Is There a Measurement Bias from Quality Adjustment in Austria and Italy?

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Abstract

Improper quality adjustment has been identified as a source of potential measurement bias for CPIs for a long time. However, as a benchmark for quality adjustment does not exist, it has always been difficult to estimate a potential bias. For this paper, we use a corridor, in which quality adjusted prices are supposed to lie, by defining its borders as the two extreme cases of attributing the whole price change to a change in quality (link-to-show-no-price-change) and assuming an unchanged quality when comparing prices (direct price comparison). Analysing micro price data for a number of non-energy industrial goods in Austria and Italy in the period 2011-2018, we find no systematic measurement bias induced by the quality adjustment methods implemented in these countries. Actual quality adjustment of prices conducted by Statistik Austria and ISTAT in most cases lies within the borders of the corridor. Nevertheless, inflation rates calculated according to different quality adjustment methods can differ substantially which calls for further harmonization of quality adjustment practices among euro area countries.

1 Introduction

In price statistics, quality adjustment is one of the major challenges. Prices are always bound to a certain product and its characteristics, which represent the quality of the product. For a price index, that compares prices over time, a problem emerges if the quality of the products for which prices are measured changes as well over time. Therefore, prices should be adjusted to represent constant product quality.[1] Adjusting prices for quality change is, however, a complex issue, as the value of the quality change is not obvious. One can argue that there is a bias in a price index if quality adjustment is not carried out "correctly". In its easiest way, a bias would exist if a quality change goes fully unnoticed. Then, the difference between an alternative index with quality adjustment and one without would constitute the bias. However, as no common sense exists on how to valuate different qualities, it seems to be more intuitive to define a corridor for meaningful quality adjustment results and define all values outside this corridor as biased. In this paper, we want to assess the quality adjustment practices in Austria and Italy based on CPI micro data for a number of selected products.[2] In particular, we investigate whether the quality adjustment conducted by the national institutes happens within such plausible corridors such that a possible measurement bias induced by too much or not enough quality adjustment can be ruled out.

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[1]Eurostat (2018, p. 92); von der Lippe (2007, p. 272)

[2]Data are collected by the Istituto Nazionale di Statistica (ISTAT) and made available to Banca d'Italia within the agreement among ISTAT and Banca d'Italia in the PRISMA framework. The data are confidential and cannot be shared with researchers outside of the Banca d'Italia. For Austria, the micro data are collected by Statistik Austria and made available to the Oesterreichische Nationalbank (OeNB) for the PRISMA network. They are equally confidential and cannot be shared with researchers outside of the OeNB.

2 Quality adjustment in theory and practice

2.1 Quality adjustment methodology

In order to account for quality changes when comparing prices of comparable but slightly different products over time, National Statistical Institutes use several quality adjustment methods. These methods can be classified as implicit and explicit methods of quality adjustment. Implicit ones are based on general assumptions about quality and price changes, while explicit ones take individual product specifications into account.[3] Most important implicit methods are Direct Price Comparison[4] (assuming zero change in quality), link-to-show-no-price change [5] (assuming zero price change, as the price difference reflects the quality difference) and bridged overlap[6]. While implicit methods are seen as easy to apply in practice and can even be automated, their results may lead to biases.[7] On the other side, there are explicit methods for quality adjustment. Most important ones are hedonic quality adjustment (a regression-based approach that explains prices by product characteristics), option pricing (adjusting for features which are now standard but were optional

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[3]For a comprehensive overview see Eurostat (2019); Eurostat (2018, pp. 105). It should be noted that there is no common nomenclature on quality adjustment methods. For example, the CPI manual (International Monetary Fund, International Labour Organization, Eurostat, United Nations Economic Commission for Europe, Organisation for Economic Co-operation and Developmend, World Bank 2020) does not contain the term "bridged overlap", but "class mean imputation" as a standalone method, while targeted mean imputation and overall mean imputation are seen as variants of the simple overlap method.

[4]Eurostat (2018, p. 106) classifies it as an explicit method; DESTATIS (2009, pp. 29) does not classify it at all, as it does for link-to-show-no-price change; von der Lippe (2007, p. 282) puts it to implicit methods, as only prices are taken into account to determine the price of the quality, not the characteristics of the products. Von der Lippe's reasoning was followed.

[5]Synonyms used for this method are "price difference equals quality difference" and "(simple) overlap". The term "overlap" is used especially when old and new products are members of the basket simultaneously within one time period, while "link-to-show-no price change" can also imply a zero price change between the two periods in which the old product leaves and the new product enters the basket of goods.

[6]Bridged overlap exists in several variants, like "targeted mean imputation", "class mean imputation" and "overall mean imputation". The difference lies in the products used for forming the bridge.

[7]Because of that, the so-called "link-to-show-no-price change" method which attaches the full price difference to quality change is ruled out already by the EC regulation 1749/96.

in the past, particularly used for cars), and supported judgemental quality adjustment ("the value of the quality change [. . .] is calculated by using supplementary information sources"[8]). The use of explicit methods requires investment in resources, data and human capital, and does not guarantee undisputed results.[9]

Different quality adjustment methods applied to the same data can lead to very different results. This applies especially to implicit methods or when comparing implicit and explicit methods.[10] Keating and Murtagh (2018, p. 6) show the striking example of the application of hedonics and bridged overlap for laptops and desktops, which only after a five months period lead to an index difference of more than 8 index points. This raises the question what "correct" quality adjustment may look like. While it is not possible to define a benchmark for correct quality adjustment, logical boundaries for the value of the quality-adjusted price can be derived, which may facilitate a bias calculation, as we will see in the next chapter.

2.2 Bias from quality adjustment methodology and logical boundaries

When talking about a measurement bias in consumer price indices, quality adjustment has always played an important role. Since the report of the Boskin commission[11] on the measurement bias in the US CPI, the assessment of the quality adjustment bias has been a standard in investigations on CPI

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[8]Eurostat (2018, p. 113)

[9]For example, hedonic quality adjustment: "The experience from some countries has shown that hedonic technique becomes extremely expensive in practice, data collection and the actual modelling are expensive and results are not always feasible. Coefficients are not stable over time, they might be of "wrong" sign, users do not understand this complicated method." Kinnunen (1998, p. 4); Ahnert and Kenny (2004, p. 26) add that the application of hedonic quality adjustment to the same products, but based on different data sources, sampling techniques, and econometrics may result in price indices that are not fully comparable.

[10]See Keating and Murtagh (2018); Goldhammer et al. (2019).

[11]Boskin et al. (1996)

measurement bias. Strange enough that against this background, no standard benchmark for quality adjustment practices has emerged. The Boskin Commission itself mixed quality adjustment bias and bias from the introduction of new products, therefore applying very different techniques for the bias estimation for each product group:[12] assessing the consumer surplus by increased variety for food and beverages; back-of-the envelope calculations for quality differences in housing and new motor cars; comparison to hedonic indices for appliances and electronics; comparison with matched-model approach for clothing; valuation of an increased service level for motor fuels; and extending the results of particular studies on medical treatments to the whole health sector.

All these techniques have been subject to heavy criticism,[13] and none of it satisfies the requirements for being an undisputed benchmark for quality adjustment. This is why Lequiller (1997) refused to provide an estimate of the quality adjustment bias in his bias study on the French CPI. Because of these experiences, Hoffmann (1998), investigating the quality adjustment bias of the German CPI, followed a slightly different approach by first examining the theoretical properties of the quality adjustment methodologies (already concluding that a bias might be prevalent) and then investigating three product groups (washing machines, fridges, freezers) in detail: his benchmark were hedonic price indices. However, the bias calculations lead to very different results depending on the hedonic method used and on the product group.[14] This made Neubauer (1999) conclude that, if no ideal of quality adjustment exists, it is impossible to determine a bias from the "real" index of cash val-

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[12]Boskin et al. (1996), pp. 27-39.

[13]Especially Moulton and Moses (1997); for a brief discussion on the methods and the criticism also see Schultze and Mackie (2002).

[14]For example, between 1.9 and 2.6 percentage points per year for washing machines and between -0.2 and 0.0 percentage points for freezers, see Hoffmann (1998), p. 105.

ues.[15] Therefore, the Schultze report (Schultze and Mackie (2002), p. 113) stated that "solutions to quality change and new good bias problems must be the fruit at the top of the tree, the kind that requires expensive tools or that may not be reachable at all."

So, if a benchmark using "correct" quality adjustment is not available,[16] the question arises if there is a corridor in which properly adjusted price indices should lie. On the level of single price quotations, such a corridor has been proposed recently. In its recommendation on the use of bridged overlap, Eurostat[17] has elaborated on critical values for a plausibility check of bridged overlap results. These critical values can be applied for any other quality adjustment method, too. The central assumption is that a quality adjusted price should lie in the corridor between two critical values, which are given by the extreme cases of quality adjustment:

- Link-to-show-no-price-change (LNP), where the total nominal price difference is assumed to be related to quality change, so the real price change Δp equals 0.

- Direct price comparison (DPC), where the total nominal price difference is seen equal to the real price change, so the quality difference Δq equals 0.

For a mathematical determination of the corridor, Eurostat (2021) starts with the following equation, showing the relationship between the price p_n^{t-1} of the

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[15]In German: "Wenn es aber schon an einem halbwegs klaren Idealtypus der Qualitätsänderung fehlt, dann ist es ausgeschlossen, einen Fehlerprozentsatz anzugeben, um den der Index der Qualitätsbereinigung wegen von einem wahren Geldwertindex abweicht."; Neubauer (1999), p. 30. In the same vein, Bank of Canada's estimation of the quality adjustment bias considerably declined when using a different method of estimating the quality adjustment bias; see Sabourin (2012).

[16]If it was available and also technically feasible with given resources, it would have been anyway used by statistical offices, one can assume.

[17]Eurostat (2021), Annex 4.

outgoing product n in the previous period, the price p_{n*}^t of the replacement product n^* in the reporting period, the quality adjustment factor $\hat{\alpha}_n$ (to be applied to p_{n*}^t) and the "bridge": the bridge is the real price change after quality adjustment between the old and the replacement product for the time period $[t-1, t]$. It is named "bridge" because of the bridged overlap method, for which Eurostat has calculated these boundaries. For our common case – to be applied to all quality adjustment methodologies – we will name it "real price change factor of product item n at time t", r_n^t. Adapting equation (3) in Eurostat (2021, Annex 4), the quality-adjusted (hypothetical) price of product item n in period t can be calculated in the following two ways:

$$p_{n,qa}^t \equiv \frac{p_{n*}^t}{\hat{\alpha}_n} = p_n^{t-1} \cdot r_n^t \tag{1}$$

In a normal case, we would assume that the quality adjusted price $p_{n,qa}^t$ would lie somewhere in between the price of the outgoing product in the previous period and the price of the replacement product in the current period, as shown in Figure 1. It is important to mention that this case is one of two regular cases, in which $p_{n*}^t > p_n^{t-1}$ (in the other case, we would observe $p_{n*}^t < p_n^{t-1}$).

The framework in equation (1) enables us to calculate, both, the quality change Δq and the "pure" price change Δp as well as the respective values of the extreme cases.

- Δq equals 0 for DPC. For LNP, we get from equation (1):

$$\Delta q = (\frac{p_{n*}^t}{p_n^{t-1}} - 1) \cdot p_n^{t-1} \tag{2}$$

Therefore, the real price change factor r_n^t equals 1, and the quality ad-

Figure 1: Regular price-quality decomposition with quality adjustment
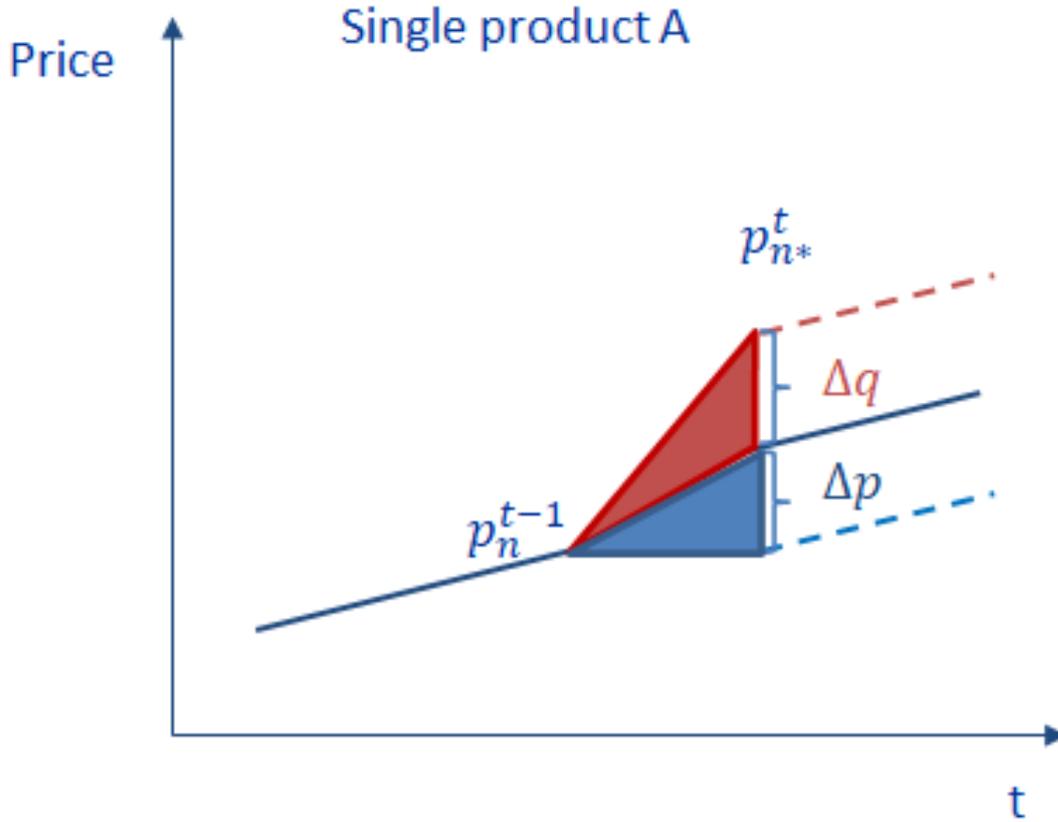
justment factor is given as $\hat{\alpha}_n = \frac{p^t_{n*}}{p^{t-1}_n}$.

- Δp equals 0 for LNP. For DPC, we get from equation (1):

$$\Delta p = (\frac{p^t_{n*}}{p^{t-1}_n} - 1) \cdot p^{t-1}_n \qquad (3)$$

Therefore, the real price change factor is given as $r^t_n = \frac{p^t_{n*}}{p^{t-1}_n}$, and the quality adjustment factor $\hat{\alpha}_n$ equals 1.

With the extreme cases, Eurostat (2021) calculates the following boundaries

for the quality adjustment factor and the real price change factor:

$$\frac{p_{n^*}^t}{p_n^{t-1}} \geq \hat{\alpha}_n \geq 1 \tag{4}$$

$$1 \leq r_n^t \leq \frac{p_{n^*}^t}{p_n^{t-1}} \tag{5}$$

These boundaries provide a good plausibility check for price index compilation practice. However, we would like to evaluate if the resulting indices are within logical boundaries, in order to avoid measurement bias. As the logical boundaries on single-price level are identical to the methods link-to-show-no-price change and direct price comparison, it seems to be most reasonable to calculate the hypothetical indices resulting from the application of these methods in all cases of quality adjustment and compare them with the quality adjusted price indices. So, the following assumptions should hold for price indices at the product group level:

$$if \ \forall i \in n : p_i^{t-1} < p_{i^*}^t : I_n^{DPC,t} >= I_n^{QA,t} >= I_n^{LNP,t} \tag{6}$$

$$if \ \forall i \in n : p_i^{t-1} > p_{i^*}^t : I_n^{DPC,t} <= I_n^{QA,t} <= I_n^{LNP,t} \tag{7}$$

i is the single product, n the product group. From that assumptions on logical boundaries, the bias calculation can emerge. No bias can only be stated if the quality-adjusted index lies inside the logical boundaries. Biases are most commonly expressed in percentage points of the average annual change rate. Hence, if the index lies outside the boundaries, the bias would then be the difference between the average annual change rate of the quality-adjusted

price index and that of the closest logical boundary. As quality adjustment practices may differ by product groups, it is advisable to conduct this analysis at the product group level rather than for the whole index.

However, equations (6) and (7) already show us the assumptions and therefore the limitations of this bias calculation: only if the conditions hold in *all* replacement situations, the corridor will be not violated for sure. However, there can always be cases when the value of the quality difference is assessed to be larger than the price difference; and it might also happen that, within one product category, replacement prices are larger in some occasions and smaller in other occasions than the price of the replaced product. These are caveats to be taken into account when doing such calculations at the index level.

After having set the framework for our calculations on quality adjustment bias, the quality adjustment practices in Austria and Italy will be presented, as the results of our research may also shed light on the index differences induced by using different quality adjustment methods.

2.3 Quality adjustment practice in Austria and Italy

2.3.1 Austria

The Austrian data are especially suitable for this analysis, because Statistik Austria primarily applies explicit quality adjustment methods which makes quality adjustment easier to understand and to calculate. Specifically, the Austrian data contain 6 different flags for quality changes when a product is replaced by a new one with a different quality:

Q0: no (or very small) quality change, the whole price change enters the index calculation. This applies when a new product or service enters the market and

the previous one is no longer available, the new product is a successor with similar or equal quality and is assumed to replace the previous product.

Q1: 25% of the price difference is attributable to the quality difference, hence 75% of the price change is included in the index calculation. This is applied for small, but relevant quality differences between the old product and the successor.

Q2: 50% of the price difference is due to the quality change and 50% are taken into account for the calculation of the price change. This is applied for relevant differences in important features between the predecessor and the new product.

Q3: 75% of the price difference is attributable to the quality change and 25% is assigned to the calculation of the price change. This is applied for significant differences in important features between the predecessor and the new product.

Q4: the product or service enters the index without any price change, the quality change fully explains the observed price change. This is often applied when the price is unchanged but, at the same time, the new product has better features.

A special case is the flag **QZ**: it signals a quality difference that can be (exactly) quantified from the characteristics of a product or service and is directly specified in the data. The QZ-price is a hypothetical price of the product in the previous period, assuming the same characteristics as the successor product. For instance, in the case of two cars with different equipment where any equipment element has a price, the difference in the equipment can be quantified and then subtracted from or added to the QZ-price. The same applies to all products with distinct characteristics that can be priced individually, like PCs or notebooks (with graphic card, processor, number of USB

plugs, etc). For other products where several product characteristics can be observed, such as books or data storage devices (memory cards, USB sticks), hedonic methods are used. In this case, the pricing of the characteristics is done in a regression where, e.g. book type and size, number of pages, kind of binding (for books) and storage space and type of card or stick (for memory cards/sticks) are used as explanatory variables.

Table 1 gives an overview of the occurrence of the different flags of quality adjustment for the 12 main groups of the COICOP classification in 2020. The numbers in the table mean that, e.g. in COICOP group 03 "Clothing and footwear", Q0 (no quality change) is applied to 2.0% of all price observations in this group, Q1-Q3 have been assigned to 0.8% of all price observations, etc. According to the last column of the table, Q0 has been applied to about 0.4% of all price observations in the whole basket of goods and services.

Table 1: Occurrence of quality adjustment flags per COICOP-2 group in 2020 in Austria in % of all observations

COICOP-2 groups	01	02	03	04	05	06	07	08	09	10	11	12	Total HICP
Q0	0	0	2	0	2	0	0	1	0	0	0	0	0.4
Q1-Q3	0.1	0.1	0.8	0.1	1	0.1	0.1	0	0.3	0.7	0.1	0.1	0.3
Q4	0	0	0.4	0.1	0.6	0	0.1	2.8	0.2	0.1	0.3	0.1	0.2
QZ	0.4	0.4	1.2	0.2	1	0.1	0.6	1	0.8	0.2	0.1	0.8	0.6

Notes: COICOP 2-digit groups: 01 Food and non-alcoholic beverages; 02 Alcoholic beverages, tobacco and narcotics; 03 Clothing and footwear; 04 Housing, water, electricity, gas and other fuels; 05 Furnishings, household equipment and routine household maintenance; 06 Health; 07 Transport; 08 Communication; 09 Recreation and culture; 10 Education; 11 Restaurants and hotels; 12 Miscellaneous goods and services. Source: Statistik Austria.

2.4 Italy

For quality adjustment, as it is required by EC Regulation No 1334/2007, in the Italian national statistical institute (ISTAT) a case-by-case approach is

adopted. In details, methods adopted to manage quality adjustment issues
are:

1. Direct comparison:

   (a) for clothing and footwear, when the product offers in two consecutive
       months are seen as being comparable on the basis of criteria defined
       by ISTAT. In the month when the replacement is done, the elemen-
       tary price is flagged, the reason of the replacement is ticked and the
       direct comparison is carried out directly by automatic procedures;

   (b) 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 evalu-
       ated 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;

   (c) for products for which best seller approach is adopted such as elec-
       tronic games, DVD movies;

   (d) 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.

2. Bridged overlap: Bridged overlap implicitly imputes a price for the new
   product-offer in the previous period and thereby values the quality dif-
   ference as the price difference between the old and new product-offers
   in that period. Two variants are possible: in the first variant, the price

variation of the incoming reference with respect to the immediately preceding period is evaluated equal to the price variation recorded by the references that have not registered any substitutions for that particular product. In the second variant, the price variation of the incoming reference with respect to the immediately preceding period is evaluated equal to the price variation recorded by the references that have registered substitutions for that particular product and for which the approach of direct comparison or explicit methods has been adopted.

   (a) 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.

3. Link-to-show-no price change ("overlap")[18]: it estimates the value of the difference in quality between the outgoing reference and the incoming one as equal to the price difference between the two references at a time when both references were available. In this case, the replacement of a reference always involves the collection of additional data in order to reconstruct the temporal price dynamics of the new reference.

   (a) 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

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[18]Compare to footnote 5.

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 estimate is used.

The Italian micro prices database contains a flag with 4 options for changes: change of collected unit, change of brand, change of reference quantity and change of variety. The change of brand and variety could be considered as quality changes.

3 Methodology for assessing a possible measurement bias related to quality adjustment

In order to assess whether the quality adjustment procedures used by Statistik Austria and ISTAT, as documented by these flags, possibly lead to a bias in the measurement of inflation, we re-calculate inflation for three different quality adjustment assumptions for a number of selected products. By that, we follow the critical boundaries outlined in chapter 2.2. One boundary index follows, for all replacement situations, the assumption underlying LNP that the new quality adjusted price is equal to the old price. The other boundary index uses the assumption of the DPC method that the quality difference is either negligible or 0, therefore directly comparing the old and the new price in a replacement situation. The third index we calculate uses actual quality adjustment (QA) conducted by Statistik Austria and ISTAT as documents in the index production systems by the flags mentioned above. Under reasonable assumptions, the new quality adjusted price should lie somewhere in between

the old and the new price and thus the price index actually calculated by Statistik Austria and ISTAT should move between the index calculated under the two extreme assumptions which represent an upper and lower bound for reasonable quality adjustment. Put differently, when the actual price index systematically and permanently exceeds the range spanned by the upper and lower bounds, we would conclude that quality adjustment is so strong that a measurement bias in inflation of that particular item cannot be ruled out.

It is important to stress that a bias can only be assumed for systematic and permanent excession of the range between DPC and LNP indices. In single cases, there can be justified exemptions from that rule, like seminal technological progress. Therefore, we have focused our judgement on the annual average change rate of all three indices for periods of six years (Austria) or seven years (Italy), respectively, taken into account a large number of replacement cases. This should help us getting a robust judgement about the possibility of a bias.

Overall, our exercise can be seen as a plausibility check of the actual quality adjustment conducted by the statistical institutes rather than a check for correctness, as quality adjustment, especially in its explicit form (Austrian data), is and will always be a subjective decision of the statisticians at work.

4 Data

4.1 Austria

The Austrian dataset which is used to calculate the quality adjusted indices consists of monthly observations from January 1996 to December 2017 for over 1,000 products and services. However, we limit our analysis to the period after the introduction of chain-linking in the Austrian HICP in 2011 since the

update of the goods basket in 5-year intervals prior to this date is usually associated with extensive redefinitions of product descriptions which would create a break in our indices. In addition, we include only selected products from the non-energy industrial goods (NEIG) component, as quality adjustment plays a minor role for the other components of the HICP, i.e. food, energy and services.[19] The products within the NEIG component were chosen on the basis of (i) a large incidence of quality adjustments and (ii) a large weight or the product being representative among subgroups of products, e.g. one furniture item, one IT product, one clothing item, etc.

Based on these considerations we chose the following 12 products for inclusion in our analysis: bedroom furniture, sofa set, dishwasher, electric razor, toothbrush, washing machine, lawn mower, sink, laundry detergent, notebook/tablet, PC and men's jeans. These products together account for about 3% of the Austrian HICP.

4.2 Italy

We use monthly micro consumer price data provided by ISTAT from January 2011 to December 2018. In particular, we use prices collected locally once a month by municipal statistical offices in over 70 provincial capitals. Hence, our sample does not include prices collected centrally (e.g., cars), and those collected locally more than once a month (e.g., some unprocessed fresh food items). It amounts to around 3.5 million observations per year, in 267 8-digit COICOP categories grouped in 69 4-digit COICOP categories. Based on the same considerations as for Austria (a large incidence of quality adjustments and a large weight or the product being representative among subgroups of

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[19]See also Table 1. Most products we include in our analysis are in COICOP group 05 (Furnishings, household equipment and routine household maintenance).

products) we chose the following 10 products for inclusion in our analysis: men's trousers, women's pullovers, washing machine/dryer and dishwasher, bedroom furniture, laundry detergent, fridge/freezer, appliances for heating and air conditioning, TV, small electronic devices (razor, toothbrush), jewellery and clocks. These products together account for about 2% of the Italian consumer price index.

5 Results

5.1 Austria

In Figure 2 we show the development of the price indices recalculated on the basis of the above-mentioned flags for the actual quality adjustment conducted by Statistics Austria (blue line) together with the indices under the assumption of direct price comparison (DPC, red line) and the assumption of link-to-show-no-price-change (LNP, yellow line). All indices start at 1 in January 2011.

As can be seen from Figure 2, for most of the displayed products the quality adjusted price index according to information from Statistik Austria moves within the upper and lower bounds as defined above. For bedroom furniture and PC, for example, the quality adjusted price index is very close to the DPC index. This means that the adjustment of prices due to quality changes is relatively small such that there is little difference to the case when there is no quality adjustment. In contrast, for sofa set and laundry detergent the major part of the price changes is assessed to be due to quality changes resulting in a close development of the quality adjusted price index and the LNP index. For most remaining products in Figure 2, the quality adjusted price index is somewhere in the middle between the upper and lower bounds. Exceptions

Figure 2: Price indices for different quality adjustment assumptions
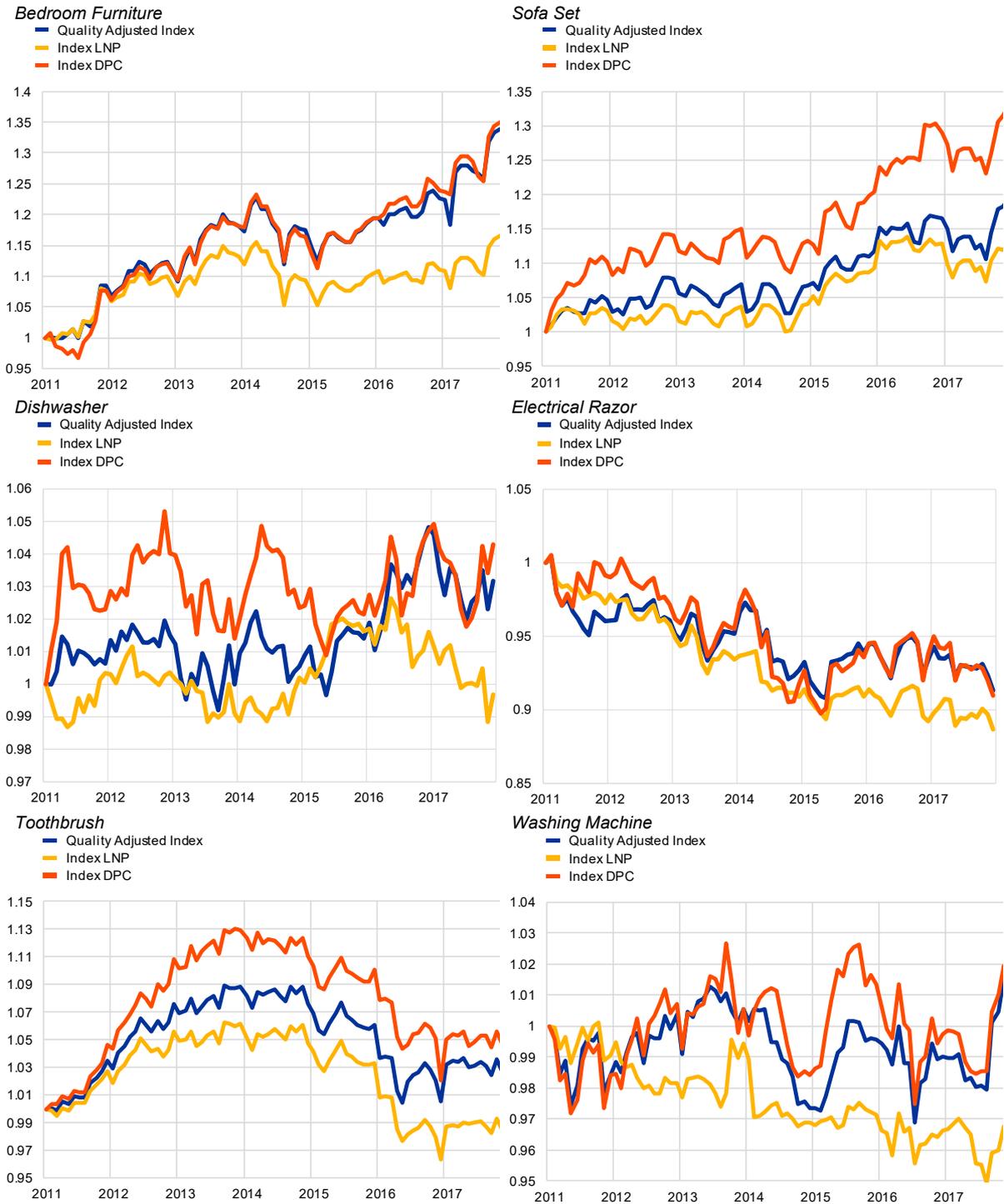
Sources: Statistics Austria, own calculations.
Notes: LNP: link-to-show-no-price-change, DPC: direct price comparison.
Latest observation: Dec. 2017.

Figure 1: Price indices for different quality adjustment assumptions (continued)
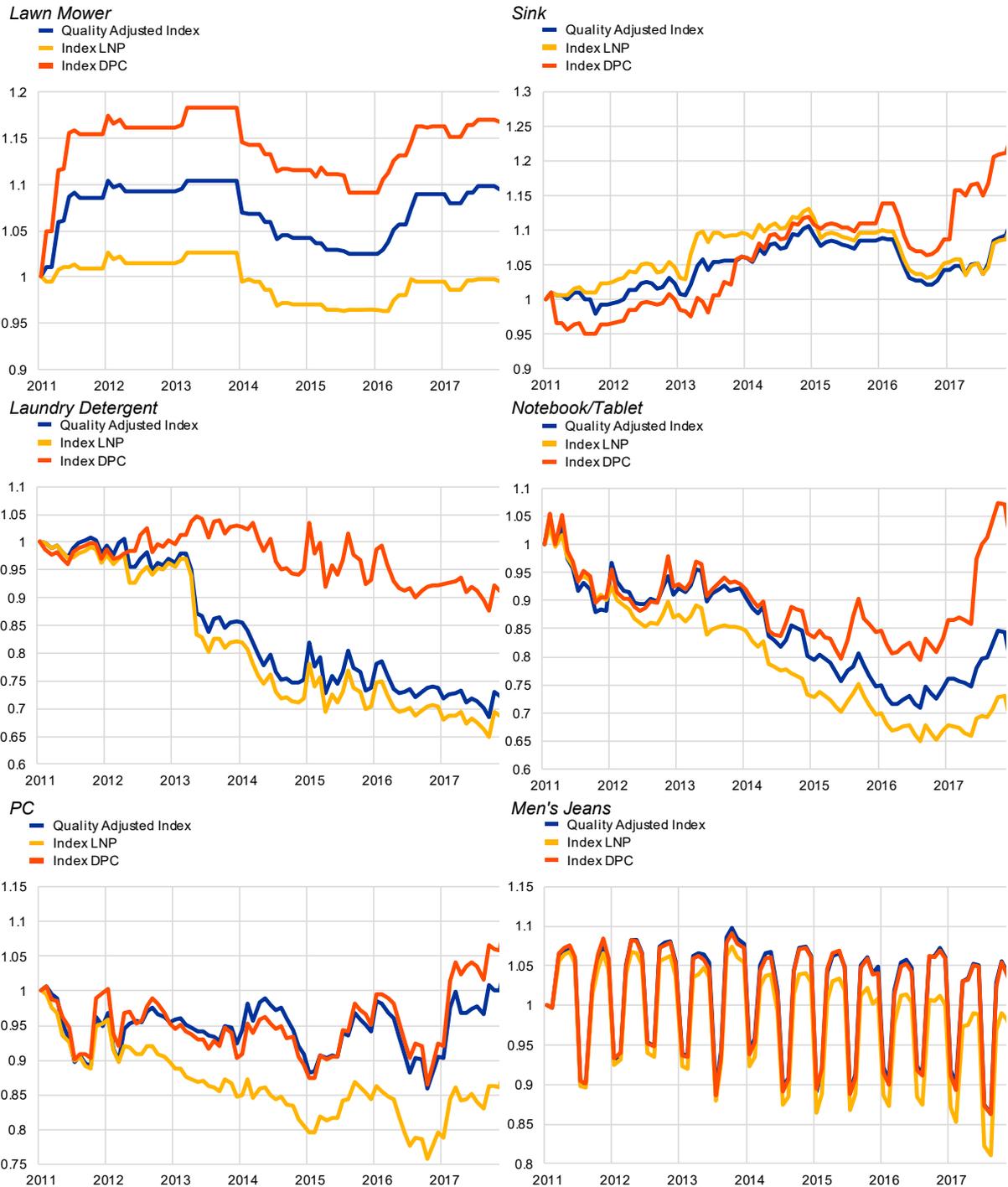
Sources: Statistics Austria, own calculations.
Notes: LNP: link-to-show-no-price-change, DPC: direct price comparison.
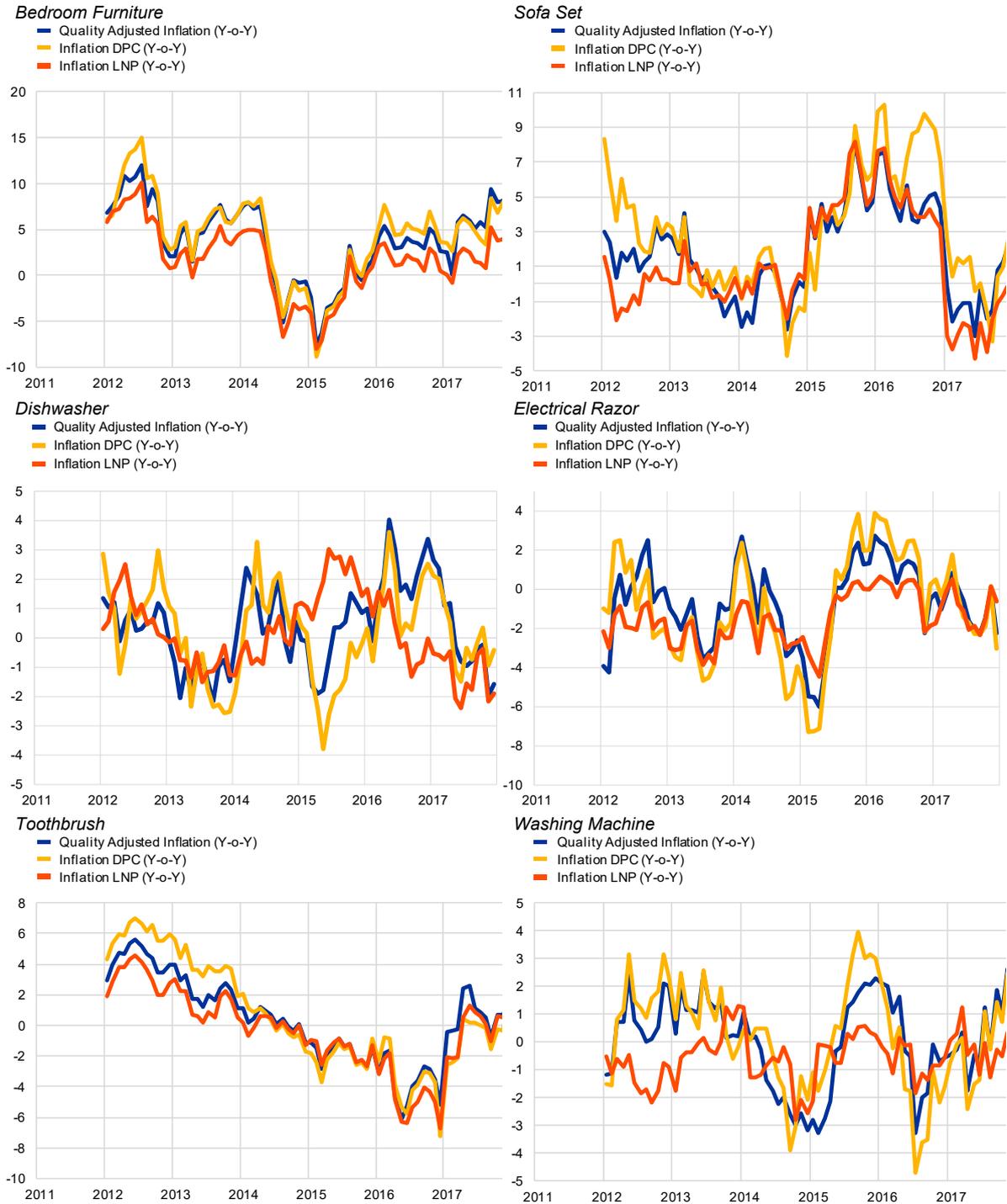Latest observation: Dec. 2017.

are sink and electrical razor for which the quality adjusted index is slightly below the lower bound in the period between 2014 and 2017 (sink) and in 2011 (razor). This can only happen when either prices increase and at the same time quality decreases or when both prices and quality decrease, but quality decreases relatively more than prices. These are quite unusual situations and should not occur in the data too often. Both examples are also remarkable as DPC and LNP indices cross each other at one point in time (razor in 2011, sink in 2015), which may point to a fundamental change in the market and probably drives the quality adjusted index out of the corridor for some time. Finally, for the only clothing item in our sample, men's jeans, all three price indices follow a clear seasonal pattern and show a very close correspondence. This implies that quality adjustment apparently only plays a minor role for clothing.

From this evidence, we conclude that with only few exceptions the quality adjustment in the Austrian data – at least for the products in our sample – is undertaken within reasonable bounds and, thus, there is no indication of a systematic measurement bias induced by quality adjustment. Of course, this conclusion is only based on a small number of products, but these products appear to be quite representative for the whole non-energy industrial goods sector.

How do the differences in the three indices for the QA, DPC and LNP cases translate into differences in inflation rates? Figure 2 shows the annual inflation rates corresponding to the indices shown in Figure 2.

From eyeballing we can see that for most products and time periods the inflation rate according to the actual quality adjustment of Statistik Austria lies between the inflation rates implied by the upper and lower bounds, DPC and LNP respectively. There are only very few and temporary exceptions.

Figure 2: Inflation for different quality adjustment assumptions

Bedroom Furniture

- Quality Adjusted Inflation (Y-o-Y)
- Inflation DPC (Y-o-Y)
- Inflation LNP (Y-o-Y)

Sofa Set

- Quality Adjusted Inflation (Y-o-Y)
- Inflation DPC (Y-o-Y)
- Inflation LNP (Y-o-Y)

Dishwasher

- Quality Adjusted Inflation (Y-o-Y)
- Inflation DPC (Y-o-Y)
- Inflation LNP (Y-o-Y)

Electrical Razor

- Quality Adjusted Inflation (Y-o-Y)
- Inflation DPC (Y-o-Y)
- Inflation LNP (Y-o-Y)

Toothbrush

- Quality Adjusted Inflation (Y-o-Y)
- Inflation DPC (Y-o-Y)
- Inflation LNP (Y-o-Y)

Washing Machine

- Quality Adjusted Inflation (Y-o-Y)
- Inflation DPC (Y-o-Y)
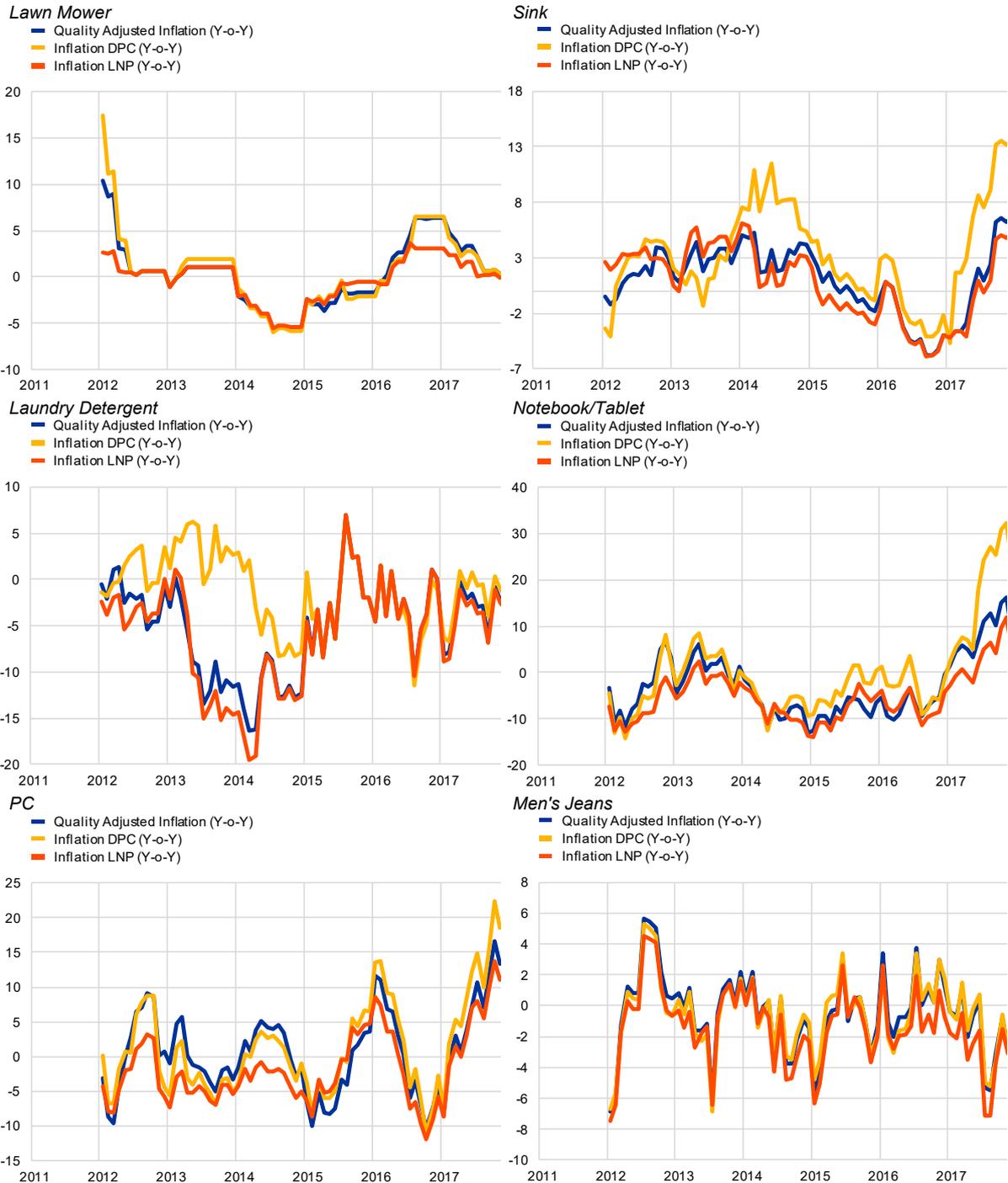- Inflation LNP (Y-o-Y)

Sources: Statistics Austria, own calculations.
Notes: LNP: link-to-show-no-price-change, DPC: direct price comparison, inflation rates in percent.
Latest observation: Dec. 2017.

Figure 2: Inflation for different quality adjustment assumptions (continued)

Sources: Statistics Austria, own calculations.
Notes: LNP: link-to-show-no-price-change, DPC: direct price comparison, inflation rates in percent.
Latest observation: Dec. 2017.

Moreover, for most products and time periods inflation rates under the three assumptions of quality adjustment appear to be quite close to each other. However, looking at the axis scale of the graphs we realize that inflation at the item level is quite volatile. For this reason, it is difficult to say from only looking at the graphs whether different ways of quality adjustment have a sizeable impact on resulting inflation rates. To see this, we report average annual inflation for the period 2011-2017 for the three versions of quality adjustment and each product in Table 2.

Table 2: Average inflation for different quality adjustment assumptions in % (2011-2017)

Products	DPC	QA	LNP
Bedroom furniture	4.3	3.8	1.7
Sofa set	2.9	1.8	1.2
Dishwasher	0.4	0.2	0.2
Electrical razor	-0.9	-0.7	-1.5
Toothbrush	0.6	0.3	-0.3
Washing machine	0.2	0.1	-0.6
Lawn mower	0.7	0.4	-0.2
Sink	3.2	1.0	0.8
Laundry detergent	-1.2	-5.3	-6.0
Notebook/tablet	-0.1	-3.1	-5.3
PC	1.3	0.6	-1.7
Men's jeans	-0.6	-0.5	-1.4

Notes: DPC denotes direct price comparison, QA the quality adjustment according to information from Statistik Austria and LNP link-to-show-no-price-change.

Table 2 reveals that for most products inflation rates based on the actual quality adjustment using information from Statistik Austria lies between the inflation rates according to DPC and LNP. Exceptions are electrical razor and men's jeans with negligible deviations. For most products the difference between the three quality adjustment methods are quite sizeable. The largest differences are observed for notebook/tablet and laundry detergent, followed by PC, bedroom furniture and sink. Taking the example of notebook/tablet,

compared to the quality adjustment conducted by Statistik Austria inflation in the period 2011-2017 would have been about 3 percentage points higher if there was no quality adjustment of prices and by 2.2 percentage points lower if all price changes were completely explained by quality changes. On average over all products considered, quality adjusted inflation turns out to be exactly in the middle between the two extreme cases represented by DPC and LNP.

5.2 Italy

Again, we report the results for price indices for three cases: the actual CPI index computed using quality adjustment (blue line) together with the indices under the assumption of direct price comparison (DPC, red line) and under the assumption of link-to-show-no-price-change (LNP, yellow line).

As can be seen from Figure 3, the official index is always close to the lower bound, which means that price changes in replacement situations are mainly attributed to changes in quality: it means that we can interpret the actually carried out quality adjustment as representing the lower bound. It can also be seen that the differences between upper and lower bound are far smaller in Italy than in Austria. This points to a different philosophy for the strategy of sampling, replacement and quality adjustment as a whole, using a rather narrow definition of products to avoid complex quality adjustment procedures in replacement situations.

From this evidence, we conclude that the quality adjustment in the Italian data – at least for the products in our sample – is undertaken within reasonable bounds and, thus, there is no indication of a systematic measurement bias induced by quality adjustment. Our conclusion is based on a small number of products that are representative, in our view, for the non-energy industrial goods sector. The same holds when we look at inflation rate as shown in

Figure 4.

Table 3: Italy Average inflation for different quality adjustment assumptions (2011-2018)

Products	DPC	QA	LNP
Men-pants	-0.016	-0.017	0.07
Womens pullovers	-0.22	-0.22	-0.09
Washing/dryer Mashine and dish washer	-0.003	-0.013	-0.01
Bedroom Furniture	0.164	0.225	0.199
Laundry detergent	0.375	-0.067	-0.066
Fridge/frezeer	-0.932	-1.337	-1.322
Appliances for heating and air conditioners	0.608	0.705	0.689
TV	-0.383	-0.631	-0.638
Small electronic appliances (razer, toothbrush)	-0.063	-0.081	-0.093
Jewel and clock	0.312	0.264	0.265

We finally present the average annual inflation for the period 2011-2018 for the three cases of quality adjustment and each product in Table 3. In the considered sample period, it seems that for seven out of ten products, the CPI index is outside of the corridor; for five cases, below the lower bound. However, in all of these cases, the difference to the corridor – and a possible bias - is small; with the exception of bedroom furniture, the bias would be within the rounding margin.

6 Discussion

The results shown in the previous section lead us to some remarkable conclusions. First, depending on national practice, the corridor for meaningful quality-adjusted prices may be of substantially different size: Austria shows rather large corridors, Italy rather small ones. As pointed out before, we can conclude that both countries follow different strategies on the complex of sampling, replacement and quality adjustment: Austria seems to use wide product descriptions and compensate for rather arbitrary replacements by

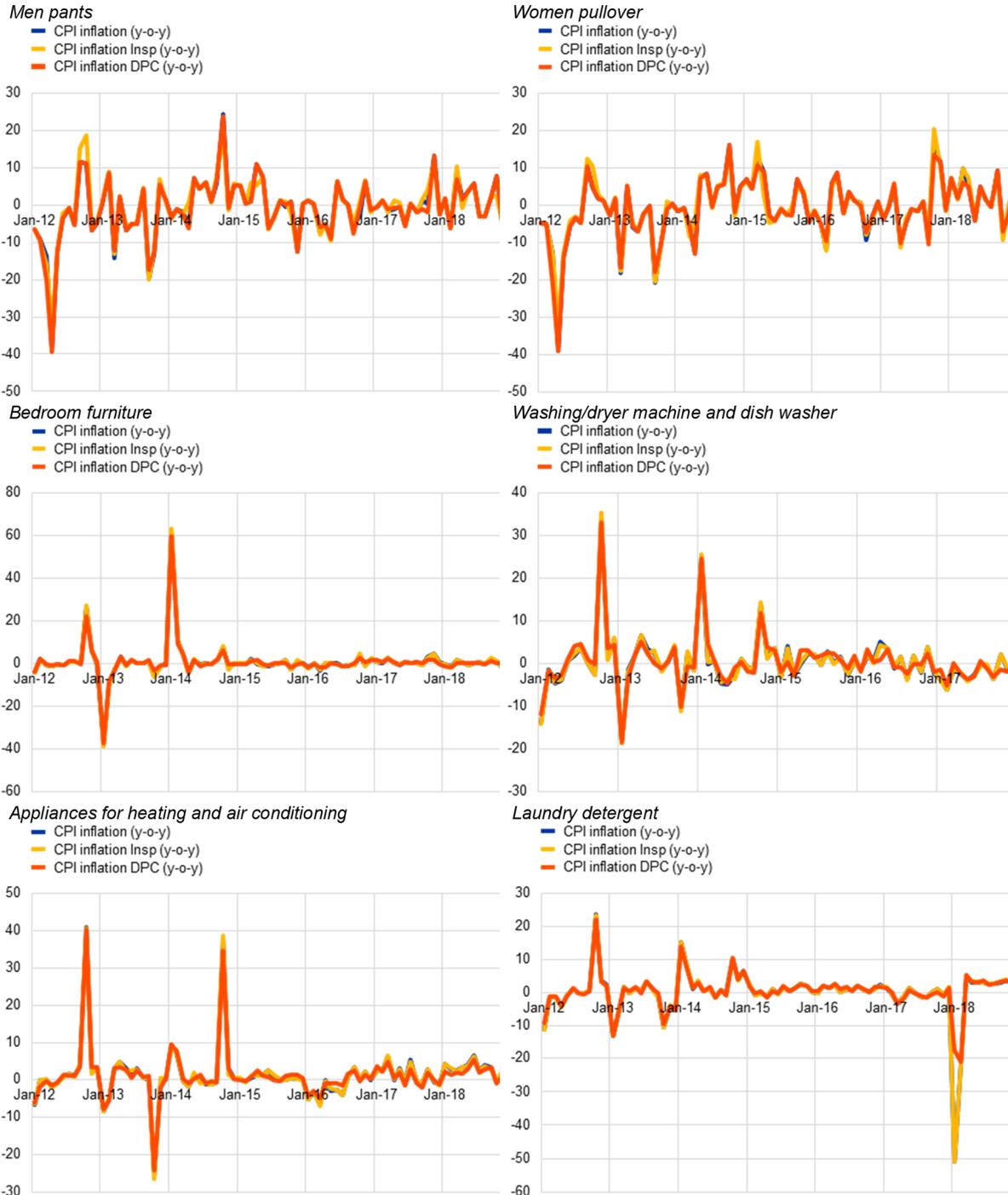**Figure 3:** Price indices for different quality adjustment assumptions
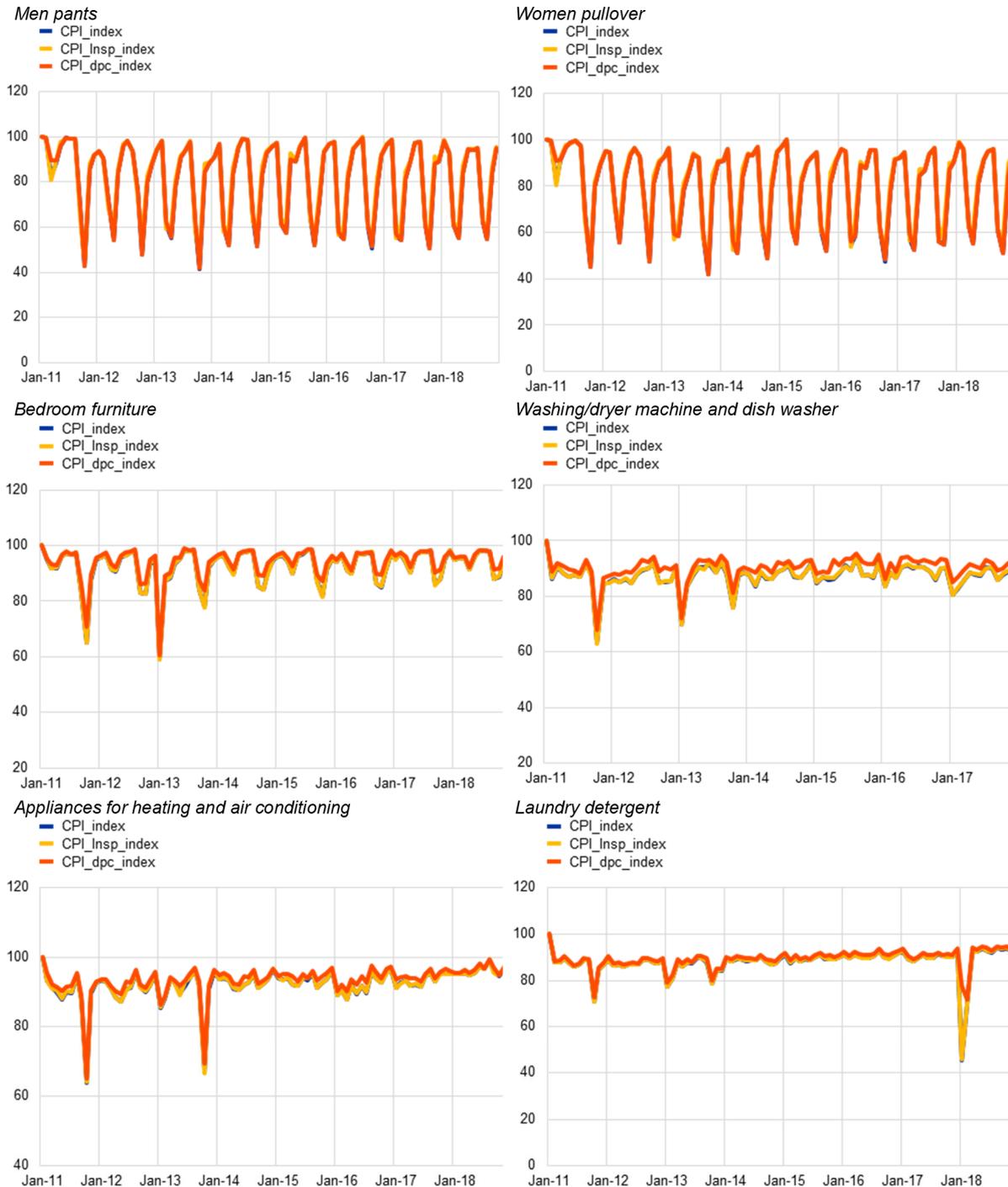
Sources: ISTAT, own calculations.
Notes: LNP: link-to-show-no-price-change, DPC: direct price comparison.
Latest observation: Dec. 2018.
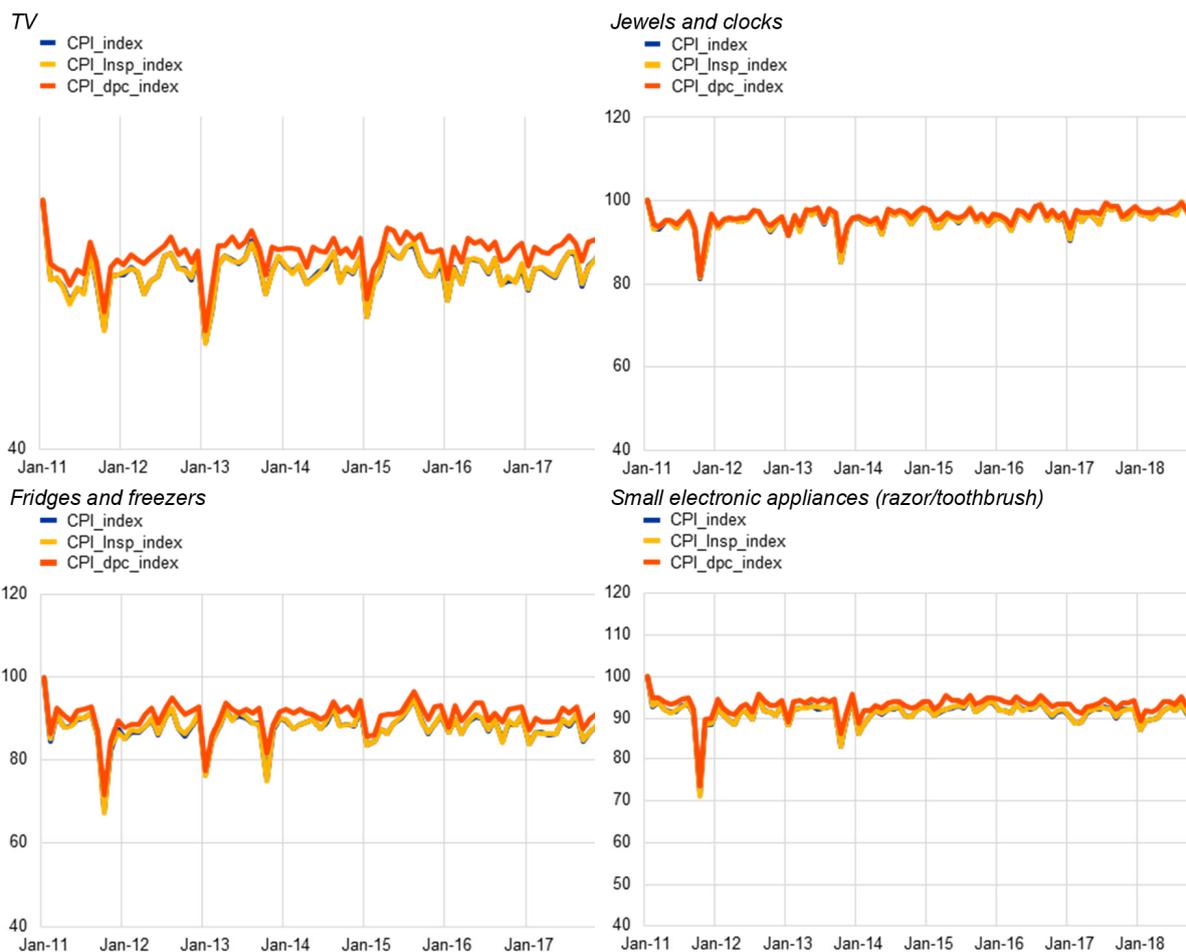
Figure 3: Price indices for different quality adjustment assumptions (continued)
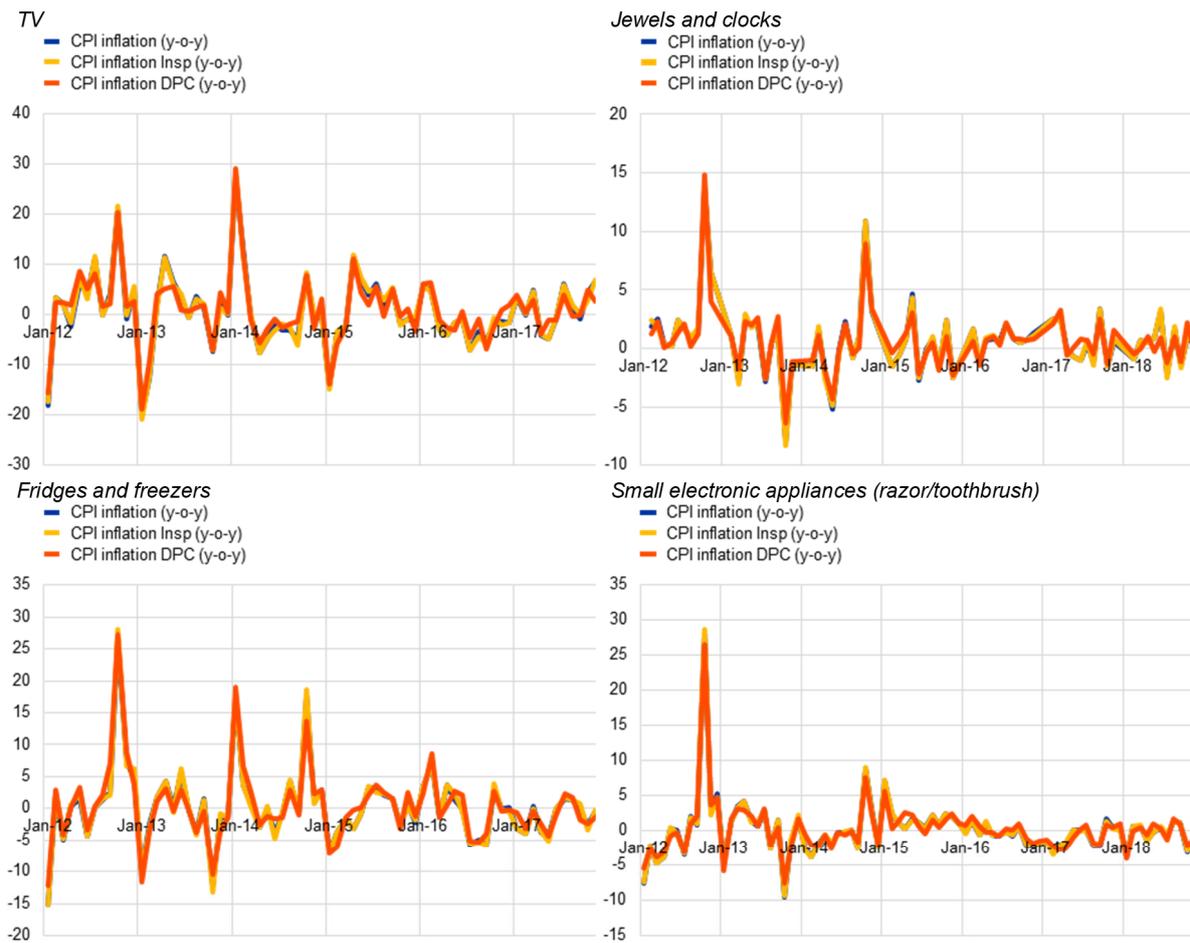

Sources: ISTAT, own calculations.
Notes: LNP: link-to-show-no-price-change, DPC: direct price comparison.
Latest observation: Dec. 2018.

Figure 4: Inflation for different quality adjustment assumptions

Sources: ISTAT, own calculations.
Notes: LNP: link-to-show-no-price-change, DPC: direct price comparison.
Latest observation: Dec. 2018.

Figure 4: Inflation for different quality adjustment assumptions (continued)

explicit quality adjustment; Italy seems to use either narrow product descriptions or narrowly defined strata, which limits the corridor and also implies rather similar quality adjustment results, independent of the method.

Second, the method we have used as well as results do not point to the existence of substantial quality adjustment biases in the CPI of both countries. If the quality-adjusted index lies outside the corridor, the difference is always rather small, and, if existing, points - if at all - to a downward bias.

Third, the results also show that even within the corridor, the use of certain quality adjustment procedures may drive the inflation rate in a certain direction. An example for that is laundry detergent in Austria, where, despite a 4.8 p.p. difference in the average change rates of DPC and LNP indices, the QA index is only 0.7 p.p. larger than the lower bound. Systematically applied, a quality adjustment policy could be used that leads to substantially different inflation rates despite using justified QA methods laying inside the corridor. This calls for additional harmonisation efforts of sampling, replacement and quality adjustment methods within the euro area.

Third, the results also show the limits of our method. First, as coming from propositional logic, we cannot conclude that a bias exists if the quality-adjusted index is outside the corridor. We can only conclude that if the index is inside the corridor, it has no bias. The example of one product whose price needs, because of technological progress, a quality adjustment that exceeds the corridor for well-justified reasons underlines this logical consideration.

Another limitation is that the method seems to need rather stable market conditions, i.e. a fixed order between DPC and LNP indices. A situation as observed for sinks in Austria, when the DPC index overtook the LNP series after several periods, makes the interpretation of the results of the quality-adjusted index at least problematic for the periods around the change. In

addition, as quality adjustment may exceed the corridor in single cases, the time range on which the method should be applied is rather long, in order to make a general judgement about maintaining the corridor. The use of indices and long-term averages is an outcome of this limitation.

7 Conclusions

The aim of this paper is to show and demonstrate a new approach for determining a potential measurement bias in the CPI caused by improper quality adjustment. In this note we try to assess – based on micro data from a number of selected non-energy industrial goods – whether the quality adjustment practices in Austria and Italy happen within reasonable boundaries or whether they lead to a possible bias in the measurement of item-specific inflation.

The approach we have taken is driven by micro data, as the results of quality adjustment can only be observed at that stage. Determining a meaningful corridor for quality-adjusted indices also takes care of the impossibility to define quality in an undisputed way and the necessity of subjective judgements by the statistician conducting quality adjustment.

Our results for Austria indicate that for most of the products and time periods the quality adjustment based on information from Statistik Austria leads to inflation rates that are lower than when no quality adjustment would be implemented and higher than when quality adjustment would be so strong to completely offset the price changes. For some of the products considered, such as bedroom furniture, toothbrush and washing machine, quality adjustment is rather small such that resulting inflation rates resemble the case when there would be no quality adjustment. For other products, however, such as sofa set, sink and laundry detergent, quality adjustment is so strong to almost

compensate the whole price change. Only for PC (in the period from 2013 to 2014) and for electrical razor (in 2016 and 2017) we find evidence of excessive quality adjustment that overcompensates price changes and should therefore be interpreted with care. If small quality adjustment is preferable or more correct than extensive quality adjustment, is difficult to assess a priori. Especially in its explicit form, which is widely used in Austria, quality adjustment always involves a subjective decision of the statistician, meaning any way of quality adjustment can be justified. What we can say, though, is that there is no evidence of systematically overstated quality adjustment across many products in Austria that would lead to a bias in the measurement of inflation.

For Italy, where ISTAT mainly uses implicit methods of quality adjustment, results are reasonable and give us no evidence of major quality adjustment biases in price indices and inflation rates. However, the official index for the example products is, with the exception of two cases, close to the lower bound, meaning that the Italian CPI might be close to a minimum of reasonable quality adjusted indices.

The differences between the explicit and implicit methods used by Statistik Austria and ISTAT eventually calls for more harmonization of quality adjustment, sampling and replacements among euro area countries in the future. Our study itself may be a trigger for more microdata-driven studies on quality adjustment, as only at this level, quality adjustment procedures can be assessed.

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