EUROPEAN CENTRAL BANK

EUROSYSTEM

Working Paper Series

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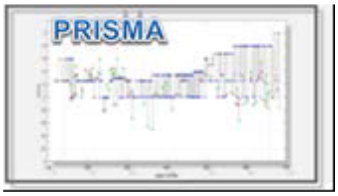
Estimating the impact of quality adjustment on consumer price inflation



No 2773 / February 2023

Price Micro Setting Analysis Network (PRISMA)

This paper contains research conducted within the Price Micro Setting Analysis Network (PRISMA). PRISMA consists of economists from the ECB and the national central banks (NCBs) of the European System of Central Banks (ESCB).

PRISMA is coordinated by a team chaired by Luca Dedola (ECB), and consisting of Chiara Osbat (ECB), Peter Karadi (ECB) and Georg Strasser (ECB). Fernando Alvarez (University of Chicago), Yuriy Gorodnichenko (University of California Berkeley), Raphael Schoenle (Federal Reserve Bank of Cleveland and Brandeis University) and Michael Weber (University of Chicago) act as external consultants.

PRISMA collects and studies various kinds of price microdata, including data underlying official price indices such as the Consumer Price Index (CPI) and the Producer Price Index (PPI), scanner data and online prices to deepen the understanding of price-setting behaviour and inflation dynamics in the euro area and EU, with a view to gaining new insights into a key aspect of monetary policy transmission (for further information see https://www.ecb.europa.eu/pub/economic-research/research-networks/html/researcher_prisma.en.html)

The refereeing process of this paper has been co-ordinated by a team composed of Luca Dedola (ECB), Anton Nakov (ECB), Chiara Osbat (ECB), Elvira Prades (Banco d'Espana), Sergio Santoro (ECB), Henning Weber (Bundesbank).

This paper is released in order to make the results of PRISMA research generally available, in preliminary form, to encourage comments and suggestions prior to final publication. The views expressed in the paper are the author's own and do not necessarily reflect those of the ESCB.

Abstract

How much does quality adjustment matter in measuring consumer price inflation? To address this question, we use different sources of micro and macro price data for Germany and the euro area. For Germany, we find that quality adjustment applies to a large range of goods and services but, on average, price adjustments due to quality changes reduce headline inflation only by 0.06 percentage points, which is balanced out by an increase due to quantity adjustment (e.g. a smaller package size) of the same amount. For the euro area, we assess the impact of heterogeneous quality adjustment methods by deriving the distribution of member states' cumulative inflation rates for typical quality-adjusted products. Our macro-based estimate makes up to ± 0.2 percentage points for headline HICP inflation and ranges between ± 0.1 and 0.3 percentage points for core inflation, when controlling for income differentials between member states. Finally, we illustrate the role of heterogeneous quality adjustment methods in the euro area based on micro price data for washing machines. We show that the price development of this product would have been lower by about 3.5 percentage points during the first years of the euro area and by about half a percentage point during recent years, if prices in the member states had been quality-adjusted in exactly the same way.

JEL Classification: E31, C43.

Keywords: inflation measurement, quality adjustment, inflation differentials, micro price data.

Non-technical summary

The measurement of consumer price inflation remains a key question for both statisticians, central bankers and policy makers. One of the most important challenges consists of adequately accounting for changes in product quantity and quality, not only in a single country but also between members of the euro area if the adjustment practices are not harmonised sufficiently. This issue has also been identified as a crucial knowledge gap in the strategy review of the Eurosystem (ECB, 2021).

We provide estimates of the impact of quality and quantity adjustment on consumer price inflation in three ways. First, we analyse the micro data underlying the German CPI and compare unadjusted and adjusted inflation figures. Second, we approximate the effect of heterogeneous quality adjustment methods within the euro area by using disaggregate HICP data. And third, we offer a more precise measure of those inflation differentials with the help of transaction level data for washing machines.

For Germany, we find that price adjustments due to quality changes have lowered the headline inflation rate by about 0.06 percentage points between 2015 and 2020, which was offset by an increase caused by quantity adjustments of about the same size. However, the effect of quality adjustment is substantially larger for industrial goods and services, also because our data set excludes some electronic goods that are typically adjusted for quality changes. Regarding the euro area, we find that headline inflation fluctuates between $\pm$ 0.2 percentage points and core inflation between $\pm$ 0.1 and 0.3 percentage points according to our estimate of heterogeneous quality adjustment methods across member states. Finally, using the same adjustment method for all countries, we find that the inflation rate for washing machines would have been about 3.5 percentage points lower between 2000 and 2005, and about 0.5 percentage points lower between 2017 and 2021 than the corresponding official inflation rate, if prices in the member states had been quality-adjusted in exactly the same way.

Overall, our estimate of the impact of heterogeneous QA methods on euro area inflation is quite substantial and of similar magnitude in comparison to measurement biases in the HICP due to substitution or the lack of owner-occupied housing (ECB, 2021). Hence, this would call for a further harmonisation of QA methods across member states to reduce or eliminate their impact on euro area inflation. On top, more efforts should be made to quantify both the size and the direction of the impact of quality adjustment in euro area inflation with greater accuracy. Using transaction data with a larger product coverage could offer valuable insights in this respect.

1 Introduction

Measuring consumer price inflation properly poses several challenges. A measurement bias can arise when new products, outlets and changes in consumption patterns are considered only with a certain time lag.[1] Moreover, in price statistics, the "pure" price change should be measured by disentangling a price decrease or increase due to a product's quality improvement or deterioration. Hence, inflation will be overestimated if rising prices are not adjusted for improved product quality or if products of different quality are taken as close substitutes.

Concerning potential measurement bias in a CPI, quality adjustment was found to explain more than half of the measurement error for US inflation (Boskin et al., 1996). For Germany, Hoffmann (1998) argued that post-euro inflation could have been biased upwards by about 0.75 percentage points mainly because of difficulties with respect to accounting for changes in product quality. Yet, little is known on the impact of quality adjustment on consumer price inflation for a more recent period, which might be due to the lack of more granular information about the underlying methods and the size of the price adjustments at the product level.

In the euro area, an additional source of measurement bias might result not only from the lack of quality adjustment (QA) itself, but from heterogeneous national QA practices. To this date, various QA procedures are at hand for National Statistical Institutes (NSIs) in the euro area, but without any binding rules, pointing out scope for further harmonisation (ECB, 2021). Heterogeneous QA practices might also contribute to the astonishingly large price differentials of certain products in the euro area. For example, the average price change of mobile phones in the HICP since 2016 ranges from +5% in Portugal to -17% in Ireland. Given the homogeneity and tradability of this item, such huge price differentials are surprising; one candidate explanation for diverging price trends – notably for industrial products with continuous technological improvements – could stem from heterogeneous QA practices across euro area member states. Likewise, a case study with Austrian and Italian Consumer Price Index (CPI) micro data by Conflitti et al. (2022) suggests that the choice of QA methods can well explain divergent HICP rates across countries. In the course of its strategy review, the Eurosystem has also stressed the importance of gaining a better understanding of the various sources of measurement bias in

[1] Camba-Mendez (2003) offers a discussion of four potential measurement biases in the Harmonised Index of Consumer Prices (HICP) - substitution bias, quality bias, outlet bias and new good bias - and Beck and Jaravel (2021) provide a comprehensive empirical assessment across more than 30 countries using scanner data for fast-moving consumption goods.

euro area inflation, pointing out a knowledge gap concerning the bias due to quality adjustment (ECB, 2021).

We contribute to filling this gap by estimating the impact of quality adjustment based on various sources of micro and macro price data. First, we update the earlier findings of Hoffmann (1998) and present some evidence regarding the scope and the size of quality and quantity adjustment in the German inflation rate. Second, we try to approximate the impact of heterogeneous QA practices across member states on euro area inflation.[2] For this purpose, we follow a macro-based approach which builds upon the official inflation series published by Eurostat and selects product categories whose prices are typically affected by quality change. Based on the dispersion across member states' cumulative inflation rates, we derive a range for euro area headline and core inflation that we interpret as an estimate for the impact of quality adjustment on the HICP. Finally, we illustrate the impact of heterogeneous QA methods on euro area inflation by means of micro price data; for this, we apply transaction prices for washing machines for ten member states from the GfK.

According to our results, taking into account changes in quantity and quality has only a very small impact on headline inflation in Germany. Since 2015, inflation has been increased on average by +0.06 percentage points due to a smaller underlying quantity but has been lowered by about the same amount due to quality improvements. Concerning the impact of heterogeneous QA methods on euro area inflation, our macro-based estimate indicates a range between ± 0.2 and 0.6 percentage points for headline inflation and between ± 0.3 and 0.8 percentage points for core inflation. Controlling for income differentials between member states, the impact is reduced to up to ± 0.2 for headline inflation and ± 0.1 to 0.3 for core inflation. Regarding our case study on washing machines, we find that the corresponding euro area inflation rate would have been lower by about 3.5 percentage points during the first years of the euro area and by about half a percentage point during recent years if the same QA method had been used across countries.

The outline of this paper is as follows. Section 2 presents some stylised facts and a literature overview on the impact of quality adjustment in consumer price statistics. Section 3 provides

[2] A precise estimate could only be derived by means of detailed micro price data. Although the Eurosystem's Price-setting Microdata Analysis Network (PRISMA) has moved somewhat in this direction, a direct comparison of the HICP micro price data across countries is hampered by the lack of information on quality adjustment and centrally collected prices such as electronics, which often undergo quality adjustment (see Gautier et al., 2022).

an estimate of the impact of quantity and quality adjustment on German inflation by using CPI micro prices for the period 2010-2020. Section 4 discusses the role of quality adjustment for euro area inflation. For this purpose, we estimate the impact of heterogeneous QA methods on euro area headline and core inflation by using official national inflation rates and a predefined list of typically quality-adjusted products (Section 4.1). Next, we illustrate the impact of heterogeneous QA methods in the euro area based on micro price data for washing machines (Section 4.2). Finally, Section 5 concludes.

2 Stylised facts and literature overview

The literature is relatively silent about the effects from quality adjustment on inflation measurement, in particular with respect to explaining price differentials between countries. As part of the traditional debate on measurement errors, quality adjustment was found to explain more than half of the measurement error for US inflation (Boskin et al., 1996). Based on this seminal contribution, some euro area countries made similar efforts to quantify the measurement bias in domestic inflation, e.g. Hoffmann (1998) for Germany, Lequiller (1997) for France and Neves and Sarmento (1997) for Portugal.[3] Hoffmann (1998) argued that German inflation before the euro introduction could have been biased upwards by about 0.75 percentage points mainly because of difficulties with respect to accounting for changes in product quality. Based on a model of price formation, the author states that – if inflation is moderate – the quality adjustment bias "might be approximately 1/2 percentage point if the average advance in quality is 1% per annum", with non-linearities applying according to the level of inflation.[4] In light of digitalisation and product innovations, the question of the impact of quality adjustment on consumer prices has become even more relevant nowadays (Reinsdorf and Schreyer, 2019). Nevertheless, to the best of our knowledge, Statistics Sweden seems to be the only institute that regularly publishes the impact of its quality adjustment on national inflation; according to its annual quality report, about

[3] Several studies also focus on the measurement bias in the HICP stemming from the underlying index formulae. Herzberg et al. (2021) calculate the upper-level aggregation bias arising from product substitution and delayed data availability in Germany and the euro area. According to their results, official HICP inflation has been biased upwards by about 0.1 percentage points. By contrast, Gabor-Toth and Vermeulen (2019) argue that the choice of the index formula on the micro level, the elementary index bias, is quantitatively more important than the upper-level substitution bias.

[4] See Hoffmann (1998), p. 154: *"Below this area, i.e. given falling prices, the bias increases rapidly. As a maximum it could be in the region of one percentage point per annum. If inflation is higher, the bias might also be over 1 percentage point p.a.."*

27% of products of the Swedish consumption basket are adjusted for quality changes. Without quality adjustment, the prices of these groups would be 1.2% higher resulting in an overall effect of +0.3 percentage points for headline inflation (Statistics Sweden, 2019).

For the euro area, on top of a bias caused by missing or insufficient quality adjustment itself, a measurement bias can result from country-specific quality adjustment; either because some countries choose to adjust prices of specific goods for quality changes and others do not, or because countries apply different QA methods. As pointed out already by Ahnert and Kenny (2004) in the early days of the currency union, this might contribute to divergent price trends across member states.[5] One illustration of the potential impact of heterogeneous QA methods across euro area countries is shown in Figure (1), which plots the index and the cumulated inflation rate of the HICP index for mobile telephone equipment (including smartphones) from January 2016 onwards.[6] Given that products in this category are assumed to be fairly homogeneous, we would expect prices to behave rather similarly across countries.[7] Yet, we observe remarkable price differentials ranging from a cumulative price decrease of more than 60% in Estonia to an increase of about 2% in Portugal. A similar pattern emerges for prices of personal computers, as shown in the lower panel of Figure (1). More generally, Byrne (2019) argues that the problem of huge unexplainable deviations in official prices for digital products becomes even worse if one considers also countries outside of the euro area.

Most recently, in its strategy review, the ECB (2021) identified a knowledge gap concerning the potential bias from quality adjustment in the euro area HICP. In a case study with Austrian and Italian CPI micro prices, Conflitti et al. (2022) show that heterogeneous QA practices might well explain divergent HICP rates and trends across countries. In this vein, Statistics Austria predominantly uses explicit QA methods whereas Istat only uses implicit methods.[8] For a selection of non-energy industrial goods, the study does not find a strong measurement bias driven by quality adjustment. However, between both countries, the results suggest that

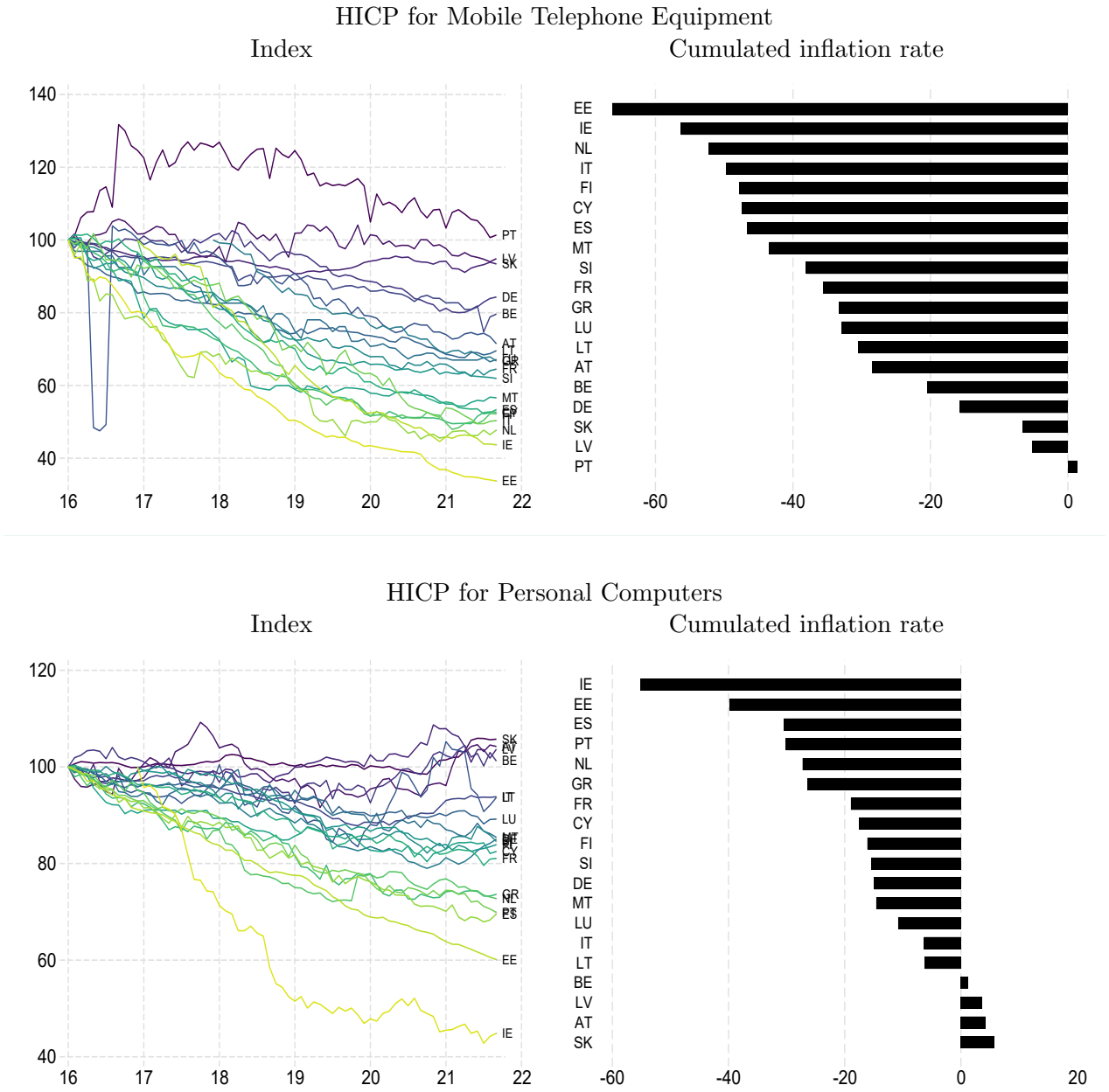
[5] See Ahnert and Kenny (2004), p. 25: *"At present, although only partial information is available on the precise quality adjustment practices at the national level in EU countries, it would seem that for many items a wide variety of different approaches are used and this may have resulted in widely divergent price developments for some individual goods and services."*

[6] Data at the lowest level of aggregation of the HICP, which refers to the 5-digit level of the European Classification of Individual Consumption according to Purpose (ECOICOP), only starts in 2015 for most euro area countries.

[7] Note that the HICP index "08.2.0.2 - Mobile telephone equipment" only comprises mobile phone handsets, whereas the mobile phone tariff falls under ECOICOP "08.3.0.2 - Wireless telephone services".

[8] Explicit methods infer quality changes by assumption or by direct computation with the help of product characteristics. By contrast, implicit methods gauge the impact of quality changes from other information.

Figure 1: Price developments for selected products



Note: The figure shows the HICP indices "08.2.0.2 Mobile telephone equipment" and "09.1.3.1 Personal computers" indexed to January 2016=100 and as cumulated inflation rate between January 2016 and September 2021. Data for Ireland and Finland are only available from December 2016 onwards. For Greece, HICP data on mobile telephone equipment only start in December 2017.

the implicit adjustment used in Italy explains a larger part of price changes due to product replacement with quality changes, in contrast to the explicit methods used in Austria. Overall, to the best of our knowledge, there is no study that estimates the impact of quality adjustment

on euro area inflation.

3 The impact of quality adjustment on the German CPI

In the current section, we make use of the micro price data underlying the German CPI to estimate the impact of quality adjustment on inflation. Moreover, this analysis also backs our selection of products which typically undergo quality adjustment that we use later in Section 4.

3.1 Data and definitions

According to the Federal Statistical Office of Germany (*Destatis*), various methods of quality adjustment are applied to the German CPI.[9] These include option pricing (e.g. for airbags in new cars) and (supported) judgemental quality adjustment (e.g. refrigerators with changed power consumption or washing machines with changed water and power consumption). Hedonic methods are applied to about 1.4% of the German CPI basket (e.g. desktop PCs, tablet PCs, notebooks, smart phones, printers and used cars). Finally, *Destatis* also accounts for changes in the quantity (e.g. package size) of a given product.

The micro price data underlying the German CPI has recently been made available for research purposes and has been applied by Adam et al. (2021) to analyse changes in relative prices over time, and Gautier et al. (2022) to investigate price setting in the euro area.[10] Prices are collected each month at the product level. Our sample covers the period from 2010:01 until 2020:12. After exclusion of imputed prices and aggregated price measures, the data set consists of about 50 million observations which represent roughly 85% of the HICP. The coverage varies somewhat between components, from 77% for unprocessed food to 79% for non-energy industrial goods, 90% for services, 94% for processed food and 100% for energy. Overall, the data contains 716 different product groups at the COICOP10 level.

Concerning quality-adjusted products, the data set lacks some centrally collected goods and services that are deemed to be strongly affected by quality changes, such as computers, smart phones, and used cars. Hence, our analysis will present a *lower benchmark* to the impact of

[9] General information about the quality adjustment procedures used in the German CPI are provided by *Destatis* online here and in Appendix (D).

[10] See Appendix (A) for a description of the data set.

quality changes on German inflation. Moreover, the data set contains a statistical break in 2015:01, since *Destatis* revises the price collection and underlying methods typically every five years when a new consumption basked is introduced. Therefore, any analysis at the product level needs to be split into the periods before and after 2015.

Based on the German CPI micro data, we estimate the impact of changes in quantity and quality on consumer prices as follows. The data set contains two price variables: p^{raw} denotes the raw price as observed by the price collector in store. p^{adj} is the quantity- and quality-adjusted price which enters the official CPI compilation.[11] Among many other product information, the data set provides information about the quantity and the measurement unit of a product. For example, we know how many grams of rice are contained in one package or how many millilitres of milk are within one bottle, but also, how many minutes are spent in a guitar lesson.[12] The quantity-adjusted price is then computed in two steps. First, we define the unit-value price $p_{i,t}^{unit}$ by dividing the raw price $p_{i,t}^{raw}$ of a given product i in month t by its corresponding quantity $quan_{i,t}$:

$$p_{i,t}^{unit} = \frac{p_{i,t}^{raw}}{quan_{i,t}} \tag{1}$$

Second, we follow the approach of *Destatis* that calculates the quantity-adjusted price relative to the corresponding quantity of the base period, i.e., to the years 2010 and 2015. However, since the reference quantity is not included in our data set, we use the first available quantity of each product spell instead. Hence, denoting $t = 1$ as the reference period, the quantity-adjusted price $p_{i,t}^{quan}$ is given as:

$$p_{i,t}^{quan} = \frac{p_{i,t}^{unit}}{p_{i,t=1}^{unit}} p_{i,t=1}^{raw} \tag{2}$$

Regarding quality changes, our data set contains a variable $qual_{i,t}$ that indicates the price differential in EUR with respect to the previous month that is caused by a change in product quality; this is the case whenever the price collector samples a replacement product which differs in terms of quality from the predecessor product. We define the quality variable such

[11] A detailed variable description can be found in the corresponding meta data report, see, for example, Forschungsdatenzentren der Statistischen Aemter des Bundes und der Laender (2022).

[12] We cleaned these variables beforehand to avoid spikes in the data arising from re-definitions of measurement units and the like.

that *negative* values denote *quality improvements* meaning that the raw price will be lowered due to an increase in product quality. Likewise, a quality deterioration is captured by positive values. Thus, the quality-adjusted price is defined as:[13]

$$p_{i,t}^{qual} = p_{i,t}^{raw} + qual_{i,t} \tag{3}$$

Finally, to assess the impact of changes in product quantity and quality on inflation, individual product prices have to be aggregated to derive inflation measures. We closely follow the official CPI compilation in Germany at the lowest available product level, which is the COICOP 10-digit level. Specifically, we apply a weighting by federal states; for higher-level aggregates, we apply the expenditure share of a given product group. We end up with four inflation measures derived from the micro data set: π_t^{adj} denotes inflation derived from the adjusted price as reported in the micro data set, and π_t^{raw} denotes inflation derived from the raw price. π_t^{quan} and π_t^{qual} denote inflation derived from the quantity-adjusted price and quality-adjusted price, respectively. As reported in Table (A1), the resulting inflation rates move very closely with the official inflation rates, as reflected by a correlation coefficient generally above 0.8.[14] In Figure (A1) in the Appendix, we plot the inflation rates over time showing that micro price inflation follows official inflation very closely.

3.2 Impact of quality and quantity adjustment on German inflation

Using these definitions, we first take a closer look at the scope and the size of quantity and quality adjustment on the product level. To this end, in Table (1) and (2), we present results for 20 product groups in the German CPI with the largest quantity and quality adjustment in absolute terms for the two sub-samples 2010-2014 and 2015-2020, sorted by the latter period.

Quantity adjustment in the German CPI mainly affects food prices (e.g. apple juice, leek, lamb) in addition to non-durable and semi-durable goods (e.g. bird food, blank CDs, clothing). The share of adjustment varies across products, from about 80% for grapefruits, kiwis and cauliflower to about 7% for fresh fish and apple juice, but also between sub-samples. For example, only

[13] Note that, if a product is replaced with a product of higher or lower quality, we count all price observations of the follow-up product as being quality-adjusted.

[14] Although the correlation seems rather low with respect to non-energy industrial goods and services, this seems to be driven by limited periods at the beginning of the sample and by the missing service component package holidays, which is highly volatile in Germany.

Table 1: Quantity-adjusted products in the German CPI

COICOP10		% share		avg. size		CPI weight
		1014	1520	1014	1520	1520
934201200	Bird food	13.2	19.0	2.8	19.5	0.05
122311100	Apple juice or similar fruit juice	8.7	7.8	0.2	14.6	0.11
117119200	Leek or celery	7.7	15.9	1.9	14.4	0.01
112300100	Lamb	16.3	15.0	8.1	13.1	0.02
116115100	Grapefruit	78.2	79.4	27.8	12.4	0.01
914210100	Blank CDs	22.7	14.7	3.4	12.2	0.00
520301100	Table cloth, table runner or the like	0.8	4.7	1.0	12.2	0.02
312343100	Children's underwear	18.6	27.7	3.1	-11.2	0.02
116111100	Oranges	40.3	38.3	10.4	10.9	0.05
1213105300	Wet shaving razor, razor blades or the like	18.8	18.4	14.5	10.7	0.03
312161200	Men's underwear	10.7	18.9	-2.0	-9.8	0.02
116170200	Kiwis, ananas or mangos	5.2	78.8	6.9	9.6	0.05
121201100	Black tea or green tea	13.4	13.1	5.0	9.0	0.02
117121100	Cauliflower	81.2	83.4	4.7	8.1	0.01
113500100	Smoked fish	13.8	13.2	18.4	8.1	0.05
113100100	Fresh fish	2.8	6.5	5.1	8.1	0.05
116165100	Grapes	16.1	15.4	6.4	8.0	0.08
113200100	Frozen fish	21.8	36.6	4.7	7.9	0.04
114501100	Hard cheese	25.7	15.5	10.7	7.9	0.09
1213211100	Hair shampoo	15.0	28.9	4.8	-7.6	0.06

Note: The table shows the 20 COICOP10 groups with the largest absolute quantity adjustment from 2015 to 2020. *% share* denotes the fraction of products adjusted for quantity changes, and *avg. size* gives the average absolute size of the adjustment in percentage terms. 1014 and 1520 refer to the sub-samples 2010-2014 and 2015-2020. *CPI weights* gives the COICOP share in the CPI.

Table 2: Quality-adjusted products in the German CPI

COICOP10		% share		avg. size		CPI weight
		1014	1520	1014	1520	1520
1255000200	Premium for legal protection insurance	5.5	47.2	-0.8	5.5	0.17
1255000100	Premium for personal liability insurance	0.0	10.4	0.0	5.1	0.24
551102100	Impact drill	8.3	19.9	-0.7	-2.5	0.04
921101100	Camper	67.4	79.2	-1.1	-1.8	0.11
1120201100	Campsite fee	0.0	28.4	0.0	-1.7	0.04
531201200	Washing machine	53.2	60.1	-1.0	-1.6	0.13
711100100	New passenger car	66.1	67.8	-2.2	-1.6	2.39
531102100	Freezer or chest freezer	51.4	44.4	-1.6	-1.5	0.03
932111100	Football or other sports ball	5.1	7.1	-0.3	1.4	0.01
911250100	Satellite kit	17.3	11.0	-0.6	1.3	0.03
914920100	USB flash drive	11.7	9.0	-0.2	-1.2	0.04
712004100	Moped	0.0	17.6	0.0	-1.1	0.03
551102200	Cordless screwdriver or cordless drill	10.0	8.9	-0.0	-1.1	0.05
1111112100	Soups, hotel	5.4	5.8	0.1	1.0	0.00
1270402100	Classified advertisement in a newspaper	3.1	1.9	0.4	1.0	0.05
532900200	Electric kettle, egg boiler or the like	8.7	7.1	0.6	0.9	0.02
911210200	Television	40.5	60.8	-0.3	-0.9	0.34
531101100	Refrigerator	50.8	39.6	-1.9	-0.9	0.06
531103100	Fridge-freezer	54.5	55.2	-2.6	-0.8	0.05
531203100	Tumble dryer	46.2	51.7	0.0	-0.8	0.04

Note: The table shows the 20 COICOP10 groups with the largest absolute quality adjustment from 2015 to 2020. *% share* denotes the fraction of products adjusted for quality changes, and *avg. size* gives the average absolute size of the adjustment in percentage terms. 1014 and 1520 refer to the sub-samples 2010-2014 and 2015-2020. *CPI weights* gives the COICOP share in the CPI.

5% of the prices of kiwis, ananas and mangos have been quantity-adjusted before 2015, compared to about 80% thereafter. The size of the quantity adjustment is typically *positive* meaning that the raw price of a given product is adjusted upwards because it is sold with a lower quantity. Exceptions apply to some clothing products (children's and men's underwear) and hair shampoo. Also note that the size varies markedly between the two sub-samples under consideration.

Quality adjustment mainly affects prices of durable goods, in addition to some services. This is especially true for insurance premia where the price adjustment has been the largest among all products. Interestingly, the quality of these insurances has deteriorated which is suggested by the positive price adjustment. By contrast, quality adjustment of the remaining products has mainly led to a price decrease, in particular for cars, tools, washing machines and the like.

Finally, in Table (3), we compute the impact of quantity and quality adjustment on German headline inflation, as well as on the five main aggregates unprocessed food, processed food, energy, non-energy industrial goods (NEIG), and services. Two findings are worth to stress. First, the share of both quantity and quality adjustments has risen over time. About 3.5% of headline inflation has been quantity-adjusted from 2010 until 2014, compared to 6.1% after 2015. As suggested earlier, accounting for changes in the package size mainly affects food prices, and also, to a lesser extent, prices of services and industrial goods. Quality adjustment is somewhat less important (keeping in mind that we lack prices for some electronic products that are largely adjusted for quality changes), amounting to 2.8% and 4.4% for headline inflation mainly stemming from industrial goods and services. Second, we find that taking into account changes in quantity and quality has only a very low impact on headline inflation. Between 2010 until 2014, inflation has been quantity-adjusted downwards by -.02 percentage points and quality-adjusted by -0.06 percentage points, whereas since 2015, inflation has been increased by +0.06 percentage points due to a smaller underlying quantity but has been lowered by about the same amount due to quality improvements. Nevertheless, taking a more disaggregate view, these effects are more pronounced. Food prices have been adjusted upwards by about +0.3 percentage points during both sub-samples due to quantity changes, wheres prices of industrial goods and services have been lowered by about -0.1 percentage points due to higher quality.

Altogether, we find a negative, but quantitatively small impact of quality adjustment on the German inflation rate. Thus, without quality adjustment (and abstracting from quantity adjustment), the average inflation rate during the period 2010-2020 would have been higher by

Table 3: Impact of quantity and quality adjustment on German inflation

	% quan	% qual	π_t	π_t^{raw}	$(\pi_t^{quan} - \pi_t^{raw})$	$(\pi_t^{qual} - \pi_t^{raw})$
			2010-2014			
Total	3.5	2.8	1.75	2.20	-0.02	-0.06
Unprocessed food	14.0	0.9	2.54	0.49	0.36	-0.01
Processed food	11.0	1.6	2.68	1.56	-0.14	-0.01
Energy	0.1	0.5	3.83	3.69	0.00	0.01
NEIG	2.8	7.6	0.86	1.56	0.02	-0.16
Services	3.1	2.4	1.41	2.48	-0.03	-0.06
			2015-2020			
Total	6.1	4.4	1.07	1.35	0.06	-0.06
Unprocessed food	13.0	0.7	2.14	1.08	0.33	-0.01
Processed food	11.1	0.9	1.81	1.29	0.23	0.00
Energy	0.4	0.2	-1.22	-1.95	0.00	0.00
NEIG	2.6	5.1	0.80	1.39	0.04	-0.11
Services	6.6	4.7	1.54	2.23	0.00	-0.08

Note: The table reports the impact of quantity and quality adjustment on German inflation. The columns *% quan* and *% qual* give the fraction of price observations that have been adjusted for changes in quantity and quality. π_t lists the official inflation rate published by *Destatis*, and π_t^{raw} the inflation rate derived from the raw price as reported in the micro price data. $(\pi_t^{quan} - \pi_t^{raw})$ and $(\pi_t^{qual} - \pi_t^{raw})$ report the difference between adjusted and unadjusted micro price inflation.

about +0.1 percentage points only. This is well below other estimates for consumer price inflation, as for Germany during the pre-Euro period (Hoffmann, 1998: +0.5 percentage points during a moderate inflation regime) and more recently for Sweden (Statistics Sweden, 2019: +0.3 percentage points). Nevertheless, as stated before, our data set misses some centrally collected prices of products which typically undergo quality adjustment. Thus, our results can be considered as a lower bound of the impact of quality adjustment on German inflation.

4 The impact of quality adjustment on euro area inflation

Measuring the impact of quality adjustment on consumer price inflation in the euro area, which currently consists of 19 member countries, is challenging because of the lack of detailed and harmonised micro price information. We try to tackle this by means of two approaches. First, we follow a macro-based approach which builds upon the official inflation series and selects product categories whose prices are typically affected by quality change. Based on the dispersion across member states' cumulative inflation rates, we derive a range for euro area headline and core inflation that we interpret as an estimate for the impact of quality adjustment on the HICP

(Section 4.1). Second, we illustrate the role of heterogeneous QA methods across euro area countries by means of micro price data for washing machines (Section 4.2).

4.1 Estimating the impact of quality adjustment in euro area inflation based on typical quality-adjusted products

Whereas there is a rich documentation of available methods and recommendations on quality adjustment for the euro area HICP,[15] eventually, little is known on the detailed share of and applied methods at the product level. Section (A) in the Appendix reproduces all public information from Eurostat's HICP Monitoring Reports about QA practices across euro area member states. Based on this, Table (4) summarises the list of product groups whose prices are typically adjusted for quality changes in euro area member states.

Overall, almost all member states adjust prices of cars, clothes and footwear as well as electronic products. In some cases, also prices of food (France, Latvia, Lithuania, Germany) or package holidays (Estonia, Slovakia) are quality-adjusted. Concerning the share of quality-adjusted products, three countries report detailed figures: In its Monitoring Report 2015, Germany indicates to adjust 5-10% of its HICP, followed by Austria with 4.6% in 2016 and Slovenia with 0.4% in 2019. In addition to the heterogeneous selection of product groups, the applied QA methods vary strongly between countries. Whereas a detailed discussion of the pros and cons of these methods is beyond the scope of this paper and has a strand of literature on its own (see, for example, Groshen et al., 2017), it is important to note that NSIs also consider adjusting prices for a change in package size as a QA method. Hence, quality adjustment should not only matter if an existing product is replaced with a new one but should also apply to the same product if only its quantity (e.g. package size) has been changed.

Based on the list of quality-adjusted products in Table (4), we define two sets of products that we believe to be rather homogeneous and hence, whose price trends should not differ too much between euro area countries. In a narrow sense, this set consists of telephones, radio and television sets, photographic instruments, information processing equipment and data storage media. More broadly, we add major household appliances, small electric household appliances, pharmaceutical products, medical products, therapeutic appliances, cars and bicycles and durable

[15] See, for example, Eurostat (2018).

Table 4: Quality-adjusted product groups in the HICP

Country	Products
Austria	Clothing and footwear, recreation and culture (books, DVDs, CDs), telecommunication, durable goods and cars.
Belgium	Cars, video games, CDs, DVDs, books, clothing and footwear.
Cyprus	Electronics, cars.
Estonia	Cars, mobile phones, clothing and footwear, restaurants and cafés, package holidays.
Finland	Cars.
France	Durable goods, clothes, cars, newspapers, books.
Germany	Clothing and footwear, technical products, books, CDs, downloads, computer games, software, cars, electronics, residential property.
Greece	No information available.
Ireland	Clothing and footwear, cars, electronics, CDs, DVDs.
Italy	Clothing and footwear, processed or fresh food, electronics, DVDs, fuels, cars.
Latvia	Cars, electronics, fruit, vegetables, clothing and footwear, books.
Lithuania	Food and beverages, clothing and footwear, furnishings, household equipment, cars, electronics, books.
Luxembourg	Cars.
Malta	Cars, laptops, mobile phones, cameras, clothing and footwear, books, recording media, computer games.
Netherlands	Clothing and footwear, tobacco, cars, electronics, boats.
Portugal	Cars, clothing and footwear, mobile phones.
Slovakia	Package holidays, cars, clothing and footwear, books, CDs, computer games.
Slovenia	Electronics, household appliances, cars, clothing and footwear, books, DVDs, computer games, medicaments, audio-video equipment, PCs.
Spain	Cars, food, medicines, personal care, fresh food, clothing and footwear, furniture, household appliances, restaurants.

Note: List of product groups whose prices are adjusted for quality changes by NSIs. Information is collected from the individual HICP Monitoring Reports published at Eurostat's web page https://ec.europa.eu/eurostat/web/hicp/methodology, also reproduced in section (A) in the appendix.

consumer goods.[16] In terms of the euro area HICP, the narrowly defined set of products makes up 1.7% of the total basket and the more broadly defined set 9.0%. Compared to the practice followed by NSIs, our choice might well miss-classify some products in some countries. Nevertheless, Reinsdorf and Schreyer (2019) argue that digitalisation should also affect prices of products in categories such as restaurants, accommodation and other services which would call for an even larger set of products whose prices are likely to depend on quality changes. In this respect, our choice will be rather cautious instead of overstating the effect of quality adjustment on inflation. To be able to classify quality-adjusted products as exactly as possible, we have used the lowest index level in the HICP, the so-called COICOP5. This has the drawback that, for most countries, inflation series at this level of aggregation are only available from 2015 onwards or even later, but we have repeated the analysis at the higher level of COICOP4 leaving the

[16] Table (B1) in the appendix reports the selected products in detail.

results broadly unchanged.

We then compute a band for the impact of quality adjustment on euro area inflation along the following lines:

1. For all products according to the narrow or broad definition of quality adjustment, we compute the minimum and maximum cumulated inflation rates across countries from January 2016 until present, i.e. the rate of change between the first and last index period.

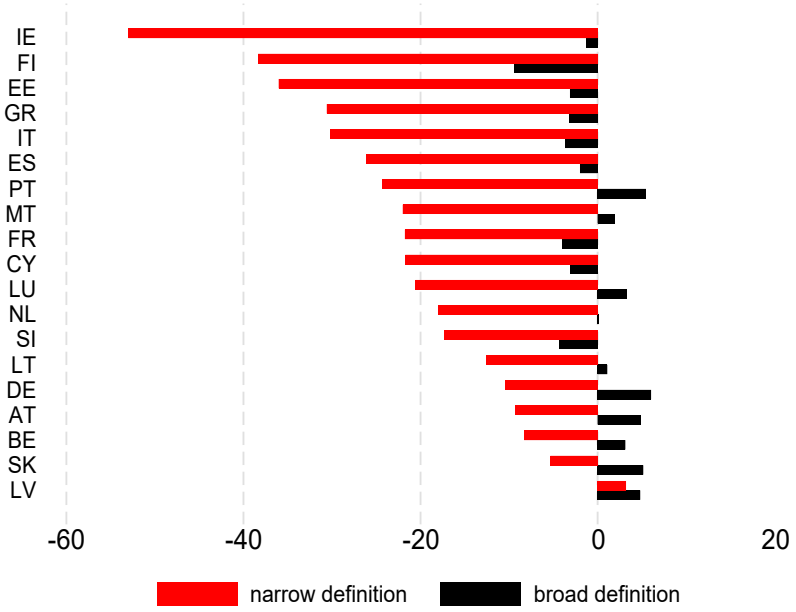
2. Next, we replace the countries' price indices of the selected products with the price index of those countries with the lowest and highest cumulated inflation rate. Returning to the mobile phone example, we find that Estonia has the lowest cumulated rate from 2016 to present and Portugal the highest. Hence, we replace the price index of mobile phones in all countries with the Estonian one when computing the lower range and with the Portuguese one when computing the upper range.

3. Using product and country weights, we aggregate the adjusted price series to obtain an upper and a lower range for quality-adjusted euro area headline and core inflation; we interpret this range as an estimate for the impact of quality adjustment on the euro area HICP.

The resulting quality-adjusted inflation rates by country are shown in Figure (2). The picture for the narrowly defined set of quality-adjusted products broadly mirrors the one for mobile phones. In contrast, the pattern looks quite different for the broad definition of products for which we observe as many negative inflation rates as positive ones.

Obviously, heterogeneous QA practices are not the only driver of inflation differentials between euro area countries. In a perfect world, their impact would be zero and homogeneous goods should only be priced differently according to the local individual preferences, market structure, local distribution costs and living conditions. Since the first two aspects are hard to measure, we focus on the latter aiming to explain euro area price differentials that are driven by heterogeneous

Figure 2: Cumulated inflation rates of quality-adjusted products by countries



Note: The figure shows the weighted average of the cumulated inflation rates of products affected by quality adjustment defined narrowly and broadly from January 2016 onwards.

living standards and business cycle conditions across member states.[17] Thereby, we follow Crucini et al. (2005) and regress the monthly country- and product-specific inflation rates $\pi_{c,i,t}$ on national GDP per capita:

$$\pi_{c,i,t} = \alpha + \beta_{i,c} GDPC_{c,t} + \varepsilon_{c,i,t}, \tag{4}$$

where $GDPC_{c,t}$ is the year-on-year growth rate of national GDP per capita (linearly interpolated from quarterly to monthly figures), c represents a euro area country and i a quality-adjusted product according to the narrow or broad definition. In this regression, we allow for the possibility that income growth affects prices of each product group in each country differently. Note

[17] The related literature can be distinguished into studies that explain price differentials within the euro area by Phillips curve type regressions (Honohan and Lane, 2003, Angeloni and Ehrmann, 2007, Lagoa, 2017) and into papers that analyse deviations from the law of one price using micro price data (Crucini et al., 2005, Lipsey and Swedenborg, 2010, Fischer, 2012, Crucini and Yilmazkuday, 2014). An earlier overview of the topic is provided by Deutsche Bundesbank (2009). Our approach is inspired by these studies, although it is not our goal to fully explain price differentials by testing and adding different explanatory variables. By contrast, we seek to estimate the (unobservable) impact of the different QA procedures conditional on income differentials between euro area countries.

that we refrain from including country- and time-fixed effects since these would basically take out the unobserved impact of country-specific QA practices. We interpret the residuals of this regression as the annual inflation rates net of income differentials.[18] In order to rule out that our estimates are affected by the Covid-19 pandemic, we split the estimation sample into a pre-Covid period from 2016:01 to 2020:02 and a Covid period from 2020:03 to 2021:09.

The resulting estimates for the impact of quality adjustment on the euro area HICP are summarised in Table (5). Over the period 2017 to 2020, we observe an average increase of 1.5% for headline inflation and 1.0% for core inflation using the aggregate series as published by Eurostat. Note that aggregating these rates ourselves by combining the available disaggregate inflation series at the COICOP5 level results in some rounding differences with official figures, since the disaggregate series are published only with one decimal or, in a very few cases, are not published due to confidentiality reasons.[19]

Concerning the potential impact of heterogeneous QA practices, the second and third rows of Table (5) report the upper and lower bound of the inflation rates adjusting the price index of the narrowly defined quality-adjusted products. Likewise, the fourth and fifth rows give the limits of the products defined more broadly. Computing the difference between these limits provides us with a range that we interpret as an estimate for the impact of quality adjustment on euro area inflation. According to our approximation, this estimate varies between $\pm$ 0.2 and 0.6 percentage points for headline inflation and between $\pm$ 0.3 and 0.8 percentage points for core inflation. Controlling for the impact of income differentials between countries, the impact of quality adjustment is reduced by up to $\pm$ 0.2 percentage points for headline inflation and $\pm$ 0.1 to 0.3 percentage points for core inflation.

Regarding the Covid period, the results shown in the lower panel of Table (5) yield a fairly similar estimate of the impact of heterogeneous QA methods on inflation without controlling for income differentials. However, accounting for income changes actually *does not lower* this estimate, which suggests that our simple regression approach is not able to capture all the different economic and statistical effects of the pandemic such as lock-down measures and estimated missing prices ("imputations") in an adequate way.

[18] Alternatively, we could have allowed for country-specific income effects and fixed effects interpreting the contribution of the latter as the impact of quality adjustment net of income effects.

[19] Since the HICP is a chain-linked price index, simply averaging the disaggregate inflation series would be incorrect; therefore, we first unchain the disaggregate price indices, compute the average and rechain again.

Table 5: The impact of quality adjustment on the euro area HICP, 2017-2021

2017:01-2020:02

	unadjusted for income		adjusted for income	
Inflation:	Headline	Core	Headline	Core
Official rates	1.5	1.0		
Own agggregation	1.5	1.0		
Narrowly defined products:				
Minimum rate	1.3	0.8	1.5	1.0
Maximum rate	1.5	1.1	1.5	1.1
Broadly defined products:				
Minimum rate	1.1	0.5	1.4	0.9
Maximum rate	1.7	1.3	1.6	1.2
Range:				
Narrow definition	0.2	0.3	0.0	0.1
Broad definition	0.6	0.8	0.2	0.3

2020:03-2021:09

	unadjusted for income		adjusted for income	
Inflation:	Headline	Core	Headline	Core
Official rates	0.9	0.9		
Own agggregation	0.9	0.8		
Narrowly defined products:				
Minimum rate	0.8	0.7	0.8	0.7
Maximum rate	1.0	1.0	1.0	1.0
Broadly defined products:				
Minimum rate	0.6	0.4	0.6	0.4
Maximum rate	1.2	1.3	1.2	1.3
Range:				
Narrow definition	0.2	0.3	0.2	0.3
Broad definition	0.6	0.9	0.6	0.9

Note: *Official rates* refers to the euro area HICP published by Eurostat, *own aggregation* gives the euro area inflation rates aggregated from disaggregate national inflation rates. The *minimum rates* and *maximum rates* denote the lowest and highest inflation rates of adjusting products affected by quality adjustment narrowly and broadly. *Range* gives the difference between the maximum and minimum rates.

Finally, it is important to note that our regression results can themselves be distorted by the impact of quality adjustment in different member states. If the link between income growth and "true" inflation is actually positive, but if the QA practice introduces a bias, the observed correlation will be lowered or estimated with the wrong sign. Keeping this in mind, plotting our estimate for the impact of quality adjustment over time in Figures (B1) and (B2) in the appendix suggests that for the pre-Covid period, the impact of quality adjustment tends to be negative for the inflation rates without controlling for income differentials, meaning that inflation would have

been lower if QA practices had been more harmonised across countries. However, controlling for income differentials yields a small positive impact of quality adjustment. These conflicting results point to the limits of this simple approximation of the impact of quality adjustment, which is why we turn to a more precise measure based on micro price data in the next section.[20]

4.2 Estimating the impact of quality adjustment based on transaction data for washing machines

To illustrate the potential impact of different QA methods on euro area inflation, we apply a micro data set from the GfK for washing machines. The data set stems from the GfK Point-of-Sales (POS) panel, which covers about 60 countries worldwide. The POS panel is a regular, comprehensive survey to monitor sales of so-called Slow-Moving Consumer Goods (SMCG) such as consumer electronics, major and small domestic appliances, and automotive. The purchases recorded include both in-store and online purchases. Our data set comprises ten euro area countries for two separate periods, 2000:01-2005:12 and 2017:01-2021:05:[21] Austria, Belgium, Finland (from 2003 onwards), France, Germany, Greece (until 2005), Italy, the Netherlands, Portugal and Spain. The frequency of the first sample runs at a two-monthly basis, whereas the second sample covers monthly data. In addition to prices and volumes (sales), several physical features of the specific washing machine model are included, such as load capacity, spinning speed and construction type. For the more recent period, the data set also covers information on energy efficiency, the noise level, spin efficiency and whether the washing machine is equipped with any smart connect functions.[22]

To set the scene for the analysis, imagine the following scenario. The GfK POS panel covers the population of washing machines available to consumers along with their prices, volumes and

[20] Note that, within this macro-based approach, we also cannot take into account several other differences in inflation measurement across NSIs in the euro area that might affect inflation and are unrelated to quality adjustment, such as differences in the sampling of products, in the definition of elementary products, in the treatment of sales, in the use of auxiliary data sources like scanner or webscraped data, as well as in the index formula used for aggregation.

[21] The GfK data set of the first period has been also used by Fischer (2012) who studied prices for washing machines in euro area countries to test for price convergence in the aftermath of the euro introduction. Likewise, several studies have investigated price convergence in single markets in the euro area, see for example Goldberg and Verboven (2001, 2005) and Brenkers and Verboven (2006) who take a detailed look at the European car market. Interestingly, these papers find a clear tendency towards price convergence until the euro introduction whereas Dvir and Strasser (2018) show that car prices do not converge further after 2003. More recently, Duch-Brown et al. (2020) also use a GfK data set (for portable computers) to analyse the impact of online market integration on consumer prices.

[22] See Table (C1) in the appendix for a description of variables.

features. Each NSI then somehow samples from this population to represent washing machines in their national CPI. Based on the samples, price indices are calculated using the nationally available data (e.g. sales information or just price quotes) and specific methodological choices, in particular on QA procedures. At all steps of the process, differences in the compilation practices between statistical offices can and will occur, be it because of differences in the available data or in the methodological choices. What we are limiting our analysis here to is the narrow field of quality adjustment.

To this end, we compute for each of the ten euro area countries in our sample different transaction-based price indices. For this purpose, we rely on three prominent approaches which are used in official price statistics to varying degrees and that can be considered to cover the range from "best practices procedures" to "no quality adjustment".[23] These three approaches are then compared to official HICP data.

First, we estimate a *Time-Dummy Hedonics* (TDH) regression, which represents "explicit" quality adjustment based on observable product characteristics. Thereby, we run a hedonic price regression to obtain a quality-adjusted washing machine price per time period. The below semi-logarithmic regression equation is estimated for any given country based on pooled data over all periods $t = 0, \ldots, T$:

$$\ln p_k = \beta_0 + \sum_{t=1}^{T} \delta^t d_k^t + \sum_{j=1}^{p} \beta_j z_{kj} + \varepsilon_k, \tag{5}$$

where p_k denotes the price of washing machine model k in a given country, the time-dummy variable d_k^t has the value 1 if the observation of washing machine k comes from period t and 0 otherwise, and z_{kj} is the j-th product characteristic of model k. The vector of product characteristics for the first sample 2000-2005 closely follows Fischer (2012) and consists of five variables, namely the load capacity in kg, the spinning speed, the degree of automation and the presence of a drying function, the loading direction, the construction type, as well as brand-specific dummies.[24] For the second sample, four additional variables (energy efficiency, noise level, smart connect functions, and spin efficiency) are added. Equation (5) is estimated by

[23] See International Monetary Fund (2020), Chapter 6 on quality adjustment, and Chapter 10 on price indices in the context of transaction (scanner) data.

[24] We differ from Fischer (2012) by estimating the hedonic regression for each country separately, allowing the shadow prices to vary by country, and weighting each observation by its expenditure share rather than the number of sales, as is common practice in index compilation. Moreover, we focus on gross prices including the value-added tax (VAT) rate, since the HICP also comprises VAT charges.

weighted least squares, with observations weighted by their corresponding expenditure share to properly represent the local market structure. The quality-adjusted price index, I_t, can be derived directly from the exponential of the coefficient on the time dummy:

$$I_{TDH}^{0:t} = 100 \times \exp(\hat{\delta}^t). \tag{6}$$

Second, we perform what is known as an "implicit" quality adjustment by means of a *Time-Product Dummy* (TPD) regression. Here, quality adjustment is performed by controlling for differences in the levels of the prices of washing machine models k as identified by the combination of brand and the specific model. The hedonic regression equation simplifies to:

$$\ln p_k = \beta_0 + \sum_{t=1}^{T} \delta^t d_k^t + \sum_{k=1}^{K-1} \gamma_k D_k + \varepsilon_k, \tag{7}$$

where D_k represents a dummy variable which equals 1 if the price relates to model k and 0 otherwise. Again, a quality-adjusted price index can be derived from the exponential of the coefficient on the time dummy, such that:

$$I_{TPD}^{0:t} = 100 \times \exp(\hat{\delta}^t), \tag{8}$$

Finally, we also consider a price index method which does not comprise any quality adjustment at all. For this purpose, we compute a *Unit Value* (UV) price index such that:

$$I_{UV}^{0:t} = \frac{\sum_{k=1}^{K^t} p_k^t \times q_k^t}{\sum_{k=1}^{K^t} q_k^t} \Bigg/ \frac{\sum_{k=1}^{K^0} p_k^0 \times q_k^0}{\sum_{k=1}^{K^0} q_k^0}, \tag{9}$$

where q_k^t (q_k^0) denotes the sales of the k-th model in period t (0).

Comparing these three transaction-based price index methods with official HICP data faces some caveats. First, the comparison is limited due to the unavailability of official data at a more disaggregate level. The best candidate for comparison, "05.3.1.2 Clothes washing machines, clothes drying machines and dish washing machines", is only available from December 2016 onwards. The closest match for the period before can be found for the HICP subindex "05.3

Household appliances", which captures mainly major household appliances.[25] However, given that the subindex "05.3.1.2" makes up about one-fourth of the higher-level index "05.3 Household appliances", we argue that the overall trend of the latter should also reflect the price development of washing machines.[26] Second, even for the more recent sample, there is no official price index solely for washing machines, which are grouped together with drying and dish washer machines. However, as stated by Fischer (2012), cross-country price deviations of washing machines should expected to be similar for drying and dish washing machines. Third, the meta data on the sampling and quality adjustment at the national level are limited. Going back to the ideal scenario, it should be possible – with the right choice of subset of observations and using different methodologies – to replicate the official HICP data.

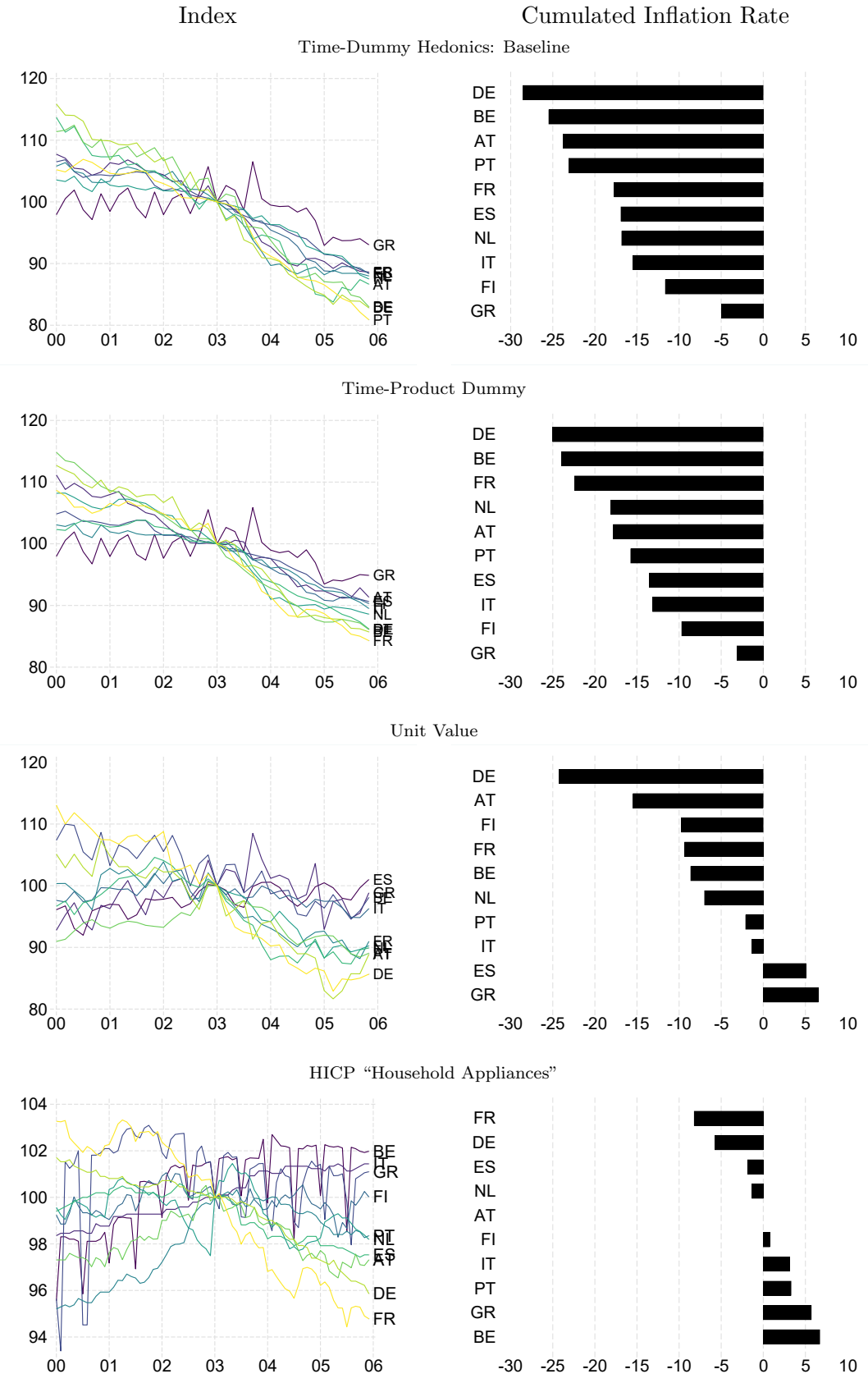
Figure (3) shows the transaction-based price indices and the cumulative rate of change from 2001 to 2005, together with the HICP counterpart "05.3 Household appliances". The resulting cumulative rates of change are consistently negative when applying the same hedonic quality adjustment across countries. In comparison to the unadjusted case of the *Unit Value* approach, the range of hedonic measures is also smaller, with a range between -3% and -29% vs. +7% and -24% in the unadjusted case. In comparison to the quality-adjusted transaction-based price indices, the cumulated rates of the HICP subindex "Household appliances" deviate less from each other in terms of the range (from 6% to -8%), but more in terms of the sign of the overall price trend, with five out of ten countries indicating a positive increase over time. Also note that all three methods do not provide a seasonal pattern for prices of washing machines as in the case of the official HICP figures for some countries (Belgium and Greece).

Figure (4) compares our transaction-based price indices and the cumulative rate of change for the later period from 2017 onwards, together with the more disaggregate HICP series "05.3.1.2 Clothes washing machines, clothes drying machines and dish washing machines". Unlike during the first period, the unadjusted case of a *Unit Value* price index signals now a strong price increase over time for all countries under consideration. This could be related to the fact that this index method is unable to control for compositional changes in the basket of washing machines, with consumers switching to more sophisticated, but also more expensive products

[25] According to the euro area HICP weighting scheme in 2017, the HICP "05.3 Household appliances" consists of three sub-indices: "05.3.1 Major household appliances whether electric or not" (71%), "05.3.2 Small electric household appliances" (21%), and "05.3.3 Repair of household appliances" (8%).

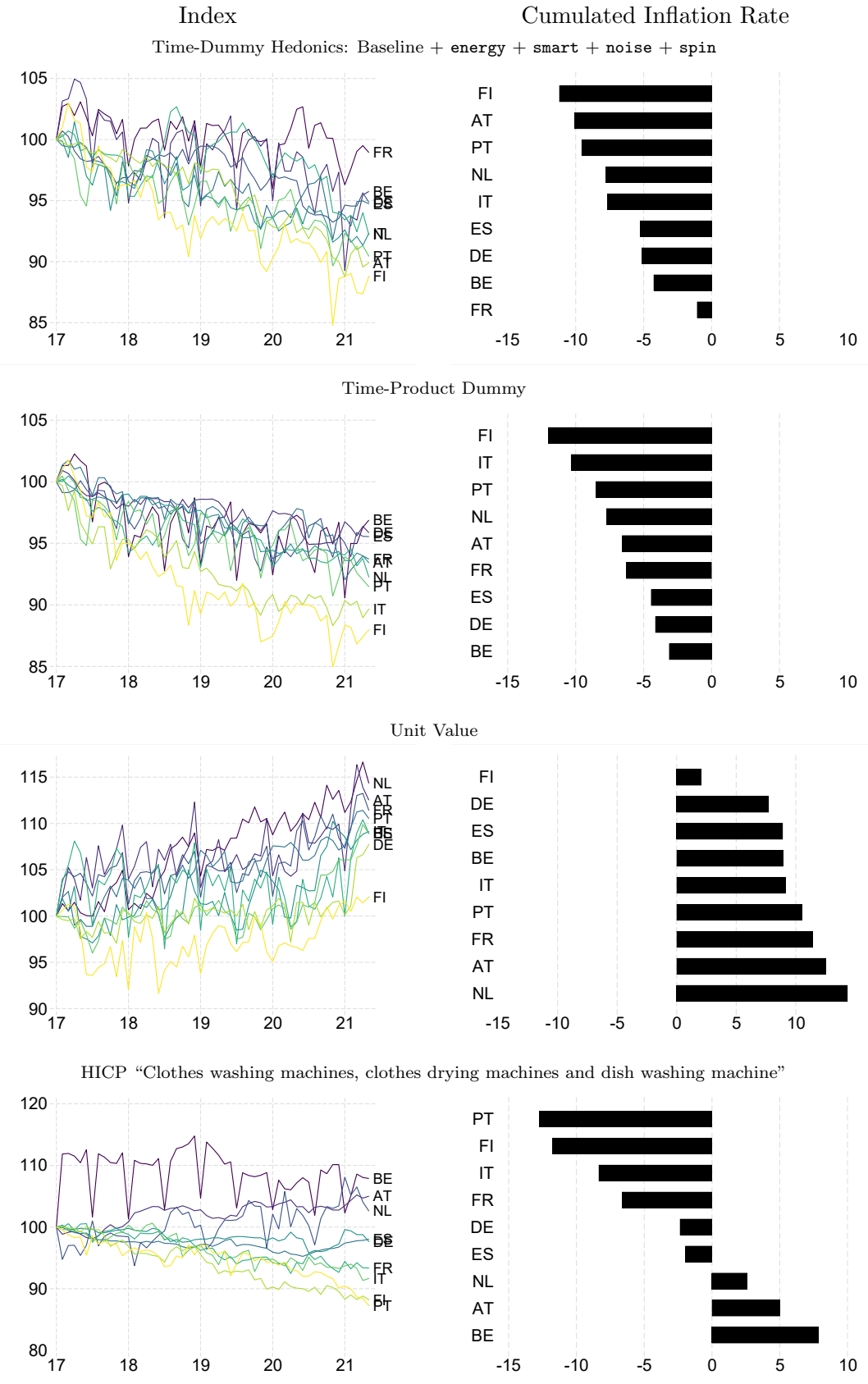
[26] A strong comovement between both series can be observed with the start of the more disaggregate series in December 2016, as reflected in Figure (C3) in the appendix.

Figure 3: Transaction-based price indices for washing machines vs. HICP, 2000-2005



Note: The figure shows the three transaction-based price indices (weighted by turnover) and the HICP series "05.3 - Household Appliances" for the years 2000-2005, indexed to January 2003=100 as well as cumulated inflation rates between 2001:01 and 2005:12. Data for Finland are only available from January 2003 onwards.

Figure 4: Transaction-based price indices for washing machines vs. HICP, 2017-2021



Note: The figure shows the three transaction-based price indices (weighted by turnover) and the HICP series "05.3.1.2 Clothes washing machines, clothes drying machines and dish washing machines" for the years 2017-2021, indexed to January 2017=100 as well as cumulated inflation rates between 2017:01 and 2021:05.

over time, known as the *Unit Value Bias*. In contrast, the resulting cumulative rates of change are consistently negative when applying the same hedonic quality adjustment across countries, as derived from the *Time-Dummy Hedonics* and *Time-Product Dummy* method. In comparison to the HICP subindex, the latter again signals mixed price trends across countries during the years 2017-2021. Figures (C1) and (C2) in the appendix also reflect various specifications of the *Time-Dummy Hedonics* method for the period 2017-2021. It reveals the sensitivity of the regression specification, with diverging price trends according to the baseline estimation (i.e. without controlling for more recent model features such as energy efficiency and smart control). Thus, the resulting price trend is not only depending on the chosen method, but also on the variable selection.

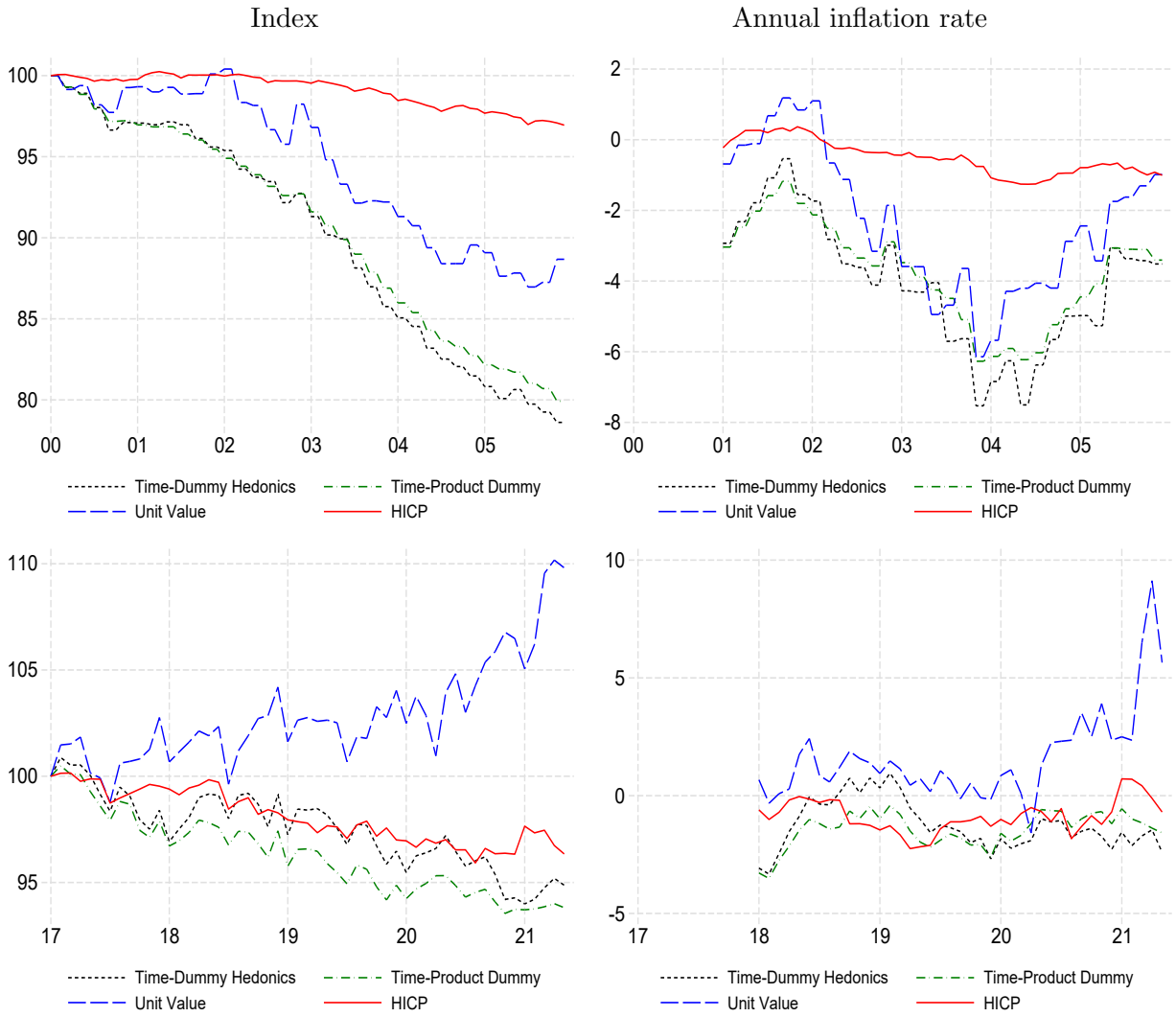
Finally, aggregating all transaction-based country indices using HICP country weights yields an estimate for euro area inflation of washing machines. For this purpose, we only use those eight euro countries with transaction data consistently available in both periods (i.e. excluding Finland and Greece). The results shown in Figure (5) again point to the fact that our quality-adjusted price indices yield a much stronger price decline compared to the official price index. In terms of monthly annual rates, during the first period under consideration, prices of washing machines declined on average by -0.5% as measured by the HICP, compared to rates between -4.1% using *Time-Dummy Hedonics* and -3.8% using *Time Product Dummy*. For the second period starting in 2017, differences become smaller, with prices of washing machines declining on average by -0.9% as measured by the HICP, compared to rates of -1.4% using *Time Product Dummy* and -1.3% using *Time-Dummy Hedonics*. Hence, *ceteris paribus*, this would result in a positive impact of quality adjustment on euro area inflation for washing machines of about 3.5 percentage points during the early years of the euro and of about half a percentage point in the more recent sample, which is quite substantial.

Concerning the ideal scenario described above, we could not perfectly reproduce the price changes as shown by the HICP subindex, notably due to limited information on QA methods as well as the unavailability of a more disaggregate HICP benchmark for washing machines. Hence, deviations between both series should not be interpreted as the impact of quality adjustment only.[27] Nonetheless, a pronounced pattern appears when comparing our transaction-based price indices and the official HICP subindex, namely consistently declining price trends across coun-

[27] As shown by Henn et al. (2019) for German package holidays, different data sources (transaction prices vs. offer prices) can also play a role.

tries. This also calls into question the QA procedures applied for the specific product "washing machines" in some of the euro area countries under consideration. Moreover, the crucial role of the choice of QA methods for the resulting price trend is also in line with micro-price findings by Conflitti et al. (2022) for Austria and Italy.

Figure 5: Transaction-based euro area price index for washing machines



Note: The figure shows the euro area aggregate price indices and annual inflation rates of washing machines derived from GfK data and from the official country-specific HICP subcomponents "05.3 - Household Appliances" (2000:01-2005:12) and "05.3.1.2 Clothes washing machines, clothes drying machines and dish washing machines" (2017:01-2021:05). Aggregation uses country weights of Austria, Belgium, Germany, Spain, France, Italy, the Netherlands, and Portugal.

5 Conclusion

In this paper, we have tried to shed some light on the impact of quality adjustment on consumer price inflation in Germany and the euro area. Based on micro and macro price data, we have documented several stylized facts. First, for Germany, we find that quality adjustment applies to a large range of goods and services but, on average, price adjustments due to quality changes reduces headline inflation only by 0.06 percentage points, which is balanced out by an increase due to quantity adjustment (e.g. a smaller package size) of the same amount. Second, we have provided an approximation of the range of euro area headline and core inflation that could be spanned by heterogeneous QA practices across euro area countries. According to our estimate, the impact of quality adjustment varies between ± 0.2 and 0.6 percentage points for headline inflation and between ± 0.3 and 0.8 percentage points for core inflation, depending on the definition of narrowly or broadly defined products affected by QA. Controlling for income differentials between countries, the impact of quality adjustment is reduced up to ± 0.2 percentage points for headline inflation and ± 0.1 to 0.3 percentage points for core inflation. Finally, we have illustrated the impact of heterogeneous QA methods in the euro area at the product level based on GfK transaction data for washing machines for a early-Euro period (2000 to 2005) and a more recent period (2017-2021). We find that euro area inflation of washing machines would have been lower by about 3.5 percentage points during the first years of the euro area and by about half a percentage point during recent years if prices had been quality-adjusted in the same way across countries.

Overall, our estimate of the impact of heterogeneous QA methods on euro area inflation is quite substantial and of similar magnitude in comparison to measurement biases in the HICP due to substitution or the lack of owner-occupied housing (ECB, 2021). Hence, this would call for a further harmonisation of QA methods across member states to reduce or eliminate their impact on euro area inflation. On top, more efforts should be made to quantify both the size and the direction of the impact of quality adjustment in euro area inflation with greater accuracy, such as it is regularly done, for instance, by Statistics Sweden (2019). Concerning future research, it would be worth to repeat our exercise with more recent micro price data, importantly by covering more euro area countries and a larger set of products and even services.

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Appendix A The impact of quality adjustment on the German CPI

German CPI micro data

The German CPI micro data set contains more than 77 million of observations for the period 2010:01-2020:12. The database is provided by the Research Data Centres (RDC) of the Federal Statistical Office and Statistical Offices of the Federal States and publicly available for research purposes.[28] Most prices are decentrally collected by the Federal States. Concerning individual price information, the database contains flag indicators on sales, replacements and imputation of the individual price (e.g. carry-forward in case of a missing price) as well as information on quality and quantity adjustment. The lowest level of product category with weight information is the COICOP10 level (e.g. "01.1.1.1.01100 - Rice"); after excluding imputed prices and aggregated price measures, our underlying data set contains 716 product categories at the COICOP10 level. The product id is constructed based on a combination of five variables (region, store id, COICOP10 number, survey id and product variant). Due to the regular revision of the survey id with every new base year, the data set contains a statistical break in 2015:01; thus, all statistics are computed on each subsample separately (base year 2010: 2010:01-2014:12 and base year 2015: 2015:01-2020:12).

Inflation measures derived from German CPI micro data

Table A1: Official CPI inflation vs. micro price inflation

HICP component	π_t^{adj}	π_t^{raw}	π_t^{quan}	π_t^{qual}
total	0.84	0.84	0.83	0.84
unprocessed food	0.84	0.81	0.83	0.81
processed food	0.64	0.63	0.56	0.62
energy	0.99	0.99	0.99	0.99
NEIG	0.28	0.35	0.29	0.36
services	0.22	0.18	0.18	0.18

Note: The table reports the correlation coefficients of the official inflation rates as reported by the Federal Statistical Office of Germany compared with the four different rates computed from the micro price data set from 2015:01 to 2020:12. π_t^{adj}: inflation adjusted for quality and quantity changes; π_t^{raw}: raw inflation without any adjustments; π_t^{quan}: inflation adjusted for quantity changes; π_t^{qual}: inflation adjusted for quality changes. NEIG: non-energy industrial goods.

[28] See "Verbraucherpreisindex für Deutschland", EVAS 61111, 2010 - 2019, DOI: https://doi.org/10.21242/61111.2010.00.00.3.1.0 to https://doi.org/10.21242/61111.2019.00.00.3.1.0.

Figure A1: Official inflation rates and micro price inflation in Germany

Note: The figure shows year-on-year inflation rates for Germany for both headline inflation and five subcomponents. π_t^{adj}: micro price inflation adjusted for quality and quantity changes (based on "adjusted price" variable); π_t^{raw}: micro price inflation without any adjustments (based on "raw price" variable); π_t^{HICP}: official CPI inflation.

Figure A2: Unadjusted and quality-adjusted micro price inflation in Germany

Figure A3: Unadjusted and quantity-adjusted micro price inflation in Germany

Appendix B Estimating the impact of quality adjustment in euro area inflation based on typical quality-adjusted products

Table B1: Defining a list of typical quality-adjusted products

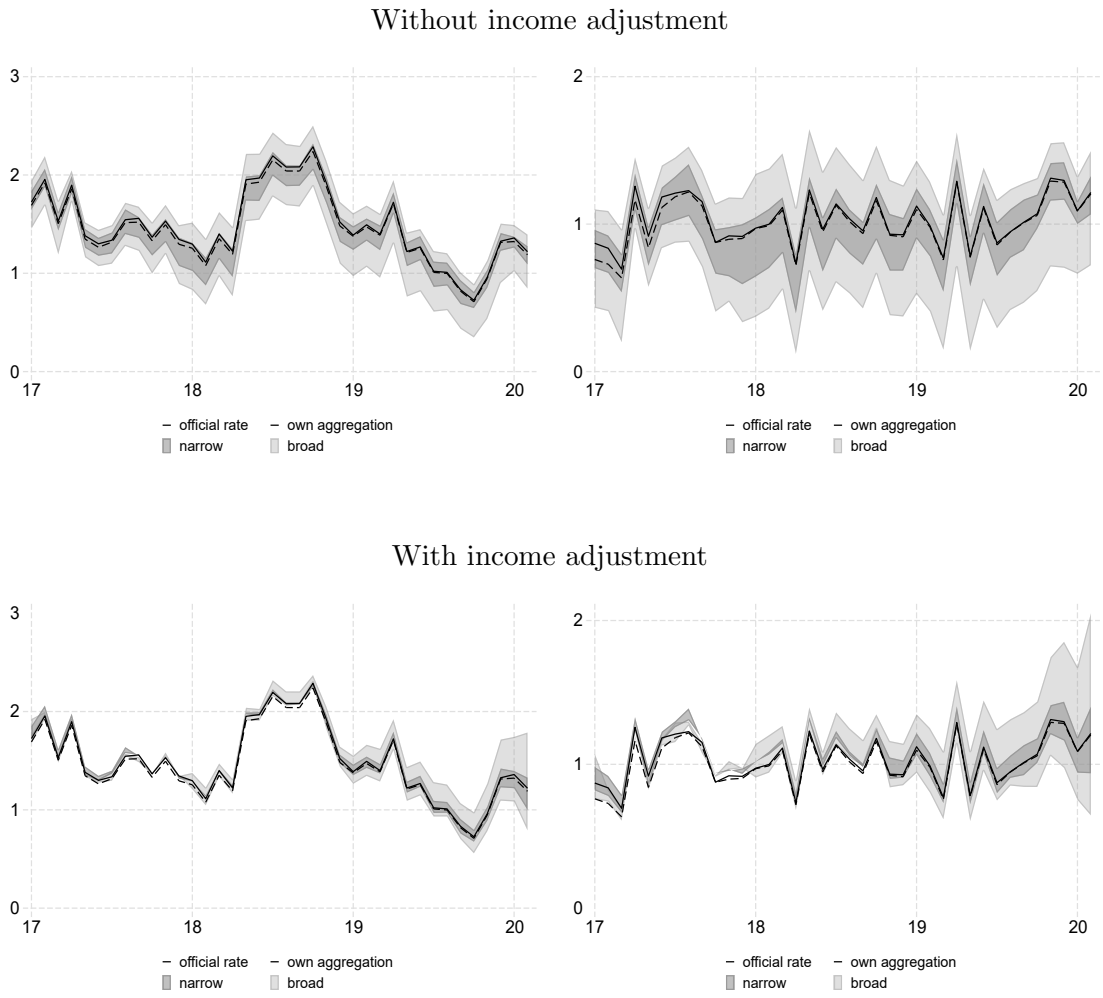
COICOP-5		EA Weight in ‰	DEFINITION	
			NARROW	BROAD
08201	Landline telephones	0.2	1	1
08202	Mobile phone without contract	3.48	1	1
09111	Equip. for the reception, recording & reproduction of sound	0.59	1	1
09112	Equip. for the reception, recording & reproduction of sound & vision	2.71	1	1
09113	Portable TV sets, sound and vision devices	0.07	1	1
09119	Other equip. for the reception, recording and reproduction of sound & picture	0.35	1	1
09121	Cameras	0.64	1	1
09122	Accessories and parts for photographic and cinematographic equip.	0.09	1	1
09123	Optical equipment	0.04	1	1
09131	Personal computers	3.45	1	1
09132	Accessories for information processing equip.	0.76	1	1
09141	Pre-recorded recording media	1.24	1	1
09142	Unrecorded recording media	0.02	1	1
09149	Other recording media	0.48	1	1
05311	Refrigerators, freezers and fridge-freezers	1.49	0	1
05312	Washing machines, dishwashers or the like	2.22	0	1
05313	Cookers	1.06	0	1
05314	Room heaters and air conditioners	1.11	0	1
05315	Vacuum cleaners and other cleaning equip.	0.64	0	1
05319	Other major household appliances nec	0.03	0	1
05321	Food processing appliances	0.81	0	1
05322	Coffee machines, tea makers and similar appliances	0.58	0	1
05323	Irons	0.29	0	1
05324	Toasters and grills	0.11	0	1

. . . continued

COICOP-5		EA Weight in ‰	DEFINITION	
			NARROW	BROAD
05329	Other small electric household appliances	0.36	0	1
06110	Pharmaceutical products	11.5	0	1
06121	Pregnancy tests, condoms or the like	0.34	0	1
06129	Other medical products nec	0.66	0	1
06131	Glasses and contact lenses	4.78	0	1
06132	Hearing aids	0.87	0	1
06139	Other therapeutic appliances and equip.	1.33	0	1
07111	New passenger cars	27.41	0	1
07112	Used passenger cars	10.57	0	1
07120	Motorcycles	1.99	0	1
07130	Bicycles	1.09	0	1
09211	Camper, caravans or other trailers	1.52	0	1
09213	Boats, outboard motors and equip. for boats	0.77	0	1
09221	Musical instruments	0.53	0	1
Total	**NARROW**	**14.12**	**1**	**0**
Total	**BROAD**	**86.18**	**0**	**1**

Figure B1: The impact of quality adjustment over time: pre-Covid

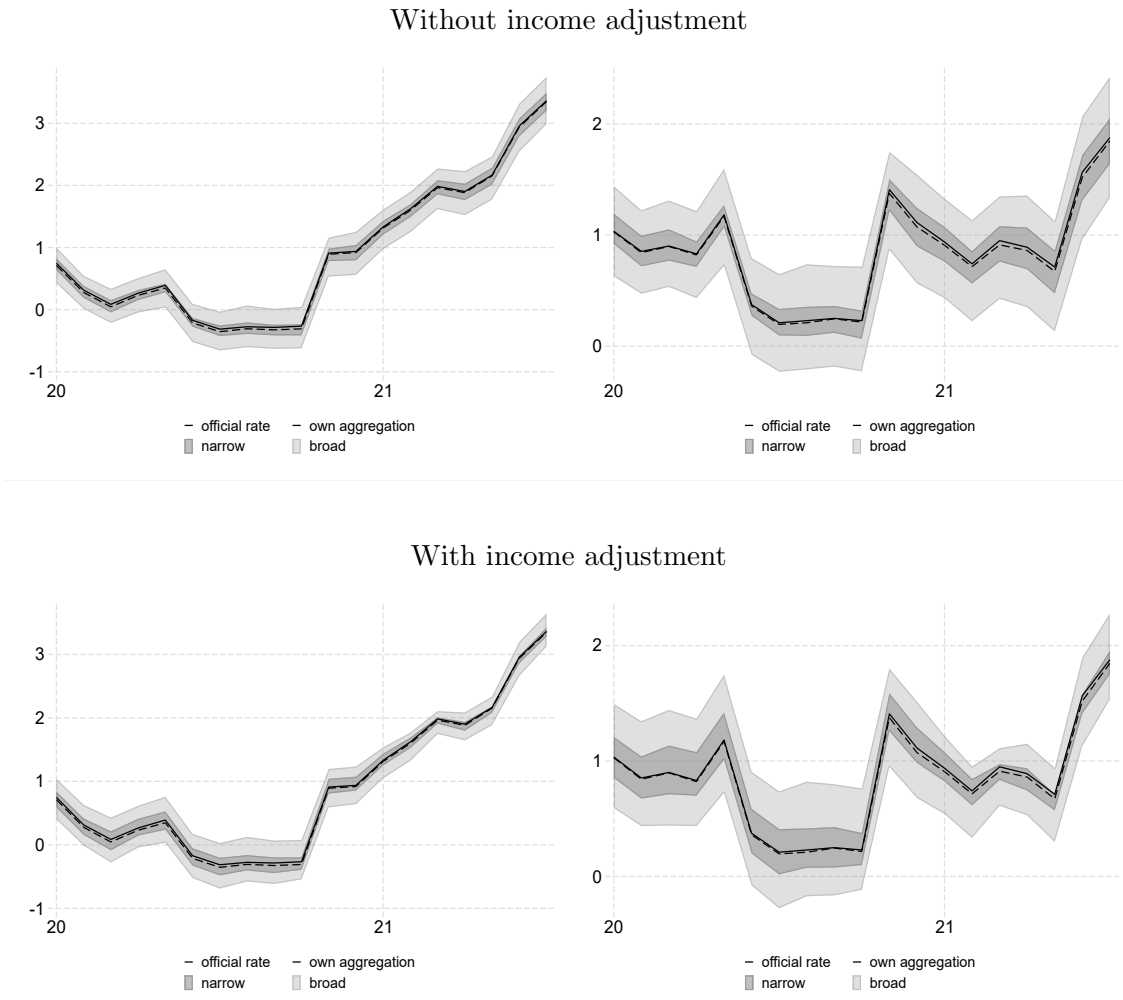
HICP HICP excluding energy & food



Note: The figure shows the annual inflation rate of euro area headline and core inflation as published by Eurostat ("official rate"), and aggregate from the disaggregate COICOP5 series ("own aggregation"). "Narrow" and "broad" denote the inflation rates using the lowest and highest inflation rates by country and product group assumed to be affected from quality changes.

Figure B2: The impact of quality adjustment over time: Covid period

HICP HICP excluding energy & food



Note: The figure shows the annual inflation rate of euro area headline and core inflation as published by Eurostat ("official rate"), and aggregate from the disaggregate COICOP5 series ("own aggregation"). "Narrow" and "broad" denote the inflation rates using the lowest and highest inflation rates by country and product group assumed to be affected from quality changes.

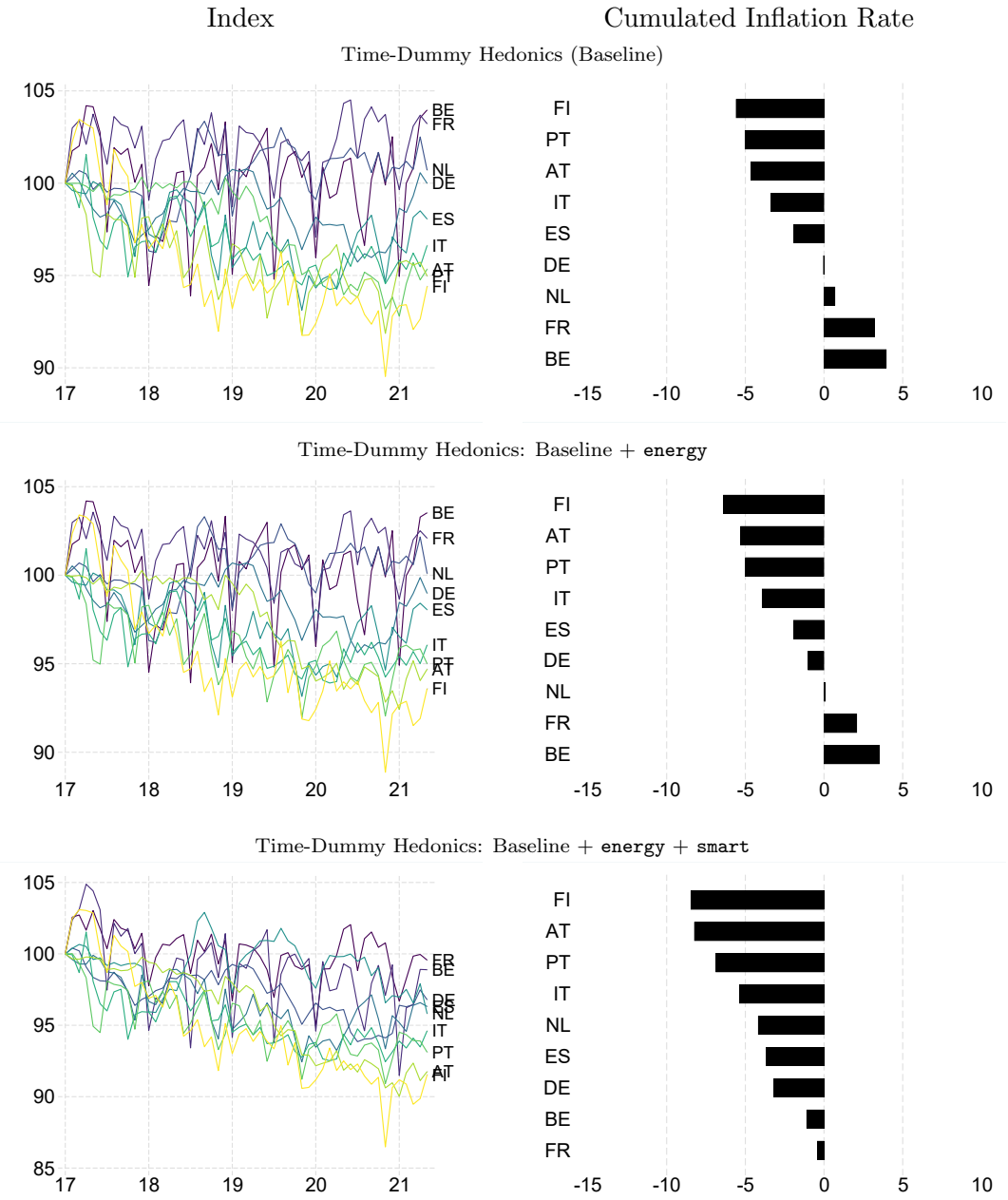
Appendix C Estimating the impact of quality adjustment based on transaction data for washing machines

Table C1: Variable description of GfK data set

Variable	Type	Variable description	Sample 2000-05	Sample 2017-21
`model`	categorical	Identifier of washing machine model	X	X
`country`	categorical	Country (local market)	X	X
`brand`	categorical	Brand's name of a given washing machine model	X	X
`lnprice`	numeric	(Log) average price of a given model (incl. value-added tax)	X	X
`turnover`	numeric	Transaction value (average price × quantity) of a given model	X	X
`construction`	categorical	Construction type (base: freestanding / built in or under / unknown)	X	X
`revpermin`	numeric	Spinning speed (revolutions per minute)	X	X
`loadingkg`	numeric	Load capacity in kg	X	X
`loadingdir`	categorical	Loading direction (base: frontloading / toploading / unknown)	X	X
`autoxdry`	categorical	Degree of automation and presence of drying function (base: fully automatic, no dryer / semi-automatic, no dryer / washdryer / unknown)	X	X
`energy`	categorical	Energy efficiency according to the EU energy label from A+++ (best) to G (worst)		X
`smart`	categorical	Equipment with any smart connect functions, e.g. smart check/diagnosis, smart app control, voice control		X
`noise`	numeric	Noise level in decibel		X
`spin`	categorical	Spin efficiency from A (best) to G (worst)		X

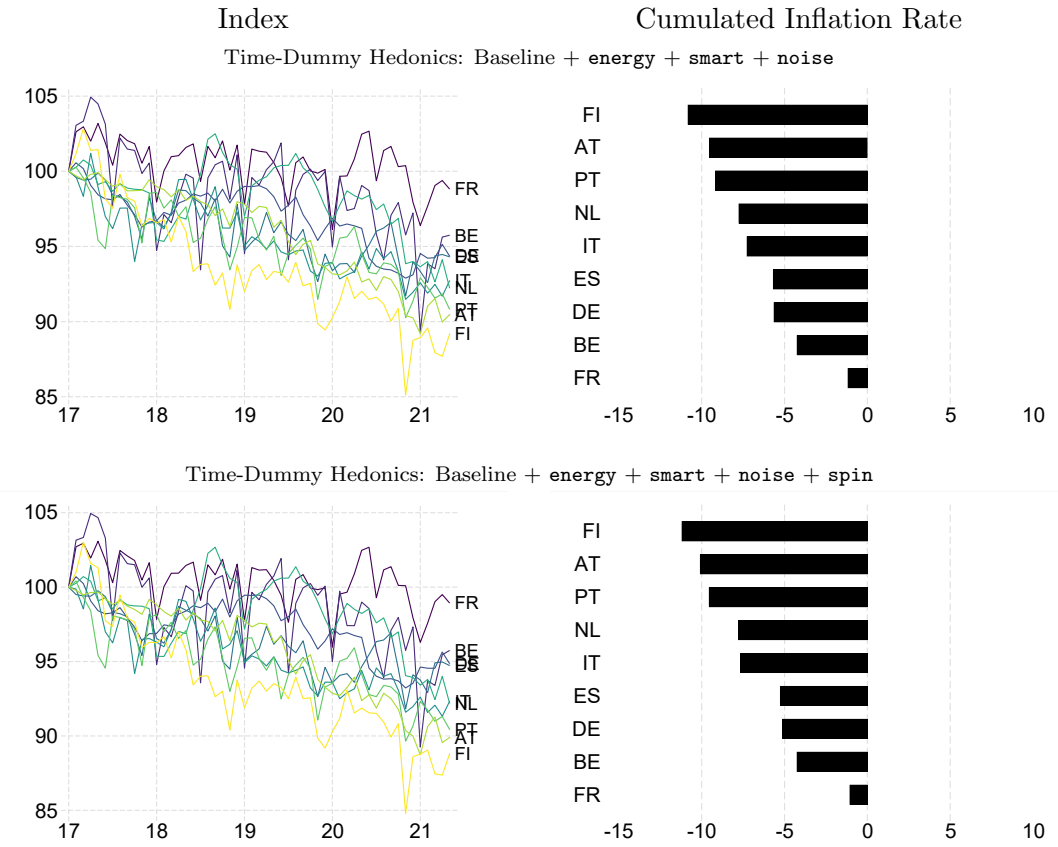
Source: GfK Point-of-Sales (POS).

Figure C1: Alternative hedonic price indices for washing machines vs. HICP, 2017-2021 (I)



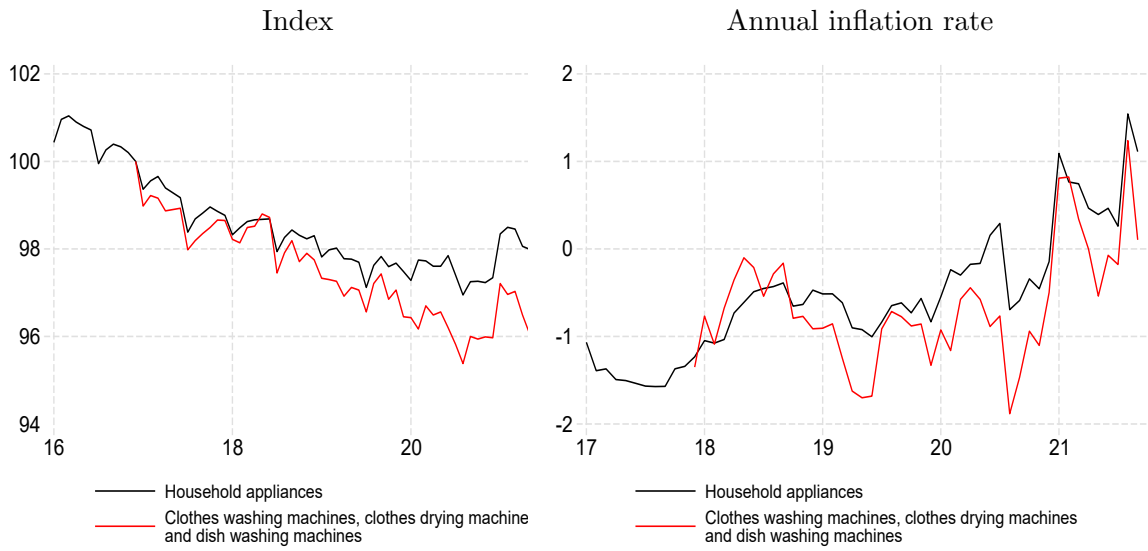
Note: The figure shows various specifications of the Time-Dummy Hedonics regression of washing machine prices for the years 2017-2021, indexed to January 2017=100 as well as cumulated inflation rates between 2017:01 and 2021:05.

Figure C2: Alternative hedonic price indices for washing machines vs. HICP, 2017-2021 (II)



Note: The figure shows various specifications of the Time-Dummy Hedonics regression of washing machine prices for the years 2017-2021, indexed to January 2017=100 as well as cumulated inflation rates between 2017:01 and 2021:05.

Figure C3: HICP on Household Appliances



Note: The figure shows the HICP subindices "05.3 - Household Appliances" and "05.3.1.2 Clothes washing machines, clothes drying machines and dish washing machines". Annual inflation rates are correlated with .8.

Appendix D Treatment of quality changes in the HICP by national statistical institutes in the euro area

This section reproduces the NSI information on quality adjustment as reported in the individual HICP Compliance Monitoring reports, published at Eurostat's website: https://ec.europa.eu/eurostat/web/hicp/methodology (section "Compliance Monitoring").

Austria:

Monitoring Report 2019:

Price collectors work with relatively broad item descriptions and choose a well-sold product that falls under the item description. If the product is not available anymore or not well-sold the price collector choses a replacement and notes all relevant information. The quality adjustments, if needed, are made later by the central office staff. An elaborate methodology is used to make quality adjustments. In 2016 quality adjustments were made in 4.6 % of the cases.

Reference Metadata:

In the year 2016 4.6 percent of all prices were subject to a quality adjustment (QA). Most QAs were applied in COICOP 03 ("Clothing and footwear") due to the rapid change of product models and the domination of seasonal products in this division. COICOP 09 ("Recreation and Culture") where the supply of best-selling books, DVDs and CDs change on a monthly basis also requires many QA. Also COICOP 08 ("Telecommunication") faces fast changing product offers, mostly in the segment of electronic devices for telecommunication, which make QAs necessary. Most used QA methods are quantity adjustment (e.g. for food), expert judgment adjustment method (e.g. for clothing), option pricing method (e.g. for durables and cars), and hedonic repricing method (for books and memory cards/sticks).

Quality adjustments in percentage of all prices in the relevant COICOP-group for the year 2019:

COICOP	% QA
01	1.9
02	1.4
03	14.1
04	1.0
05	5.2
06	0.3
07	1.1
08	8.5
09	5.7
10	1.6
11	1.7
12	1.5

Belgium:

Monitoring Report 2014:

Mostly implicit quality adjustment is performed, using the bridged overlap method. Option pricing is used for cars, while direct comparison is used for products such as video games, CDs, DVDs, books and clothing and footwear.

Reference Metadata:

Explicit quality adjustment tends to be avoided. This means that quality adjustments are mostly implicit and done using the bridged overlap method. Option pricing is used for cars, while direct comparison is normally used for products such as video games, CDs, DVDs, books and clothing and footwear. The number of quality adjustments carried out is not kept in a database, so no figures can be given.

Cyprus:

Monitoring Report 2020:

In case a product is not available and no price can be collected for two consecutive months, the product will be replaced by the most popular variety of the same product. In case it is known earlier that the product will not be available again, the replacement is carried out immediately. Price collectors are responsible for identifying quality changes. The method of the quality adjustment is decided by the central office on a case-by-case basis. The prices of replacement products are directly compared to the last price of the replaced product in case the quality difference is not significant. This method is used in most of the cases. Overlap replacement is only applied for products for which the price in the previous period is known. In the case of products that show frequent changes and therefore require replacements on a regular basis such as consumer electronics, prices of potential replacement products are being collected on reserve so as to enable an immediate replacement. Explicit quality adjustment methods used are quantity adjustment, option pricing and expert judgement. In case of option pricing, the added option's price is taken into account to 50% in most of the cases. In the case of new cars, however, the added option's price is taken into account to 100%.

Reference Metadata:

Generally, in the case of a replacement is important to apply quality adjustment procedures in order to determine pure price change.

Explicit quality adjustment procedures are used to estimate directly the price change of a product whose characteristics change over time. The differences in the physical characteristics of two products are evaluated based either on quantity adjustment (when the only difference is in the quantity included) or on expert judgment (when the quality change is estimated by experts) and no hedonic methods are used. Also, in cases where the replacement incorporates features formerly available as option at additional cost then the option costs method is applied, whereby the additional characteristics are priced separately as optional features and then a percentage of this value (usually 50 per cent) is used.

Implicit quality adjustment procedures are applied in the cases of an overlap replacement (bridging) when the value of the quality change is assessed to be equal to the price difference in the overlap period, where the two products were available.

Also in the cases where the quality does not change significantly (the change is assessed as zero) the prices are directly compared (direct comparison).

Initially, the quality control is made by the price collectors, who are instructed to carefully monitor all the product characteristics and to identify any quality changes. Then the central office decides which quality adjustment method to apply in each case. The incidence of quality changes and adjustments is monitored but there no available sufficient statistics about this.

CYSTAT cannot provide an overview of the quality adjustment methods applied.

There is not any documentation that is readily available on the quality adjustments methods applied. Even though quality adjustment methods are carried out, those are not clearly marked thus is not easy to prepare corresponding documentation. As of January 2019 and onwards the quality adjustments methods will be clearly identified and recorded in the developed excel files in order to be able to provide respective documentation in the future.

Estonia

Monitoring Report 2020:

When a product offer cannot be observed because the item is said to be temporarily out of stock, no replacement takes place. If a product-offer continues to be out of stock for two consecutive months, the price collector selects a replacement product-offer which matches the product description. Replacements for new cars typically do not happen in the middle of the year, although they are possible if a certain model disappears from the market. When a model changes, SE uses direct comparison for minor changes. Otherwise, expert judgement and option pricing may be used; SE calculates a factor to account for the most important characteristics that may have influenced the price, such as horse power and fuel consumption. For used cars, SE scrapes data from the websites of the most popular used car dealers, controlling for model, vintage, engine size, and mileage. The sample includes 20 models, stratified by large, medium, and small. The average age of sampled cars is kept fixed. The sample is updated on a rolling basis, based on the year of registration of the car. As regards mobile phones, SE carries forward for two months the price of a model that has disappeared from the market. If a model disappears from one out of four outlets, SE will use the average price for the model from the other three outlets. When a model disappears from the market permanently, SE finds the nearest model and considers the parameters that have changed between the two models and how much they would influence the price up or down. SE relies on expert judgement to carry out the comparison. Direct comparison can be used for any good or service taken into account in the Estonian HICP. Only direct comparison is used for clothing and footwear. The bridge overlap method is most commonly used for restaurants and cafes and in the treatment of package holidays.

Reference Metadata:

Restricted from publication.

Finland:

Monitoring Report 2012:

No information provided.

Reference Metadata:

The Finnish price statistics uses the following quality adjustment methods:

- Quantity adjustment (=Package Size Adjustment) can be used for any good where a change in size/ weight is relevant to the quality of the product and where we do not pre-specify a weight/volume - e.g. a kilo of apples. Adjusting the package size quantity is necessary when the quantity of a packaging unit has changed while holding its quality constant. It is crucial for the application of this method that the quantity directly and proportionally affects the monetary value of the product. Thereby, also "hidden" price increases (through reduced quantities at the same price) are captured.
- Hedonic regression is currently applied only to second hand cars. Hedonics are particularly applied to calculate the price increase of products which features and properties (=characteristics) has strong effect on the price. The hedonic quality adjustment is a statistical procedure which calculates by means of a

regression the influence of individual product characteristics such as age, driven miles, etc.

- Direct price comparison may be used for virtually any good or service. The direct price comparison can be applied if a replacement model of equivalent quality is available. It is an extreme of a quality adjustment method as the prices of both products are directly compared, hence the share of quality is zero percent and the price change fully enters the index calculation. Particularly for technical products it is precisely defined, for which characteristics of models explicit quality adjustment should not be applied.
- Class mean imputation may be used for any good or service. Although the number of times this method is used varies year on year.
- Judgmental quality adjustment: For some product changes, none of the previously mentioned methods is able to identify in which dimension the price difference between the replaced model and the new model is affected by quality differences. In this case, experts (CPI staff) are asked for a subjective judgment. Based on their experience (and specialist knowledge), they determine the share of the price difference due to quality differences.

Importance by prevalence of the method in use are in Finland: a) quantity adjustment B) direct comparison C) class mean imputation. Option costing and overlap pricing are used only occasionally.

France:

Monitoring Report 2015::

Quality adjustment is done for prices of products from all COICOP divisions. Where there are agreed European standards, methods that can be classified as B-methods (in accordance with Article 5 of Regulation no 1334/2007) are applied. Decisions about quality adjustment are made on a case by case basis. The most used method is direct comparison which applies to around 90% of the replacements. For household durables bridged overlap (at regional or national level) or hedonic adjustment is applied. For clothes mainly direct comparison is applied. Option pricing is used for new cars. In the case of newspapers and periodicals there is an adjustment of the price according to the number of pages.

Reference Metadata:

Quality adjustments are carried out primarily in the framework of the replacement of products. For field recordings, several methods are used according to the expertise of the collector, manager or sector expert:

- If the replacement product is considered to be a perfect substitute for the replaced product, then the replacement product will have the same base price as the old product. There is no "quality effect" and the entire price difference is likened to a "pure" price variation (direct price comparison method). In 2015, this method was applied to 44.0% of replaced products.
- If the replacement product is not considered to be a perfect substitute, then its base price is estimated according to the base price of the replaced product monitored in month m-1 and the change in prices between m-1 and m of products belonging to the same consumption segment as the replaced product for which observations are available (bridged overlap method). In addition, if the collector knows the price of

the replacement product in the month m-1 or in the month of December, the estimate will take account of this price. The quality adjustment is applied to all products but especially to durable goods.

- A base price can also be estimated by hedonic models using the specifications of the replacement and the replaced product. This method requires a sufficient number of products in order to estimate the effects of each technical specification that contributes to the model. It is used for several durable goods (washing machines, dishwashers, refrigerators, televisions, computer) and also for "best sellers".
- The Option pricing model has been adopted for replacements relating to new motor vehicles.

Germany:

Monitoring Report 2015:

The application of quality adjustment methods is kept to a minimum. Around 5 to 10 percent of price observations are affected. Where there are agreed European standards, methods that can be classified as B-methods (in accordance with Article 5 of Regulation no 1334/2007) are applied. The product sample is stratified into consumption segments. Replacements within a consumption segment will lead either to direct price comparison (e.g. for clothing and footwear) or to explicit quality adjustment (e.g. for technical products). Replacements outside the consumption segments, if unavoidable, are seen as sample refreshment and lead to bridged overlap. Quality adjustments for differences resulting from latest fashion trends are not carried out. The bestseller approach is pursued for books, CDs, downloads, computer games and software. Otherwise, quantity adjustment, option pricing (cars), hedonic regression and bridged overlap are applied.

Reference Metadata:

The German price statistics uses the following quality adjustment methods:

- Direct Price Comparison: The direct price comparison can be applied if a replacement model of equivalent quality is available. It is an extreme of a quality adjustment method as the prices of both products are directly compared, hence the share of quality is zero percent and the price change fully enters the index calculation. Particularly for technical products it is precisely defined, for which characteristics of models explicit quality adjustment should not be applied. Usually these are characteristics such as design, fashion or other, very subjective assessment of quality. Typical examples for the consumer price index are amended designs of durable consumer goods as toasters or fashion for clothing.
- Price change taken as quality change: As opposed to the direct price comparison a price change between replaced and replacement model is completely attributed to a quality change, i.e. the share of quality thus amounts to 100 percent of the price change. Hence, no price change is measured between the two periods in which the replacement takes place. This method may be suitable if no similar replacement model can be found and the price collector has to choose for example a device of another type of construction or a different product variety as replacement model.
- Overlap: Sometimes it may occur that a producer offers various product variants, which differ by a certain characteristic or a combination of characteristics. If both product variants are simultaneously available on the market (overlap period), the price difference can be used as an estimate for the quality change, as the

buyer has the choice between the alternatives. The changeover from a replaced to a replacement model has no impact on the price index, hence the price difference between predecessor and successor will not be considered.

- Bridged Overlap: This procedure can be used when the new model and the replaced model are not simultaneously available on the market. The method of bridged overlap uses the average price development within the same product group or the average price development of appropriately equivalent models as a reference. Especially in cases of product changes in which it is reasonable to assume that also a price change has been taken in addition to changed material or personal costs, the price development of an appropriate comparison group (of models) is used as a substitute.
- Package Size Adjustment: Adjusting the package size quantity is necessary when the quantity of a packaging unit has changed while holding its quality constant. It is crucial for the application of this method that the quantity directly and proportionally affects the monetary value of the product. Thereby, also "hidden" price increases (through reduced quantities at the same price) are captured. In the consumer price index for Germany, package size adjustments are typically conducted in the group of foods and the groups of other consumer goods.
- Option Pricing: Using option prices, the estimation of the monetary value of a quality change between a new and its replaced model is conducted by applying list prices of individual product characteristics. This procedure is usually used for more complex products when a certain characteristic turned in the meantime from being an additional option to being part of the standard equipment. In such cases, a part of the amount which had to be paid for the optional equipment can be set as the monetary value of the quality difference. Even optional equipment of other manufacturers can be implemented into the calculation. New cars with additional equipment like special airbags in the consumer price index are an example where this procedure is carried out. However, in most cases it is not known whether the customer really requires a product characteristic which turned from optional to standard (such that s/he also would have bought it earlier when it was only an additional option). Then, according to international conventions, a share of 50% of the purchase price is usually considered as the monetary value of the quality change.
- Supported judgmental quality adjustment: For some products, there exist transparent procedures involving additional information sources which are able to determine concretely the consumer's added value of a recently launched model. Typically, this concerns the consumption value of technical products (fuels, energy) or other follow-up costs (maintenance). Examples are refrigerators with amended power consumption or washing machines with amended water and power consumption. Calculating the monetary value of such a quality change, assumptions are needed, e.g. regarding frequency of use and useful life of the new model. Actual market prices are used for the calculation of follow-up costs due to energy sources. This implicitly presumes that also the consumer takes actual prices of energy sources etc. into consideration in order to evaluate the quality of a product.
- Hedonics: Hedonics are particularly applied to calculate the price increase of products which strongly change in a short period of time. In the official price statistics, products which are currently quality adjusted by hedonics are desktop PC, printers, hard drives, notebooks, processors, RAM, servers, used

cars, tablet PC and residential properties. The hedonic quality adjustment is a statistical procedure which calculates by means of a regression the influence of individual product characteristics, e.g. the size of hard drives in desktop PC, on the price of the product. Thereby, the monetary value of the quality difference between a new model and the replaced model can be determined and taken out of the price change.

Currently there is a labelling in the processing program to indicate prices which are subject to quality adjustment but the applied method of quality adjustment is not recorded. Consequently we cannot provide the percentage or the number of the different methods for quality adjustment. Furthermore the pure percentage/number of quality adjusted prices (independent of the method used) can currently not be provided without considerable effort. Due to the organisation of the consumer price statistics in Germany, only the respective Laender office has access to the price data collected by itself. The FSO does not have permanent access to the price data. In the medium term, it is planned to adjust the processing program to enable the provision of information about the application of quality adjustment.

Greece:

Monitoring Report 2013:

No information provided.

Reference Metadata:

No information provided.

Ireland:

Monitoring Report 2017:

Quality adjustments are made by price collectors and checked by the central office staff. Price collectors have a choice, when making a replacement, between direct comparison (no quality change) and bridged overlap, i.e. implicit quality adjustment. Bridged overlap is applied to approximately 7% of 48 000 collected prices. The bridged overlap approach might not be the most appropriate approach to quality adjustment of products if it is applied by default. The CSO is running a project in 2017 aiming at improving the quality adjustment methods and bringing these more in line with HICP recommendations. The project focusses on clothing and footwear, cars and electronic goods. The treatment of second hand cars is now consistent with HICP recommendations and takes depreciation into account.

Reference Metadata:

Whenever a product has to be replaced by another product, some statistical adjustment has to be made in order to link the price indices and create continuous price series. In principle, this situation may happen for any product covered in the HICP.

In most cases, we apply the "Bridged-overlap" method (implicit QA). This approach consists in estimating a price development between the replaced product and the replacement product which is equal to the actual average price development (geometric mean) observed for the products belonging to the same consumption segment. In duly motivated circumstances, we may also apply direct comparison (if the two products are deemed to be almost

identical) or link-to-show-no-price-change (if no reliable quality adjustment method can be applied).
In all COICOP divisions Bridged-overlap is the dominant method of implicit QA. Explicit quality adjustment tends to be avoided. Direct Comparison normally occurs on items such as CD's and DVD's.

Italy:

Monitoring Report 2014:

Decision on the need of quality adjustment is taken on a case-by-case basis. In these cases where there are agreed European standards, methods classified as B-methods (in accordance with Article 5 of Regulation no 1334/2007) are applied. In particular:

- Direct comparison is carried out in some cases for clothing and footwear, in some cases for processed or fresh food, for products for which the best seller approach is adopted such as electronic games, DVD movies and fuels.
- For most of the products for which prices are centrally collected by ISTAT, direct comparison within the specific stratum is conducted.
- A combination of bridged overlap and class mean imputation is adopted in some cases for clothing and footwear. Quantity adjustment is adopted only when the difference between a product offer in a month and a product offer in the following one, is due exclusively to a difference in the package size.
- Direct comparison in combination with monthly deletion and replenishment is used for tablet PCs.
- For new cars, direct comparison or reconstructed overlap is applied in the case of minor changes and overlap is applied in the case of major changes. Eurostat welcomes ISTAT's efforts to use quality adjustment methods classified as A or at least B methods in more product groups.

Reference Metadata:

For quality adjustment, as it is required by EC Regulation No 1334/2007, a case-by-case approach is adopted and therefore group of products by group of product. In details, methods adopted to manage quality adjustment issues are:

- Direct comparison:
  - for clothing and footwear, when the product offers in two consecutive months are evaluated comparable on the basis of criteria defined by ISTAT. In the month when the replacement is done, the elementary price is flagged, the reason of the replacement is ticked and the direct comparison is carried out directly by automatic procedures;
  - in some cases for processed or fresh food (for which prices are monthly collected) when, for a list of product defined by ISTAT, the change of the product offer is due exclusively to a change of brand, and therefore the product offers in two consecutive months are evaluated comparable. In the month when the replacement is done, the elementary price is flagged, the reason of the replacement is ticked and the data collector has to register the price of the product offer available in the previous month as the price of the previous month of the new product offer;

  - for products for which best seller approach is adopted such as electronic games, DVD movies;
  - for fresh food and fish, for which prices are collected twice a month, in the month when the replacement is done, the elementary price is flagged and the reason of the replacement is ticked (quantity collected or collection unit; brand and variety are not take into account). In the following figure there is an example of direct comparison for fresh fruits as it is showed in the web application available to ISTAT and Municipal Statistical Offices.
  - for most of the products for which prices are centrally collected by ISTAT, it allows direct comparison inside each specific stratum.

- A combination of bridged overlap and class mean imputation:
  - in some cases for clothing and footwear, when the product offers in two consecutive months are evaluated not comparable on the basis of criteria defined by ISTAT. In the month when the replacement is done, the elementary price is flagged, the reason of the replacement is ticked and an automatic procedure estimates the price of the previous month of the new product offer in order to build the bridge between the two consecutive months. To calculate the price of the previous month, the rate of change m/m-1 of the geometric mean of the micro indices is used, within the same product of the basket in the same town, both of the product offers for which no replacements take place and for the product offers for which direct comparison was carried out. The information available within the same product, in the same town is used only if at least for the 50% of the sample for that specific product aggregate in that specific town, prices are collected for the same product offers of the previous month (indeed without replacements) or for product offers for which direct comparison was carried out. If the latter condition is not respected, the overlap approach is adopted.

- Overlap:
  - for the other products, for which prices are collected monthly at territorial level (except clothing and footwear, products for which prices are collected centrally, fresh and processed food for which direct comparison is carried out). In the month when the replacement is done, if the data collector has collected the price of the previous month of the replacing product offer (or the seller is able to provide this information) this information is used and the elementary price is flagged. If the data collector has not collected the price of the previous month of the replacing product offer (and the seller is not able to provide this information), an automatic procedure estimates the price of the previous month of the new product offer using the current price of the replacing product offer (link-to-show-no-price-change). However, in order to avoid (when it is possible) the link-to-show-no-price-change, the software for the data collection allows 'booking' a product offer when the sampled product offer is on the way to exit the market.

- Explicit quality change:
  - it is adopted only when the difference between a product offer in a month and a product offer in the following one, is due exclusively to packaging and the replacing product offer is actually new. In this case the data collector has to specify the reason of the replacement and to insert the information

about the quantity of the new product offer; the elementary price registered is flagged. An automatic procedure calculates the price of the new product in the previous month taking into account the difference between the new and the old quantity collected. If the quantity increases or declines by 50% as compared to the previous month, the procedure estimates the price of the new product offer in the last month, calculating the cost of the new quantity on the base of the previous price. If the new one is different from the previous one of an amount that is more than 50%, the procedure calculates the price of the previous month of the new product offer as in the case of overlap when the link is built to show no price change). When the replacing product offer was already available in the previous month, the situation is ascribable to cases when it is adopted the overlap approach.

Latvia:

Monitoring Report 2013:

Decision about the quality adjustment is always based on the specific conditions reported by the price collectors. Where there are agreed European standards, mainly methods that can be classified as B-methods (in accordance with Article 5 of Regulation no 1334/2007) are applied. Option pricing is applied for new and used cars and desktop computers. In other cases bridged overlap, quantity adjustment, judgemental (expert) adjustment and, in most cases, direct comparison (equivalent replacement) is applied.

Reference Metadata:

Price collectors perform the initial steps for quality adjustment, by selecting the most suitable replacement, estimating the comparability of both products and reporting on the differences in characteristics between them. The instructions and examples are described in the manual for price collectors. Staff of the CPI unit makes the final quality adjustment. For fruit, vegetables, clothing, footwear, audio recordings, books in rapidly-changing market direct comparison is the primary (most often used) quality adjustment method. For other product categories, mostly the bridged overlap in case of major changes and direct comparison in case of minor changes is used.

Divisions	% Bridged overlap	% Direct compariso	% Option cost, expert estimation, etc.
01	1.3	2.9	0.3
02	0.9	0.5	0.3
03	1.0	7.1	0.4
04	1.3	1.5	0.3
05	2.2	1.8	0.6
06	0.6	0.6	0.1
07	1.2	2.1	0.1
08	1.2	6.4	1.4
09	2.0	2.7	0.3
10	0.1	5.0	0.0
11	1.0	1.3	0.1
12	1.2	2.1	0.4

50% option cost or indirect option cost regarding fuel consumption approach for new cars in case of minor changes is used. For second-hand cars, supported expert judgement based on age and mileage is used, combined with direct comparison or bridged overlap. In special cases judgmental (expert) adjustment and quantity adjustment are used as well. There are no automatic quality adjustment procedures for any product group. Instead, the choice of method depends on the specific replacement situation and selected replacement product-offer.

Lithuania:

Monitoring Report 2013:

Quality adjustment is usually done for prices of food and beverages, clothing and footwear, furnishings, household equipment, new cars, equipment for the reception, recording and reproduction of sound and picture, personal computers, and books. Where there are agreed European standards, methods that can be classified as B-methods or A-methods (in accordance with Article 5 of Regulation no 1334/2007) are applied. Option pricing is applied for new cars. Prices of used cars are compared directly. For minor quality differences for clothing, direct comparison is used, while for substantial quality differences, expert judgement or bridged overlaps are applied. Hedonic regressions are applied for top-ten fiction books. In other cases bridged overlap, quantity adjustment, judgemental (expert) adjustment, option pricing and, in most cases, direct comparison (equivalent replacement) is applied.

Reference Metadata:

Explicit ("expert judgment", "option pricing", "hedonic", "quantity adjustment") and implicit ("bridged overlap") quality adjustment methods are used for particular goods. In some cases, the overlap method is used.

Using "expert judgement" method, the impact of the change in quality on the price is estimated by the price collector assisted by the employee of the outlet. The price collector has to inform the Price Statistics Division about the change in quality and the impact thereof on the change in the price. The information obtained is analysed and, taking into account the impact of the change in quality, the staff of the Price Statistics Division recalculates the price of the replaced product of the previous month and the price of the replacement product in the current month is compared with adjusted price of replaced product in the previous month.

Using "option pricing" method, expenditure is assessed for the new characteristic of the product that was not present in the replaced product. Then, the price of the replaced product in the previous month is recalculated based on the assumption that the new characteristic was presented in the replaced product, and then, the price of the replacement product in the current month is compared with the recalculated price of the replaced product of the previous month.

"Hedonic" method based on a regression equation, which expresses the price of a product as a function of its qualitative characteristics which determine the change in the product price.

According to "quantity adjustment" method, the price of a replaced product is recalculated proportionally, taking into account the quantity ratio of the replaced to the replacement products.

A "bridged overlap" method is used in case when the price collector cannot record the price of the replaced product in the current month and selects a replacement product whose price in the previous month cannot be determined. The price of the replaced product in the previous month is computed on the basis of a short-term price ratio of an identical or similar product calculated on the basis of prices recorded in other outlets of the same

territorial unit or other territorial units.

According to the "overlap" method, the prices for replacement product and replaced product are collected at the same time, when both products are available in the outlet.

Hedonic quality adjustment methods is used for the books.

Divisions	Bridged overlap, %	Direct comparison, %
01	0.8	0.0
02	0.4	0.1
03	1.3	3.5
04	0.4	0.2
05	1.2	1.0
06	0.1	0.0
07	0.5	1.0
08	2.1	1.6
09	1.5	0.4
10	0.4	0.2
11	0.3	0.0
12	1.3	0.4

Luxembourg:

Monitoring Report 2012:

No information provided.

Reference Metadata:

In most cases, the following methods are used in case of replacements:

- Bridged Overlap
- Overlap pricing (in case the price of t-1 of the replacement variety is known)
- Direct comparison

For some specific product groups (e.g. cars), explicit quality adjustment (QA) is performed.

Division	Bridged Overlap	Direct Comparison	Other QA	Total Replacement	No Replacement
1	0.8%	0.5%	0.1%	1.4%	98.6%
2	0.9%	0.4%	0.0%	1.3%	98.7%
3	1.0%	1.7%	0.1%	2.8%	97.2%
4	0.5%	0.1%	0.1%	0.7%	99.3%
5	2.0%	1.2%	0.3%	3.5%	96.5%
6	0.2%	0.1%	0.2%	0.5%	99.5%
7	0.7%	0.4%	0.9%	2.0%	98.0%
8	2.6%	2.9%	0.2%	5.7%	94.3%
9	1.4%	1.1%	0.6%	3.0%	97.0%
10	0.3%	0.5%	0.0%	0.8%	99.2%
11	1.1%	0.4%	0.1%	1.5%	98.5%
12	0.7%	0.6%	0.1%	1.4%	98.6%

Malta:

Monitoring Report 2019:

Price collectors work with relatively broad item descriptions and choose a well-sold product that falls under the item description. If the product is not available anymore or not well-sold the price collector choses a replacement and notes all relevant information. The commonly used methods for quality adjustment are direct comparison, if the differences are considered negligible or else bridged overlap. Hedonic quality adjustments are made for new and second-hand cars, laptops, mobile phones and cameras.

Reference Metadata:

When a replacement model differs significantly from the replaced model, an implicit method or explicit method of quality adjustment is used. We use three different quality adjustment methods, namely the Direct Comparison method (comparing prices of the old and the new product over two periods without adjustment), the Bridged Overlap method (derives the price change between the old and new item from the observed price change of other items in the sub-index) and the Hedonic method (regression analysis is used to assess the extent to which the observed variability in the price of a product can be explained by variability in the product's attributes).

All changes are assessed on a case-by-case basis. The Direct Comparison Method is used only when the change between the replacement and replaced models is not radical.

For Clothing and Footwear, the direct comparison method (B method) is used for all replacements which are deemed essentially equivalent. In the rare cases where a replacement model differs significantly from the replaced model, the bridged overlap method used. For Books, recorded media and computer games, the items falling within this group of products are characterised by "rapidly-changing markets". The HICP does not cover any books or other recorded media which have a relatively long commercial life-span, and low rates of introduction of new products, as these are deemed unrepresentative. The direct comparison method of quality adjustment, which is considered a B method, is used in all cases. The Hedonic method (B method) of quality adjustment is used in compilation of both new and used cars indices. For the latter we use the hedonic re-pricing method described in

great detail in the handbook drafted by CENEX HICP Quality Adjustment (16th draft). In the case of new cars the coefficients of the regression are used for quality adjustment.
Products which are characterised by continuous technological advancements are regularly quality adjusted.
Where quality changes occur, in most cases we carry out direct comparison.

Netherlands:

Monitoring Report 2012:

No information provided.

Reference Metadata:

Hereby an overview of all the quality adjustment methods we are using:

- Direct comparison (e.g. clothing)
- Quantity adjustment (e.g. for tobacco)
- Option Prices (e.g. for cars)
- Expert Judgement (e.g. for electronics and boats)
- Overlap (not commonly used)
- 50% method (not commonly used)
- Targeted Mean imputation (not commonly used)

We can't indicate per ECOICOP division as a percentage of all prices, how often a method was used. It is diverse and it doesn't depend on the COICOP but on the article. Hedonic quality adjustment methods are not used.

Portugal:

Monitoring Report 2019:

When a product-offer cannot be observed, a price is estimated at most for two months, after which a replacement product-offer is selected. A temporarily missing price is imputed using the average price change of the prices collected in other outlets in the same town for the same product. INE uses mainly bridged overlap as a quality adjustment method for non-comparable replacements. In some circumstances, the prices of the old and the new product-offer are available in the same month, which makes it possible to apply overlap pricing. If the replacement product-offer is considered to be of the same quality, the prices are directly compared. Changes in package-sizes are taken into account for those products where the collected prices are transformed into a standard unit. For new cars, option pricing is applied on some occasions. Except for new cars, explicit quality adjustment methods, which estimate the quality difference based on the product characteristics, are generally not used. The current production system does not record the type of quality adjustment method that is applied in a given replacement situation. Direct comparison is mostly used for clothing and footwear. It is also applied in the context of mobile phones which had led to an upward impact on the indices. To mitigate this effect, INE now restricts the selection of replacement mobile phones to more similar models. INE also applies direct comparison for cars when it is

difficult to quantify small quality differences. A downward bias may appear in the indices if replacements and quality adjustments are carried out for products which enter the sample at high prices and exit the sample at low prices.

Reference Metadata:

The following quality adjustment methods are used:

- Simple overlap, when the prices of the old and replacement items are available in the same period
- Bridged overlap, when the price change of the product within the same municipality used as a bridge for the price changes of the replacement product
- Direct comparison, when the replacement product is deemed comparable
- Option pricing, when the price of the options of the item are available (used only for new cars)
- Judgmental quality adjustment and supported judgmental quality adjustment, when additional information is available and assessed by expert judgment.

The most commonly used are bridged and simple overlap. Direct comparison is used mostly when the price collector indicates that products are comparable (usually for clothing and footwear).

Slovakia:

Monitoring Report 2018:

Missing prices are carried forward for at most two consecutive months before they are replaced within the product range according to the description and, if possible, the same brand. Exception to this rule is seaside package holidays that are only collected during the summer season and the last price is carried forward until the beginning of the next season. (See also point 8.) Quality adjustments are made at the head office of SO SR. In most cases bridged overlap or direct comparison is used. The calculation software allows for the application of explicit quality adjustment methods but such methods are rarely used. Option pricing is only applied for new cars, where it is applied on a rather ad hoc basis. For minor changes in models, direct price comparison is carried out in most cases. For used cars, the quality adjustment is carried out by the external data provider, who takes into account technical specifications of the car and the mileage. The bridged overlap approach is not the most appropriate approach to quality adjustment of products if it is applied by default. The bridged overlap approach is applied to nearly 0.5% of the observed prices. The SO SR has run a project aiming to apply explicit adjustment methods. However, it is deemed that relevant information to run the calculations cannot be obtained.

Reference Metadata:

The following introduction part regarding the quality adjustment process is given in the "Methodological instructions for price collection, verifying and reporting of data on consumer prices": If the price collector replaces a previously priced product offer by a new product offer and if in the price of replacement also the change of quality of the new product offer in comparison with the previously priced product offer is reflected, then the change of quality shall be adjusted from the price development (in the compilation of price index for this product). The process of quality adjustment (QA) is aimed at the fact that consumer price index shall reflect the pure price change not the price change influenced by the change in quality of the priced products. However the quality

adjustment is in practice a complex process. A prerequisite for proper quality adjustment and for assessment of quality change are properly filled "Table comments" by the price collectors in the prescribed structure (maximum 20 characters for "brand" of the product offer and maximum 80 characters for other important information related to the product offer). Though the software introduced within the grant projects on the implementation of Commission Regulation (EC) No 1334/2007 on sampling and QA enables the use of explicit QA methods (e.g. the option price method), in practise, in most of the cases the implicit QA methods (bridged overlap) and/or direct price comparison are used. The reason for a rare use of explicit QA is the fact that in practise it is difficult to obtain enough "explicit" information related to the characteristic of the products needed for evaluation of quality change.

The QA process is done at the central level of the compilation of consumer price indices. As we mentioned above, the properly filled "table comments" are very important for the assessment of quality change and for the QA. From this point of view, "The report of Table comments" produced by the software is important. It contains information related to the collected prices in the prescribed structure (maximum 20 characters for "Brand" and maximum 80 characters for "Comments" with the other important information related to the collected price). The table comments refer first of all to the prices collected for the new (replacement) product offers and/or to the product offers collected in the new outlets and also to the prices with the month-on-month change greater than 20%. This report of table comments also serves for the assessment whether the collected price for the replacement product offer had been collected in compliance with the descriptions of the representative items. If not, the price may be excluded from further processing. The QA is done on the basis of evaluation of the information given in the table comments. In most of the cases the implicit QA (bridged overlap) and/or direct price comparison is used. In the cases of bridged overlap, the software calculates the month-on-month price development of the products "without" quality change and according to this month-on-month movement, the software adjusts the price of December of the previous year for those representative items in which QA was done. Every QA process is documented in the special kind of report related to the process of QA: every month the software developed in Oracle forms produces output report not only concerning source prices data but also the Production (Output) data - aggregated data for the Slovak Republic, average prices and price indices for the individual representative items, as well as for all ECOICOP categories (including the divisions, groups, classes and subclasses) compiled in 4 phases of the compilation of consumer price indices:

- Production (Output) data compiled from the "gross-unverified" data
- Production (Output) data compiled after the correction of "typo" mistakes in prices
- Production (Output) data compiled after the process of quality adjustment taking into account the change of quality of priced products
- Final production (Output) data compiled after the imputation of seasonal goods prices outside the season

The reports on QA are available on monthly basis.

Quality adjustment (QA) issues for Clothing and footwear, Books, CDs and computer games and for Cars:

- Clothing and footwear

In compliance with the standards, the direct price comparison (B method) is used in Quality adjustment for clothing and footwear. The bridged overlap method is used very rarely for QA of clothing and footwear.

- Books, CDs and computer games

In compliance with the standards, the direct price comparison is used for Long-selling markets approach as well as for rapidly-changing markets approach.

- Cars

Regarding QA for new cars: direct price comparison is used most often at present. The option pricing method is used rarely. However the option pricing method was used in the cases where additional equipment of car was provided for 1Eur "additional" charge or the additional equipment of car was offered as a special bonus free of charge. SOSR is provided with the prices of second hand cars from external company – specialists at the pricing of cars. They make some QA taking into account the technical stage of the car and the milage.

Slovenia:

Monitoring Report 2016:

All quality adjustments are performed by the central office staff. For the quality adjustment a case by case approach is adopted, i.e. there are no automatic procedures. The quality adjustment method chosen depends on the specific replacement situation. Bridged overlap is the most commonly used method e.g. for technical products, computers and household appliances. Both option pricing and supported expert judgment are used for cars. In rare cases, if there is a significant quality change in assortment of clothing, only 50% of the price change is shown in the index.

Reference Metadata:

Explicit methods: Direct price comparison is used for clothing and footwear, books (the list of most read books is changed every month, since we monitor the major publishing house in the country, which publishes monthly the list of most sold, i.e. popular, books - Top 10 for adults and children/youth). DVDs and computer games are replaced on a monthly basis with more popular ones - direct comparison is used. As regards new cars, mixed/combined approaches are used; in the case of significant change, quality adjustment is made (mostly option pricing complemented with supported judgemental methods). For quantity adjustment, package size adjustment is used (e.g. medicaments). Option pricing is the most commonly used explicit method (a half of the price difference between the two models is attributed to the difference in quality). Sometimes, when other methods can't be applied, we change the base price of a replaced model with the replacement's base price (only if the December price of the replacement is known).

Implicit methods: The choice of a method also depends on the data available: overlap method for audio-video, photo equipmet (if data on prices in two consecutive periods are available). Bridge overlap method is applied in most cases when quality changes are detected. It's applied for PCs, technical products, household appliances, audio-video goods and in a case of significant change in quality when no other useful information is available.

In 2019, the percentage of quality adjustments (ECOICOP 03-12) was 0.4%.

ECOICOP	QA method (%)			
Division	Option pricing and mixed approaches	Bridged overlap	Package size adjustment	Other Base price change
01				
02				
03		0.01		0.11
04	0.09			0.43
05	0.06	0.30	0.004	0.21
06				0.23
07	0.18	0.06		0.25
08	0.40	2.51		0.40
09	0.10	0.30		0.40
10				
11				0,10
12	0.02	0.04		0.16

Spain:

Monitoring Report 2020:

The chosen quality adjustment method depends on the specific replacement situation. INE assess the comparability of the replacement with the obsolete product and decides the most appropriate quality adjustment procedure. The regional offices make the quality adjustments for regionally collected prices and the central office checks these. The most commonly used method is direct comparison. When the direct comparison is not possible due to important changes in the item characteristics, the bridge overlap is applied. Besides, for some specific products, other methods are also used. For instance, INE uses expert judgment, combined with option pricing, for the adjustment of quality changes in the price indices covering the purchase of motorcars and motorcycles. The overlap pricing method is used for the quality adjustment of books and music.

Reference Metadata:

The different quality adjustment methods that are commonly applied in the Spanish HICP can be summarized as follows:

- Implicit methods: overlap, bridged overlap, class mean imputation, direct comparison, link-to-show-no price change.
- Explicit methods: expert judgement, option costs and quantity adjustment.

All the items in the HICP basket are grouped by "types", according to similar features, and there is a list of advised and unadmitted quality adjustment methods for each, depending on product features. Quality adjustment procedures are applied every time there is a replacement, in order to assess whether there is any quality difference and decide the most appropriate treatment accordingly.

The percentage of prices for which each method is applied is not available because adjustments for quality changes

are not counted. Nevertheless, the quality adjustment methods that are usually applied by groups of products are the following:

- Fast-moving consumer goods (food, medicines and personal care products)

Price imputation, direct comparison and quantity adjustments. Also class mean imputation and expert judgement for fresh products (meat, fish, fruit, vegetables and eggs)

- Centrally collected products

Expert judgement, overlap, option pricing.

- Clothing and footwear

Direct comparison, bridged overlap, class mean imputation, expert judgement.

- Furniture, household appliances and equipment

Expert judgement.

- Restaurants

Overlap and price imputation.

Acknowledgements

We thank Fabio Rumler for a thorough discussion of this paper. We are also grateful to Henning Weber, Malte Knüppel, Annette Fröhling and Stefan Schaefer for valuable comments and suggestions. Concerning the German CPI micro data, we are especially grateful to Malte Kaukal and Markus Stahl (Statistical Office of Hesse, Germany) for explaining to us the underlying data in great detail. We also thank Christoph Fischer (Deutsche Bundesbank) for his valuable comments and for sharing the underlying cross-country micro price data set on washing machines with us. Finally, we are very grateful to Günter Beck (University of Siegen, Miggroprices) for providing updated estimates of transaction-based price indices on washing machines for the more recent sample.
The views expressed in this paper are those of the authors only and do not necessarily reflect those of the Deutsche Bundesbank or the Eurosystem.

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PDF ISBN 978-92-899-5515-7 ISSN 1725-2806 doi:10.2866/3481 QB-AR-23-010-EN-N