Price Index Numbers of Complementary Goods

A novel treatment of quality changes and new goods, experimentally applied to inpatient medical care

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Abstract: In current practices of the compilation of price and volume measures, different commodities usually are treated separately. One basic assumption is that a commodity with unchanged technical characteristics needs no quality adjustment; its observed price change is considered a pure price change. (In a context of utility theory: the commodity is considered to yield the same utility in all the years of measurement). However, if complementarity exists between different commodities, it is the *combination* of the complementary commodities which is relevant to the consumer. In such cases this basic assumption has to be abandoned. The paper shows that the current practice leads to incorrect results. A price index of inpatient medical care is estimated in which inpatient days (hospital services) and physicians operations are treated as complementary commodities. This leads to a price index that differs substantially from the result of current practice. The conclusion is that the treatment of complementary commodities is an urgent point for research in the field of price and volume measures. This could result in an important contribution to the abatement of biases in the CPI and the GDP volume.

1. Introduction

Price and volume measures are quite difficult economic statistics. At the same time the CPI and the volume of GDP are the key economic indicators. Recently, the quality of these statistics has become a major issue within *and outside* the scientific community. The CPI is assumed to be seriously upwardly biased; the growth of the volume of GDP is assumed to be underestimated.

The users of economic statistics are less familiar with serious biases than the users of social statistics. A one or two percent bias in the unemployment figures would fall within the margin of error perceived by the common user. But a 1.1% bias of the CPI, as published by the Boskin Commission (Boskin et al., 1996), gives rise to political and statistical headaches. And a corresponding potential bias in the GDP volume measure and its sectoral components once led a President of the American Economic Association to the conclusion that "We are caught up in a mixture of unmeasurement, mismeasurement, and unrealistic expectations" (Griliches, 1994, pp. 17). Recently, The Economist used headlines like *Economic statistics are in a bad way* and *The unmeasurable lightness of being* and opened a major article mainly devoted to price and volume measures with the following lead: "Economic statistics can cause governments to lose elections or wipe billions off share prices. Unfortunately, many of the numbers are wrong." (The Economist, November 23rd 1996, pp. 85)

Statisticians do well to realise that the problems with price and volume measures could lead to a démasqué of economic statistics. If the CPI and GDP turn out to be inadequate statistics in the eyes of the general public because of a substantial systematic mismeasurement of year to year changes, the credibility of official statistics runs a serious risk. Therefore, at Statistics Netherlands we feel that research on price

[1] The authors thank Bert Balk, Leendert Hoven, Piet Verbiest and Paul Warns for helpful comments.

and volume measures deserves top priority in official statistical agencies of countries with relatively well developed economic statistics.

Statistics Netherlands is initiating a new research project on price and volume measures. The first author concluded earlier that the effectiveness of current practices is limited, especially because the treatment of quality changes and new products seriously falls short (Van Tuinen, 1995). In our project we will explore new practices. One of our experiments concerns the treatment of complementary goods. Current practices generally neglect the complementarity of items in the consumers basket and this could be a serious source of mismeasurement. In section 2 we show why complementarity has to be taken into account and how the treatment of complementarity in some cases can be a relatively easy way of estimating quality changes. In section 3 we present a first experimental application of this approach to the price index of appendectomy, and in section 4 we roughly generalise it to the total inpatient medical care. Section 5 indicates the magnitude of changes in other aggregates when the results of section 4 would be adopted. In section 6 we indicate how these experiments can be improved in the near future. Section 7 presents conclusions and suggestions for further research.

2. Why current approaches fall short in the treatment of complementary goods

Current CPI practices treat items in the consumers basket as inputs in the utility function. This overlooks the fact that in certain cases consumer behaviour can be described more realistically when certain items in the basket are seen as inputs in the consumers production function. Nordhaus developed a price index of light, treating light as input in the utility function, and the consumption of electricity and bulbs as inputs in a production function of light (Nordhaus, 1994).

In other cases the consumer basket contains commodities which, from the consumer's point of view, could be considered inputs in the producers production function. For example, days spent in hospital are part of medical treatment; the treatment as a whole (or its result) can be considered input in the consumers utility function. When the consumer feels incapable of choosing among the separate parts of the treatment, it seems especially unrealistic to treat those parts as items which directly generate utility. Shapiro and Wilcox developed a price index of cataract treatment in which they consider the complete treatment as the relevant item in the utility function, rather than what the current practice is, namely: inpatient days, and operations by medical specialists (Shapiro and Wilcox, 1996).

Let us take the example of the price of light. A standard CPI does not explicitly include a price index number for light. In calculating a CPI there are at least two subindices: one for electricity and one for bulbs. We will first define a simple hypothetical price index of light as it is implicitly included in a CPI. Then we will consider what happens if new bulbs use less electricity than old ones. This will lead to the conclusion that the hypothetical price index of light cannot yield correct results when new bulbs save more money on electricity than the costs of old bulbs.

The hypothetical price index could be calculated using the following formula (Laspeyres):

$$PI_t^{light} = \frac{q_0^{el} * p_0^{el} * \left[\frac{p_t^{el}}{p_0^{el}} \right] + q_0^{bulb} * p_0^{bulb} * \left[\frac{p_t^{bulb}}{p_0^{bulb}} \right]}{q_0^{el} * p_0^{el} + q_0^{bulb} * p_0^{bulb}}$$

Let us assume (for the sake of convenience) that the price of electricity does not change. If a new bulb produces more lumen-hours of light per watt-hour of electricity than the old bulb, the quality of the new bulbs *ceteris paribus* may be considered higher. If the quality of the new bulbs is considered to be infinitely higher than that of the old bulb, the price index of bulbs will drop till zero, which causes the right hand part of the numerator in the above formula to become zero. In that case the Laspeyres price-index of light is reduced to the value of electricity used by the old bulb divided by the sum of that value and the cost of the old bulb in the base year. That is the lowest possible level of the price-index (as long as electricity is treated as a homogeneous commodity).

We now take the case where the new bulb saves more money on the total costs of electricity and new bulbs during its life span than the price paid for the old bulbs. In other words, the costs of producing a lumen-hour falls below the costs of the number of watt-hours needed in the base year to produce a lumen-hour. Then a correct price-index of light ought to fall below the lowest possible level of the hypothetical Laspeyres price-index. In this case, no treatment of the quality change applied to bulbs as a separate item in the basket will yield a correct price index (unless negative prices for bulbs are accepted, but working with negative prices in a price index number context seems highly unpractical).

The standard treatment of bulbs and electricity, as separate items in the consumers basket, prevents the Laspeyres price index of the total of electricity and bulbs from falling below the share of electricity in the total costs of light in the base year (assuming the price of electricity is unchanged). But when the base year is not very recent, the development of energy saving bulbs must have reduced the costs of producing a lumen-hour of light to below that level.

In this case, the only way to construct a correct price index is to treat electricity and bulbs as complementary commodities. If one simply calculates the total costs of a lumen-hour in both the base-year and the year of reporting, one can calculate a price index of light in which the quality change of bulbs is reflected correctly (assuming that saving electricity is the major quality change in bulbs).

Electricity and bulbs are not the only complementary items in the consumers basket. The insolation of dwellings saves energy, but is this correctly reflected in the CPI? There is a sharp drop in the incidence of repairs and the energy use of many consumers durables. Are these improvements fully taken into account?

This point is also mentioned by the Boskin Commission (Boskin et al., 1996, pp. 38-39). But in its treatment of e.g. the price index of vehicles, the Commission seems to have failed to draw the logical conclusion. Why shouldn't we try to estimate a price index of vehicle-kilometres instead of separate price indices of vehicles, repairs, fuel, insurance, etc.? Of course the estimated price index of vehicle-kilometres does not solve all measurement problems facing the price of vehicles. Other problems, such as the valuation of the quality change associated with the increased safety of vehicles, still remain to be solved. But the solution of these problems is not complicated substantially by taking complementarity into account.

Current practice seems to be based upon neo-classical micro-economics. If consumers are fully aware of complementarities, and of the technical and service characteristics of commodities, and if consumers can be expected to be able to react immediately to all changes in the market, price differentials may be considered to reflect quality differences. But these are rather unrealistic assumptions for commodities undergoing rapid technical changes, or goods with life spans of ten years or more. The assumptions are even more unrealistic when they concern commodities like health care, because the consumer feels highly dependant on the supplier, in a market that is far from transparent; in The Netherlands prices of medical operations are set by an administrative board.

In many cases price differentials cannot be expected to reflect quality differences. In other cases information on price differentials is not available. In current practice, there are analyses of technical characteristics of commodities in order to make explicit quality corrections when the quality of an existing good has been improved, or when a new commodity has been introduced.

In a context of utility theory the basic assumption is that a good with unchanged technical characteristics yields unchanged utility. If we apply this assumption to electricity, the illuminating example of light shows that current CPI practice necessarily runs into problems by neglecting complementarity. It is not realistic to consider the price difference between old and new bulbs on the market at a certain point in time, to be a correct approximation of the long run quality change. As we have seen, an estimate of this quality change, based upon the technical characteristics of the bulbs, can only yield a satisfactory result if electricity and bulbs are treated as complementary.

3. First experiment: towards a better price index of appendectomy

We intend to develop a number of experimental price indices of complementary commodities. A first project concerns inpatient medical care. We think the idea of systematically taking complementarity into account is relatively new in price index estimation, but we are aware of the fact that in the field of medical care similar experiments have been carried out earlier. As far as we know, in these experiments the notion of complementarity has not been applied explicitly; but in constructing price indices for medical *treatments* in stead of separate items of medical services, complementarity is implicitly taken into account. In the preceeding section we already mentioned the price index of cataract treatment by Shapiro and Wilcox; a thirty years old example is the work by Scitovsky (1967).

As mentioned before, prices of medical operations in The Netherlands cannot be expected to reflect marginal utilities of the consumer. On the other hand, medical care faces rapid technological change. One of the effects is that better operation techniques result in a reduction of complications, which results in a reduction of the number of inpatient days needed for a certain kinds of treatment. Therefore, the complementarity of nursing and medical operations has to be taken into account. Our experiment intends to explore the potential effect on the price index of medical care when we treat nursing and medical operations as complementary commodities.

Our first experiment concerns a price index of appendectomy. Table 1 presents two series of index numbers; following Shapiro and Wilcox (1996) we call them the hypothetical and the prototypical index. The *hypothetical* price index is the result of the standard CPI procedure, treating inpatient days and specialist services for appendectomy as separate items. The calculations are made using the basic CPI information. The formulas are presented in Appendix 1.

The second series in table 1 is called the *prototypical* price index. This index number is calculated using the same basic CPI information. In addition, information on the average number of inpatient days for an appendectomy is used to calculate a series of the total costs of an appendectomy treatment (the sum of the costs of inpatient days and specialist services). This series, divided by the total costs in 1980 (and multiplied by 100), is called the prototypical index. Again, the formulas are presented in Appendix 1.

Table 1. Hypothetical and prototypical price indices for appendectomy

	1980	**1981**	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**
	1980=100														
Hypothetical	100	107	116	118	120	124	129	132	139	142	144	165	182	184	183
Prototypical	100	107	112	110	108	109	110	108	111	111	109	121	129	126	123

The prototypical price index of appendectomy is substantially lower than the hypothetical index. The reason is that the average number of inpatient days for an appendectomy decreased from almost 11 in 1980 to less than 7 in 1994. This causes the total costs of an appendectomy to increase at a much slower pace than the Laspeyres price index using inpatient days and specialist services as separate items. The prototypical price index increases by an average rate of 1.5% a year as against a 4.4% increase of the hypothetical index.

The hypothetical index shown in table 1 is a chain of Laspeyres indices with base years *1980=100*, *1985=100* and *1990=100* respectively. We chose that chain because the Dutch CPI applies the same practice. But we calculated some other hypothetical indices in order to investigate which part of the difference between the hypothetical and the prototypical index varies with the frequency of reweighting. We found that the Laspeyres index *1980=100* without any reweighting increased by an average yearly rate of 4.6%; on the other hand the yearly reweighted Laspeyres chain index increased by 4.4% and the Paasche chain index by 4.3% a year. Consequently, the differences between the various hypothetical indices are very small in comparison to the difference with the prototypical index.

In discussions about substitution biases and cost of living indices frequently reweighting is often recommended, although one is mostly aware of the fact that the problem is not really solved that way. Our context is quite different; not substitution, but technical change affecting complementarity is the fundamental phenomenon. (Of course, technical change may be influenced by changes in relative prices and indeed we see that the tariffs for inpatient days increased relatively to the tariffs for physicians services). We conclude that in the case of appendectomy frequent reweighting is no solution to the complementarity problem.

Is the prototypical price index of appendectomy superior to the hypothetical index? If patients are sent home four days earlier in 1994 than in 1980 only for reasons of cutting costs, one can argue that an appendectomy in 1994 creates less utility than the 1980 treatment. The patient may still need a lot of care at home, and the prototypical index may be inferior to the hypothetical.

If the condition of the 1994 patients is no worse after 7 days in hospital than that of a patient in 1980 after an 11 day stay, the prototypical price index is superior. This seems a more plausible assumption; better operation techniques and technical advances in medical care will have resulted in a reduction of complications in standard treatment, and this could be the main reason why the stay in hospital is shorter. Furthermore, the planning of operations and examinations in Dutch hospitals seems to have improved substantially.

We intend to discuss this assumption with experts, together with the other assumptions made in this paper.

An appendectomy is a relatively homogeneous commodity. Of course every patient is unique and every physician is, so each appendicitis treatment will have its own unique characteristics. But from the viewpoint of the inexpert consumer suffering from acute appendicitis, these characteristics may not be critically relevant. So we assume that the treatment of an appendicitis is a homogeneous commodity. And indeed, this is the fundamental assumption on appendectomy behind the present Dutch price indices as well.

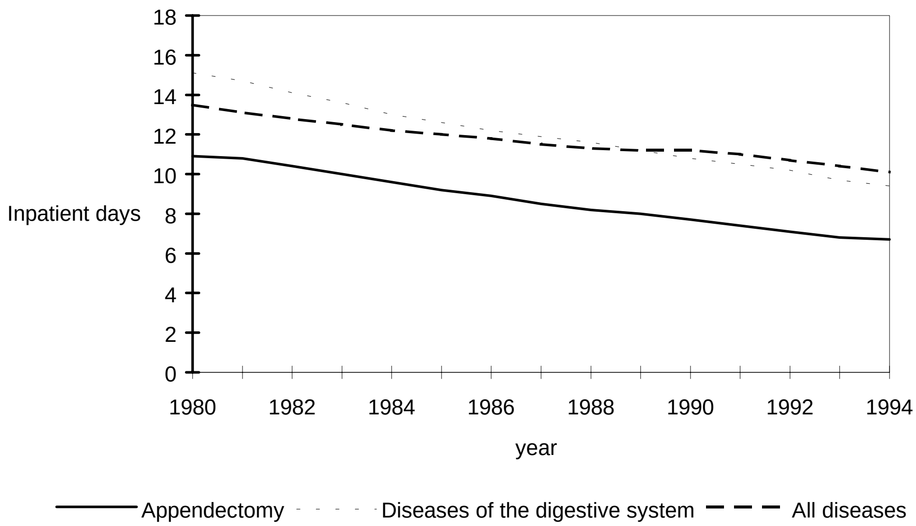
Unfortunately, the combination of data needed to estimate the prototypical price index for an number of other homogeneous treatments, is not available at the moment. Especially the *combination* of a time series on tariffs, and time series on the average number of inpatient days per treatment *and* a good estimate of the proportion of hospital and physician services in the total costs of the treatment, is currently not available for homogeneous treatment.

However, the combination of data needed for the calculation of prototypical and hypothetical price index numbers is available at the level of 17 sections of the International Classification of Diseases (ICD) (Koopmanschap et al., 1991). These groups cover almost all inpatient treatments. So, our second experiment concerns the estimation of price index numbers for inpatient treatments, considering the 17 groups as if they were homogeneous.

4. Second experiment: a first approximation of a better price index of inpatient medical care

Figure 1 shows that the downward trend in the average number of inpatient days is not unique for appendectomy. In fact it is observed for the whole period 1980-1994 in 16 out of the 17 groups of diseases, including the group *Diseases of the digestive system*, which is the group including appendicitis. Appendix 2 presents the time series of the average number of inpatient days for each of the groups of diseases.

Figure 1 Average number of inpatient days for inpatient medical treatments



Applying the formulas of Appendix 1, we estimated the hypothetical and prototypical price index numbers for the total of the 17 groups of diseases. We will call them the price index numbers of inpatient treatment. Not surprisingly, the hypothetical index increases faster than the prototypical index because of the downward trend in the average number of inpatient days per treatment in almost all groups of diseases. The average rate of increase of the hypothetical index was 4.8% in 1980-1994, as opposed to 2.5% of the prototypical index. The difference being 2.3 percent points a year.

The effect of more or less frequent reweighting is extremely small. The Laspeyres index *1980=100* increased by 4.9%; both yearly reweighted Laspeyres and Paasche chain indices increased by 4.8% yearly.

Table 2. Hypothetical and prototypical price indices for inpatient care

	1980	**1981**	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**
	1980=100														
Hypothetical	100	108	117	119	121	126	131	136	143	146	148	171	190	195	193
Prototypical	100	105	110	109	109	111	113	115	119	119	119	134	146	146	141

Is the prototypical price index of inpatient treatment superior to the hypothetical? We intend to explore this question further in our research project. For the moment we can offer the following suggestions.

It is quite implausible to assume that the decrease of the average number of inpatient days per treatment is caused mainly by changes in the *composition* of the groups of diseases. This would be the case if the number of treatments requiring only a few inpatient days in 1980 grew faster than the number of treatments needing relatively many inpatient days. The opposite seems more plausible because available information indicates:

- that there has been a shift in less complicated treatments from inpatient to outpatient treatment, and
- that technical progress introduced inpatient treatments of diseases which in 1980 were too complicated to perform.

We conclude that the most plausible hypothesis is that the decline in the average number of inpatient days is not caused by the change in the composition of the groups of diseases. An indicative affirmation of this hypothesis can be found in table 3, which displays the hypothetical and prototypical index numbers for diseases of the digestive system.

Table 3. Hypothetical and prototypical price indices for diseases of the digestive system

	1980	**1981**	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**
	1980=100														
Hypothetical	100	108	118	120	122	127	133	138	145	148	151	175	195	200	198
Prototypical	100	106	111	110	107	109	110	112	115	114	112	127	137	135	130

The hypothetical price index for diseases of the digestive system shows an average growth rate of 5.0% a year, which is 0.6% above the index of appendectomy (see table 1). The prototypical index increased by 1.9% a year, which is 0.4% above the index of appendectomy. Consequently, the difference between the hypothetical and the prototypical index for the ‘homogeneous’ appendectomy (2.9%) is of the same magnitude as that of the ‘heterogeneous’ group diseases of the digestive system.

5. Potential implications for higher aggregates

The difference between the hypothetical and the prototypical price index of inpatient medical care was 2.3% a year during 1980-1994. What would be the effects on other aggregates of substituting the prototypical index for the hypothetical?

The effect on the development of the volume of value added of inpatient medical care is higher than that on gross output, because intermediairy input is not affected by choosing another deflator for gross output. Table 4 shows that the yearly growth rate of gross value added is 3.28% higher using the prototypical price index. Cumulative over a 14 year period, this implies a volume of more than 50% higher than with the hypothetical index.

Table 4. The effects of a change from the hypothetical to the prototypical price index for inpatient medical services on some aggregates, 1980-1994 [2]

	Average	Cumulative
	%	
Gross value added inpatient medical services	3.28	57.2
Gross value added health and veterinary services	1.42	21.9
Gross Domestic Product	0.07	1.0
Final consumption by households	0.12	1.7

The effect on the value added of total medical care is substantially smaller, because inpatient care is less than half of total medical care.

The effects of using the prototypical price index of inpatient medical care on macro economic variables are small, because medical care is less than 10% of household consumption and less than 7% of GDP. But a systematic difference in macro economic growth rates in the order of 0.1% a year is not to be neglected. The potential effect on the Dutch CPI is zero, because inpatient medical care has a zero weight in the CPI. The reason is that generally insured (including collectively insured) medical care is not considered part of the cost of living; the insurance premiums are considered to be subtracted from disposable income.

6. Future developments in price and volume measures of medical care

We intend to develop the prototypical price index of inpatient medical care further by conducting a few more experiments.

First we hope to capture the data needed to estimate prototypical indexes for other homogeneous treatments like appendectomy. The results of those experiments will be discussed with experts in the field. If we could estimate prototypical indices for a representative set of homogeneous treatments, the weighted average could be an interesting alternative to the results of section 4. Even if only a few more experiments in homogeneous treatments are possible, we can learn a lot about the wider validity of the estimates.

As a second step we will try to improve the estimates for total inpatient care. A hopeful development is that initiatives are taken to improve the administrative systems. Some hospitals are working on a classification of standardised diseases into about 400 DRGs (Diagnosis Related Groups; in fact it concerns combinations of diagnoses and treatments). In a few years time this should result in information about the total costs of the treatment of these diseases on the bases of which Statistics Netherlands could make prototypical price indices. These 400 DRGs will be fairly homogeneous compared to the 17 groups applied in section 4.

Simultaneously, we will discuss the results of our experiments inside and outside Statistics Netherlands in order to prepare decisions on the deflation of medical care in the near future.

[2] Based on National Accounts figures for 1993

A lot of work remains to be done. We not only have to study the complementarity of medical services, but also the estimation of the changes in the quality (or utility) of medical treatments (or results). Cutler, McClellan, Newhouse and Remler recently published an interesting article on the Cost of Living Index with an application to heart attack treatment. They value explicitly the quality of medical treatment using indicators of the value of life during the remaining years of life (Cutler et al., 1996).

At the moment we do not have any set opinion on the treatment of quality changes of medical treatments or results. If we could succeed in gathering time series on total costs for a (large) number of fairly homogeneous medical treatments, and if we could then realistically assume that the quality of each of these treatments does not deteriorate systematically, then the estimation of prototypical price index numbers for those treatments could be considered a big step forward. We expect that these price indices will be substantially lower than our currently available deflators. This will result in higher volume measures of medical care, which in turn could be considered understandable minimum estimates in the absence of generally accepted quality of life valuations.

7. Conclusions

We conclude that the potential effects on price and volume statistics of taking the complementarity of commodities into account are important, and not for medical services only. It is worthwhile to start experimental estimates in other areas: of course on light, and on other household production (or production of services of consumer durables), mobility, and communication. Maybe priority should be given to those consumption functions that are most affected by technological progress.

Our proposed strategy can be formulated in more general terms. We define the consumer basket as a matrix. Every row stands for a commodity which could form an item in the standard weighting scheme of some price index like the CPI. In the columns we define *usual combinations* (e.g. consumption functions in a CPI or in a deflator of intermediary consumption, bundles of complementary products in an output deflator). Then the question is how to define homogeneous quantities for these usual combinations.

If the columns can be disaggregated and regrouped into usual combinations of which the quantity can be measured relatively simply, the price movement can be measured as the total costs per unit of that combination. Examples of this are lumen hours of light (usual combination: electricity, bulbs, etc.), vehicle kilometres (usual combination: vehicles, fuel, repair services, road tax, insurance premiums, etc.) and medical treatment (usual combinations: bundles of medical services like inpatient care, operations by physicians, etc.).

For the columns where the usual combinations do not result in a variable of which the quantity can be measured relatively simply, the current practice of measuring along rows may be preferable. If the commodity of the row is homogeneous *and* no complementarity exists with other items in the weighting scheme, this treatment is satisfactory. But in all other cases there is a problem.

In our view this treatment of complementarity is an indispensable technique in the abatement of biases in price and volume measures.

In some cases the technique is easier to apply than current methods of the treatment of quality change. E.g. it is easier to construct a series of costs per lumen-hour of light than to compile a long time series of price index numbers for bulbs with changing technical characteristics which is corrected for quality changes.

In other cases (vehicle kilometers, medical treatments) the technique is not easier and it may need more data. But our experiment concerning inpatient medical care suggest a high return to investment in this treatment of complementarity.

Of course, this treatment of complementarity is not a panacea to all problems of the treatment of quality changes and new goods. In the words introduced two paragraphs above, there are rows in the matrix where measurement will not become easier. However, we expect the distinction between complementarity changes and other quality changes to be a fruitful element in the future development of less biased price and volume measures.

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Appendix 1

1. HYPOTHETICAL PRICE INDEX

1.1 Hypothetical price index for treatment of appendicitis

$$PI_t^{hyp,\,ap} = w_b^{in,ap} * PI_t^{in} + w_b^{sp,ap} * PI_t^{sp,ap}$$

$PI_t^{hyp,\,ap}$	hypothetical price index for appendectomy
$w_b^{in,ap}$	share of the costs of inpatient days in total costs of appendectomy in 1980, 1985 and 1990[**]
$w_b^{sp,ap}$	share of the costs of specialist treatment of appendicitis in total costs of appendectomy in 1980, 1985 and 1990 [**]
PI_t^{in}	price index for inpatient day
$PI_t^{sp,ap}$	Price index for specialist treatment of appendicitis

1.2 Hypothetical price index for inpatient treatment of diseases of the digestive system

The diseases of the digestive system (including appendicitis) refer to section 9 of the International Classification of Diseases (ICD).

$$PI_t^{hyp,\,ds} = w_b^{in,\,ds} * PI_t^{in} + w_b^{sp,ds} * PI_t^{sp}$$

$PI_t^{hyp,\,ds}$	Hypothetical price index for diseases of the digestive system
$w_b^{in,\,ds}$	Share of the costs of inpatient days in total costs of inpatient treatment of diseases of the digestive system in 1980, 1985 and 1990 [**]
$w_b^{sp,ds}$	Share of the costs of specialist treatment in total costs of inpatient treatment of diseases of the digestive system in 1980, 1985 and 1990 [**]
PI_t^{in}	Price index for inpatient day
PI_t^{sp}	Price index for inpatient specialist treatment

[**] In fact, we estimated three index number series: one *1980=100* for the years 1980-1985, one *1985=100* for the years 1985-1990, and one *1990=100* for 1990-1994. The series are chained, using 1985 and 1990 as linking years.

1.3 Hypothetical price index for inpatient medical care

$$PI_t^{hyp} = w_b^{in} * PI_t^{in} + w_b^{sp} * PI_t^{sp}$$

PI_t^{hyp}	hypothetical price index for inpatient care in hospital
w_b^{in}	share of the costs of inpatient days in total costs of inpatient care in hospital in 1980, 1985 and 1990 **
w_b^{sp}	share of the costs of specialist treatment in total costs of inpatient care in hospital in 1980, 1985 and 1990 **
PI_t^{in}	price index for inpatient day
PI_t^{sp}	price index for inpatient specialist treatment

2. PROTOTYPICAL PRICE INDEX

2.1 Prototypical price index for inpatient treatment of appendicitis

$$PI_t^{prot,\,ap} = \frac{\textit{average costs of a treatment of appendicitis in year t}}{\textit{average costs of a treatment of appendicitis in base year}} * 100$$

$$= \frac{C_t^{in,ap} + C_t^{sp,ap}}{C_b^{in,ap} + C_b^{sp,ap}} * 100$$

$PI_t^{prot,\,ap}$	Prototypical price index for an inpatient treatment of appendicitis
$C_t^{in,ap}$	Costs of inpatient days associated with the treatment of appendicitis in a hospital in year *t*
$C_t^{sp,ap}$	Costs of specialist treatment of appendicitis in hospital in year *t*

$$C_t^{in,ap} = N_t^{ap} * P_t^{in}$$

N_t^{ap}	Average number of inpatient days spent in a hospital with diagnosis appendicitis in year *t*
P_t^{in}	Average price of an inpatient day spent in hospital in year *t*

** We estimated three index number series: one *1980=100* for the years 1980-1985, one *1985=100* for the years 1985-1990, and one *1990=100* for 1990-1994. The series are chained, using 1985 and 1990 as linking years.

The costs of a specialist treatment of appendicitis in the hospital is estimated by means of the proportion of the costs of inpatient days and the costs of specialist treatment of appendicitis, which is known for the year 1988:

$$C_t^{sp,ap} = a_{1988}^{ap} * (N_{1988}^{ap} * P_{1988}^{in}) * \left(\frac{PI_t^{sp,ap}}{PI_{1988}^{sp,ap}} \right)$$

$$a_{1988}^{ap} = \frac{costs\ specialist\ treatment\ of\ appendicitis\ in\ 1988}{costs\ inpatient\ days\ associated\ with\ appendicitis\ in\ 1988}$$

2.2 Prototypical price index for inpatient treatment of diseases of the digestive system

$$PI_t^{prot,ds} = \frac{average\ costs\ of\ a\ treatment\ of\ diseases\ of\ the\ digestive\ system\ in\ year\ t}{average\ costs\ of\ a\ treatment\ of\ diseases\ of\ the\ digestive\ system\ in\ base\ year}$$

$$= \frac{C_t^{in,ds} + C_t^{sp,ds}}{C_b^{in,ds} + C_b^{sp,ds}} * 100$$

$PI_t^{prot,ds}$ Prototypical price index for an inpatient treatment of diseases of the digestive system

$C_t^{in,ds}$ Costs of inpatient days associated with a treatment of diseases of the digestive system in hospital in year *t*

$C_t^{sp,ds}$ Costs of a specialist treatment of diseases of the digestive system in hospital in year *t*

$$C_t^{in,ds} = N_t^{ds} * P_t^{in}$$

N_t^{ds} average number of inpatient days spent in hospital with diagnosis diseases of the digestive system in year *t*

P_t^{in} average price of an inpatient day spent in hospital in year *t*

$$C_t^{sp,ds} = a_{1988}^{ds} * (N_{1988}^{ds} * P_{1988}^{in}) * \left(\frac{PI_t^{sp}}{PI_{1988}^{sp}} \right)$$

$$a_{1988}^{ds} = \frac{costs\ specialist\ treatment\ of\ diseases\ of\ digestive\ system\ in\ 1988}{costs\ inpatient\ days\ associated\ with\ diseases\ of\ digestive\ system\ in\ 1988}$$

2.3 Prototypical price index for inpatient care

$$PI_t^{prot,\,ic} = \sum_{y=1}^{17} w_b^y * PI_t^{prot,\,y}$$

$PI_t^{prot,\,ic}$ Prototypical price index for inpatient care

y Section *y* of the ICD

w_b^y share of costs of ICD-section y in total costs of inpatient care 1980, 1985 and 1990 **

$PI_t^{prot,\,y}$ prototypical price index for ICD-section *y*

$$PI_t^{prot,\,y} = \frac{\textit{average costs of an inpatient treatment of diagnosis y in year t}}{\textit{average costs of an inpatient treatment of diagnosis y in base year}}$$

$$= \frac{C_t^{in,y} + C_t^{sp,y}}{C_b^{in,y} + C_b^{sp,y}} * 100$$

$C_t^{in,y}$ costs of inpatient days associated with the treatment of ICD-section *y* in hospital in year *t*

$C_t^{sp,y}$ costs of specialist treatment of ICD-section *y* in hospital in year *t*

$$C_t^{in,y} = N_t^y * P_t^{in}$$

N_t^y Average number of inpatient days spent in hospital with diagnosis ICD-section *y*
In year *t*

P_t^{in} Average price of an inpatient day spent in hospital in year *t*

$$C_t^{sp,y} = a_{1988}^y * (N_{1988}^y * P_{1988}^{in}) * \left(\frac{PI_t^{sp}}{PI_{1988}^{sp}} \right)$$

$$a_{1988}^y = \frac{\textit{costs specialist treatment of diagnosis ICD - section y in 1988}}{\textit{costs inpatient days associated with diagnosis ICD - section y in 1988}}$$

** In fact, we estimated three index number series: one *1980=100* for the years 1980-1985, one *1985=100* for the years 1985-1990, and one *1990=100* for 1990-1994. The series are chained, using 1985 and 1990 as linking years.

Appendix 2

International Classification of Diseases

Section	Nos	Group of diagnosis
1.	001-139	Infectious and parasitic diseases
2.	140-239	Neoplasms
3.	240-279	Endocrine, nutritional and metabolic diseases and immunity disorders
4.	280-289	Diseases of blood and blood-forming organs
5.	290-319	Mental disorders
6.	320-389	Diseases of the nervous system and sense organs
7.	390-459	Diseases of the circulatory system
8.	460-519	Diseases of the respiratory system
9.	520-579	Diseases of the digestive system
10.	580-629	Diseases of genitourinary system
11.	630-676	Childbirth and complications of pregnancy, childbirth and the puerperium
12.	680-709	Diseases of the skin and subcutaneous tissue
13.	710-739	Diseases of the musculoskeletal system and connective tissue
14.	740-759	Congenital anomalies
15.	760-779	Certain conditions originating in the perinatal period
16.	780-799	Symptoms, signs and ill-defined conditions
17.	E800-E999	Injury and poisoning

Average length of stay in hospital

ICD-section	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
1975	20,7	20,1	21,6	21	34,7	13	20,6	7,9	16,7	11,7	10,2	19,9	18,4	14,6	22,5	14,4	19,8
1976																	
1977	19	19,1	20,4	18,7	36,6	12,2	19,1	8,3	16,3	11,2	9,7	18,9	17,2	13,2	19,2	13,2	18,2
1978	18,3	18,5	19,9	18	35,1	11,7	18,7	8,6	15,9	10,8	9,4	18,7	16,4	12,5	18,2	13,1	17,9
1979	17,9	18,5	19,7	17,4	36	11,4	18,3	8,5	15,6	10,5	9	18,4	15,8	11,9	16,9	12,6	17,5
1980	18,2	18,5	19,7	17,4	35,6	11,2	17,5	8,6	15,1	10,2	8,8	18	14,9	11,5	15,1	12,7	17
1981	17,3	17,6	19,4	16,3	36,3	11,2	16,8	8,7	14,7	9,9	8,2	17,7	14,2	10,7	13,8	12,2	16,3
1982	16,9	17	18,8	14,9	36,9	10,7	16,2	8,8	14,1	9,5	7,9	17,2	13,7	10,2	12,9	11,5	16
1983	15,6	16,4	18,1	14,3	36,1	10,6	15,5	9,1	13,6	9,3	7,6	16,5	13,1	10,2	11,9	11,1	15,4
1984	15,2	15,8	17,6	13,7	35,6	10,5	15	9,7	13	9,2	7,2	16,5	12,6	9,5	11,5	10,8	15
1985	14,7	15,6	17	13	35,1	10,3	14,6	10,1	12,6	9,2	7	15,9	12,2	9,4	11,2	10,5	14,7
1986	14,3	15,4	16,4	13,1	35,4	10,1	14,4	9,9	12,2	9	6,7	15,6	11,7	9,3	10,6	10,3	14,5
1987	14,3	14,8	15,8	12,6	35,6	9,7	14	9,7	11,9	8,9	6,5	15,6	11,2	9,1	10,2	9,9	14,4
1988	13,9	14,4	15,4	12,2	36,6	9,3	13,7	9,8	11,6	8,9	6,3	15,2	10,8	8,9	10,1	9,8	14,2
1989	13,8	14,1	15,1	11,8	36,3	8,8	13,3	9,7	11,2	8,7	6,1	14,8	10,5	8,7	9,9	9,6	13,9
1990	13,8	13,8	14,9	11,4	36	8,3	13	9,6	10,8	8,5	6	14,5	10,2	8,5	9,7	9,3	13,6
1991	13,7	13,5	14,5	11,1	35,7	7,8	12,7	9,6	10,5	8,4	5,8	14,2	9,9	8,3	9,6	9	13,4
1992	13,6	13,2	14,1	10,8	34,8	7,3	12,2	9,8	10,2	8,2	5,7	13,7	9,9	8,4	9,3	8,6	12,9
1993	13,2	12,8	13,7	10,5	33,6	6,8	11,8	9,8	9,7	8	5,6	13,3	9,9	8,4	9	8,3	12,6
1994	12,7	12,4	13	10,3	32,5	6,9	11,3	9,6	9,4	7,8	5,4	12,7	9,9	8,6	8,8	8	11,9

Source: National Medical Registration (LMR), Dutch Centre for Health Care Information (SIG).