# PROBLEMS OF QUALITY CHANGES
# IN THE COMPILATION OF INDEX NUMBERS

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In attempting to construct price or quantum index numbers, we usually (although not correctly) assume that the same commodities included in the index are present in both periods of comparison, and also assume that price quotations are obtainable for the commodities in the base and the current years.

In practice, these two assumptions may not hold true, especially if the two periods of comparison are remote from each other. Moreover, one of the main features of the dynamic world today is the change — sometimes rapidly — of the commodities from old products to new, the change in the design of products, etc.

In effect, the problem of quality arises when two or more varieties of a commodity would sell at the same time for different prices in the same stable market. The introduction of new products also leads to the existence of quality problems in index number compilation.

A case intermediate between a mere change in variety (such as the average strength of beer or the average size of eggs) and a wholly new product is the appearance of new models. Practically, the problem of new models arises in a wide range of products and is particularly noticeable in the case of motor cars.

In constructing index numbers, care must be taken in order to adjust the data in hand for differences in quality so that the result would not be distorted.

The first author who paid attention to this problem was G.H. Knibbs[1] in 1912 when he was dealing with the problem of differences in the thread content of textiles. He noticed that in textiles a tweed at the second date may have the same general appearance and weight and replace the use of that at the first date, but the number of threads in warp and woof may be wholly different and this may, of course, have affected the price. Such a case of pseudo-identity may be treated, Knibbs suggests, in one of two ways according to the purpose of the investigation. For one economic purpose it may be regarded as not a case of identity of regimen, since the difference in price is due to difference in quality, and would vitiate the deduction of a change in the purchasing-efficiency of money. For another economic purpose, however, we may ignore this difference and treat it as if it were identical and deduce the purchasing-efficiency of money regarded as under the compulsions of social habits, which are continually replacing the usage-commodities of any date by others of different quality, or even of different character.

Knibbs' method can be called the splicing method, which was used in Sweden for the Swedish cost-of-living index. An example may clarify this approach :

If at year "0" we have only one variety of goods, say "a"; and in year "1" this variety has disappeared and been substituted by variety "b" ; then in order to compare the quality of one article with that of the other, we put the quality of article "b" to the quality of article "a" equal to a constant, say "g to 1". Then multiplying the average price by this constant, one would obtain :

$$I_{01} = \frac{1}{g} \cdot \frac{P_1^b}{P_o^a}$$

where $P_1^b$ and $P_o^a$ refer to prices of the two commodities.

(1) Knibbs, G.H. : Prices, Price Indexes and Cost of Living in Australia, 1912.

This procedure was applied, as mentioned above, by the Swedish statisticians in connection with index numbers of milk prices, where in 1941 the milk with fat content of 3.6 percent was sold for 30 ŌRE per litre (the Swedish currency). But in autumn of the same year the authorities reduced the fat content to 3.0 percent and at the same time reduced the price per litre to 29 ORE. To calculate an ordinary price index we will get :

$$\frac{29}{30} = 0.97, \qquad \text{i.e. } 3\% \text{ reduction in price.}$$

But this is not a proper index that reflects the actual situation since no attention is paid to the reduction in fat content of milk. In order to do so, the Swedish authority resorted to the caloric content as a measure of quality, and it was calculated so that higher fat content corresponded to "650" and the lower to "600" caloric percent. Now if we put

$$\frac{600}{650} = 0.923 = g$$

Then the true index will be

$$\frac{1}{g} \cdot \frac{p_1^b}{p_o^a} = \frac{1}{0.923} \cdot \frac{29}{30} = 1.05$$

i.e. 5% increase in prices.

After this simple example we reach a point that necessitates the discussion of the nature of the factor "g" and methods of its estimation.

This factor has been introduced by Von Hofsten in his book "Price Indexes and Quality Change" in 1952 in which he proposed several methods to estimate it. But before presenting these methods let me give another example which may clarify — in mathematical terms — the problems connected with quality changes due to the presence of varieties of one or more commodities.

Let us take the case of beer as an example. In this case there are two measures of quantity : one is the "bulk barrel", which is a measure of the volume liquid; and the other is the "standard barrel", which is the measure of alcoholic strength.

Now put :

$Qr$ = the quantity of beer in liquid volume.

$Qs$ = the quantity of beer in alcohol volume

$Pr$ = the price of beer per unit of liquid

$Ps$ = the price of beer per unit of alcohol.

It follows that :

$$V = P_r Q_r = P_s Q_s = \text{expenditure on beer}$$

$$Z = \frac{Q_s}{Q_r} = \text{the quality of beer, that is the strength.}$$

Furthermore, suppose that in the base year a price-quality relationship has been found between $Pr$ and $Z$ such as :

$$P_{ro} = A_o + B_o Z$$

$$= A_o + B_o \left( \frac{Q_{so}}{Q_{ro}} \right) \qquad 1.1$$

If we multiply equation 1.1 by $Q_{ro}$, we get :

$$P_{ro} Q_{ro} = A_o Q_{ro} + B_o Q_{so} \qquad 1.2$$

Equation 1.2 means that expenditure on beer in the base year is expressed as a weighted sum of two quantities : $Q_{ro}$ and $Q_{so}$, where the weights are $A_o$ and $B_o$ respectively. If equation 1.1 gives a realistic relation between prices and quality in the year, then a Laspeyres quantity index which takes quality into consideration can be obtained, and a Paasche price index also obtainable.

To derive a price-quality relation for $P_{so}$, we proceed as follows, since :

$$P_{ro} \quad Q_{ro} = P_{so} \; Q_{so} = V \qquad 1.3$$

it follows that :

$$P_{so} = \frac{P_{ro} \; Q_{ro}}{Q_{so}} = P_{ro} \frac{Q_{ro}}{Q_{so}} = \frac{P_{ro}}{Z} \qquad 1.4$$

then if we multiply equation 1.1 by $\frac{1}{Z}$, ( that is by $\frac{Q_{ro}}{Q_{so}}$ )

we get:

$$P_{ro} \frac{Q^{ro}}{Q^{so}} = \frac{A_o}{Z} + B_o$$

but :

$$P_{ro} \frac{Q_{ro}}{Q_{so}} = P_{so} \quad \text{( see equation 1.4 above )}$$

hence :

$$P_{so} = \frac{A_o}{Z} + B_o \qquad 1.5$$

Multiply 1.5 by $Q_{so}$'

$$P_{so} \quad Q_{so} = A_o \, Q_{ro} = B_o \, Q_{so} \qquad 1.6$$

Formula 1.6 is the same as 1.2.

Now the Laspeyres quantity index for beer is :

$$L\,q = \frac{A_o \; Q_{r1} + B_o \; Q_{s1}}{A_o \; Q_{ro} + B_o \; Q_{so}} \qquad 1.7$$

and a Paasche price index can be obtained immediately

If the other complementary indexes are needed (i.e. Laspeyres price index and Paasche quantum index), then we should find a current price-quality relation in order to estimate $A_1$ and $B_1$.

It is important, however, to remark here that :

(i) If $B_0 > 0$ and $A_0 = 0$, then the quantity of beer is appropriately measured by Qso (i.e. the alcohol content).

(ii) If $B_0 = 0$ and $A_0 > 0$, then the liquid volume is the measure of beer.

**Methods for Measuring the Factor "g"**

The measurement of the factor "g", which is considered by Von Hofsten to be the appropriate quality indicator, is sometimes easy to calculate and some other times not.

It is easily calculated when the change from one variety to another is taking place gradually. But when the change is abrupt, the calculation method becomes complicated.

One common method of treating a simple aspect of the quality problem can be applied when goods are graded by size or by weights. Thus eggs are frequently graded by size and large ones, other things being equal, cost more than small ones. If information were available about the number of eggs in each grade, it would be possible to treat each grade as a separate commodity.

This result could be reproduced exactly if there were an exact relationship between price and size (or weight) and if information were available about the average size (or weight) of eggs sold as well as about their number. Such information could be obtained by sampling methods without the necessity for detailed records of all quantities sold classified by grade.

Another method for dealing with quality changes is to use price index numbers for the deflation of value changes. The advantage of this method lies in the fact that price movements for different varieties of a commodity which are made from similar materials by similar processes are likely to be very much alike. Thus, the average price movement for the members of a class or sub-class of commodities may be approximated by an average of a limited number of price quotations for goods of constant quality. If it is difficult to obtain price quotations for a particular specification or if this specification ceases to by representative of the varieties now traded, it is necessary to shift to a new specification, and in doing so to allow for any shift in quality involved. Precisely how this shift should be introduced depends on whether a base or a current weight price index is being used. Provided that the value of transactions is known at each date, a base weighted price index requires only a knowledge of the parameters in the price-quality relationship in the current periods; whereas a current-weighted price index requires the knowledge of the corresponding parameters in the base period.

Finally, as the problem of quality changes is rather a complicated matter in the compilation of index number, and because there is no unique method to be followed, we would suggest four approximate methods[1] for the measurement of the factor "g".

### 1. Substitution Method:

When the change in the specification of an item is trivial, such as changing the colour of a foutainpen, substitution may be used for the purpose of estimating"g". It is also appropriate to use substitution in case of minor improvements in the composition or performance of an item which is linked with an increase in the price of the same magnitude as the rise in"pure" price for related articles.

(1) For more details see U.N. Statistical Commission, Document E/CN. 3/246, 4th March 1958.

When appropriate measurable changes occur in the make-up or operating characteristics of articles, it is meaningless to use substitution to evaluate "g".

**2. Splicing Method :**

This method, to which we have referred above, is suitable in the case of abrupt replacement of one variant by another if it is judged that the difference in prices between the two variants approximates the market value of the difference in quality between them, especially when "pure changes" in price are not taking place for related items. When considerable changes occur in the design of industrial machinery, splicing method becomes practical because of the impossibility of assessing the economic value of the differences between the new article in the market and the old one. In these circumstances prices quotations for new articles must be introduced into the series after enough time has been allowed for efficient production and marketing. It is also important that time interval between price quotations for the new and old articles must be as short as possible.

Splicing may also be used in dealing with substitution in imports or even exports of one item by another, particularly for countries whose external trade is not diversified.

**3. Evaluating "g" by the Hedonic Index :**

When substitution or splicing does not seem appropriate to evaluate "g", or when the relationship between market value and difference in quality is not simple in character, it is desirable to evaluate "g" by the hedonic index.

The hedonic index is an estimate of the factor "g" by valuing two variants of an item, before and after a change in quality, in terms of the value which would, on the same market, be imputed to each of their significant measurable attributes. The process of the hedonic index can be reduced to be the estimation of the value which would be imputed to the difference in the significant measurable characteristics between two variants, when one of them (either the old variant or the new one) was on sale(1).

The imputed value to each characteristic is derived from an equation expressing market prices as a function of each of the attributes. The functional relation is derived from data on market price and the magnitude of each attribute for varieties of the commodity actually on sale at the same time as either of the two variants being compared.

The measurable characteristics chosen will probably be suggested by observation of the market and consultation with trade. It is desirable to work with a linear function between market prices (or the log of market prices) and the selected measurable attributes ; but when the results are not satisfactory, then it is necessary to turn to second or third degree functions. The parameters of the function could be obtained by the method of least squares.

Hedonic method has been used in several fields especially in the case of the price of automobiles, fruits and vegetables. It is also applied when there are not too marked changes in the operating characteristics of mass production, industrial machinery, such as electric motors, or consumer goods, especially household appliances.

### 4. Evaluating "g" from the Cost or Supply Price Data :

The relative cost or producer's asking price of two variants may be used to determine the value of "g". The method of evaluating "g" from cost data is based on the assumption that relative costs or producer's asking price for two variants of a commodity are proportional to relative market values. The relative cost can be obtained from the relative volume index of inputs of materials and labour. It is also obtained from the cost of producer's asking price of the difference in components, materials, etc. between the two variants.

(1) An example of this is the difference in horsepower of the motor between two variants of a particular type of automobile.

The cost approach in determining the value of "g" is an objective one when changes in quality are abrupt and are not measurable, or when widespread alterations in the design or composition occur. It is also less costly than the hedonic index method.

This method, however, needs full cooperation from important producers of the varieties of the commodity under consideration, and it is up to the statistical authority to decide to use a volume index of direct inputs or relative total cost or producer's asking price to evalute "g", and of course his decision depends entirely on the availability of data.