Balancing the Swedish CPI

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Abstract

Traditional field data collection in the Swedish CPI (HICP) has successively been replaced by alternative data sources while adhering to the fixed base methodology and sampling procedures, at large. The transition should conceptually arrive at less uncertainty by reducing price collector variations while increasing sample sizes. Herein, we address variance due to sampling in the Swedish CPI (HICP) through a bootstrap approach applied to some specific parts of the basket. The expected outcome from the paper is to balance focus between areas in the CPI with respect to obtained variances. The results will be connected to the corresponding estimates provided in the annual Quality Declaration of Official Statistics at Statistics Sweden.

Key words: inflation variance estimation, Swedish CPI, bootstrap, two-dimensional sampling, new data sources

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1 Introduction

The purpose of this paper is to assess variance of the Swedish CPI by examining some influential parts of the index that comprise various data collection methods. The analysis will be connected to the existing assessment of sampling variance and serve for balancing of focus between divisions in the CPI and respective data sources. The period of study is the years 2018-2021, which is the ending phase of a long period of low inflation followed by the pandemic.

1.1. Background

Official statistics published by Statistics Sweden is disseminated with a quality declaration per survey year (Statistics Sweden 2022c). This is the case with the Swedish CPI and HICP for which sampling uncertainty measures are assessed annually for the *monthly change*, the *annual change* (inflation rate) and the *monthly change in inflation rate*. The past decade has rendered a highly modernized data garden in the Swedish CPI with various transaction data sources, web scraping and API data, in parallel with remaining manual price collection both from the internet as well as from on-site (field) as well as a few remaining accounts of one-to-one correspondence through telephone. This transition towards a highly crisp CPI data collection has presumably increased precision. Strongly connected to the fixed base approach, especially with transaction data, sample selection, random or cut-off, is still predominantly employed to safeguard quality changes of products over time as this is a specific process in production, often performed manually– until newer methods have been explored, communicated to the users and implemented.

1.2. **The CPI statistic**

The CPI is a chained index based on annually computed and fixated links that are chained with an intermittent link for the latest full year to the current month the in actual year. The chain formulates for some month m in e.g. year 2021 as[1]

$$CPI_{1980}^{2021,m} = I_{2019}^{2021,m} \times I_{2018}^{2019} \times \ldots \times I_{2004}^{2005} \times \left\{ I_{2003,dec}^{2004} \times I_{2002,dec}^{2003,dec} \times \ldots \times I_{1980,dec}^{1981,dec} \times I_{1980}^{1980,dec} \right\} \quad (1)$$

of which the bracketed part is an old construction abridged in 2005 to the current linking apparatus. The current month index link $I_{y-2}^{y,m}$ consists of a short-term component $K_{y-1,12}^{y,m}$, an intermediary link $I_{y-1,12}^{y,12}$ and an intermittent normalising factor, the latter being immaterial to this study. Most of this chain is constant in comparisons between years, and the three statistics in the analysis are

I) The *short-term* link (HICP variant): $K_{y-1,12}^{y,m} = \sum_g^G w_{y,g} I_{y-1,12,g}^{y,m}$ for elementary product groups g.[2]

[1] C.f. the guideline for the Swedish CPI/HICP in which the index construction is explained (Statistics Sweden 2022b).

[2] There is a difference in final aggregation between the Swedish CPI and the Swedish HICP. The HICP final aggregation is used here as a proxy for the CPI, assuming no loss of validity in results when bypassing the intermediary link per product group.

II) The *inflation rate* expressed as twelve-month change: $\frac{CPI_{1980}^{y,m}}{CPI_{1980}^{y-1,m}}$, of which the variable components $Inf^{y,m} = K_{y-1,12}^{y,m} * K_{y-2,12}^{y-1,12} / K_{y-2,12}^{y-1,m}$ are subject here.

III) The *change in inflation rate*: $\Delta Inf_{y,m-1}^{y,m} = Inf^{y,m} - Inf^{y,m-1}$

Weights for groupings also below 2-digit COICOP categories are based on a Household Budget Survey (HBS) and from annually consumption values from National Accounts. Access to various data sources during last years[3] have additionally provided high-quality information on actual products within categories. Thus, baskets, sampling frames and weighing at all levels are adapted to reflect actual consumption. COICOP division weights and data sources are given in Table 1.

Table 1 Swedish CPI: Main division weights 2022 and data sources

COICOP	Weight	Grouping	Data sources	Coverage	Methods
01	**14.3**	**Food & non-alcoholic beverages**	TD	≈85%	S
02	**3.9**	**Alcohol and tobacco**	TD	100%	CO
03	**4.0**	**Clothing and footwear**	MPC	-	S
04	**24.1**	**Housing**	Mixed	-	S/CO
05	**7.1**	**Furnishing, etc.**	Mixed	-	
-05.1	2.676	*Furnishing and furnishings*	*-WS, MPC*	-	S
06	**3.6**	**Health care**	Mixed		
-06.1	0.84	*- Drugs (prescribed/non-prescr.)*	*-TD/-TD*	100% / N/A	CO/S
-06.1	0.92	*- Other medicinal products*	*-WS/-TD/MPC*	N/A	
-06.2	0.912	*- Dental fees*	*-TD*	100%	CO
07*	**13.4**	**Transportation**	Mixed: TD, WS, MPC		
-07.3	0.19	*-Train travel, long-haul*	*-TD*	≈100%	CO
	0.048	*-Domestic air travel*	*-WS from API*	-	S
	0.14	*-International air travel*	*-WS from API*	-	S
08	**3.2**	**Communication**	Mixed:		
-08.2	0.978	Telephone equipment	*-TD, API*	High	S
09	**12.7**	**Recretation and culture**	Mixed:		
-09.1	2.33	*-Equipment*	*-TD, API, MPC*	High	S
10	**0.3**	**Education**	MPC	-	S
11	**5.9**	**Restaurants and hotels**	MPC	-	S
-11.1	5.3	*Restaurants*	*-MPC*	-	S
12	**7.5**	**Miscellaneous goods/ services**	Mixed: TD, MPC		S

Abbreviations: TD = Transaction data. MPC = Manual Price Collection (on-site or online). WS = Web Scraping. API = Application Programming Interface. S = Sampling. CO = Cut Off.
* Weights in 07 downed significantly in 2021/2022 due to the pandemic.

Subdivisions for which sampling errors can be estimated are indicated in Table 1. Alongside and intensive usage of transaction data and online data collection (manual or web scraped/API), some manual on-site collection remains especially within 03 Clothing and footwear, sports equipment (09 Recreation and culture) and e.g. bicycles (07 Purchase of Vehicles) alongside these other collection methods. The main motive for the need for manual operations is the necessity of collecting quality attributes for hedonic quality

[3] Not the least due to pandemic circumstances related to consumption changes, c.f. Carlsson and Ståhl (2020) and Ståhl 2020.

assessments (Norberg 1995)[4] or making judgmental quality assessments (such as for bicycles or furniture). Use of modern data sources through sampling or in some cases through cut-off may appear as a modest approach given the vast information but works well in connection with the fixed base method and with quality adjustments of replacements and allows for assessments of uncertainty.

1.3. Previous work

Estimates of variance of CPI has been subject for several studies and through varying approaches. Uncertainty in the Swedish CPI has previously been assessed in several aspects. Dalén and Ohlsson (1995) outlined a theoretical variance estimator of the within-year index link in the context of two-dimensional sampling design, and Ohlsson (1996) elaborated on variance estimators for cross-classified sampling designs. Norberg (2004) compared several variance estimators and their suitability for different parts of the CPI, with focus on between-year assessment to capture inflation variance. In an internal variance estimation project, Nilsson et al (2008) made variance assessments to cover other product groups in the Swedish CPI, also for the within year index link. Scanner data for food was compared with manual price collection and variance within year assessed by Norberg et al (2011), which Tongur (2019) further elaborated on after a few years with scanner data in production. Resource rebalancing assessments for the CPI based on available variance estimates were formalized by Norberg et al (2018) through an optimization approach to render relative sample size needs to increase overall accuracy with given resources.

Smith (2021) surveys notable work on estimating sampling errors in CPI, with some emphasis on variance estimations for the US CPI, and distinguishes between design-based and model-based approaches. Shoemaker and Johnson (1999) and Shoemaker (2002) employ model-based maximum likelihood for the US CPI, stressing its functional superiority over ANOVA especially due to unbalance in realized samples in the two-dimensional sampling, highly reminiscing the Swedish design. Bialek (2020) models the variance of Carli and Jevons index through properties of a geometric Brownian motion process. Shoemaker (2015) provides theoretical and empirical calculations for stratified random groups (SRG) and Jackknife approaches –two methods applied by Norberg (2004) and Tongur (2019) based on the outline by Wolter (1985).

2. Survey design in the Swedish CPI

Surveying for the CPI adheres to *outlet* and *product* dimensions. Outlet stratification is applied and products may be stratified (or predefined to some extent) also below COICOP subdivisions according to some homogeneity aspect and representativeness such that product *varieties* may be sampled - usually by different means. Far from always probability sampling is applicable but whenever that is the case, size-proportional sampling is preferred, yielding self-weighted data, often in combination with practical assertions to ensure targeted coverage of products (Statistics Sweden 2022, Ohlsson 1990). Realized CPI samples may be subject to purposive annual rotations and/or maintenance due to outlet

[4] Cf. Norberg (1995), "Quality Adjustment in the Swedish Price Index for Clothing", presented at the Ottawa Group Meeting in Stockholm 1995.

obsolescence, besides product replacements necessary to maintain the basket relevance. In addition, stratification due to size of parent retail chain or some unique characteristic is sometimes employed to outlets.

A feature specifically within food, non-alcoholic beverages and tobacco has been the employment of a two-dimensional sampling approach. Outlets and products are in effect sampled independently from frames per retail chain, which is unique to this part of the CPI. The sampling variance formulation provided for this scenario by Dalén and Ohlsson (1995) decomposes into *outlet*, *product* and an *interaction* variance,[5]

$$\hat{V}_{D\&O} = \hat{V}_{Outlet} + \hat{V}_{Product} + \hat{V}_{Interaction} \qquad (2)$$

The formulation $\hat{V}_{D\&O}$ compares somewhat to ANOVA as a design-based counterpart.[6] However, the cross-classified structure in (2) does not really apply in general to the sampling in the CPI as most second stage sampling is independent between outlets, while usage of (aggregate) transaction data per retailer serves both as frame and price data per retailer as whole rather than per outlet within retailer, in many cases.

3. Resampling

CPI data is merely *one* realization of several possible from the population of price spells. A resampling procedure is applied through *bootstrap* to assess the variance for some of the sampled parts of CPI. The bootstrap (c.f. eg. Efron and Tibshirani 1993) is a method to re-use existing data in pseudo-repeated sampling, while adhering to existing data structures such as - stratification and prevalent sampling schemes, as outlined by Särndal et al. (1992) for a size-proportional sampling and estimation. Data replication is achieved by resampling with replacement from a pool of original data with estimations from resamples instead of the single original sample. Sample sizes are set to original sizes (per stratum) and often result in multiples of the originally sampled units in the resamples, especially in small sized strata.

[5] Formerly, list prices were employed as thematized in Dalén and Ohlsson (1995). Since late 1990s, annual aggregate scanner data over product sales (EAN/bar code) per retail chain has been use for sampling frames within COICOP 01/daily necessities (food/non-food).

[6] The meaning of an *interaction* term does perhaps not arrive intuitively, whereas seeing it as the correspondence to the residual in ANOVA appears slightly more comprehensible. Ohlsson (1996) notes the tendency for the first two terms to dominate over the interaction term when analytically examining cross-classified sampling and a generalization thereof to size-proportional sampling.

3.1 The bootstrap variance estimator

A bootstrap algorithm for estimating the variance of a statistic $\boldsymbol{\theta}$**,** as provided by Efron and Tibshirani (Algorithm 6.1, p.47, 1993) was adapted to the problem according to the following.

- B bootstrap samples $\boldsymbol{x}^{*\boldsymbol{1}}, \boldsymbol{x}^{*\boldsymbol{2}}, \ldots, \boldsymbol{x}^{*\boldsymbol{B}}$ of size *n* were selected with replacement. From each sample, the price index $\widehat{\boldsymbol{\theta}}^{*}(\boldsymbol{b})$ was computed, *b=1,2,..B*, per month and product category, aggregated accordingly by formulae in subsection 1.2.

- The set of *B* resamples rendered *B* price indices $\widehat{\boldsymbol{\theta}}^{*}(\boldsymbol{b})$ to compute the variance estimate by

$$\hat{V}(\hat{\theta}) = \sum_{b=1}^{B}(\hat{\theta}^{*}(b) - \hat{\bar{\theta}}^{*})^2/(B-1) \qquad (3)$$

In formulation (3), finite population correction can be considered "neutral" when applied to each replicate $\hat{\theta}^{*}(b)$ and their mean $\hat{\bar{\theta}}^{*}$ within the parenthesis in the numerator and therefore immaterial to the resulting variance estimate $\hat{V}(\hat{\theta})$.[7] In this manner, the variance is estimated för the *short-term* link, the *inflation rate* and the *change in inflation rate.*

3.2 Defining the setting for bootstrap

3.2.1. Subpopulations

Surveying for CPI divides into subpopulations to represent market structures of outlets and corresponding products. The subpopulations of interest in this study are mutually exclusive with respect to data collection methods and outlets and comprise all possible data collection methods available, as listed in Table 1.

1. *COICOP 01 & 02.2 Food and non-alcoholic beverages, Tobacco. Also, non-food.*
   Outlet-specific transaction data from multi-store companies and retail chains (strata) are used in the Swedish CPI. Resampling is performed per stratum with corresponding number of outlets in the sampling pool. As an addition, non-food items of daily necessities", such as products within personal hygiene, toilet paper etc. that are typically found at food retailers are included as they are comprised in the same data sources and originally sampled along with food (not in 01 or 02.2).

2. *COICOP 03 Clothing and footwear*
   Sampled outlets are mainly surveyed online from retailer homepages and in some cases on-site in physical stores (less than a third of the current sample). Stratification applies to ascertain that influential multi-store companies and retail chains are included proportionally also in the bootstrap resampling. Price collectors sample product varieties (product offers) according to instructions. Quality adjustments are from a hedonic method on collected attributes for entering products.

[7] This not exact since the number of unique outlets may vary between bootstrap runs due to replacement in sampling.

3. *COICOP 05.1 Furniture*
   Retailer stratification applies as markets are heavily oriented towards large multi-store companies and retail chains. Price collectors make judgmental quality adjustment on-site or in-house for online data.

4. *COICOP 07.1 Transportation services: domestic and international air travel*
   One single API serves as the frame and price pool for schematic collection at specific days prior to departure to render multiple prices per travel, as suggested by HICP guidelines (Eurostat 2018). An average of the lowest observed prices is taken for journeys according to specifications and no quality adjustments are done.

5. *COICOP 11 Restaurants*
   Data collection for this sub-survey is by telephone and online, i.e., from home pages of sampled units. Occasionally, subjective quality adjustments by price collectors are necessary when menus change. Also, holiday menus may offset the sample and render non-response.

The total CPI weight (2022) for these divisions/subdivisions summarizes to (14.3+1.32) + 4 + 2.676 + 1.88 + 5.9 = 30.076%.[8]

3.2.2. Year-on-Year cohesion

Sample structures due to exits/remains/entries and stratification are accounted for when taking years pairwise. Year-on-year estimations are necessary for inflation and change in inflation so resampling synchronises biannually through the following properties for each pair of years (*t*∈*y-1, t*∈*y*):

- Outlets included merely in either year (*t*∈*y-1 or t*∈*y)* make up the (possibly) two non-overlap resampling pools.
- Outlets included in both years (*t*∈*y-1* and *t*∈*y*) make up the overlap sampling pool.

On these three pools of originally sampled units with sizes $n^{(t\,\in\,y-1)\emptyset\,y}, n^{(t\,\in\,y)\,\emptyset\,y-1}$, $n^{t\,\in(y-1\cap y)}$ and for each pair of years studied, stratification is imposed such that sampling is stratum-wise from respective overlapping/non-overlapping pool. Denoting unit *j* in stratum *h* ⊆ *1,2,3..H,* per stratum size is

$$n_h^{t\in(y-1,y)} = \left[n_{j,h}^{(t\,\in\,y-1)}\right] \cup \left[n_{j,h}^{(t\,\in\,y)}\right]$$

which occasionally renders a minimum resample size of 1 unit per stratum in each year/pool in the pair of years whilst the total $n_h^{t\in(y-1,y)}$ bounds to the original sample size per year. The approach accounts for interdependencies between years in the resamples.

3.2.3. Two-dimensional design adherence

To account for the two-dimensional sampling design applied to the original subpopulation for 01 food, non-alcoholic beverages and tobacco, an additional resampling layer is employed. Strata in the outlet dimension are defined as *retail chain* with sample sizes (number of outlets) equivalent to original size per retail chain, with replacement. Merely

[8] The additional weight due to non-food products added to 01/02.2 is not included.

outlets $n_h = n_h^{t \in (y-1 \cap y)}$ existing in the pair of years are included and *product* resampling is done[9] in parallel to outlet stratification. Strata in the product dimension are defined as items (identified through bar code/EAN) either existing in both years or single year items, per retail chain and year, rendering $m_{h,g}^{y-1,y} = m_{h,g}^{(t \in y-1) \emptyset y} + m_{h,g}^{t \in (y-1 \cap y)} + +m_{h,g}^{(t \in y-1) \emptyset y}$. The biannual items are taken simultaneously per pair of years whereas single year items are sampled per year such that resampling depends on corresponding actual sample size for that stratum per year.

3.3 Specific issues in bootstrapping

Due to a few extreme but yet correct values, corresponding bootstrap replications showed a significant variability. It could be seen that every now and then, some peculiarity in data had rendered highly unusual price ratios. These few cases were seen to affect the variability in the bootstrap disproportionally. The problem is in essence the counter-issue to the stopping problem for the bootstrap, i.e., setting the adequate replication number (c.f. e.g. Andrews and Bushinsky 2000, Pattengale et al 2009) based on diminishing changes in variability after a certain amount of runs.

Simple random sampling with replacement was done and price spells were weighted with corresponding product offer weights. Unequal weights, sometimes highly "refined" weights for sampled products in this study, are an issue to observe and if possible, account for in resampling in some elaborate way. Especially when cut-off samples are in effect, weights can be highly dispersed. This was not remedied here and is likely to render a slightly overestimated variance, it could thus deserve some elaboration on a strategy to neutralise such bootstrap variability.[10]
The transition to web scraping/online stores, appeared to render single outlet strata which were included in all bootstrap runs. This needs to be remedied in some elaborate way for the bootstrap to achieve variability since outlets in this case cannot render variance between them.

4. Simple standard variance estimation

In interest of analysing design effects of sampling both outlets and products, and possibly finding a simple procedure to assess sampling variance broadly, we used a standard variance estimation formula $\hat{V}(\log (^{P_t}/_{P_0}))$ for price observations per month and per by product group. Observations were pseudo-stratified further to homogenous subgroups through their product offer weight (lowest level weight) in order to account for the influence per outlet grouping (chain).[11] This estimation was applied to the short-term index links based on the single real sample per year. It was not applicable to find variance of inflation since that would require simultaneous assessment of two adjacent years' samples. Norberg (2004)

[9] There is little practical impairment from this restriction since outlets are stable in this subpopulation (COICOP 01/02) during the years of study.

[10] We do not provide numerical support for this statement but it is based on our observations of the bootstrap estimations.

[11] This of course does not imply at all that *price changes* may be different merely because sampling weights are different.

denoted this estimator as the simple random sampling (SRS) estimator. Estimates for this SRS are given in graphical comparisons with the bootstrap estimates.

5. Results

Variance estimates are reported in Tables 5.1—5.3. Estimations were for coupled years 2018-2019, 2019-2020 and 2020-2021 in order to account for inflation more accurately, i.e., mitigate variability due to outlets existing or not existing between years. We introduce a ratio between the estimated inflation variance and the short-term variance, denoted V(I)/V(S) in tables. This reported number in tables is an average over months. In December this ratio equals the short-term variance.

Our presumption is that this relationship is somewhat relevant and could serve as a basis for assessing inflation variance from the much simpler calculation of the short-term index variance. It also indicates the importance of not changing samples more than necessary without substantiation.

5.1 Food and non-alcoholic beverages, Tobacco, and non-food

Bootstrap variance estimates for 01 are reported in Table 1, considering the four aspects:

1) *Food,* in which two- dimensional bootstrapping is applied;
2) *Food: products* in which merely the product dimension is bootstrapped and outlets fixated to the original sample;
3) *Food: outlets* in which merely outlets are bootstrapped and products fixated to the original sample, i.e. do not vary between runs;
4) *Daily necessities including non-food products but fresh items excluded*, the latter adhering to two-dimensional bootstrapping while adding products that usually vary less (non-food at food markets/daily necessity retailers) and excluding meat and fruit that usually show a larger varying pattern.

Table 5.1 *01 & 02.2 Food and non-alcoholic beverages, Tobacco, and non-food*

Subpopulation (Aspects 1-4)	Measure	Variance (avg.)	V(I) / V(S)	+/- 2 std. errors
1. Food	Short-term	0.043		0.414
B=400	Inflation	0.058	1.360	0.482
	Δ(Inflation)	0.053		0.460
2. Food: products	Short-term	0.028		0.337
B=400	Inflation	0.037	1.315	0.386
	Δ (Inflation)	0.038		0.388
3. Food: outlets	Short-term	0.014		0.235
B=400	Inflation	0.017	1.229	0.260
	Δ(Inflation)	0.012		0.216
(1-2-3) Food:	Short-term	0.001		
Interaction	Inflation	0.004		
B=400	Δ(Inflation)	0.003		
4. Daily necessities	Short-term	0.035		0.374
excl. fresh items*	Inflation	0.046	1.321	0.429
B=400	Δ(Inflation)	0.039		0.392

*Fresh items comprise fruit, vegetables and fresh meat and fish.
N.b. Some 61-77 outlets per year from the major retail chains are included.

Average estimates in Table 5.1 show expectable magnitudes, variation due to products is larger than due to outlets and inflation variation is slightly larger than the short-term index variance, i.e., the within-year uncertainty. The damping from including non-food and excluding fresh items (aspect 4) is in some sense an approximation to "underlying"/core variability as product categories with presumably highly volatile price movements are removed. Fresh fruit and vegetables are surveyed by selecting the most sold variety during the month, whereas for fresh meat and fish, a cut-off sample is taken and followed through the year.

The interaction term in $\hat{V}_{D\&O}$ (2) can be residually obtained from Table 5.1, although it is subject to irregularities from independent estimations of the three components (aspects 1-3):

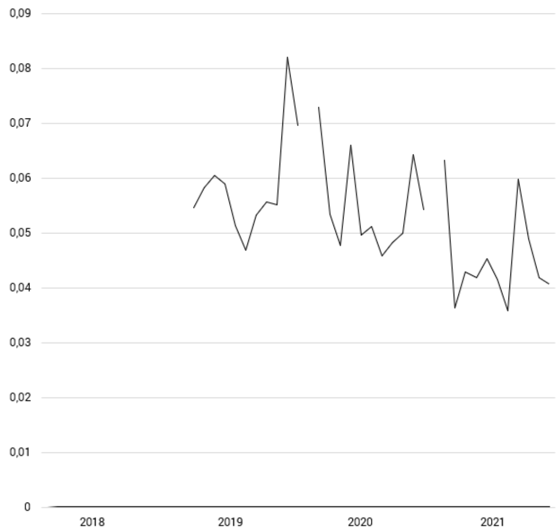
$$\hat{V}_{Interaction} = \hat{V}_{Food} - \hat{V}_{Products} - \hat{V}_{Outlets} \qquad (4)$$

The interaction is $\hat{V}_{Interaction}$ estimates to 0.001 or 0.1% of the total $\hat{V}_{Food}$ for the short-term index, which seems smaller than the result illustrated by Dalén and Ohlsson (1995). It should be borne in mind the residuality in derivation of (4) unlike the result obtained from the cross-classification design with second order inclusion probabilities by Dalén and Ohlsson (1995, equation 3.7).[12] As our data is from stratification per retail chain, our expectancy is that the interaction effects would tend to be non-observable, if existing at all. The ratio V(I)/V(S) seems to hover around 1.3, which is in accordance with the corresponding number (1.36) derived from the results in Norberg (2004) for this COICOP division (01).

[12] It can be concluded from Sections 3 and 4 in Dalén and Ohlsson (1995) that the interaction term from second order sampling appears to be somewhat theoretical and not always observed in expected sense.

Figure 5.1.1 Food: Inflation variance

Figure 5.1.2 Food: Change of inflation variance



The variance of the monthly change of inflation is almost as high as the inflation variance. The "simple standard variance estimation" underestimates variance significantly for daily necessities, by some relation one to eight (1:8). This is so because data consists of samples of outlets per retail chain within which prices correlate. Especially for multi store companies, correlation in price change is observed to be significant between outlets. The simple standard variance estimation assumes independent samples for each outlet as in two-stage sampling which thus is not fulfilled.

5.2 Clothing, footwear, furniture, and restaurant services

In these areas we conclude that sampling can be approximated to be two-stage with outlets in the first stage, and stratification of products with independent sampling of product offers in the second stage. Only outlets are bootstrapped with no resampling products within outlets. This is analogous for the simple standard variance estimation.

Estimation results for the three divisions (03, 05.1 and 11) are in Table 5.2. For clothing, which is known to have high volatility, replications were drawn *B=4000* instead of *B=400* precautionarily but this did not appear to be necessary.

Table 5.2 *03 Clothing and footwear, 05.1 Furniture and 11 Restaurants*

Subpopulation	Measure	Variance (avg.)	V(I) / V(S)	+/- 2 std. errors
Clothing	Short-term	0.728		1.706
B=4000	Inflation	1.088	1.496	2.087
	Δ (Inflation)	0.93		1.928
Furniture	Short-term	0.407		1.276
B=400	Inflation	0.721	1.772	1.699
	Δ(Inflation)	0.618		1.572
Restaurants	Short-term	0.187		0.864
B=400	Inflation	0.313	1.679	1.120
	Δ(Inflation)	0.085		0.583

N.b. For clothing and footwear, number of outlets average around 150 per year and decreasing due to transition to web scraping. Furniture averages around some 30 outlets. For restaurants, some 100-110 establishments are included yearly.

Annual average variance is many times larger for clothing than food. The survey has comparatively smaller samples, high churn/product turnover and significant price volatility. Variances are seemingly smaller than previous studies, in general. Increased online price collection, which from our experience appear to render longer “shelf lives” of products in the basket. This is likely influencing the estimates since replacements become necessary less frequently in comparison with manual price collection on-site.[13] Also, one realized ambition over the past years has been to narrow down variety descriptions to which price collectors adhere when selecting varieties of products (=implicit stratification), which altogether should have reduced variances over time.

[13] Although we do not provide calculations for this circumstance, this is an observable feature for products in general that availability in the online store of retailers is broader than in physical stores. The pro’s and con’s and whether there should be an “exit” strategy in measurements is under elaboration at Statistics Sweden regarding Clothing 03.

Figure 5.2.1 Clothing and footwear: Short-term index link variance from actual prices, and without quality adjustment (dashed) and simple variance (dotted)

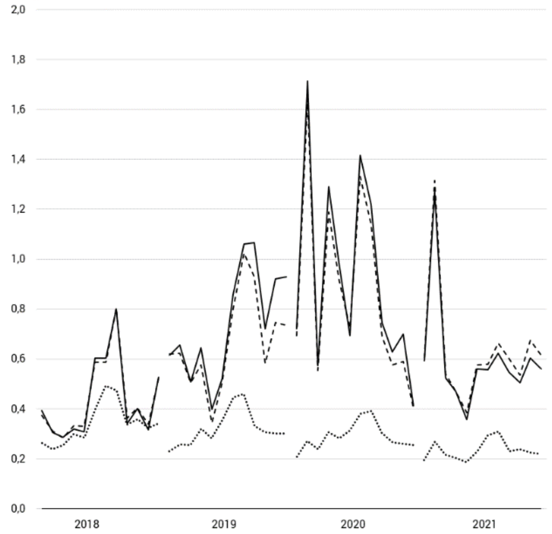
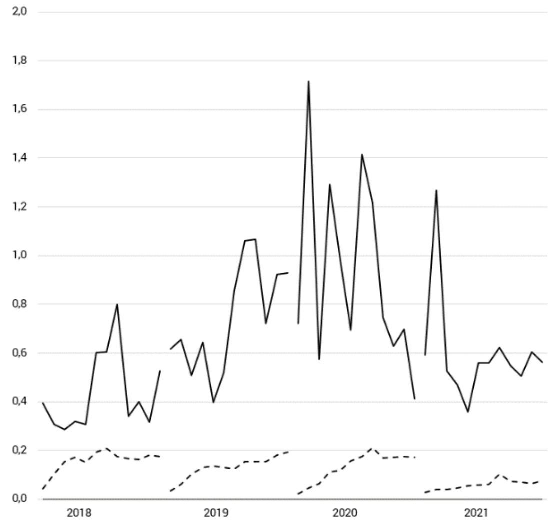


Figure 5.2.2 Clothing and footwear: Short-term index link variance from actual prices and regular prices variance (dashed)

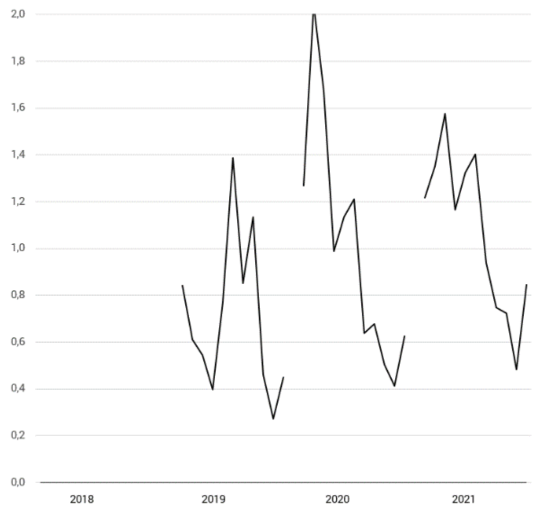


The hedonic quality adjustment method, applied since 1993, does not reduce the variance significantly in contrast to what we would expect.

The major sources of variation in prices within clothing are campaigns and stock clearance sales, which cannot be anticipated individually in the survey design. Hence some mitigation is desirable. For instance, if we can collect both actual prices and regular prices (plus the synchronous quantities) through a census from transaction data and collect the same regular and actual prices for a statistical sample, we could combine two data types in a model assisted estimation of the short-term index link.

Figure 5.2.3 Clothing and footwear: Inflation variance

Figure 5.2.4 Clothing and footwear: Change of inflation variance



The variance of inflation and for the change of inflation varies largely between months.

Figure 5.2.5 Furniture: Short-term index link variance and simple variance (dotted)

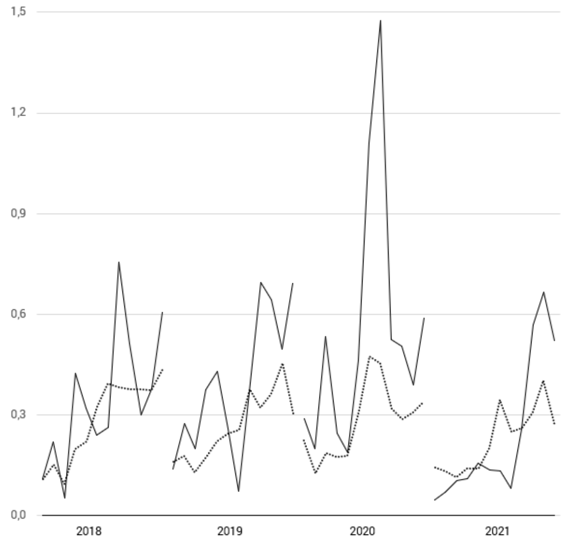
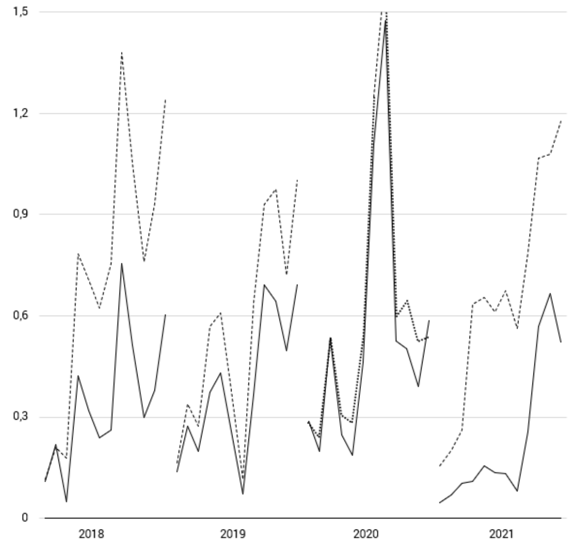


Figure 5.2.6 Furniture: Short-term index link variance, with quality adjustment and without (dashed)



For furniture it is seen, in contrast to clothing and footwear, that estimated variance for the short-term index link is in most cases significantly lower at quality adjusted prices. This may be explained by forced replacements which result in another price level while the price difference from the exiting item is assigned as quality. As indicated in subsection 3.3, sample size per stratum was in a few cases merely one unit ($n_h = 1$) for year 2021 when web scraping was implemented, while the same strata had multiple outlets prior to 2021. In the manner bootstrap was implemented herein, this caused a fixed outlet sample in these strata for 2021 and consequently an underestimation of the variance to a certain extent. This appears to be of smaller influence than the impact from long shelf lives on the internet as implied above since the latter renders fewer replacements.

Figure 5.2.7 Furniture: Inflation variance

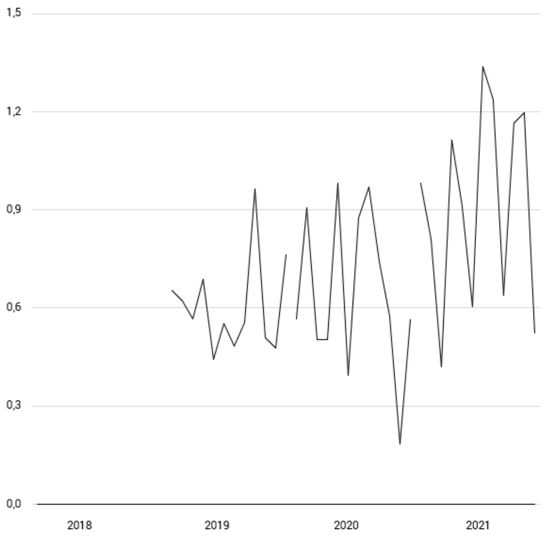


Figure 5.2.8 Furniture: Change of inflation variance

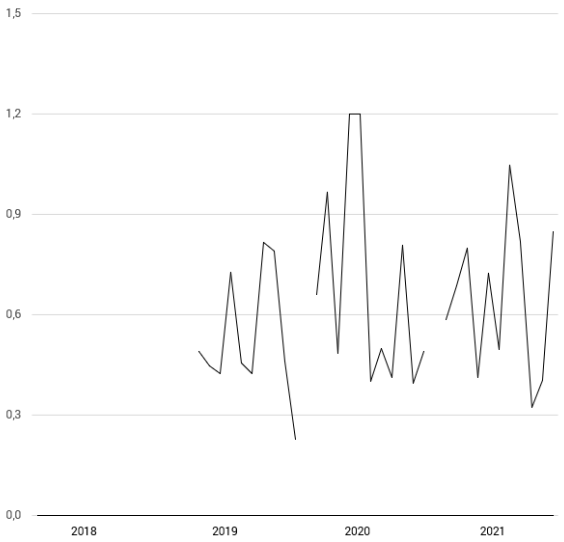


Figure 5.2.9 Restaurants: Inflation variance

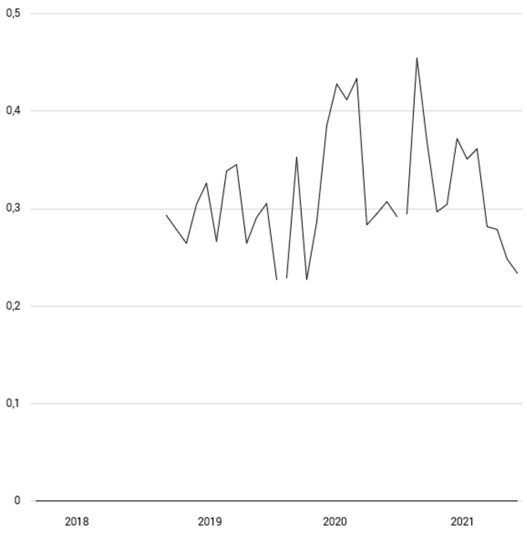


Figure 5.2.10 Restaurants: Change of inflation variance

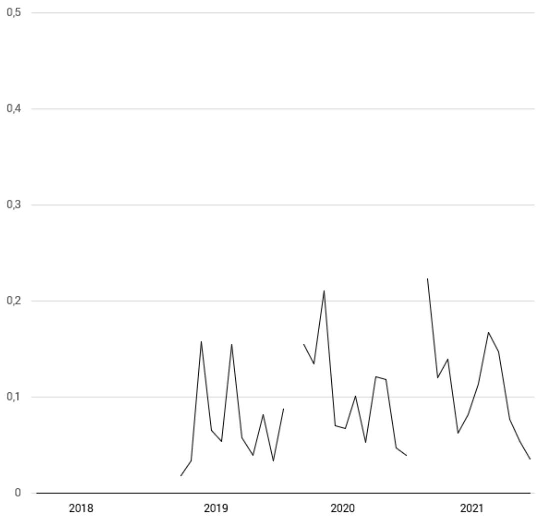
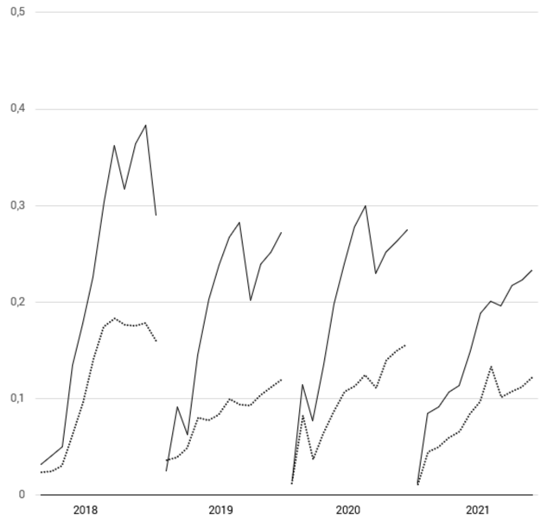


Figure 5.2.11 Restaurants: Short-term index link variance and simple variance (dotted)



For restaurants, it appears that the simple variance underestimates the sampling variance by half in comparison with the bootstrap estimate, although the two show similar trends in their evolution within year.

5.3 Domestic and international air travel

In Table 5.3, bootstrap estimates for domestic and international air travel are reported. This division is known for large data volatility, at least regarding the pre-pandemic consumer prices. During the time of study, 2018-2021, several survey changes affected this price index (07.1), hence the following results perhaps may not qualify in relevance. In 2018, price collection, at different time points prior to departure per destination, was completely manual from a travel price site and, consequently, significantly fewer destinations were covered than in the following years when a web scraping procedure was implemented by using an API solution.[14]

[14] A similar and well elaborate approach to air travel prices is undertaken by Statistics Canada, in which also carriers are specifically considered in sampling, c.f. Statistics Canada (2020) homepage, "Enhancements to the Air Transportation Index in the Consumer Price Index". Link provided in references.

Table 5.3 *07.1 Domestic and international air travel*

Subpopulation (Aspects 1 and 2)	Measure	Variance (avg.)	V(I) / V(S)	+/- 2 std. errors
1. Air travel	Short-term	1.820		2.698
B=4000	Inflation	5.417	2.976	4.655
	Δ (Inflation)	4.468		4.227
2. Air travel, coupled	Short-term	11.94		6.91
B=4000	Inflation	27.26	2.284	10.44
	Δ(Inflation)	21.73		9.323

N.b. The pair of years 2018-2019 were excluded due to extreme volatility, c.f. explanation in text.

The difference between aspects 1 and 2 is the coupling of destinations over years.[15] In aspect 2, *destination pairs* were subject to bootstrapping, i.e. taken as sampling units within which *all* corresponding booking occasions for the destination were included, i.e. not randomized further down the line. In contrast, aspect 1 takes specific booking occasions regardless of destinations as sampling units and resembles a rudimentary random sampling approach and relates to the coupled estimates by some relation one to five or six (1:5 or 1:6). We observe this as a design effect revealed by the bootstrap procedure – destinations' price spells are observed at several time points prior to departure but our complimentary analysis has shown that the volatility between booking occasions is small in comparison with variation between destinations, which is confirmed by the outcomes for aspects 1 and 2. This hints at lower effective sample size than assumed, perhaps since choice of measured price is "lowest fares" per destination.[16]

Further, as of April 2020, air travel was restricted due to pandemic conditions, hence the index was imputed either completely or partly when possible in the following time.[17] Thus, the results in Table 5.3, altogether with post-pandemic effects on airline travel, may be of limited validity but can be taken as indicative of the known issue with measuring this kind of demand-driven/dynamic prices.

[15] De Gregorio (2012) outlines a schematic approach to aggregation for airline travel.

[16] This kind of dynamically priced products are preferably surveyed at multiple occasions per destination, c.f. the special attention in the HICP Methodological Manual (Eurostat 2018, chapter 12.5, pp 284-298).

[17] C.f. CPI official communication on pandemic imputations (Statistics Sweden 2022a).

Figure 5.3.1 Air travels: Short-term index link variance and simple variance (dotted)

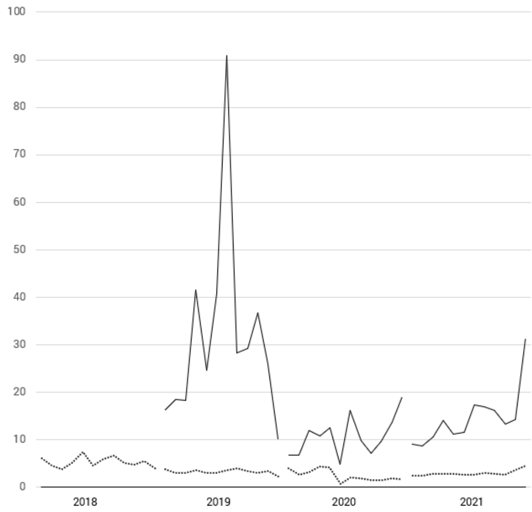


Figure 5.3.2 Air travels: Inflation

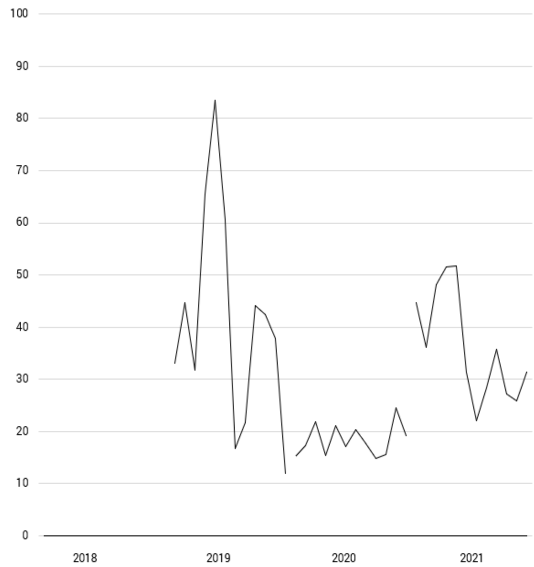
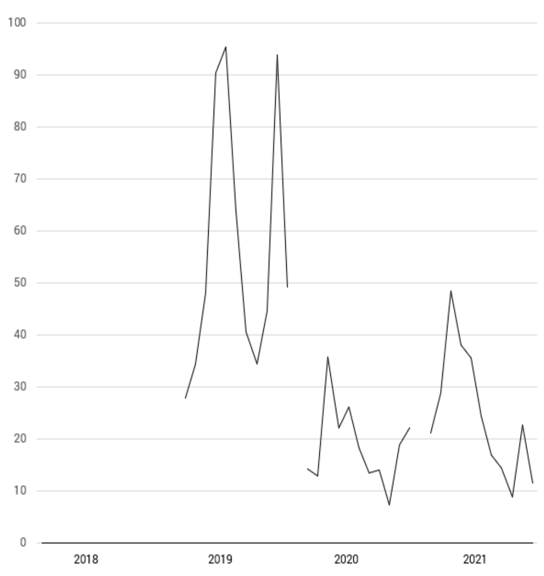


Figure 5.3.3 Air travels: Change of inflation



6. Special cases beside the bootstrap assessments

6.1. Fixed base index replacing *MCR* for high-tech products

One approach in specific focus in the Swedish CPI was the use of *monthly chaining and replenishment* (MCR) for *Mobile phones, Computers* and *Computer equipment*. Price indices for these products showed steady decreases which in turn compounded in the continuous chaining of monthly indices. In 2021, a census approach was adopted due to new transaction data and API data whence eliminating sampling errors. This did however not alter the fact that the price index so far had shown decreasing patterns for the new items entering the market.[18] To mitigate the downward pressure from price changes, so vividly manifested through MCR with bridging, the standard fixed base method and sampling was taken in as of 2022 for the new data which also serves as base for supported quality adjustments. In an analysis prior to changing methodology, the following variances were estimated for the first 8 months in 2021.

Table 6.1 *Simple standard errors for Mobile phones and Computers*

	Mobile phones		**Computers**	
Month	Index	(+/-) 2× std.err.	Index	(+/-) 2× std.err.
1	98.2	2.0	98.3	1.4
2	96.0	3.4	98.5	1.9
3	94.2	3.9	97.8	2.3
4	95.6	6.2	98.8	2.2
5	95.0	6.1	96.9	2.7
6	94.1	6.4	97.5	2.7
7	93.2	6.3	97.5	2.6
8	88.3	8.2	96.5	2.8

N.b. Mobile phones *n=59, Computers n=161.*

In Table 6.1, standard errors are seen to increase with time for Mobile phones and level out for Computers, perhaps with a slight increase over time. Additional to these estimates,[19] one aspect was explored further, namely the immediate variability from replacements. The supported quality adjustments in the study were from hedonic modelling from the new data sources. The following variabilities were observed, in Table 6.2.

[18] Post-pandemic economic conditions unaccounted for in this statement, as are the effects from the ongoing crisis in Europe.

[19] Eliasson et al. (2021) provided this analysis for the Swedish CPI Board prior to change of methodology.

Table 6.2 Estimated standard errors for replacements

Adj.	Month	Mobile phones #OBS	Index	(+/-) 2 std.err	Computers #OBS	Index	(+/-) 2 std.err
0	1	59	98.17	2.0	161	98.3	1.4
0	2	54	97.19	2.4	107	97.2	1.9
1	2	5	83.77	34.0	45	102.0	4.3
0	3	42	94.40	3.0	80	95.2	2.4
1	3	17	93.54	11.9	66	101.0	4.0
0	4	37	93.40	5.8	74	95.5	2.7
1	4	22	99.53	13.9	74	102.0	3.5
0	5	31	92.40	3.4	61	92.7	3.8
1	5	28	98.03	12.6	78	100.0	3.5
0	6	25	91.45	4.3	57	93.8	2.9
1	6	32	96.30	11.2	86	100.0	4.1
0	7	23	90.38	5.7	52	93.7	2.8
1	7	33	95.27	10.1	84	99.9	3.8
0	8	21	82.75	6.7	48	92.3	3.4
1	8	35	91.81	12.6	83	99.0	3.9

N.b. Adj. (0,1) indicates when replacements are made.

Table 6.2 shows observable variability connected to replacements. Although replacements dampened a decreasing index, it also added variability. This is remedied partly by keeping samples considerably large (as with computers).[20] This is a total survey error (TSE) perspective to the variance computations and can be illustrated simply by dividing the estimate into remaining and replaced products as

$$\hat{V}(\theta)_G = f\left(\hat{V}(\theta)_{Remaining}, \hat{V}(\theta)_{Replaced}\right)$$

in which $\hat{V}(\theta)_{Replaced}$ additionally comprises modelling variance added by explicit quality adjustments, besides the sampling variance. Whether these adjustments are valued to zero or not does not affect the variance itself but the size of it. To summarize, quality adjustments reduce potential bias/drifting while its contribution to variance decreases with growing samples. However, the effect as such exists, is abridged in some way depending on methodology and thus deserves some consideration also when using large-data methods (c.f. Eurostat 2022).

Product group weights (2022) for Mobile phones is 0.925% and 0.739% for Computers, including desktop/laptop computers and tablets. The introduced approach of model-assisted quality adjustments from these new data sources also applies to other product groups within home electronics, comprising some additional 2.5% of the basket total. To summarize, the change from MCR to fixed basket has introduced a modelling variance and not the least a sampling variance while presumably mitigating a downward push from following product "lives" too long in the unweighted implementation of MCR.

[20] For computers, several one-to-one direct replacements could be made, as observed in the study.

6.2. Rental survey

A single influential subdivision in the Swedish CPI is the rental survey, with a price index carrying 7.449% of the CPI weight, or approximately one fourth of 04 Housing. This is a fairly small sample, some 700 apartments belonging to fewer than so landlords, many of which public, are surveyed monthly until their rents change for the year. In general, this is a regulated process in Sweden and not known for many irregularities, rendering price changes mainly in connection with the (single) annual adjustment or when apartments undergo significant restauration that affects the rent.[21] In an internal analysis, the simple variance for the rental survey was found to average around 0.0014 per year in 2018, 2019 and 2020. A presumption for the rental survey is that the sampling variance is low due to the specific circumstances for rents.

7. Balancing and conclusions

The presumption with the study was to find a viable approach for assessing variance in the CPI, especially in connection with design/method changes or change of data sources.

The bootstrap method is straightforward and easy to implement, however, as experienced, requires elaboration if results are to carry meaning. The underlying survey design must be mimicked properly to render valid results from the bootstrap, and this is not always straightforwardly achievable.

Variance of inflation, which comprises baskets from two adjacent years, is observed to be affected when samples differ between years (either in products or outlets) and also from changing data collection mode. Consequently, there is a balancing issue when making changes in the CPI as this may affect inflation rates bottom-up through aggregation.

Sample or resource allocation is facilitated from having reliable variance estimates. From the analysis, we do realize that there is a substantial difference between using simple variances directly from the CPI data versus more qualified assessments of variance as tried out by bootstrap since the latter provides variability from another decomposition of already realized samples, while simple variances appear to underestimate variance practically all the time in comparisons with the bootstrap.

The current variance statements for the Swedish CPI provided in the Quality Declaration relies on earlier assessments mainly by Dalén & Ohlsson (1995) and Norberg (2004). This study provided input to almost half the basket weight, with some product categories remaining to assess. In large, this study confirmed findings in previous studies or provided updates.

To reference, the following table from the annual quality declaration (Statistics Sweden 2022c) shows the confidence interval for 1) *monthly change*, 2) *inflation* and 3) *change of inflation*:

[21] Again, a component of quality adjustment does enter here, although far more seldom than in other surveys and more attentive.

Table 1 Estimated sampling inaccuracy, length of 95% confidence interval 2021

Statistics	Length of 95% confidence interval	Comments
Monthly change	±0.14	Somewhat shorter for April, May, June and November
Annual change (inflation rate)	±0.23	Somewhat shorter for December*
Monthly change in inflation rate	±0.20	Somewhat shorter for April, May, June, November and December, somewhat longer for other months

* The change from December to December is based on one and the same sample.

From the current study it obtained that the variance contribution from food/daily necessities is approximately one sixth of overall variance – in essence confirming existing estimates. It was observed that we may have smaller effective samples from multi-store retailers as price changes within these tend to correlate. However, it is beneficial from a safety perspective to still sample multiple stores per retail chain (despite transaction data), should there be some non-response.

Clothing and footwear variances, as presumed and estimated in this study, are high, especially due to sales' prices, and the survey is costly in terms of feeding the hedonic method from large samples. Despite large cost for data collection in comparison with other durable goods, contribution to overall CPI variance is approximately one tenth, in line with current calculus.[22] We acknowledge the need of focus on this category in the CPI.

Restaurants and furniture together contribute with less than one seventh and clothing contributes with slightly less than one tenth of the variance, in accordance with the existing estimate.

For airline travel, variance contribution to overall variance is less than 1 percent, highly affected by lower weights from pandemic adaptations of the basket. We acknowledge the need of reassessing air travel variance when some steady state is observed.

To summarize, the confidence interval for the variance of inflation is a slight adjustment from 0.23 as reported in the table above to 0.22, with December being shorter (0.2). The confidence interval for the change in inflation rate is estimated to 0.19, slightly shorter in certain months (0.143) if computed in the same manner, but we do not see similar strong indications of seasonality in *change of inflation* from this study as reported in the third row of the table.

[22] This is estimated for the Quality Declaration (Statistics Sweden 2022c), see the final section on balancing.

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Documentation on the Swedish CPI are available (mainly in Swedish) from:
hiips://s cb.se/hitta-statistik/statistik-efter-amne/priser-och-konsumtion/konsumentprisindex/konsumentprisindex-kpi/#_Dokumentation