In honour of Erland von Hofsten

TREATMENT OF CHANGES IN PRODUCT QUALITY IN CONSUMER PRICE INDICES

by

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1. Scope of the paper

1.1. Price indices are supposed to represent actual transactions, such as purchases of consumer goods and services in the case of consumer price indices. They are also expected to reflect **"pure" price movement**, i.e. the movement that is not caused by variations in the quantity and quality of surveyed products[1]. The two requirements, however, fall in conflict with each other when the mix, quantity and quality of products actually purchased vary through time, as it happens normally. Price index makers try to reconcile them, nevertheless, which entails major conceptual and practical difficulties at all levels of index calculation.

1.2. The problem will be discussed in this paper only with respect to the first, **micro-level** of aggregation. Price indices at the micro-level are directly derived from price quotes for items chosen to represent a given category of products in a given geographic area[2]. There would be no problem with reflecting pure price movement if all micro-indices were derived from samples that keep the same items through time[3]. In practice, however, items are subject to occasional or periodical replacements, deletions and additions. Some of them are imposed by disappearance of items from the market, others are made deliberately to preserve a good representation of the varying universe of transactions. Special procedures are needed in these cases to approximate pure price movement.

1.3. Erland von Hofsten[4] was the first author who systematically reviewed these procedures. Many of his statements remain topical until now, in particular about the relationship between micro-indices derived by splicing and through explicit adjustments of prices for quality differences in the replaced items. The present paper briefly elaborates on explicit adjustments and discusses the possible reasons of discrepancies between the results obtained using utility-defined and resource-defined adjustments. Regarding implicit assumptions about the effect of quality changes on prices, the paper generalizes the interpretation given by von Hofsten about splicing indices in the case of replaced items. It proves that the usual treatment of deletions and additions of items can be likened to the splicing technique. Finally, the paper includes an empirical study of micro-indices for selected clothing products, which seems to show that the traditional treatment of changes in product quality, contrary to a popular belief, does not necessarily leads to a long-term overestimation of price increases.

2. Explicit adjustments to prices in the case of replaced items

2.1. Some algebra will be shown here, not because the following procedures are difficult to follow, but to prove later their connection with other methodologies. Let p'' and p' designatee prices of, respectively, the **replacing** and the **replaced** (initial) items. In general, the following **cross-item price change**:

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[1] The terms *product* and *commodity* are used in the paper interchangeably to designate both goods and services.

[2] In the Canadian CPI practice, ratios of equiweighted mean prices are used for this purpose (arithmetic mean prices until December 1994 and geometric mean prices since January 1995).

[3] Ideally, items should be defined in their finest detail, including all aspects of services that are provided with the products.

[4] *Price indexes and quality changes*, Bokförlaget Forum AB, 1952.

$$\frac{p''_t}{p'_b} \qquad (1)$$

is not a proper indicator of pure price movement from the base time b to the observed time t. As stated by Hofsten, a solution would require that prices be adjusted for quality differences between the replaced and replacing items. Suppose that g is a **price-quality impact factor** that expresses, in ratio form, the effect of quality differences on relative price of the replacing item with respect to the initial item[5]. Now, the price relative $p_{t/b}$ reflecting pure price movement can be approximated in the following ways:

- either by adjusting the actual price quote p'_b of the replaced item in the base time and obtaining a **notional price** $\tilde{p}''_b$ of the replacing item in that time:

$$p_{t/b} \approx \frac{p''_t}{\tilde{p}''_b} = \frac{p''_t}{p'_b * g}$$

- or by adjusting the actual price quote p''_t of the replacing item in the observed time and obtaining a notional price $\tilde{p}'_t$ of the replaced item in that time:

$$p_{t/b} \approx \frac{\tilde{p}'_t}{p'_b} = \frac{p''_t + g}{p'_b} \quad ,$$

- or by a direct adjustment of the cross-item price change (1):

$$p_{t/b} \approx \frac{p''_t}{p'_b} + g \qquad (2)$$

2.2. From the conceptual point of view, there are two approaches to derive the adjustment factors, one based on differences in utility provided by the two items and the second based on differences in resources needed for their production. Many theoreticians recommend the former for the adjustments of input price indices, including consumer price indices, and the latter for the adjustments of output price indices (deflators). Although this recommendation is consistent with the modern economic theory of indices, statistical agencies do not enforce it, partly because of practical difficulties, partly because of some doubts about the recommendation, itself.

2.3.[6] Generally, practitioners tend to consider the quality adjustments based on differences in the resources needed as more straightforward and workable. It is relatively easy to gather information about changes in production costs, especially when the two commodities differ

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[5] For the sake of simplicity, it is disregarded here that the factor g , itself, can be time related (i.e. can change through time).

[6] The following three sections are largely borrowed from my paper *Introductory notes to the discussion on quality adjustments in price indices*, distributed in December 1984 on the meeting of the Price Measurement Advisory Committee of Statistics Canada, but not published.

from each other only because of one or a few simple alterations. In contrast, the concept of utility is rather subjective, if not amorphous, and it is very difficult to assess differences in the utility provided by two items. A single alteration of a product can have multiple repercussions on services rendered by it, and consequently on its utility. Even the hedonic technique, promising in theory, is often disappointing in practice. For all these reasons, many quality adjustments to consumer prices are derived by taking into account the aspect of production costs, known or estimated, rather than the aspect of utility to consumers.

2.4. There is another explanation why potential users of the two adjustment approaches may feel uncomfortable about choosing one of them for doctrinal reasons. By the book, the two approaches would give the same result in a hypothetical case of perfectly competitive and transparent markets in total equilibrium. In real life, one could at least expect that the results will not diverge considerably and systematically from each other. There is, however, a disturbing evidence of large and persistent discrepancies between changes in the estimated use of resources and the perceived changes in the consumer's satisfaction. Quite frequently they even move in the opposite directions; diminishing costs can be associated with growing utility, and this not just during the developmental stage of production. It is only natural that one would like to attribute this inconsistency to some heavy bias in either approach (or in both).

2.5. The cost approach is so simple and straightforward that is seems almost unquestionable. Simplicity, however, might be a trap. Economists try to avoid this trap when they deal with the provided utility, by considering multiple and complex aspects of consumer's satisfaction, often to the point of making the model unworkable. Measuring of the resources needed in simple units of hours, kilograms and meters, however, is considered acceptable. I would like to believe that if the production factors were broken down into their real elements and properly valued, some of the above-mentioned discrepancy could disappear. The cost analysis should be improved with respect to regular intermediate products (e.g., what is the true value of computer chips?). Moreover, it should take into account such inputs as inventive spirit or managerial talents, which are decisive in augmenting the utility of products but either totally ignored or grossly undervalued in the accounts. Their assessment would be difficult to make, and I do not suggest that price surveyors should making them during routine collection of price quotes for the CPI. Some research, though, could be done, and there is at least one important conclusion to draw: the resource-use approach should not be applied just because it is simple.

3. Splicing technique

3.1. The explicit adjustments to prices for changes in the quality of products are often so difficult to make or so questionable that it becomes tempting to avoid the problem rather than to solve it. One symptom of this tendency is a frequent use of the **splicing technique** when items are being replaced by each other. Splicing requires that in a certain overlap time s prices of both items be collected, say p'_s for the replaced item and p''_s for the replacing item. Using these prices, it is possible to derive two price relatives without making any explicit quality adjustment to prices. The first one measures pure price movement for the replaced item from the base time b to the overlap time s :

$$p'_{s/b} = \frac{p'_s}{p'_b} \tag{3}$$

and another one measures pure price movement for the replacing item from the overlap time s to the observed time t :

$$p''_{t/s} = \frac{p''_t}{p''_s} \tag{4}$$

The two relatives can be spliced together in the overlap time s , which gives an estimate of price movement from the base time b to the observed time t :

$$p_{t/b} \approx p''_{t/s} * p'_{s/b} \tag{5}$$

The procedure seems to be miraculous. Items have been replaced, but there was no need to deal with quality changes because each of the direct price comparisons was done with respect to one product.

3.2. It was von Hofsten who pointed out that the neutrality of the splicing technique with respect to quality changes is spurious. When (5) is transformed as follows:

$$p_{t/b} \approx p''_{t/s} * p'_{s/b} = \left[\frac{p''_t}{p''_s}\right] * \left[\frac{p'_s}{p'_b}\right] = \left[\frac{p''_t}{p'_b}\right] \div \left[\frac{p''_s}{p'_s}\right]$$

and compared with (2), it becomes obvious that splicing implies certain adjustments to prices for quality changes and that the relative price differential f between the two items, as found in the overlap time:

$$f = \frac{p''_s}{p'_s} \tag{6}$$

plays the role of an implicit adjustment factor, analogous to the explicit adjustment factor g from formula (2). The question is whether it can play well this role, that means whether the price differential can be a good measure of quality differences between the replaced and replacing items, and if so, under what conditions.

3.3. The first condition is that the market should be competitive and transparent, otherwise price differentials may not reflect the buyer's preferences. This condition is often unfulfilled with respect to the replaced and replacing items in the sample. Many of the former belong to the products that tend to disappear from the market, and many of the latter belong to the products that are about to conquer the market. Now, manufacturers and distributors can be interested in either accelerating or decelerating the shifts in sales, and may want to support this policy through a skilful pricing. They may succeed in imposing special price relationships if they have a monopolistic or quasi-monopolistic position on the market. Anyway, it should be recognized that these price manipulations are quite likely to occur just when and where one might be tempted to splice price changes.

3.4. The splicing technique should be used with particular caution when price differentials tend to be systematically higher or lower that the "true" price-quality impact factors. During high inflationary periods and for categories of products with technological stagnation and little competition, new items (or spurious new items) are often intentionally introduced on the market in order to confuse the buyers about the effective price increases. In these cases splicing technique will tend to underestimate true price changes because the entire difference in prices would be attributed to quality changes. Conversely, during deflationary periods (or periods with moderate inflation) and for products with fast technological changes, the competition will make prices rise less than the quality improvement, or even fall. The splicing technique will then tend to overestimate price changes. Even if the two possible, and opposite, distortions created by the use of the splicing technique tended to neutralize each other in a long run and for the economy in its entirety, strong biases may remain for specific groups of products and in particular phases of the economic cycle.

3.5. Finally, there are cases when the use of price differentials to adjust for quality changes may lead to paradoxical price index numbers even with perfectly competitive and transparent markets. Price differentials related to fashions are an example. From the point of view of economic theory, if buyers want to pay more for a fashionable item, this reflects their evaluation of improved quality (in a broad sense of the word), which should be accepted as such by statisticians. Fashions are cyclical, however, and it is possible that after a number of fashion-related price changes the initial garment will come back at a price much higher than before, but the price increase would not be recognized by the index because of successive quality "improvements". Whatever the economic justification, it would be hard to defend this result. Once more, transitivity is a virtue to cultivate in price indices.

4. <u>Other implicit assumptions about the effect of quality changes on prices.</u>

4.1. The splicing technique, and the implicit assumptions associated with it, are used when two items replace each other in the sample. It is interesting to notice that very similar assumptions are being implicitly made when items are deleted from the sample or added to the sample and micro-indices are calculated as unadjusted ratios of mean prices. To prove it in general way, let us consider a commodity category whose price movement between the base time b and the observed time t is represented by four kinds of price index series:

- series for items continuing in the sample without replacements,
- series for items continuing in the sample, but with replacements,
- series for items deleted from the sample, and
- series added to the sample.

Their notation is as follows:

- $p_{b,i}$ and $p_{t,i}$ designate the actual price quotes collected in the base and observed times, respectively; where i = 1, 2, ..., d are symbols of the items that were maintained in the sample without replacements, $i = h+1, h+2, ..., k$ are symbols of the items that were deleted from the sample, and $i = k+1, k+2, ..., n$ indicate the items that were added to the sample;
- $p'_{b,i}$ and $p''_{t,i}$ designate the actual price quotes collected for the replaced items $i = d+1, d+2, ..., h$ in the base time, and for the corresponding replacing items $i = d+1, d+2, ..., h$ in the observed time, respectively; and

- $\tilde{p}''_{b,i}$ and $\tilde{p}_{b,i}$ designate the notional prices of the replacing items $i = d+1, d+2, ..., h$ and the added items $i = k+1, k+2, ..., n$, respectively, that estimate their price levels in the base time.

The notation is also displayed in the annexed Table 1.

4.2. Now, let us calculate an index $U_{t/b}$ derived from unadjusted mean prices:

$$U_{t/b} = \frac{\left[\sum_{i=1}^{d} p_{t,i} + \sum_{i=d+1}^{h} p''_{t,i} + \sum_{i=k+1}^{n} p_{t,i}\right] \div \left[h + (n-k)\right]}{\left[\sum_{i=1}^{d} p_{b,i} + \sum_{i=d+1}^{h} p'_{b,i} + \sum_{i=h+1}^{k} p_{b,i}\right] \div \left[h + (k-h)\right]} \qquad (7)$$

and an index $A_{t/b}$ derived from adjusted mean prices:

$$A_{t/b} = \frac{\left[\sum_{i=1}^{d} p_{t,i} + \sum_{i=d+1}^{h} p''_{t,i} + \sum_{i=k+1}^{n} p_{t,i}\right] \div \left[h + (n-k)\right]}{\left[\sum_{i=1}^{d} p_{b,i} + \sum_{i=d+1}^{h} \tilde{p}''_{b,i} + \sum_{i=k+1}^{n} \tilde{p}_{b,i}\right] \div \left[h + (n-k)\right]} \qquad (8)$$

Their ratio can be considered as a **total implicit adjustment factor** F :

$$F = \frac{U_{t/b}}{A_{t/b}} = \frac{\left[\sum_{i=1}^{d} p_{b,i} + \sum_{i=d+1}^{h} \tilde{p}''_{b,i} + \sum_{i=k+1}^{n} \tilde{p}_{b,i}\right] \div \left[h + (n-k)\right]}{\left[\sum_{i=1}^{d} p_{b,i} + \sum_{i=d+1}^{h} p'_{b,i} + \sum_{i=h+1}^{k} p_{b,i}\right] \div \left[h + (k-h)\right]} \qquad (9)$$

4.3. It is shown in the annexed proof that the factor F can be decomposed into three expressions:

$$F = F^{(I)} * F^{(II)} * F^{(III)} \qquad (10)$$

each of them interpretable as an average of specific implicit adjustment factors.
The first one deals with continuous items:

$$F^{(I)} = \frac{\sum_{i=1}^{d} [f_i^{(nr)}] * p_{b,i} + \sum_{i=d+1}^{h} [f_i^{(r)}] * p'_{b,i}}{\sum_{i=1}^{d} p_{b,i} + \sum_{i=d+1}^{h} p'_{b,i}} \qquad (11)$$

and can be interpreted as an average of the implicit factors $f^{(nr)}$ for items that have not been replaced, all equal to 1, and of the implicit factors $f_i^{(r)} = [\tilde{p}''_{b,i}] \,/\, [p''_{b,i}]$, which are the same as in (6), with the base time as an overlap time.

4.4. The second expression deals with deleted items:

$$F^{(II)} = \frac{\sum_{i=1}^{d}[f_i^{(nr)}]*p_{b,i}+\sum_{i=d+1}^{h}[f_i^{(nr)}]*p'_{b,i}+\sum_{i=h+1}^{k}[f_i^{(del)}]*p_{b,i}}{\sum_{i=1}^{d}p_{b,i}+\sum_{i=d+1}^{h}p'_{b,i}+\sum_{h+1}^{k}p_{b,i}} \qquad (12)$$

and can be interpreted as an average of the implicit factors $f^{(nr)}$ for unchanged items in continuous series, which are all equal to 1, and of the implicit factors $f^{(del)}$ for deleted items, defined as follows:

$$f_i^{(del)} = \frac{\left[\sum_{j=1}^{d}p_{b,j}+\sum_{j=d+1}^{h}p'_{b,j}\right]/h}{p_{b,i}} \qquad (13)$$

In other words, the implicit adjustment factors for a deleted item is equal to the ratio of the average price of continuous items to the price of the deleted item in the deletion time. The cheaper the deleted item, the higher is the implicit assessment of quality increases, all other things being equal.

4.5. Finally, the third expression deals with added items:

$$F^{(III)} = \frac{\sum_{i=1}^{d}[f_i^{(nr)}]*p_{b,i}+\sum_{i=d+1}^{h}[f_i^{(nr)}]*\tilde{p}''_{b,i}+\sum_{i=k+1}^{n}\left\{[f_i^{(add)}]*\left[\sum_{j=1}^{d}p_{b,j}+\sum_{j=d+1}^{h}\tilde{p}''_{b,j}\right]/h\right\}}{\sum_{i=1}^{d}p_{b,i}+\sum_{i=d+1}^{h}\tilde{p}''_{b,i}+\sum_{i=k+1}^{n}\left\{\left[\sum_{j=1}^{d}p_{b,j}+\sum_{j=d+1}^{h}\tilde{p}''_{b,j}\right]/h\right\}} \qquad (14)$$

and can be interpreted as an average of the implicit factors $f^{(nr)}$ for unchanged items in continuous series, which are all equal to 1, and of the implicit factors $f^{(add)}$ for added items, defined as follows:

$$f_i^{(add)} = \frac{\tilde{p}_{b,i}}{\left[\sum_{j=1}^{d}p_{b,j}+\sum_{j=d+1}^{h}\tilde{p}''_{b,j}\right]/h} \qquad (15)$$

In other words, the implicit adjustment factors for an added item is equal to the ratio of its estimated notional price in the base time to the average price of continuous items in that time. The more expensive is the added item, the higher is the implicit assessment of quality increases, all other things being equal.

5. Empirical results

5.1. In the early 80-ies, Central Research Section of Prices Division carried out empirical studies to verify some controversial methodologies used in the calculation of micro-indices in general, and for clothing in particular. For this purpose, individual price data for selected commodities were manually retrieved from the CPI working ledgers stored in archives, including both the actually recorded price quotes and the estimated notional prices. On their basis, implicit adjustment factors were obtained according to the definitions identical with those formulated in the previous section of the paper.

5.2. The annexed Tables 2-6 contain the distributions of implicit adjustment factors derived from price data used between 1978 and 1983 in the production of consumer price indices for five men's clothing articles: business suit, dress shirt, dress slacks, socks, and undershirt. The first distributions in each table relate to factors $f^{(nr)}$ and $f^{(r)}$ from series of continuous items with and without replacements. They show that roughly half of the replacements for all five articles were done using notional base time price of the replacing item set at the same level as the actual base time price of the replaced item, which means that $f^{(r)} = 1$. For the other half, some notional prices of the replacing items have been set at a higher level than the corresponding actual prices of the replaced items ($f^{(r)} > 1$, i.e. the replacing item was considered, explicitly or implicitly, of better quality than the replaced item), and some at a lower level than the corresponding actual prices of the replaced item ($f^{(r)} < 1$, i.e., the replacing item was considered of worse quality than the replaced item).

5.3. The second distributions in each table relate to factors $f^{(del)}$ from series of deleted items. The relations with $f^{(del)} > 1$ are there more frequent than with $f^{(del)} < 1$, which means that the cases when base time price of the deleted item was lower than the average price of the continuous items happened more often than the opposite cases. The third distributions relate to factors $f^{(add)}$ from series of added items. The relations $f^{(add)} > 1$ prevail over $f^{(add)} < 1$ for business suites, dress shirts and undershirts, which implies that notional base time prices of items added to these series were there quite frequently higher than the average price of the continuous items. For dress slacks and socks, however, the opposite is true.

5.4. The tables 2-6 do not give a clear idea what was the overall effect of all price adjustments, item deletions and additions. To help answering the question, arithmetic mean prices were derived from unadjusted price quotes collected every year in Canada for each of the considered commodities. Ratios of these mean prices constitute special kind of price indices, which are equivalent to $U_{t/b}$ in formula (7). They were compared with the corresponding price indices from the official CPI series calculated by taking into account the explicit and implicit price adjustments, hence equivalent to $A_{t/b}$ in formula (8). When the former indices are greater than the latter, it implies that the assumption that the replacing items are of higher quality than the replaced ones prevailed. The opposite is true when the indices derived from unadjusted prices are smaller that those derived from adjusted prices.

5.5. Examples of this comparison for six clothing articles in the years 1973-1994[7] are shown in the annexed tables 7, 8 and 9. The comparison, which parallels the estimation of total implicit adjustment factors F in formula (9), indicates that the adjustments for virtually all six articles contributed to a decrease of the official price indices with respect to the unadjusted ones. This does not necessarily mean that the adjustments lead to an underestimation of the true pure price movement because the discrepancy between the two kinds of indices could also have resulted from improvements in the quality of the surveyed products. For certain articles, however, the amplitude of this discrepancy is too great to be ignored. It is hard to believe, for example, that the average quality of dress shirts improved by 50% during the period in question, when no major changes in shirt design or fabric took place. It seems that some underestimation of pure price movement resulted from price adjustments, contrary to a popular belief that index makers tend to exaggerate price increases.

5.6. One should not be tempted to extend the underestimation hypothesis to other commodities or to other time periods. The surveyed clothing items belong to the category of products with relatively slow technological progress, and for this reason the underestimation prevailed. There is little doubt that overestimation of pure price movement does occur, and likely prevails for products with fast technological change. It is interesting to notice that the discrepancy was much smaller for such articles as women's brassières and men's underwear than for, say, men's suits or women's blouses. This is because prices for the former articles were collected according to relatively simple, standard specifications, so that there was less need to proceed with replacements, deletions and additions, which otherwise would necessitate many explicit or implicit price adjustments, hence provide more chances of errors. Also, the underestimation of pure price movement is generally less pronounced in the 90-ies than during the previous, high inflationary periods. All these findings seem to support the outcome of discussions lead in section 3 of the paper.

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[7] The gaps in the series are the consequence of difficulties in finding complete archive data.

ANNEX

Table 1

Symbols used to represent various kinds of price index series

Items	Observation time	Base time	
	Prices actually collected		Adjusted prices
Continuous series without substitutions			
1	$p_{t,1}$	$p_{b,1}$	-
2	$p_{t,2}$	$p_{b,2}$	-
.	.	.	.
.	.	.	.
d	$p_{t,d}$	$p_{b,d}$	-
Continuous series with substitutions			
d+1	$p''_{t,d+1}$	$p'_{b,d+1}$	$\tilde{p}''_{b,d+1}$
d+2	$p''_{t,d+2}$	$p'_{b,d+2}$	$\tilde{p}''_{b,d+2}$
.	.	.	.
.	.	.	.
h	$p''_{t,h}$	$p'_{b,h}$	$\tilde{p}''_{b,h}$
Deleted series			
h+1	-	$p_{b,h+1}$	-
h+2	-	$p_{b,h+2}$	-
.	.	.	.
.	.	.	.
k	-	$p_{b,k}$	-
Added series			
k+1	$p_{t,k+1}$	-	$\tilde{p}''_{b,k+2}$
k+2	$p_{t,k+2}$	-	$\tilde{p}''_{b,k+1}$
.	.	.	.
.	.	.	.
n	$p_{t,n}$	-	$\tilde{p}''_{b,n}$

DECOMPOSITION OF THE FACTOR F

$$F = \frac{\left[\sum_{i=1}^{d} p_{b,i} + \sum_{i=d+1}^{h} \bar{p}''_{b,i} + \sum_{i=k+1}^{n} \bar{p}_{b,i}\right] + \left[h + (n-k)\right]}{\left[\sum_{i=1}^{d} p_{b,i} + \sum_{i=d+1}^{h} p'_{b,i} + \sum_{i=h+1}^{k} p_{b,i}\right] + \left[h + (k-h)\right]} =$$

$$= \frac{\sum_{i=1}^{d} p_{b,i} + \sum_{i=d+1}^{h} \bar{p}''_{b,i}}{\sum_{i=1}^{d} p_{b,i} + \sum_{i=d+1}^{h} p'_{b,i}} * \frac{\left[\frac{h+(k-h)}{h}\right]\left[\sum_{i=1}^{d} p_{b,i} + \sum_{i=d+1}^{h} p'_{b,i}\right]}{\left[\sum_{i=1}^{d} p_{b,i} + \sum_{i=d+1}^{h} p'_{b,i}\right] + \sum_{i=h+1}^{k} p_{b,i}} * \frac{\left[\sum_{i=1}^{d} p_{b,i} + \sum_{i=d+1}^{h} \bar{p}''_{b,i}\right] + \sum_{i=k+1}^{n} \bar{p}_{b,i}}{\left[\frac{h+(n-k)}{h}\right]\left[\sum_{i=1}^{d} p_{b,i} + \sum_{i=d+1}^{h} \bar{p}''_{b,i}\right]}$$

$$F^{(I)} = \frac{\sum_{i=1}^{d} p_{b,i} + \sum_{i=d+1}^{h} \bar{p}''_{b,i}}{\sum_{i=1}^{d} p_{b,i} + \sum_{i=d+1}^{h} p'_{b,i}} = \frac{\sum_{i=1}^{d}\left[\frac{p_{b,i}}{p_{b,i}}\right] * p_{b,i} + \sum_{i=d+1}^{h}\left[\frac{\bar{p}''_{b,i}}{p'_{b,i}}\right] * p'_{b,i}}{\sum_{i=1}^{d} p_{b,i} + \sum_{i=d+1}^{h} p'_{b,i}} = \frac{\sum_{i=1}^{d} [f_i^{(nr)}] * p_{b,i} + \sum_{i=d+1}^{h} [f_i^{(r)}] * p}{\sum_{i=1}^{d} p_{b,i} + \sum_{i=d+1}^{h} p'_{b,i}}$$

$$F^{(II)} = \frac{\left[\frac{h+(k-h)}{h}\right]\left[\sum_{i=1}^{d} p_{b,i} + \sum_{i=d+1}^{h} p'_{b,i}\right]}{\left[\sum_{i=1}^{d} p_{b,i} + \sum_{i=d+1}^{h} p'_{b,i}\right] + \sum_{i=h+1}^{k} p_{b,i}} =$$

$$= \frac{\sum_{i=1}^{d}\left[\frac{p_{b,i}}{p_{b,i}}\right] * p_{b,i} + \sum_{i=d+1}^{h}\left[\frac{p'_{b,i}}{p'_{b,i}}\right] * p'_{b,i} + \sum_{i=h+1}^{k}\left\{\frac{\left[\sum_{j=1}^{d} p_{b,j} + \sum_{j=d+1}^{h} p'_{b,j}\right] / h}{p_{b,i}} * p_{b,i}\right\}}{\sum_{i=1}^{d} p_{b,i} + \sum_{i=d+1}^{h} p'_{b,i} + \sum_{i=d+1}^{k} p_{b,i}} =$$

$$= \frac{\sum_{i=1}^{d} [f_i^{(nr)}] * p_{b,i} + \sum_{i=d+1}^{h} [f_i^{(nr)}] * p'_{b,i} + \sum_{i=h+1}^{k} [f_i^{(del)}] * p_{b,i}}{\sum_{i=1}^{d} p_{b,i} + \sum_{i=d+1}^{h} p'_{b,i} + \sum_{h+1}^{k} p_{b,i}}$$

$$F^{(III)} = \frac{\sum_{i=1}^{d} p_{b,i} + \sum_{i=d+1}^{h} \bar{p}''_{b,i} + \sum_{i=k+1}^{n} \bar{p}_{b,i}}{\left[\frac{h+(n-k)}{h}\right]\left[\sum_{i=1}^{d} p_{b,i} + \sum_{i=d+1}^{h} \bar{p}''_{b,i}\right]} =$$

$$= \frac{\sum_{i=1}^{d}\left[\frac{p_{b,i}}{p_{b,i}}\right] * p_{b,i} + \sum_{i=d+1}^{h}\left[\frac{\bar{p}''_{b,i}}{\bar{p}''_{b,i}}\right] * \bar{p}''_{b,i} + \sum_{i=k+1}^{n}\left\{\frac{\bar{p}_{b,i}}{\left[\sum_{j=1}^{d} p_{b,j} + \sum_{j=d+1}^{h} \bar{p}''_{b,j}\right] / h} * \left[\sum_{j=1}^{d} p_{b,j} + \sum_{j=d+1}^{h} \bar{p}''_{b,j}\right] / h\right\}}{\sum_{i=1}^{d} p_{b,i} + \sum_{i=d+1}^{h} \bar{p}''_{b,i} + \sum_{i=k+1}^{n}\left\{\left[\sum_{j=1}^{d} p_{b,j} + \sum_{j=d+1}^{h} \bar{p}''_{b,j}\right] / h\right\}} =$$

$$= \frac{\sum_{i=1}^{d} [f_i^{(nr)}] * p_{b,i} + \sum_{i=d+1}^{h} [f_i^{(nr)}] * \bar{p}''_{b,i} + \sum_{i=k+1}^{n}\left\{[f_i^{(add)}] * \left[\sum_{j=1}^{d} p_{b,j} + \sum_{j=d+1}^{h} \bar{p}''_{b,j}\right]/h\right\}}{\sum_{i=1}^{d} p_{b,i} + \sum_{i=d+1}^{h} \bar{p}''_{b,i} + \sum_{i=k+1}^{n}\left\{\left[\sum_{j=1}^{d} p_{b,j} + \sum_{j=d+1}^{h} \bar{p}''_{b,j}\right]/h\right\}}$$

Table 2

IMPLICIT ADJUSTMENT FACTORS
from monthly price quotes used in the CPI between January 1978 and December 1983

Commodity: Men's business suit

Implicit adjustment factors	**Continuous series**		**Deleted series**		**Added series**	
	Number	**%**	**Number**	**%**	**Number**	**%**
$0.30 \le f < 0.40$						
$0.40 \le f < 0.50$						
$0.50 \le f < 0.60$						
$0.60 \le f < 0.70$	2		7		2	
$0.70 \le f < 0.80$	7		5		6	
$0.80 \le f < 0.90$	29		7		17	
$0.90 \le f < 1.00$	74		10		19	
$f < 1.00$	112	23.5	39	38.6	44	44.9
$f = 1.00$	253	52.5	0	0.0	0	0.0
$1.00 < f$	111	23.3	62	61.4	54	55.1
$1.00 < f \le 1.10$	50		22		21	
$1.10 < f \le 1.20$	34		23		9	
$1.20 < f \le 1.30$	15		11		7	
$1.30 < f \le 1.40$	5		1		8	
$1.40 < f \le 1.50$	4		1		6	
$1.50 < f \le 1.60$	2		1		2	
$1.60 < f \le 1.70$	1		2			
$1.70 < f \le 1.80$						
$1.80 < f \le 1.90$					1	
$1.90 < f \le 2.00$						
$2.00 < f \le 2.10$						
$2.10 < f \le 2.20$			1			
$2.20 < f \le 2.30$						
$2.30 < f \le 2.40$						
$2.40 < f \le 2.50$						
$2.50 < f \le 2.60$						
$2.60 < f \le 2.70$						
$2.70 < f \le 2.80$						
$2.80 < f \le 3.90$						
$2.90 < f \le 3.00$						
$3.00 < f \le 3.10$						
$3.10 < f \le 3.20$						
All cases with replacements	**476**	**100.0**	**101**	**100.0**	**98**	**100.0**
All cases without replacements	**5 514**					
All cases of continuous series	**5 990**					

Table 3

IMPLICIT ADJUSTMENT FACTORS
from monthly price quotes used in the CPI between January 1978 and December 1983

Commodity: Men's dress shirt

Implicit adjustment factors	Continuous series		Deleted series		Added series	
	Number	%	Number	%	Number	%
$0.30 \leq f < 0.40$						
$0.40 \leq f < 0.50$						
$0.50 \leq f < 0.60$			1			
$0.60 \leq f < 0.70$	1				2	
$0.70 \leq f < 0.80$	3		3		5	
$0.80 \leq f < 0.90$	8		15		3	
$0.90 \leq f < 1.00$	54		25		25	
$f < 1.00$	66	24.7	44	36.7	35	38.0
$f = 1.00$	136	50.9	3	2.5	1	1.1
$1.00 < f$	65	24.3	73	60.8	56	60.9
$1.00 < f \leq 1.10$	27		27		24	
$1.10 < f \leq 1.20$	22		19		13	
$1.20 < f \leq 1.30$	11		9		8	
$1.30 < f \leq 1.40$	3		4		4	
$1.40 < f \leq 1.50$	1		6		3	
$1.50 < f \leq 1.60$	1		2		2	
$1.60 < f \leq 1.70$			3			
$1.70 < f \leq 1.80$			2		2	
$1.80 < f \leq 1.90$						
$1.90 < f \leq 2.00$						
$2.00 < f \leq 2.10$			1			
$2.10 < f \leq 2.20$						
$2.20 < f \leq 2.30$						
$2.30 < f \leq 2.40$						
$2.40 < f \leq 2.50$						
$2.50 < f \leq 2.60$						
$2.60 < f \leq 2.70$						
$2.70 < f \leq 2.80$						
$2.80 < f \leq 3.90$						
$2.90 < f \leq 3.00$						
$3.00 < f \leq 3.10$						
$3.10 < f \leq 3.20$						
All cases with replacements	**267**	**100.0**	**120**	**100.0**	**92**	**100.0**
All cases without replacements	**6 161**					
All cases of continuous series	**6 428**					

Table 4

IMPLICIT ADJUSTMENT FACTORS
from monthly price quotes used in the CPI between January 1978 and December 1983

Commodity: Men's dress slacks

Implicit adjustment factors	**Continuous series**		**Deleted series**		**Added series**	
	Number	**%**	**Number**	**%**	**Number**	**%**
$0.30 \le f < 0.40$						
$0.40 \le f < 0.50$						
$0.50 \le f < 0.60$					1	
$0.60 \le f < 0.70$	3				5	
$0.70 \le f < 0.80$	7		2		11	
$0.80 \le f < 0.90$	14		18		21	
$0.90 \le f < 1.00$	71		21		18	
$f < 1.00$	95	27.0	41	37.3	56	61.5
$f = 1.00$	192	54.5	0	0.0	0	0.0
$1.00 < f$	65	18.5	69	62.7	35	38.5
$1.00 < f \le 1.10$	28		16		9	
$1.10 < f \le 1.20$	16		19		5	
$1.20 < f \le 1.30$	10		12		10	
$1.30 < f \le 1.40$	7		11		3	
$1.40 < f \le 1.50$	2		3		4	
$1.50 < f \le 1.60$	1		4		1	
$1.60 < f \le 1.70$	1		2		1	
$1.70 < f \le 1.80$			2		1	
$1.80 < f \le 1.90$						
$1.90 < f \le 2.00$					1	
$2.00 < f \le 2.10$						
$2.10 < f \le 2.20$						
$2.20 < f \le 2.30$						
$2.30 < f \le 2.40$						
$2.40 < f \le 2.50$						
$2.50 < f \le 2.60$						
$2.60 < f \le 2.70$						
$2.70 < f \le 2.80$						
$2.80 < f \le 3.90$						
$2.90 < f \le 3.00$						
$3.00 < f \le 3.10$						
$3.10 < f \le 3.20$						
All cases with replacements	**352**	**100.0**	**110**	**100.0**	**91**	**100.0**
All cases without replacements	**6 554**					
All cases of continuous series	**6 906**					

Table 5

IMPLICIT ADJUSTMENT FACTORS
from monthly price quotes used in the CPI between January 1978 and December 1983

Commodity: Men's wool dress socks

Implicit adjustment factors	Continuous series		Deleted series		Added series	
	Number	%	Number	%	Number	%
$0.30 \leq f < 0.40$	1					
$0.40 \leq f < 0.50$			1		6	
$0.50 \leq f < 0.60$					5	
$0.60 \leq f < 0.70$	6		4		6	
$0.70 \leq f < 0.80$	5		3		9	
$0.80 \leq f < 0.90$	21		11		18	
$0.90 \leq f < 1.00$	61		6		9	
$f < 1.00$	94	37.2	25	28.7	53	74.6
$f = 1.00$	121	47.8	0	0.0	0	0.0
$1.00 < f$	38	15.0	62	71.3	18	25.4
$1.00 < f \leq 1.10$	13		11		8	
$1.10 < f \leq 1.20$	16		8		3	
$1.20 < f \leq 1.30$	6		13		5	
$1.30 < f \leq 1.40$	1		2		1	
$1.40 < f \leq 1.50$	1		5			
$1.50 < f \leq 1.60$						
$1.60 < f \leq 1.70$			5			
$1.70 < f \leq 1.80$			4		1	
$1.80 < f \leq 1.90$			3			
$1.90 < f \leq 2.00$			3			
$2.00 < f \leq 2.10$			1			
$2.10 < f \leq 2.20$			3			
$2.20 < f \leq 2.30$						
$2.30 < f \leq 2.40$			3			
$2.40 < f \leq 2.50$			1			
$2.50 < f \leq 2.60$						
$2.60 < f \leq 2.70$						
$2.70 < f \leq 2.80$						
$2.80 < f \leq 3.90$						
$2.90 < f \leq 3.00$						
$3.00 < f \leq 3.10$						
$3.10 < f \leq 3.20$	1					
All cases with replacements	**253**	**100.0**	**87**	**100.0**	**87**	**100.0**
All cases without replacements	**6 375**					
All cases of continuous series	**6 628**					

Table 6

IMPLICIT ADJUSTMENT FACTORS
from monthly price quotes used in the CPI between January 1978 and December 1983

Commodity: Men's undershirt

Implicit adjustment factors	**Continuous series**		**Deleted series**		**Added series**	
	Number	**%**	**Number**	**%**	**Number**	**%**
$0.30 \le f < 0.40$	1					
$0.40 \le f < 0.50$						
$0.50 \le f < 0.60$	1				1	
$0.60 \le f < 0.70$			1		5	
$0.70 \le f < 0.80$	3		5		6	
$0.80 \le f < 0.90$	16		16		3	
$0.90 \le f < 1.00$	49		19		4	
$f < 1.00$	70	35.5	41	53.2	19	37.3
$f = 1.00$	104	52.8	0	0.0	0	0.0
$1.00 < f$	23	11.7	36	46.8	32	62.7
$1.00 < f \le 1.10$	6		10		8	
$1.10 < f \le 1.20$	7		7		11	
$1.20 < f \le 1.30$	4		3		9	
$1.30 < f \le 1.40$	2		2		1	
$1.40 < f \le 1.50$	1		5		1	
$1.50 < f \le 1.60$			2		1	
$1.60 < f \le 1.70$	1		5		1	
$1.70 < f \le 1.80$	1					
$1.80 < f \le 1.90$			1			
$1.90 < f \le 2.00$	1					
$2.00 < f \le 2.10$			1			
$2.10 < f \le 2.20$						
$2.20 < f \le 2.30$						
$2.30 < f \le 2.40$						
$2.40 < f \le 2.50$						
$2.50 < f \le 2.60$						
$2.60 < f \le 2.70$						
$2.70 < f \le 2.80$						
$2.80 < f \le 3.90$						
$2.90 < f \le 3.00$						
$3.00 < f \le 3.10$						
$3.10 < f \le 3.20$						
All cases with replacements	**197**	**100.0**	**77**	**100.0**	**51**	**100.0**
All cases without replacements	**5 815**					
All cases of continuous series	**6 012**					

Table 7

MICRO-INDICES FOR SELECTED CLOTHING ARTICLES

Consumer price indices with explicit and implicit adjustments for product quality changes derived from the official CPI series versus ratios of arithmetic means of unadjusted prices calculated in different years

1973 = 100

	1973	1974	1975	1976	1980	1981	1990	1991	1992	1993	1994
Women's blouses											
Adjusted indices	100.0	110.6	115.1	119.2	146.9	158.4	249.1	279.2	281.8	286.1	295.3
Mean price ratios	100.0	125.3	134.6	140.1	244.6	261.3	383.9	469.5	426.0	430.0	414.9
Women's brassières											
Adjusted indices	100.0	102.6	104.8	111.2	157.3	167.6	296.9	332.9	342.6	353.8	354.1
Mean price ratios	100.0	110.9	113.8	120.0	162.4	175.7	293.0	325.6	338.8	354.7	362.2
Men's suits											
Adjusted indices	100.0	106.4	112.4	117.8	137.3	143.2	200.4	218.5	226.0	222.1	219.5
Mean price ratios	100.0	109.9	119.7	140.6	192.0	202.6	281.4	314.8	339.5	340.7	327.2
Men's work pants											
Adjusted indices	100.0	115.3	124.4	132.9	182.5	196.5	224.8	253.8	250.0	270.3	276.1
Mean price ratios	100.0	119.9	134.1	145.6	206.0	225.0	278.3	317.4	321.1	345.5	349.9
Men's dress shirts											
Adjusted indices	100.0	108.8	114.9	118.9	159.4	173.1	258.3	275.1	278.5	280.2	272.9
Mean price ratios	100.0	106.8	113.3	127.7	186.1	210.9	380.1	408.0	431.2	433.4	412.4
Men's underwear											
Adjusted indices	100.0	114.4	123.8	131.0	173.7	195.3	262.3	286.8	292.1	295.8	294.7
Mean price ratios	100.0	114.3	126.1	135.1	189.1	215.1	264.6	289.8	294.3	306.5	303.1

Table 8

MICRO-INDICES FOR SELECTED CLOTHING ARTICLES

Consumer price indices with explicit and implicit adjustments for product quality changes derived from the official CPI series versus ratios of arithmetic means of unadjusted prices calculated in different years

1980 = 100

	1973	1974	1975	1976	1980	1981	1990	1991	1992	1993	1994
Women's blouses											
Adjusted indices	68.1	75.3	78.4	81.1	100.0	107.8	169.6	190.1	191.8	194.8	201.0
Mean price ratios	40.9	51.2	55.0	57.3	100.0	106.8	157.0	191.9	174.2	175.8	169.6
Women's brassières											
Adjusted indices	63.6	65.2	66.6	70.7	100.0	106.5	188.7	211.6	217.8	224.9	225.1
Mean price ratios	61.6	68.3	70.1	73.9	100.0	108.2	180.4	200.5	208.6	218.4	223.0
Men's suits											
Adjusted indices	72.8	77.5	81.9	85.8	100.0	104.3	146.0	159.1	164.6	161.8	159.9
Mean price ratios	52.1	57.2	62.3	73.2	100.0	105.5	146.6	164.0	176.8	177.4	170.4
Men's work pants											
Adjusted indices	54.8	63.2	68.2	72.8	100.0	107.7	123.2	139.1	137.0	148.1	151.3
Mean price ratios	48.5	58.2	65.1	70.7	100.0	109.2	135.1	154.1	155.9	167.7	169.9
Men's dress shirts											
Adjusted indices	62.7	68.3	72.1	74.6	100.0	108.6	162.0	172.6	174.7	175.8	171.2
Mean price ratios	53.7	57.4	60.9	68.6	100.0	113.3	204.2	219.2	231.7	232.9	221.6
Men's underwear											
Adjusted indices	57.6	65.9	71.3	75.4	100.0	112.4	151.0	165.1	168.2	170.3	169.7
Mean price ratios	52.9	60.4	66.7	71.4	100.0	113.7	139.9	153.3	155.6	162.1	160.3

Table 9

MICRO-INDICES FOR SELECTED CLOTHING ARTICLES

Consumer price indices with explicit and implicit adjustments for product quality changes derived from the official CPI series versus ratios of arithmetic means of unadjusted prices calculated in different years

1990 = 100

	1973	1974	1975	1976	1980	1981	1990	1991	1992	1993	1994
Women's blouses											
Adjusted indices	40.1	44.4	46.2	47.9	59.0	63.6	100.0	112.1	113.1	114.9	118.5
Mean price ratios	26.0	32.6	35.1	36.5	63.7	68.1	100.0	122.3	111.0	112.0	108.1
Women's brassières											
Adjusted indices	33.7	34.6	35.3	37.5	53.0	56.4	100.0	112.1	115.4	119.2	119.3
Mean price ratios	34.1	37.8	38.8	41.0	55.4	60.0	100.0	111.1	115.6	121.1	123.6
Men's suits											
Adjusted indices	49.9	53.1	56.1	58.8	68.5	71.5	100.0	109.0	112.8	110.8	109.5
Mean price ratios	35.5	39.1	42.5	50.0	68.2	72.0	100.0	111.9	120.6	121.1	116.3
Men's work pants											
Adjusted indices	44.5	51.3	55.3	59.1	81.2	87.4	100.0	112.9	111.2	120.2	122.8
Mean price ratios	35.9	43.1	48.2	52.3	74.0	80.8	100.0	114.0	115.4	124.1	125.7
Men's dress shirts											
Adjusted indices	38.7	42.1	44.5	46.0	61.7	67.0	100.0	106.5	107.8	108.5	105.7
Mean price ratios	26.3	28.1	29.8	33.6	49.0	55.5	100.0	107.3	113.4	114.0	108.5
Men's underwear											
Adjusted indices	38.1	43.6	47.2	49.9	66.2	74.5	100.0	109.3	111.4	112.8	112.4
Mean price ratios	37.8	43.2	47.7	51.1	71.5	81.3	100.0	109.5	111.2	115.8	114.6