket. The core HICP weight for a given category is the share of the expenditure over total expenditure. The incidence is the monthly core HICP inflation rate multiplied by the weight. The sum of the incidence numbers equals the monthly core inflation rate.

4.6 EU Inflation 2021-2022

4.6.1 All-items HICP

Table 4.15 shows the monthly and annual inflation rates of the EU during the period January 2021 until March 2022. It should be mentioned that most of the time the measurement bias is relatively low. For the monthly inflation rates the HICP is larger than the COVID HICP in January and February 2021, when the COVID cases were still relatively low, which indicates overestimated inflation numbers.

Table 4.15 Monthly and Annual EU Inflation Rates During COVID-19, 2021-2022

	Monthly Inflation Rate (1-month change, %)		Annual Inflation Rate (12-month change, %)	
	HICP	COVID HICP	HICP	COVID HICP
January 2021	0,17	0,00[14]	1,17	1,17
February 2021	0,27	0,16	1,24	1,12
March 2021	1,04	1,08	1,73	1,51
April 2021	0,64	0,66	2,16	1,79
May 2021	0,29	0,28	2,53	2,03
June 2021	0,29	0,26	2,42	2,10
July 2021	0,03	-0,12	2,72	2,56
August 2021	0,35	0,34	3,50	3,40
September 2021	0,58	0,72	3,96	3,68
October 2021	0,93	0,92	4,74	4,36
November 2021	0,46	0,46	5,55	5,01
December 2021	0,47	0,48	5,67	5,38
January 2022	0,55	0,45	5,64	5,41
February 2022	0,86	0,84	6,29	6,12
March 2022	2,36	2,35	7,83	7,63

Note: This table shows the monthly and annual inflation rate for all-items in 2021-2022, not seasonally adjusted, EU HICP, and the COVID-19 HICP using consumption expenditure during COVID-19.

During the spring of 2021 the third COVID wave spreads through Europe. There are shortages of vaccines, the UK variant emerges and the population is getting tired of the corona measures. For example, in April 2021 the French president announced a national lockdown, school closures and travel restrictions (Mallet et al., 2021). These factors might be the reason why the inflation numbers

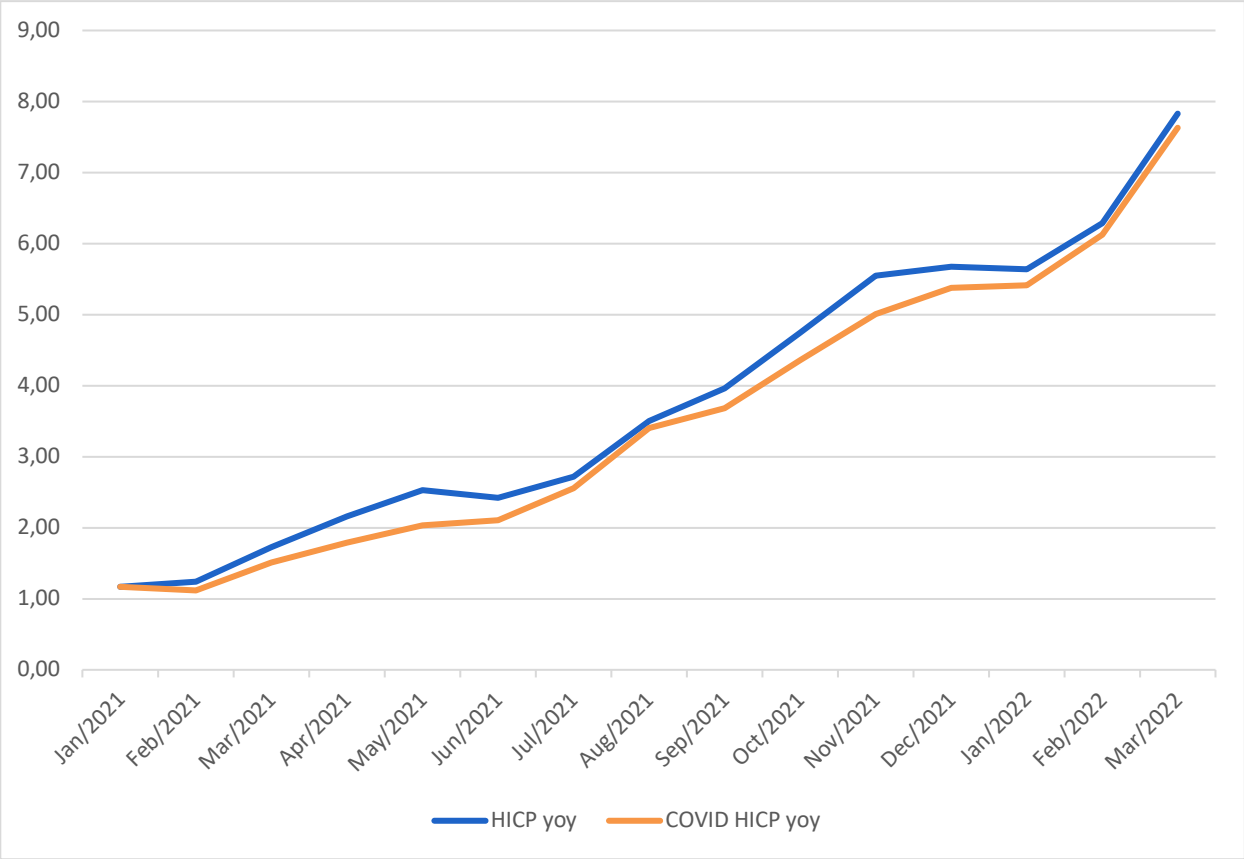
[14] In January 2021 the COVID HICP is 0,00% and this needs some extra explanation. In fact, the COVID HICP is not 0,000% but 0,00319260215813078 and this level is nearly zero because the negative and positive incidences cancel each other our when they are summed up together.

are declining form March 2021 onwards. Important to mention is the fact that the third COVID surge was very different across the European countries. This was due to the heterogeneous approach by the governments, the different vaccination rates and the motivation of the population (Buchholz, 2021; Chazan et al., 2021).

The next COVID wave started in June 2021 and reached a peak in July 2021. Mainly the delta variant of the virus caused new restrictions and decreasing inflation rates. Especially for unvaccinated people the restrictions were tightened (Mallet et al., 2021). Remarkably, the COVID HICP experienced a deflation of -0,12% in July 2020 as the all-items HICP was 0,03% and the rate was overestimated. More details about the inflation rates of July will be discussed later on. With the number of COVID cases declining in the fall of 2021 after the surge, the economy recovered and inflation rates went up. A fifth wave started in November 2021 with the infectious omicron variant spreading across Europe and inflation rates declining again. Finally, during the three months of 2022 the COVID HICP is smaller than the all-items HICP, which indicates overestimated inflation rates. Furthermore, both the COVID HICP and all-items HICP reaches their maximum value from March 2022, respectively 2,35% and 2,36%. As mentioned in section 3.1, the war caused by the invasion of Russia in Ukraine and its economic consequences, especially for European countries, pushed up energy and commodity prices to very high levels and thus also inflation. It should also be recalled that the inflation numbers of March 2022 can also be distorted by the Russian-Ukrainian war.

When analyzing the annual inflation rates, the conclusion is that there was overestimated inflation the entire period because the HICP is larger than the COVID HICP for all months. However, the HICP and COVID HICP were close to each other. This can probably be explained by consumption patterns recovering and slowly returning to their pre-pandemic levels. Furthermore, similar to the US in that period, the inflation numbers were climbing to unseen levels at the end of 2021 and the beginning of 2022. These evolutions are shown in figure 4.8.

Figure 4.8 EU Annual Inflation rates (12-month change, %), 2021-2022



Note: The HICP and COVID HICP from table 4.15 (column 4 and 5) are shown in this figure. The COVID HICP yoy is built by updating the official CPI weights with the OI data.

These overestimated inflation rates from January 2021 onwards can be explained by on the one hand some categories such as 'Transportation' and 'Recreation and culture' that were given too much weight. These categories were of less importance according to the OI tracker data. On the other hand, categories such as 'Food and alcoholic beverages' were given too little weight. This will be explained in detail when discussing table 4.16. Furthermore, factors that pushed up the inflation in the EU from February 2021 onwards are factors such as the further recovery of the economy, supply bottlenecks and increasing prices of commodities that were discussed in section 3.1.

As there is only one month in this entire period that experienced deflation according to the COVID HICP, more details about these inflation numbers are shown in table 4.16. In July 2021 the COVID HICP of -0,12% was smaller than the HICP of 0,03%, which clearly indicates an overestimated HICP. The categories experiencing negative monthly HICP inflation are 'Food and non-alcoholic

beverages', 'Clothing and footwear, 'Furnishings, household equipment and routine household maintenance', 'Health' and 'Communication'. A deflation between -0,02% and -9,77% was found in these categories. This might not be surprising as the number of COVID cases were rising across Europe because of the emergence of the delta variant. All other categories such as 'Restaurants and hotels' and 'Transportation' experienced a positive monthly HICP inflation in July as no strict restrictions had been implemented yet in July. The category 'Clothing and footwear', with a monthly HICP inflation of -9,77% and a COVID incidence of -0,70%, caused the all-items COVID HICP to turn negative. To conclude, the deflation rate is caused by the fact that categories experiencing deflation were given more weight and the category 'Transportation' experiencing inflation was given less weight due to the changing consumer behavior and the OI tracker data.

Table 4.16 HICP Weights EU and Incidence – July 2021

HICP Category	Monthly HICP Inflation	Expenditure Change (vs December 2019, %)	Weight		Incidence	
			HICP	COVID HICP	HICP	COVID HICP
Food and non-alcoholic beverages	-0,05	6,38	16,04	18,17	-0,01	-0,01
Alcoholic beverages, tobacco and narcotics	0,18	6,38	4,44	5,03	0,01	0,01
Clothing and footwear	-9,77	17,10	5,78	7,21	-0,56	-0,70
Housing, water, electricity, gas and other fuels	0,80	6,80	15,79	17,96	0,13	0,14
Furnishings, household equipment and routine household maintenance	-0,11	6,80	6,19	7,04	-0,01	-0,01
Health	-0,02	3,91	4,95	5,48	0,00	0,00
Transportation	1,52	-21,69	15,19	12,67	0,23	0,19
Communication	-0,05	6,80	3,04	3,46	0,00	0,00
Recreation and culture	1,23	-1,45	8,77	9,21	0,11	0,11
Education	0,02	6,80	1,04	1,18	0,00	0,00
Restaurants and hotels	1,45	3,25	9,44	10,38	0,14	0,15
Miscellaneous goods and services	-0,04	6,80	1,94	2,20	0,00	0,00

Note: This table shows the HICP category, monthly inflation, weights and incidence with and without the use of the COVID basket. The HICP weight for a given category is the share of the expenditure over total expenditure. The incidence is the monthly HICP inflation rate multiplied by the weight. The sum of the incidence numbers equals the monthly inflation rate.

4.6.2 Core HICP

The last part of our analysis deals with the EU core HICP in the period of January 2021 until March 2022 and the inflation rates are shown in figure 4.17.

Table 4.17 Monthly and Annual EU Core Inflation Rates During COVID-19, 2021-2022

	Monthly Inflation Rate (1-month change, %)		Annual Inflation Rate (12-month change, %)	
	Core HICP	COVID Core HICP	Core HICP	COVID Core HICP
January 2021	-0,57	-0,72	1,83	1,65
February 2021	0,14	0,08	1,58	1,34
March 2021	1,05	1,24	1,42	1,25
April 2021	0,65	0,68	1,29	1,37
May 2021	0,21	0,21	1,46	1,47
June 2021	0,27	0,25	1,36	1,49
July 2021	-0,32	-0,48	1,23	1,45
August 2021	0,30	0,28	2,10	2,38
September 2021	0,62	0,81	2,40	2,43
October 2021	0,38	0,41	2,65	2,61
November 2021	0,02	0,04	3,13	2,94
December 2021	0,41	0,37	3,19	3,19
January 2022	-0,48	-0,61	2,86	2,81
February 2022	0,59	0,58	3,33	3,31
March 2022	1,16	1,23	3,60	3,52

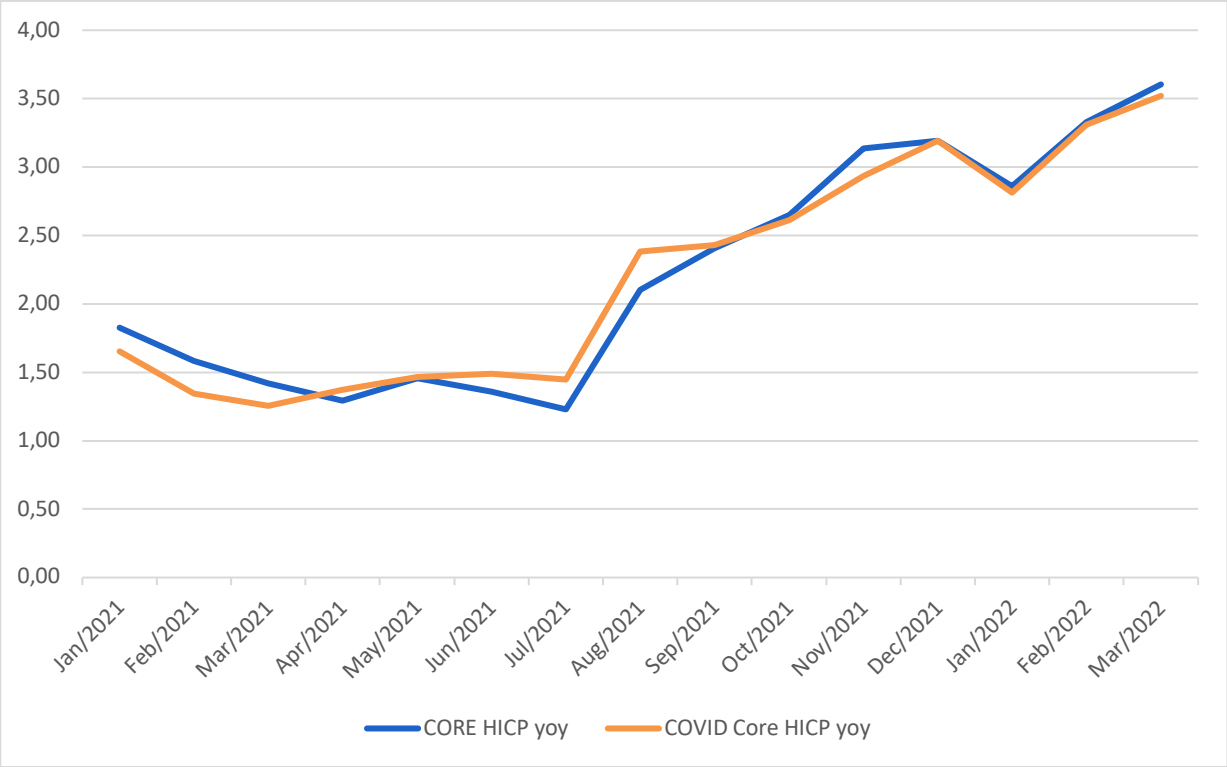
Note: This table shows the monthly and annual core inflation rate for all-items less food and energy of the EU, and the COVID-19 core HICP using consumption expenditure during COVID-19.

The monthly inflation rates are fluctuating and short periods of slightly overestimated and slightly underestimated core HICP alternate. First of all, in January 2021 the inflation rates show deflation and this is the result of the third COVID wave starting in the end of 2020. Afterwards, the number of cases decreases and inflation rates go up and peak in March 2021. Unfortunately, during the spring of 2021 a third wave breaks out and, in the summer of 2021, a fourth wave spreads out. Due to the UK variant and delta variant and the related restrictions, the inflation rates fall again. In July 2021, the center of gravity of the wave, inflation rates show deflation. Next, the monthly core HICP and COVID core HICP decrease once again in November 2021, respectively to 0,02% and 0,04%. This slowdown might be due to the fifth wave of COVID cases, starting in November 2021. The restrictions that are health-related were strengthened. Next, in December 2021 the number of daily cases decreased again, and the inflation rates went up. Unfortunately, the biggest and sixth wave

of COVID-19 started in January 2022 with the omicron variant (Worldometer, 2022b). Once again, as shown in table 4.17, the inflation rates declined and fell below zero.

In general, the annual inflation rates, shown in figure 4.9, have two turning points, April 2021 and October 2021. Before April 2021 there was an overestimated core HICP, afterwards an underestimated core HICP and from October onwards an overestimated Core HICP. In addition, the first half of 2021 shows almost constant inflation. As noted, this might the result of the third and fourth wave of COVID-19 spreading across Europe. After the fourth wave during summer, the inflation rates start rising as the restrictions are more relaxed and the economy is recovering. A final decrease of the inflation rates takes place around January 2022. The number of COVID cases are increasing again. In that period, the omicron variant is everywhere and many families gather inside for the holidays (Chazan et al., 2021).

Figure 4.9 EU Annual Core Inflation rates (12-month change, %), 2021-2022



Note: The core HICP and COVID core HICP from table 4.17 (column 4 and 5) are shown in this figure. The COVID core HICP yoy is built by updating the official HICP weights with the OI data.

The difference between the monthly core HICP and COVID core HICP is largest in March 2021 and September 2021 but the difference between the annual indices is larger in March 2021. Therefore, table 4.18 shows the details of the core HICP of March 2021. In general, all weights included in the calculation of the HICP differ from the expenditure chance, which might indicate a bias. We are just mentioning the most important categories. ‘Alcoholic beverages, tobacco and narcotics’, ‘Clothing and footwear’, ‘Recreation and culture’ and ‘Restaurants and hotels’ were given too little weight. This might be the result of the healing economy after the second COVID wave during winter. With corona measures relaxing, people could go back to shopping, to the theatre, to the restaurant etc. With an incidence of 1,09% the category ‘Clothing and footwear’ had the biggest impact on the inflation rates. Unfortunately, the peak in the inflation numbers did not last long as the next wave and delta variant were growing rapidly in April 2021 (Mallet et al., 2021).

Table 4.18 EU Core HCIP – March 2021

HICP Categories	Monthly HICP Inflation	Expenditure change (vs December 2019, %)	Weight		Incidence	
			Core HICP	COVID Core HICP	Core HICP	COVID Core HICP
Alcoholic beverages, tobacco and narcotics	0,35	12,22	4,44	8,25	0,02	0,03
Non-alcoholic beverages	0,14	12,22	1,45	2,69	0,00	0,00
Clothing and footwear	9,71	16,77	5,78	11,18	0,88	1,09
Actual rentals for housing	0,10	6,78	5,80	10,26	0,01	0,01
Maintenance and repair of the dwelling	0,37	6,78	1,49	2,63	0,01	0,01
Water supply and miscellaneous services relating to the dwelling	0,13	6,78	2,63	4,65	0,01	0,01
Furnishings, household equipment and routine household maintenance	0,27	6,78	6,19	10,94	0,03	0,03
Health	0,09	3,66	4,95	8,51	0,01	0,01
Purchase of vehicles	0,40	-47,43	4,05	3,53	0,03	0,01
Transport services	0,79	-47,33	2,61	2,27	0,03	0,02
Communications	-0,24	6,78	3,04	5,38	-0,01	-0,01
Recreation and culture	0,04	-28,75	8,77	10,35	0,01	0,00
Education	0,07	6,78	1,04	1,84	0,00	0,00
Restaurants and hotels	0,20	-10,03	9,44	14,07	0,03	0,03
Miscellaneous goods and services	0,19	6,78	1,94	3,43	0,01	0,01

Note: This table shows the HICP category, monthly core inflation, weights and incidence with and without the use of the COVID basket. The core HICP weight for a given category is the share of the expenditure over total expenditure. The incidence is the monthly core HICP inflation rate multiplied by the weight. The sum of the incidence numbers equals the monthly core inflation rate.

4.7 Comparison of Inflation Rates in the US and the EU

In this section, we compare the all-items annual inflation indices of our analysis for the US and the EU from January 2020 until March 2022. A better understanding is gained of the main differences in the inflation rates between the two regions.

Table 4.19 Annual (COVID) Inflation rates of the US and EU (12-month change, %), 2020- March 2022

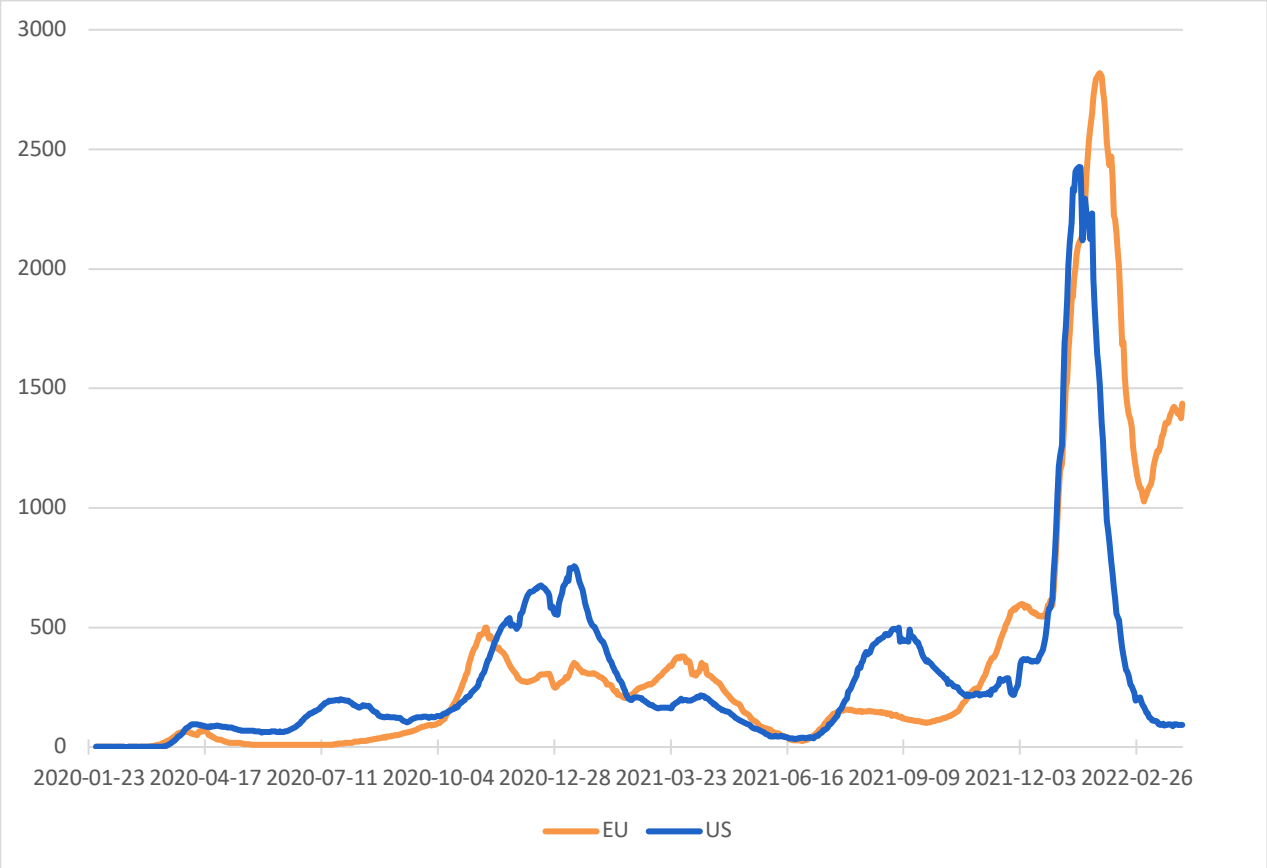
	Annual Inflation Rate (12-month change, %)		Annual COVID Inflation Rate (12-month change, %)	
	CPI US	HICP EU	COVID CPI US	COVID HICP EU
January 2020	2,50	1,90	2,49	1,91
February 2020	2,35	1,75	2,35	1,76
March 2020	1,56	1,28	1,68	1,43
April 2020	0,35	0,73	1,10	1,05
May 2020	0,13	0,47	0,99	0,90
June 2020	0,66	0,74	1,40	0,97
July 2020	1,03	0,85	1,55	0,77
August 2020	1,35	0,34	1,81	0,20
September 2020	1,41	0,22	1,87	0,39
October 2020	1,22	0,23	1,66	0,48
November 2020	1,21	0,19	1,62	0,58
December 2020	1,38	0,19	1,78	0,36
January 2021	1,46	1,17	1,82	1,17
February 2021	1,74	1,24	1,98	1,12
March 2021	2,66	1,73	2,59	1,51
April 2021	4,16	2,16	3,28	1,79
May 2021	4,97	2,53	3,82	2,03
June 2021	5,31	2,42	4,17	2,10
July 2021	5,26	2,72	4,32	2,56
August 2021	5,16	3,50	4,33	3,40
September 2021	5,32	3,96	4,56	3,68
October 2021	6,13	4,74	5,33	4,36
November 2021	6,69	5,55	5,85	5,01
December 2021	6,91	5,67	6,09	5,38
January 2022	7,83	5,64	6,92	5,41
February 2022	8,19	6,29	7,36	6,12
March 2022	8,76	7,83	8,09	7,63

Note: This table shows the annual all-items (COVID) inflation rates for the US and the EU from January 2020 until March 2022. The COVID inflation rates are built by updating the official weights with the expenditure changes of the OI data.

Table 4.19 provides an overview of the annual inflation rates and the annual COVID inflation rates of the US and the EU, from January 2020 until March 2022. A first conclusion that can be drawn

from table 4.19 is that the annual inflation rate of the US is almost always higher than the inflation rate of the EU, except for April 2020 to June 2020. This can also be seen in figure 4.11. As mentioned in section 3.1, the difference between the CPI of the US and the HICP before the pandemic started, was due to the European countries not getting inflation up to their targets. This can be explained by the European economy that is still recovering from the euro and sovereign debt crisis (Jordà et al., 2022). The fact that for the period April 2020 until June 2020 the annual inflation rate of the US is lower than the annual inflation of the EU might be due to the higher COVID cases in the US, shown in figure 4.10.

Figure 4.10 Daily New Confirmed COVID cases per million people in the US and the EU, 2020 - March 2022

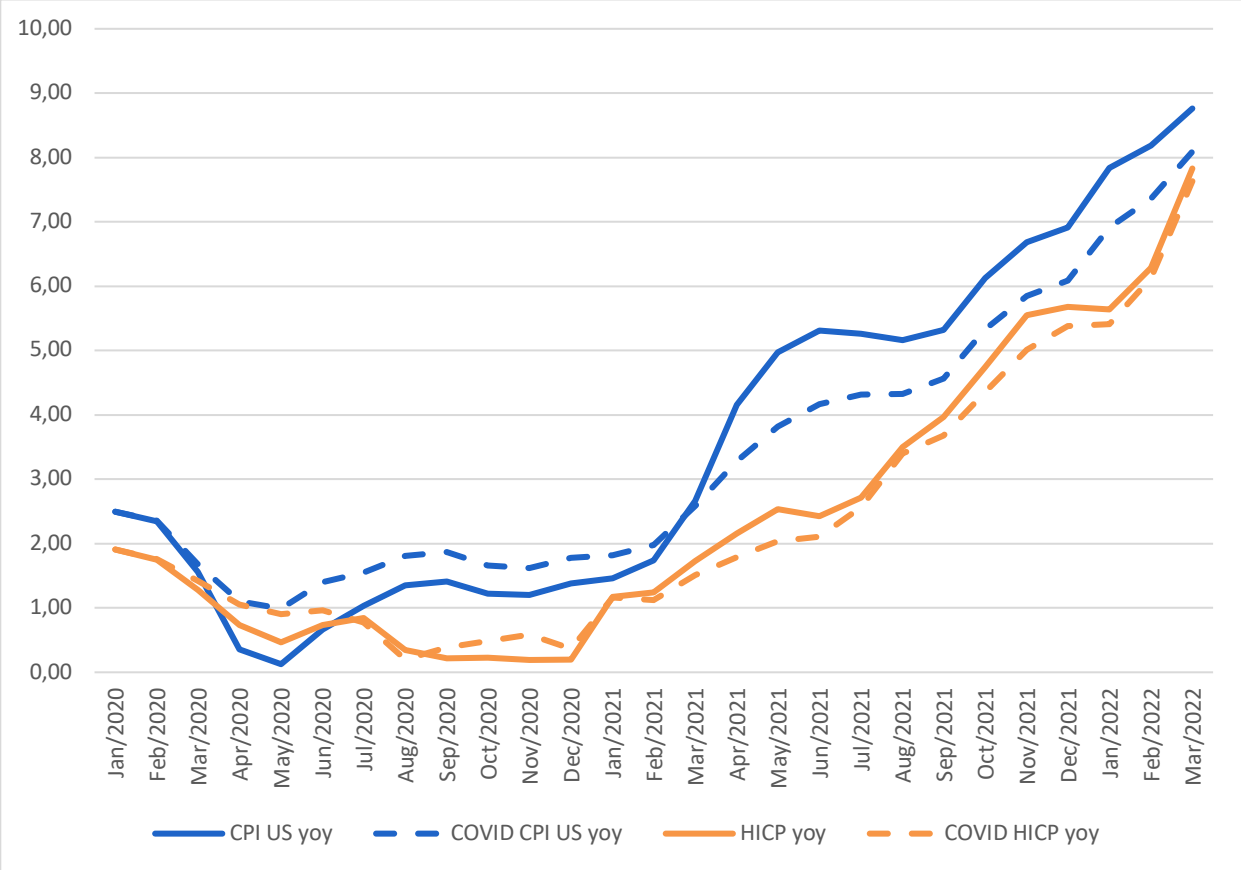


Note: This figure represents the daily COVID cases (7-day rolling average) in the EU and the US. Data obtained from (Roser et al., 2020).

From March 2020 onwards, when the first wave of COVID-19 cases started, the inflation rates of both the US and the EU declined sharply. In May 2020, the US reached its overall lowest inflation number of 0,13%. Afterwards, the US economy already started to recover. By contrast, the EU kept

having low inflation numbers throughout the first two quarters of 2020 and reached its lowest inflation number of 0,19% in November 2020. The main factors of the early recovery of the US were the enormous fiscal support of the government, the substantial and rapid rebound of domestic consumer spending, second-round effects and labor shortages. Also, the US reached its pre-pandemic GDP level earlier than the EU countries and the lockdowns in the EU were stricter (noted in section 3.1). As discussed in section 3.3.1.2 together with the global supply disruptions, these factors strongly pushed up inflation. The EU fell further behind during the third quarter of 2020 due to lagged vaccine availability and lockdowns that were imposed (Jordà et al., 2022; Milesi-Ferretti, 2021). The rapid recovery of the US compared to the EU is also visible in the inflation numbers. In December 2020, the annual inflation rate of the US was almost seven times as large as the inflation rate of the EU, with official inflation rates of 1,38% and 0,19% respectively.

Figure 4.11 Annual CPI and COVID CPI of the US vs Annual HICP and COVID HICP of the EU (%), 2020-2022



Note: Both the CPI (HICP) and COVID CPI (HICP) from the US and EU from table 4.19 are shown in this figure. The COVID CPI (HICP) yoy is built by updating the official CPI (HICP) weights with the OI data.

In January 2021, the vaccination campaign in the EU really took off and the EU economy started to recover (Mallet et al., 2021). The vaccination rate in the US also kept on rising. Additionally, COVID restrictions reduced in both economies throughout 2021 because these increasing vaccinations caused reduced restrictions (Milesi-Ferretti, 2021). By consequence, the inflation rates raised remarkably. As discussed in previous sections, this is also the result of rising energy and commodity prices, supply chain disruptions and the vaccination program. Further, economies reopened rapidly, but many companies were struggling to keep up with the high demand, e.g. due to the shortage of sea containers. Furthermore, the companies pass-through their costs of high energy prices and supply shortages to their clients (European Central Bank, 2021b). In December 2021, the annual inflation rate of the US was significantly larger than the inflation rate of the EU, with official inflation rates of 6,91% and 5,67%. Further, in March 2022 the official CPI of the US was 8,76%, while at the same time the official HICP of the EU was 7,83%. As mentioned before, the result for March 2022 could be biased due to the war in Ukraine.

Similarly, the COVID inflation rate of the US is always higher than the EU COVID HICP. While the COVID CPI of the US already reached 2,59% in March 2021, the COVID HICP was only 1,51% for the EU. In May 2021 the COVID HICP surpassed the threshold of 2%. Afterwards, both COVID indices kept on rising and reached high levels of inflation by the end of our research period. In March 2022, the COVID CPI was 8,09%, while at the same time the COVID HICP was 7,63%.

Looking at the difference in magnitude between the official CPI (HICP) and the COVID CPI (HICP), the difference between the US indices has always been larger, except for March 2021. This might be explained by the weights that are given to certain categories. Meanwhile, it has become clear that the categories of food and transportation experienced the largest changes during the pandemic. Their weights for both the US and the EU are shown in table 4.20. As the table clearly shows, the US gives more weight to the category transportation compared to the EU, except for 2021 (however, the difference is rather small). At the same time, the US gives much less weight to the category food. As transportation has the largest decline and food the largest increase in COVID weights during the pandemic, the measurement bias between the official inflation rate and the COVID rate is most of the time larger in the US than in the EU.

Table 4.20 Official Weights for the Categories Transportation and Food, 2020-2022

Category	EU	US
Transportation 2020	15,02	15,74
Food 2020	15,92	7,58
Transportation 2021	15,19	15,16
Food 2021	16,04	7,77
Transportation 2022	13,44	18,18
Food 2022	18,04	8,17

Note: The US category of food is 'Food at home' and for the EU 'Food and non-alcoholic beverages'.

Furthermore, from March 2020 to March 2022, the difference in magnitude between the indices of both the US and the EU becomes smaller. This can be explained by the consumer behavior that went almost completely back to its pre-pandemic level, as shown in figure 4.1. In March 2022 the EU indices were 7,83% and 7,63%, while the US indices were 8,76% and 8,09%.

5. Conclusion

Measuring inflation during economic disruptions is challenging. Consumption patterns are heavily affected due to the COVID-19 pandemic and the related restrictions, such as lockdowns and social-distancing. It became clear that these drastic changes in consumption patterns might lead to official weights no longer reflecting the real consumption. Especially, the categories transportation and food experienced a large decrease and a respectively large increase in consumption. Further, due to social restrictions also data collection of prices becomes more difficult. These factors could lead to a potential bias when measuring inflation.

Similar to Cavallo, 2020, we used OI data that represented the real-time changes in consumption expenditures during the pandemic to update the official weights of the CPI. These new COVID weights were used to calculate the COVID CPI for the US and the EU. During 2020, both for the US as well as the EU, the official CPI underestimated the real inflation in most months. In contrast to 2022, the official CPI overestimated the real inflation rate in most months. This difference between the official inflation rate and the COVID inflation rate was primarily due to categories related to transportation and food. The measurement bias was also found in the core inflation rates, which means that the bias was not only the consequence of the categories related to food and energy. In addition, it is important for many policy-making bodies and for the population to know whether published inflation rates are over- or underestimated. Not only central banks, but also national governments and household make decisions based on inflation. Moreover, if inflation is measured incorrectly, other important economic variables will also be affected.

The COVID-19 pandemic has underlined the importance of high-frequency data. To have an accurate CPI that represent consumer expenditure during the COVID-19 pandemic, new and more frequent basket information is necessary. One solution could be the establishment of a continuous consumer expenditure survey. Furthermore, wider availability of credit- and debit card data would be promising in a rapidly changing economy. Tracker data of changes in consumption patterns for the EU would have made our research and associated conclusions more precise. More extreme, moving away from the fixed basket completely is also a possibility. Statistical offices need to consider using Fisher indices or approximate the Laspeyres and Paasche indices better.

Because the pandemic is not at its end yet, the mentioned issues are still relevant. Even after the pandemic, measurement biases in the inflation stays a relevant topic and further analyses is recommended. An example of further research could be the analysis of EU countries separately to get a better insight into the heterogeneity between countries. Furthermore, research on better methods to compile the CPI and the HICP would contribute to having a more up-to-date inflation measure.

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Appendix

A. Classifications

Table A.1 Broad Structure COICOP 2018

Code	Description
01	Food and non-alcoholic beverages
01.1	Food
01.2	Non-alcoholic beverages
01.3	Services for processing primary goods for food and non-alcoholic beverages
02	Alcoholic beverages, tobacco and narcotics
02.1	Alcoholic beverages
02.2	Alcoholic production services
02.3	Tobacco
02.4	Narcotics
03	Clothing and footwear
03.1	Clothing
03.2	Footwear
04	Housing, water, electricity, gas and other fuels
04.1	Actual rentals for housing
04.2	Imputed rentals for housing
04.3	Maintenance, repair and security of the dwelling
04.4	Water supply and miscellaneous services relating to the dwelling
04.5	Electricity, gas and other fuels
05	Furnishings, household equipment and routine household maintenance
05.1	Furniture, furnishings, and loose carpets
05.2	Household textiles
05.3	Household appliances
05.4	Glassware, tableware and household utensils
05.5	Tools and equipment for house and garden
05.6	Goods and services for routine household maintenance
06	Health
06.1	Medicines and health products
06.2	Outpatient care services
06.3	Inpatient care services
06.4	Other health services
07	Transport
07.1	Purchase of vehicles
07.2	Operation of personal transport equipment
07.3	Passenger transport services
07.4	Transport services of goods
08	Information and communication
08.1	Information and communication equipment

08.2	Software excluding games
08.3	Information and communication services
09	Recreation, sport and culture
09.1	Recreational durables
09.2	Other recreational goods
09.3	Garden products and pets
09.4	Recreational services
09.5	Cultural goods
09.6	Cultural services
09.7	Newspapers, books and stationery
09.8	Package holidays
10	Education services
10.1	Early childhood and primary education
10.2	Secondary education
10.3	Post-secondary education
10.4	Tertiary education
10.5	Education not defined by level
11	Restaurants and accommodation services
11.1	Food and beverage serving services
11.2	Accommodation services
12	Insurance and financial services
12.1	Insurance
12.2	Financial services
13	Personal care, social protection and miscellaneous goods and services
13.1	Personal care
13.2	Other personal effects
13.3	Social protection
13.9	Other services
14	Individual consumption expenditure of non-profit institutions serving households (NPISHS)
14.1	Housing
14.2	Health
14.3	Recreation and culture
14.4	Education
14.5	Social protection
14.6	Other services
15	Individual consumption expenditure of general government
15.1	Housing
15.2	Health
15.3	Recreation and culture
15.4	Education
15.5	Social protection

Note: Table obtained from the United Nations (2018).

Table A.2 Broad Structure ECOICOP

Code	Description
01	Food and non-alcoholic beverages
01.1	Food
01.2	Non-alcoholic beverages
02	Alcoholic beverages, tobacco and narcotics
02.1	Alcoholic beverages
02.2	Tobacco
02.3	Narcotics
03	Clothing and footwear
03.1	Clothing
03.2	Footwear
04	Housing, water, electricity, gas and other fuels
04.1	Actual rentals for housing
04.2	Imputed rentals for housing
04.3	Maintenance and repair of the dwelling
04.4	Water supply and miscellaneous services relating to the dwelling
04.5	Electricity, gas and other fuels
05	Furnishings, household equipment and routine household maintenance
05.1	Furniture and furnishings, carpets and other floor coverings
05.2	Household textiles
05.3	Household appliances
05.4	Glassware, tableware and household utensils
05.5	Tools and equipment for house and garden
05.6	Goods and services for routine household maintenance
06	Health
06.1	Medical products, appliances and equipment
06.2	Out-patient services
06.3	Hospital services
07	Transport
07.1	Purchase of vehicles
07.2	Operation of personal transport equipment
07.3	Transport services
08	Communication
08.1	Postal services
08.2	Telephone and telefax equipment
08.3	Telephone and telefax services
09	Recreation and culture
09.1	Audiovisual, photographic and information processing equipment
09.2	Other major durables for recreation and culture
09.3	Other recreational items and equipment, gardens and pets
09.4	Recreational and cultural services
09.5	Newspapers, books and stationery
09.6	Package holidays
10	Education

10.1	Pre-primary and primary education
10.2	Secondary education
10.3	Post-secondary non-tertiary education
10.4	Tertiary education
10.5	Education not defined by level
11	Restaurants and hotels
11.1	Catering services
11.2	Accommodation services
12	Miscellaneous goods and services
12.1	Personal care
12.2	Prostitution
12.3	Personal effects n.e.c.
12.4	Social protection
12.5	Insurance
12.6	Financial services n.e.c.
12.7	Other services n.e.c.

Note: Table obtained from the European Central Bank (2022).

B. Category Matching

Table B.1 Matching of US CPI Categories and Expenditure Categories

CPI Category US	OI Expenditure Category
Food at home	Grocery
Alcoholic beverages	Grocery
Apparel	Apparel and general merchandise
Housing	Total
Medical care	Health care
Transportation	Transportation
Recreation	Entertainment and recreation
Education and communication	Total
Food away from home	Restaurants and hotels
Other goods and services	Total

Note: The categories 'Housing', 'Education and communication' and 'Other goods and services' assume the same change as the total expenditure.

Table B.2 Matching of US Core CPI Categories and Expenditure Categories

Core CPI Category US	OI Expenditure Category
Alcoholic beverages	Grocery
Apparel	Apparel and general merchandise
Household furnishings and operations	Total
Shelter	Total
Water and sewer and trash collection services	Total
Medical care	Health care
Motor vehicle fees	Transportation
Motor vehicle insurance	Transportation
Motor vehicle maintenance and repair	Transportation
Motor vehicle parts and equipment	Transportation
New and used motor vehicles	Transportation
Public transportation	Transportation
Recreation	Entertainment and recreation
Education and communication	Total
Other goods and services	Total

Note: The categories 'Household furnishings and operations', 'Shelter', 'Water and sewer and trash collection services', 'Education and communication' and 'Other goods and services' assume the same change as the total expenditure.

Table B.3 Matching of EU HICP Categories and Expenditure Categories

ECOICOP Category	OI Expenditure Category
Food and non-alcoholic beverages	Grocery
Alcoholic beverages, tobacco and narcotics	Grocery
Clothing and footwear	Apparel and general merchandise
Housing, water, electricity, gas and other fuels	Total
Furnishings, household equipment and routine household maintenance	Total
Health	Health care
Transportation	Transportation
Communication	Total
Recreation and culture	Entertainment and recreation
Education	Total
Restaurants and hotels	Restaurants and hotels
Miscellaneous goods and services	Total

Note: The categories 'Housing, water, electricity, gas and other fuels', 'Furnishings, household equipment and routine household maintenance', 'Communication', 'Education' and 'Other goods and services' assume the same change as the total expenditure.

Table B.4 Matching of EU Core HICP Categories and Expenditure Categories

Core HICP Category EU	OI Expenditure Category
Non-alcoholic beverages	Grocery
Alcoholic beverages, tobacco and narcotics	Grocery
Clothing and footwear	Apparel and general merchandise
Actual rentals for housing	Total
Maintenance and repair of the dwelling	Total
Water supply and miscellaneous services relating to the dwelling	Total
Furnishings, household equipment and routine household maintenance	Total
Health	Health care
Purchase of vehicles	Transportation
Transport services	Transportation
Communications	Total
Recreation and culture	Entertainment and recreation
Education	Total
Restaurants and hotels	Restaurants and hotels
Miscellaneous goods and services	Total

Note: The categories 'Actual rentals for housing', Maintenance and repair of the dwelling', 'Water supply and miscellaneous services relating to the dwelling', 'Furnishings, household equipment and routine household maintenance', 'Communications', 'Education' and 'Miscellaneous goods and services' assume the same change as the total expenditure.

C. Constructing the COVID Price Index for Switzerland

To calculate this alternative COVID index Seiler (2020) chose the use of the Paasche index. Further, he constructs his COVID index as a weighted sum of all sectoral categories and uses the two following separate weighting schemes.

$$I_{t,w=t} = \sum_{i=1}^{12} {s'}_{i,t} I_{i,t}$$

$$I_{t-k,w=t} = \sum_{i=1}^{12} {s'}_{i,t} I_{i,t-k}$$

In these formula k $\in \{0,12\}$ for calculating the monthly or annual inflation. Next, the inflation rates are compared to the indices of the same weighing schemes.

In case of monthly inflation:

$$\pi_{t,t-1} = \frac{I_{t,w=t} - I_{t-1,w=t}}{I_{t-1,w=t}} \cdot 100$$

In case of annual inflation:

$$\pi_{t,t-12} = \frac{I_{t,w=t} - I_{t-12,w=t}}{I_{t-12,w=t}} \cdot 100$$