STATISTICS AND SCIENCE

Handbook on the application of quality adjustment methods in the Harmonised Index of Consumer Prices

Developed within the European project "CENEX HICP Quality Adjustment"

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Preface

This handbook is the result of a new form of co-operation within the European Statistical System. The basic idea of that new way of co-operation is that statistical experts from various countries co-operate in developing specific methods and then make their results available to all statistical institutes in the European Union. The present handbook shows that this form of co-operation can be very successful.

The idea underlying such forms of co-operation is contained already in the Palermo action plan of the European Statistical System adopted in 2002. Based on it, and chaired by the Federal Statistical Office, a Task Force was set up which proposed the "Centres and Networks of Excellence (CENEX)" as modern co-operation networks. The goal was to concentrate the development of statistical methods in various areas in a few member states which are particularly competent in the relevant area. The Task Force had proposed price statistics for a CENEX pilot project; in 2006 it was implemented under the chairmanship of the Federal Statistical Office.

The principles of co-operation have in the meantime been developed further. CENEX has been renamed ESSnet (European Statistical System networks) and has been included as a model into the European Communities Statistical Programme for 2008 – 2012. With the "Regulation of the European Parliament and of the Council on European statistics", which took effect on 1 April 2009, co-operation networks such as ESSnet have been laid down in a European legal basis and have thus gained even more importance in the European Statistical System. The Regulation contains comprehensive framework conditions for the development, production and publication of European statistics.

The Federal Statistical Office is proud of having actively participated in that promising form of co-operation from the start. I would like to thank all experts involved for their commitment and contribution. Their work has advanced price statistics and has contributed to shaping the way towards a future in the spirit of partnership in European Statistics.

Yours,

Roderich Egeler

President of the Federal Statistical Office

Preliminary remarks

This "CENEX Handbook" is a result of the project "CENEX HICP Quality Adjustment". It is dedicated to the price statisticians within the European Statistical System (ESS) and shall assist them with the introduction and development of quality adjustment methods. At the same time it aims at the harmonisation of quality adjustment practices within the ESS. The ambition is to provide as concrete examples as possible to supplement the general training of price statisticians in a useful way.

The principle of CENEX (Centre and Network of Excellence) is that statistics experts from different countries join forces to elaborate practicable approaches to the solution of a certain methodological problem and afterwards make their findings available to all national statistical institutes (NSIs) of the European Union.

From October 2006 until September 2008 price statistics experts from Austria, Belgium, Germany, Ireland, the Netherlands, Portugal and Sweden have worked together and discussed practical approaches to quality adjustment in consumer price statistics. Various practical issues have been intensely discussed and practical solutions were tested on authentic examples from different product areas.

The project has been coordinated by the Federal Statistical Office of Germany. It was co-financed by Eurostat [1] and was accompanied by a Steering Group which included members from Eurostat, the European Central Bank, and from the national statistical institutes of Finland, Italy, and the United Kingdom.

The Handbook is meant as an offer for the NSIs helping them fulfil the existing standards. The proposals in the Handbook do not impose any obligations on the NSIs to use them and thus do not lead to additional statistical requirements. In this way, the Handbook can be seen as a self-helping instrument of the member states to reach the requirements of the ESS.

Even if the examples in the Handbook are meant to be as concrete and instructive as possible it may not always be possible to copy them exactly in regular practice of NSIs for the following reasons: First, there are country-specific surrounding conditions which may require individual solutions in some cases. Second, examples may become obsolete over time which especially applies to the products that underlie technical progress which are dealt with in this Handbook. Third, in the field of quality adjustment methods the methodological discussions have not yet come to an end in all respects. Thus the Handbook will likely have to be updated by time. This does not only apply to the product-specific examples but also to the more general parts of the Handbook in which the basic ideas of the product-specific proposals are summarised. The present text can therefore only give a current snapshot of the ongoing discussion on the application of quality adjustment methods in practice.

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1) The CENEX project on HICP Quality Adjustment was co-financed by the European Community, represented by the Commission of the European Communities ("the Commission"). The sole responsibility for this Handbook lies with the authors. The Commission is not responsible for any use that may be made of the information contained therein.

The CENEX team would like to thank the members of the HICP Working Group for their very helpful comments and advice throughout the duration of the CENEX project.

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1 Basic concepts and definitions

1.1 The HICP as a Laspeyres-type index

An important regulation for European price statistics, Council Regulation No. 2494/95, states that the HICP shall be a Laspeyres-type index. When sticking to the Laspeyres principle the price development is calculated for a previously established expenditure pattern which is fixed for a certain time period – one year in many cases.

In order to apply the Laspeyres principle to the HICP, so-called consumption segments are identified. A consumption segment embraces a set of product-offers, which are deemed to serve a common consumption purpose. The identification of consumption segments remains constant for the whole index period.

> **Definition of the HICP as a Laspeyres-type index**
>
> Council Regulation No. 2494/95 forms the legal basis for the HICP. According to Article 9 of this Regulation, "Member States shall process the data collected in order to produce the HICP, which shall be a Laspeyres-type index . . ."

The Laspeyres principle *does not mean* that the different product-offers, which are representing the consumption segments, need to be kept constant with their quality of models, outlet types and locations. Instead, the product-offers which are selected for price observation should be chosen in order to represent the consumption segments with respect to models, outlet types and locations they are belonging to as accurately as possible. This does not only apply for the initially chosen product-offers, but must rather be fulfilled at any point of time.

From this follows an important implication: The price statistician faces the challenge of choosing such product-offers for price observation, which adequately represent the consumption segments, outlet types and locations in question at any time. Markets and products continuously change. This dynamic requires that models losing their representativity have in due time to be replaced by new ones in order to ensure the sample of product-offers being representative of their respective consumption segments *at any point of time*. This is especially true for markets showing significant technical progress.

However, introducing a more representative product-offer or model as replacement for an obsolete one which has lost its representativity violates another important goal, the comparability of subsequent product-offers. As soon as there is any important change in product quality, in outlet types or in the location of price observation, two subsequent product-offers are no longer comparable. The difference of the last price from the replaced and the first price of the replacement product-offer may not only consist in the so-called "pure" price change but may, for example, also include price deviations which are due to quality differences. Another challenge for the price statistician therefore consists in elaborating the "pure" price change, unbiased by changes in product quality or other factors, when comparing the last and first prices of subsequent product-offers.

The handling of methods which are suitable to reach this end – against the background of maintaining the representativity of the sampled product-offers – is the focus of this handbook.

1.2   Basic definitions

The **consumption segments** can be seen as a starting point for the construction of quality adjusted price indices. They can be subcategories of the 4-digit COICOP classes. The notion of consumption segments is introduced by Regulation No. 1334/2007. According to this concept, individual product-offers are categorised on the basis of a common basic purpose of consumption. Product-offers belong to the same consumption segment if they refer to products which are used in similar situations, which can largely be described by a common specification, and may be considered by consumers as equivalent.

A **product-offer** is assigned to one series of observed prices for a model at one period, location and outlet type. So, a product-offer defines a unique entity for a certain time span. The term "model" is in this text used to refer to one specific variant of a product. The hierarchy of consumption segments, models and product-offers is illustrated in Chart 1.

Chart 1
Basic terms
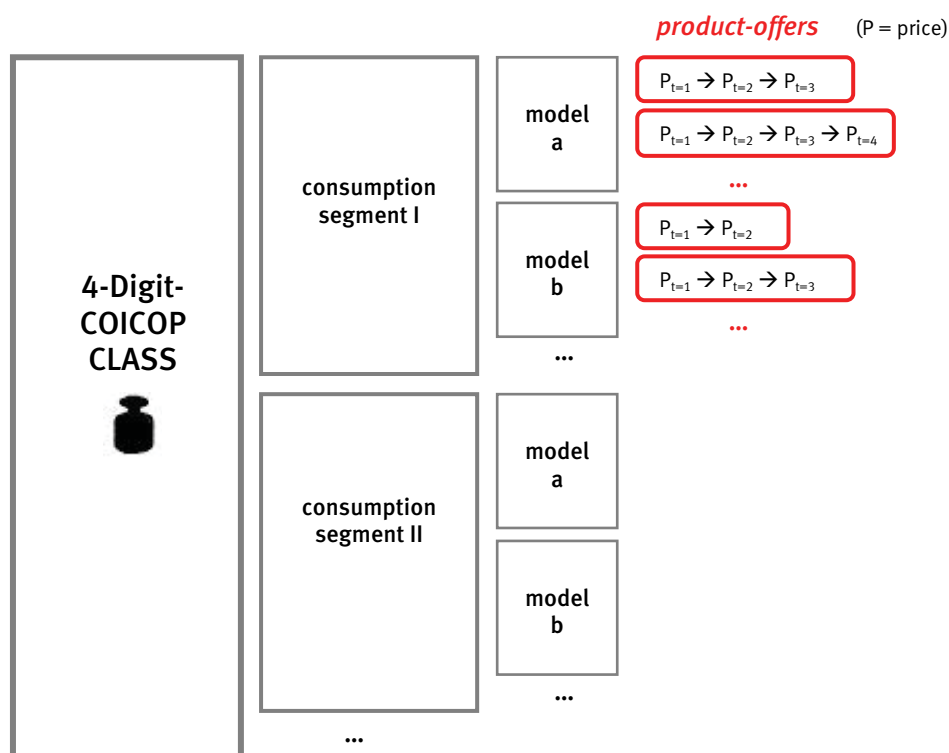
The set of product-offers initially selected by the price statistician in order to observe prices is called the **"target sample"**. It is vital for the construction of the HICP that these product-offers should be chosen in order to represent the consumption segments they belong to. The product-offers of a target sample should be representative in terms of the dimensions model type, outlet type and region.

The price-series belonging to one product-offer is by definition uninterrupted, whereas the uninterrupted price-series can have different durations. An interruption would for example be a change in the model's quality or in the outlet type or a change in the location of price observation, and causes a **replacement situation**: As soon as such an interruption occurs, the current product-offer ends and should be replaced by a successor. Regulation No. 1334/2007 uses the terms "replaced" and "replacement" product-offer and states that replacement product-offers shall be selected "so as to maintain the representation of consumption segments" (Article 7). That means that the product-offers should be representative *at any point of time*.

Chart 2
Notation of subsequent product-offers (p = price)

"replaced" product-offer   "replacement" product-offer

$P_{t=1} \rightarrow P_{t=2} \rightarrow P_{t=3}$ → $P_{t=4} \rightarrow P_{t=5} \rightarrow P_{t=6} \rightarrow P_{t=7}$

The regulation also states that the replacement product-offer should be selected from the same consumption segment as the replaced one. Normally, samples are managed in the way that every obsolete product-offer should have one explicit successor. So, *within one consumption segment*, a general practice is **one-to-one replacement** – the initially chosen product-offers are replaced one-to-one by subsequent replacement product-offers seeking to represent the universe of transactions taking place in reality within this consumption segment, whereas this universe is called **"target universe"**.

In the case of a replacement, the price-series of the replaced product-offer has to be connected to the price-series of the replacement product-offer in order to maintain a continuing series of price observations. Two cases can be distinguished here:

Either the replacement product-offer is **essentially equivalent** to its predecessor in terms of quality. In this case the last price of the replaced offer can be directly compared to the first price of the replacement product-offer in order to calculate the price development. **Quality** means in this context the degree to which products fit to serve the purpose of the consumption segment to which they belong.

Or the replacement product-offer differs significantly in quality from its preceding offer. In this case methods of quality adjustment have to be applied. This can for example be done by estimating the monetary value of the quality difference between the replaced and replacement product-offer and adjusting the last price of the replaced product-offer respectively. According to the terminology of Regulation No. 1334/2007 – which amended Regulation No. 1749/1996 – the product-offers are then "equivalent by quality adjustment".

Chart 3
Equivalent replacements

```
                    ┌─────────────────┐
                    │  product-offer  │
                    └─────────────────┘
                      /             \
    ┌──────────────────────┐   ┌──────────────────────────┐
    │ replaced product-offer│   │ replacement product-offer │
    └──────────────────────┘   └──────────────────────────┘
                                   /             \
                      ┌──────────────────────┐ ┌──────────────────┐
                      │ essentially equivalent│ │ equivalent by QA │
                      └──────────────────────┘ └──────────────────┘
```
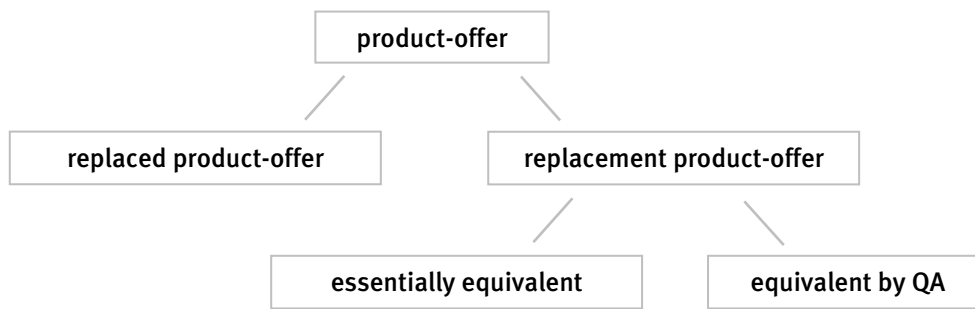
In the following, a description is given of how to calculate a quality-adjusted price index for a type of good in, generally, four steps. The four steps are:

• identify consumption segments,

• construct target samples for each consumption segment,

• decide on replacement strategies,

• apply quality adjustment methods where required.

2 Identification of consumption segments

2.1 The role of consumption segments

As stated above, the Laspeyres principle means for the HICP that the identified consumption segments remain constant for the whole index period (one year in many cases). So the overall price development is represented continually by the same consumption segments throughout one index period. Once the definition of the consumption purpose is established it should not be changed during the index period, not even to react to market changes.

Role of consumption segments

"Consumption segments shall form the fixed objects in the index basket to be followed by the HICP."

Regulation 1749/1996 as amended by 1334/2007, Article 2a (4).

The consumption segments are linked to the consumers' usage of the products and to their perception thereof. This in turn implies that over time consumption segments tend be about as stable as people's habits. Thus they are usually much more stable than specific models, but on the other hand they are far from being *perfectly* constant. Sometimes new ones are born and subsequently grow, while others fade away and die. For example when mobile telephones were introduced some years ago, they led to drastic changes in people's telephoning habits, taking the phones outdoors etc. Hence, mobile telephones placed themselves in at least one newly born consumption segment within a short time period.

However, normally, during just one year changes in consumption segments will be rather limited. As HICPs are annually chained it is thus an acceptable Laspeyres approximation to compute the index with the consumption segments treated as fixed during each year.

If the principle of one-to-one replacements as described in the previous section is considered within the consumption segment, as a result the number of price-series per consumption segment normally stays the same during the index period – obsolete product-offers are each replaced one-to-one by a more representative successor. The replacement shall always be carried out within the same consumption segment, and not beyond the boundaries of a consumption segment. On the other hand, quality adjustment methods should be applied in general when replacing product-offers within a consumption segment – except if the replacement is essentially equivalent to the replaced offer.

2.2 Identification of consumption segments in practice

According to Regulation 1334/2007, a consumption segment means a set of transactions relating to product offers which, on the grounds of common properties, are deemed to serve a common purpose, in the sense that they:

- are marketed for predominant use in similar situations,
- can largely be described by a common specification, and
- may be considered by consumers as equivalent.

From the definition in the Regulation it follows that consumption segments are basically determined by consumers' habits. They should thus be seen as an aspect of consumer reality, not primarily as an administrative device for price collection. Trying to identify consumption segments should be essential in the index production, in order to make the index reflect consumer reality appropriately. Consumption segments are thus basically defined by consumer habits in these respects.

To identify consumption segments practically, proxy variables can be useful. For example, for new cars the size of the car can serve as a proxy variable: Small new cars are predominantly used for short distance rides in urban areas, e.g. for shopping, whereas large new cars may also be appropriate for long distances such as vacation trips. Furthermore, the consumption purpose to transport persons and luggage (e.g. the family cars) also depends on the size of the car. Using proxy variables as the size of a car to define consumption segments is (of course) only an imperfect solution. The size of the car can have multiple meanings, it could refer to the number of doors, size of engine, gross tare weight, etc. The example does also not implicate that the consumer uses different cars for different consumption purposes. Furthermore the understanding of short- or long-distance rides can be different depending on country-specific surroundings. However, it illustrates one possible approach to the problem of identifying segments with respect to consumption purpose.

As another example serve TV sets for which the size may, for example, provide an indication of the consumption purpose. Thus, small TV sets could, for example, be situated in the bedroom or in the children's room or, more generally, be interesting for less-frequent users (e.g. for watching the news), whereas large TV sets tend to be bought for usage in the living room and for watching motion pictures. Here again, the size of the TV set can-

not be a definitive indicator of usage and the example once again demonstrates the unavoidable subjective element in the identification of consumption segments. One could also argue that TV sets can be used for different purposes at different stages of their life-cycle – e.g. the new flat screen TV being placed in the living room whereas the old tube TV set is used in the bedroom. For the time being, an objective theory-based procedure to identify consumption segments is not in sight. So NSIs will have to agree on conventions here. This example also demonstrates the not avoidable subjective element in the identification of consumption segments. Finally, a totally automatic procedure to identify consumption segments will not be possible and one has to agree on some conventions.

As there are so far no general guidelines on how to identify consumption segments, proposals on identification of these are included in the product-specific guidance of this handbook on a case-by-case basis. These specifications are in general open to country-specific realisations.

In practice price collection generally has to encompass only a sample of consumption segments. An example: Different kinds of hand-held tools such as hammers and screwdrivers have different uses, and by the definition they should thus be considered as belonging to different consumption segments. Now, it is not practically necessary to collect prices for all those consumption segments of different kinds of tools. Instead one or a few of them may be sampled for price collection, to represent them all. If a weight is applied here (see next section), it shall pertain to the consumption in the entire set of consumption segments represented (such as the set of all hand-held tools), not just those in the sample (such as hammer or screwdriver).

2.3 Consumption segments with or without weighting

Consumption segments can be weighted implicitly or explicitly. A weighting is, however, not prescribed by Regulation No. 1334/2007. An implicit weighting can result from the number of price-series if not a mean value per consumption segment but a mean value of all price-series of a COICOP 4-digit class is computed when aggregating the individual price developments. Then a consumption segment for which a greater amount of price-series has been collected enters the sub-index of the respective COICOP 4-digit class with a higher weight. When weighting explicitly on the other hand, the mean price development per consumption segment would be calculated and this mean value would obtain a weight corresponding to the household expenditure on this segment just as the COICOP 4-digit class.

3 Construction of target samples

3.1 HICP as sample statistics

Price statistics is a sample survey. The following section therefore deals with how product-offers can be selected for price observation. An initial "target sample" has to be constructed which represents the relevant product-offers within the consumption segment. In doing so, not only the issue of which models to choose plays a role but also which outlets and which regions or locations are relevant.

For a more thorough treatment on the construction of target samples, please refer to the "HICP Draft Manual"[1]. The inclusion of a sampling section into this Handbook has the limited scope of setting the stage for the treatment of quality adjustment.

3.2   Dimensions to be considered

In principle, when planning the target sample, three dimensions have to be considered, the dimensions of models, outlets and regions, which are building up the target universe. However, that does not mean that all three dimensions always have to be covered by price collection. If, for example, a retail firm runs several outlets on its own and establishes the same prices in all outlets it is sufficient to collect prices in one of these outlets to represent the entire chain. Just as well local price collection can be replaced by central price collection from the internet under certain preconditions. The precondition – namely that the price development at internet retailers can be regarded as representative of the total market – should, however, be checked beforehand. The price statistician should be able to provide a reason for confining price collection to only one or two dimensions.

The target universe puts the identification of the consumption segment in concrete terms of models, outlets and regions.

Chart 4
Dimensions of the target universe
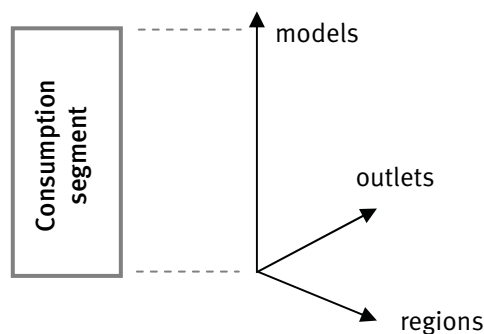
When selecting particular models, the challenge is to compile a representative sample from a sometimes wide variety of different models within the consumption segment. Multi-stage sampling approaches are often used in practice, for which different approaches will be described as examples here. When following the first one, relevant models are chosen first and then the question is to be answered in which regions and outlets the prices of these models can best be observed. With the second example, regions and outlets are chosen first and then the relevant models are chosen within the outlets.

The first example is more of a theoretical nature. It can only be used in its pure form if a register of all available models exists and if the particular market shares are known. To some extent this approach is suitable in the case that a bestseller list is available for a

1) Eurostat (2008).

product, as it is sometimes the case for books, for example. But above that, the example is suitable to clarify the basic concept that is outlined in the following:

Chart 5
Multistage sampling, Example A

> **Example A: models › outlets**
>
> (1) Choose the relevant models.
>
> (2) Choose representative regions.
>
> (3) Choose representative outlets there.

The second example is helpful in reducing the complexity of the task to find the relevant models. In this case first outlets are chosen and then the relevant models are determined within the outlets.

Chart 6
Multistage sampling, Example B

> **Example B: outlets › models**
>
> (1) Choose representative regions.
>
> (2) Choose outlets there which are relevant for this type of good.
>
> (3) Choose representative models in the outlets.

By pre-selecting the outlets, the set of models that have to be considered is reduced: only models that are offered in the pre-selected outlets are considered. This simplifies the compilation of the model sample. From a theoretical point of view Example A and B can yield the same results. From a practical point of view Example B facilitates the selection of particular models.

These two approaches rather serve as examples and can be combined or diversified in different respects. For example in some cases information is available on market shares of model types, but not on the share of concrete models. Data from market research institutes might show how market shares for example of LCD and tube TVs are distributed, but not which market shares can be attributed to specific models in the consumption segment. In this case the information on model types can be used to pre-select model types and concrete models can be chosen within the outlets. Such an approach will be described below in the section on "stratification".

Please note: The selection of outlets and regions is a very comprehensive issue in connection with the calculation of HICPs. This Handbook basically aims at exemplifying that the

dimensions models, outlets, and regions can be closely connected when compiling a target sample. However, the focus of this Handbook lies on the dimension of "models".

Please be aware that the expression "choose outlets which are relevant for this type of good" shall not be restricted to the selection of product-specific shops. The selected outlets may rather be relevant for other products of the HICP as well.

3.3   Selecting models

In the following, selection procedures are described that can be applied in order to compile a representative target sample. The selection procedure should assure that the price development of the sample reflects the real price development within the consumption segment to a high degree.

3.3.1   Cut-off sampling

A frequent approach when choosing relevant models is cut-off sampling. In the case of Example A (models › outlets), the first step is to compile a picture of the models which are offered in the respective consumption segment, including information on the sales volumes of these models.

In the next step, the most important models according to their turnover can subsequently be selected for inclusion into the price observation – until a given cumulated market share of the included models is reached, for example a share of 60 %. Chart 6 illustrates the process of selecting models by cut-off sampling.

Chart 7
Selecting models by cut-off sampling
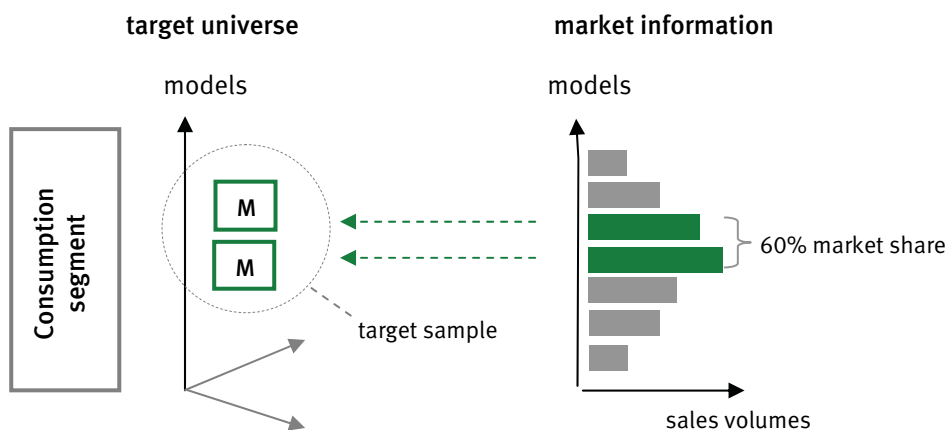
A precondition for applying the method is that market information on the sales volumes [2] of the models is available – at least for the most important models in the consumption

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2) Total sales are used as a proxy for the expenditure by households. Market share and sales volume are used as proxy for relative expenditure share.

segment. If there is a market which is mostly made up of a small amount of top-selling models and the remainder of the market is made up of a large amount of models each with a small market share, this remainder of the market does not necessarily need to be observed. It would suffice to include the top-selling models into the sample as long as they make up the desired cumulative market share.

A drawback of cut-off sampling is that the price developments of the remaining models, which are not selected for price observation, may be significantly different from the price trend of the included models. In this case, the sample would not be representative for the whole target universe. It is thus not only the market share which has to be considered when selecting models for the sample – the different price developments within the universe should also be taken into consideration.

In the case of Example B (outlets › models) cut-off sampling can be realised by instructing the price collector to choose the best-sold models within the selected outlet. The models can be selected by consulting the sales staff in the particular outlet. However, although the choice of potentially selected models is in this case reduced to those which are available in the respective shop, the identification of the "most sold" model within a shop may in many cases be subject to a judgemental decision (see next section on purposive sampling). Moreover, the second disadvantage of cut-off sampling persists – the price development of the best-sold models might not necessarily be representative for the total market. In this case it might become necessary to also consider other models in order to mirror the price development of the entire consumption segment in a more representative way.

3.3.2 Purposive sampling

Another way to compile a target sample would be to conduct "purposive sampling", which is sometimes also referred to as "judgemental sampling" or "typical selection". When using purposive sampling, models are chosen which are considered to show a typical price development. The decision on the inclusion or exclusion of models is based on judgements from the statistician's subjective point of view. The advantage shows in the circumstance that one can deliberately choose other than the most sold models if they are considered to show more typical price developments and are therefore better suited for representing the whole market. Furthermore, in the case of judgemental sampling one does not require a list of models that are for sale and their corresponding sales volumes. However, with Example A (models › outlets), the price statistician still has to get a general idea of the models offered in the respective consumption segment including a rough picture of their sales volumes.

For Example B (outlets › models) the selection of a model which shows a price development which is typical for all models sold within this outlet will again be subject to judgemental decisions. The subjective element will even be stronger than in the case of applying cut-off sampling for Example B: where it may be difficult, but still possible, to identify the most sold models within the shop, it will be even more difficult to identify one which shows a rather typical price development.

The disadvantage of judgemental sampling shows in the circumstance that the decisions on the model selection strongly depend on the decision maker. It is therefore not always intersubjectively verifiable whether the decision of including a certain model is really

based on the criterion of representativity – or whether the sample is rather a result of "convenience sampling", what means to select those models which can be included into price observation with the least effort or costs.

3.3.3   Random sampling

Random sampling is a way to avoid subjective decisions and at the same time not to confine the sample to the most sold models only. In this case, the models are chosen via a random process whereby top-selling models shall be selected with a higher probability than slow-selling models ("probability sampling proportional to size"). This procedure has the advantage that the selection follows clearly stipulated rules and is therefore not subjective. Furthermore, top-selling models are still considered more than less relevant models. However, the selection is not from the beginning limited to top-selling models. [3]

A practical problem arising is that a complete list of all models including their market shares must be available – which will for many products not be the case. The approach is therefore normally used only for parts of the selection process and in combination with other selection approaches – for example when primary car models are pre-selected as model types for a new car price index, where information on the market shares of primary car models are normally available from the national car registers. The selection of concrete car models within the definition of the pre-selected model types can then be done by applying cut-off sampling for example.

Another disadvantage of random sampling may be that the selected models or model types must be included into price observation, disregarding the practical circumstances of price observation. The selected units may not be available in the outlets or internet shops which are normally used for price collection and it can be time consuming or even not desired to switch to other shops for the price observation (procedures have been invented to cope with this problem by allowing the price collector to switch to evasion products, however this again means watering down the principle of random selection).

3.4   Stratification

In practice, mixtures of different sampling approaches are used often. These mixtures do in many cases include a so called stratification, where the target universe is first divided into several strata and the units are then selected within each or within the most important strata [4]. As mentioned above, the sample could for example at first be stratified according to model types. For the selection of concrete models representing the strata, one can for example again first choose relevant outlets and then within the outlets select representative models which fit into the definition of the respective stratum.

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3) Random sampling is in principle the only form of sampling that is fully justified by scientific statistical theory. This means that correct use of random sampling is in principle the only way of ensuring absence of potentially disturbing uncontrolled selection bias due to sampling. The use of random sampling in consumer price statistics is however strongly limited by practical problems.

4) In the theory of random sampling stratification is known as a technique for reducing random errors at a given sample size. However in price statistics stratification is particularly valuable in attempting to achieve representativity in use of other sampling methods than random sampling.

Chart 8
Multistage sampling, Example C

Example C (with stratification): model types › outlets › models

(1) Stratify the target universe according to model types.

(2) Pre-select relevant model types.

(3) Choose outlets which are relevant for the type of good, accounting for the regional dimension.

(4) In the outlets, select representative models which belong to the pre-selected model types.

Information about the market significance of the model types may be gained from market research institutes, associations or from a small pilot-survey of the national statistical institute for which in some outlets a short description of all available models including their order of market significance needs to be collected.

Chart 9
Target sample with stratification
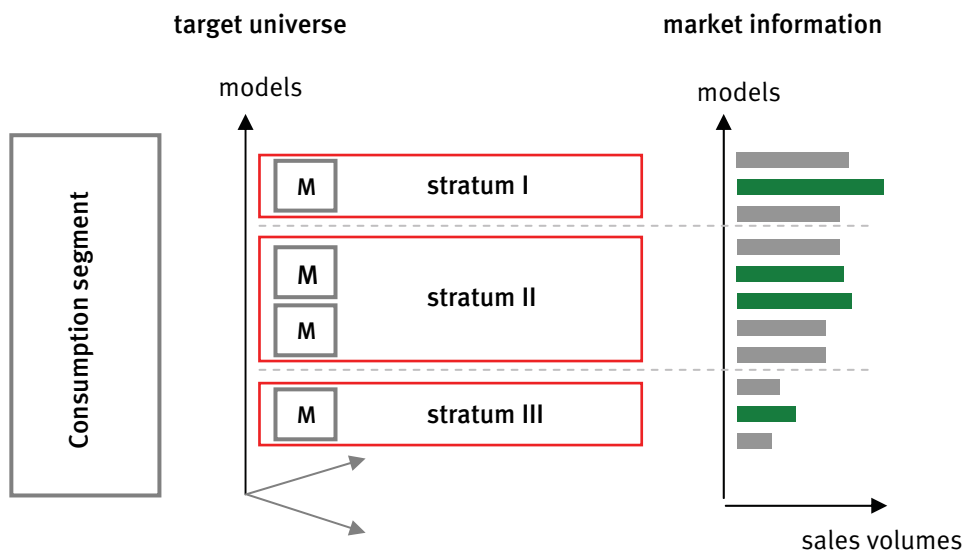
Ideally, stratification should be accompanied by an implicit weighting of the strata in order to integrate the information about the market relevancy of the strata. This means, the higher the relevance of the stratum with respect to market share, the more concrete models should be selected from the stratum in order to represent the entire consumption segment. For reasons of practicability, one often has to cope with a rough approximation of the number of observations per stratum to the market relevancy of the respective stratum.

Implicit weights have the advantage that the principle of one-to-one replacement can be maintained and that in the case of replacements the weights are adapted automatically (as will be seen in the next section).

Note that it is not necessary to include every stratum into price observation. Analogously to cut-off sampling, one could pre-select the most important strata and choose the concrete models within these strata only. In this case, the number of models chosen within each stratum should reflect the market importance of the pre-selected strata only.

The advantages of stratification are that a good cross-sectional representation of the market can be achieved and that even in the case of cut-off sampling, the sample is not confined to the most important models from the beginning. By stratification, it can be assured that also other important model types enter the sample in any case.

The approach can be expanded to the outlet dimension if information on outlet-types is available. In this case, one stratum would contain the product offers belonging to one certain model type and one certain outlet type.

3.5   Sample size

In this section a few hints concerning the sample size of products or product groups are given. Minimum standards for sampling are stated in Article 8 of Commission Regulation No. 1749/96. The regulation states that the weight of the product category, the diversity of items within the category, and the variation of price movements in the population should be taken into account when a sample is compiled (see box).

First of all the weight of a product category could be taken as a rough estimate for the optimal sample size. Second, the diversity of items has to be taken into account in order to include important market segments. Third, enough prices for categories with volatile price movements have to be collected taking into consideration resource constraints concerning the maximum number of monthly collected prices.

Theoretically, the optimum allocation of the number of prices can be calculated by the so-called Neyman allocation. The standard form of the Neyman allocation takes into account the total sample size, the standard deviations of the price relatives in the product groups and the weight of the product groups. (For more details see HICP Draft Manual.) In practice the implementation of such allocation formulae is difficult especially as the variance of the price development would have to be measured in advance. Furthermore, the diversity of items within the respective categories can be country-specific. This Handbook can therefore not suggest concrete benchmarks regarding the sample size.

> **Minimum standards for sampling**
>
> "HICPs constructed from target samples which, for each category of COICOP/HICP and taking into account the **weight of the category,** have sufficient elementary aggregates to represent the **diversity of items within the category** and sufficient prices within each elementary aggregate to take account of the **variation of the price movements in the population** shall be deemed reliable and comparable."
>
> Regulation 1749/96, Article 8 (emphasis added)

Expert knowledge of the particular markets and conditions is necessary especially concerning weights of the product groups, unbiased estimates of the standard deviation, and detailed data on cost structures regarding the price observations. If detailed data are on-hand allocation formulae could serve as tool for optimising the cost-effectiveness.

4 Replacement strategies

4.1 Replacements and revisions

This section deals with the question of when product-offers have to be replaced and which replacement offers are most suitable as a successor. The replacement of product-offers has consequences for the task of quality adjustment, which will be addressed in the section on quality adjustment.

Replacements are needed to maintain the representation of a consumption segment over time – between the comprehensive annual or less frequent revision of the HICP samples. The fundamental difference between replacement and revision shows in the fact that in the case of replacements the price difference between the replaced and the replacement model enters the price index. In the case of a revision, models are also replaced but the price difference between replaced and replacement model is eliminated through chain linking and does therefore not enter the price index.

Many countries combine replacement and revision so that a yearly comprehensive revision is performed in December whereby a sampling procedure is applied, for example, as described in the preceding section on the target sample. Between these revision dates the sample is sustained representative with the help of replacements. There are, however, countries that do not revise the sample (at least as regards models) in certain time intervals but rather whenever it seems necessary.

4.2 Focus on the dimension of models

The regulations on the HICP do not specify, whether replacement should only refer to the model dimension, or also to the outlet dimension or even to the regional dimension of the target sample. First there is no regulation requirement for replacement and quality adjustment in the outlet and regional dimensions. Forced replacements between outlets may be an occurring practice, but for the sake of maintaining representativity of the outlet sample, frequent enough comprehensive sample revisions can be seen as a more adequate method. Thus, prices would be observed in a fixed choice of outlets and models would always be replaced within the same outlet.

On the other hand one can take the view that the *type* of outlet, in which the models are offered, does also constitute a price-determining characteristic, just as a model's brand, material or make. Outlet types could for example be retail warehouses or online-shops. Thus, outlet types which have lost consumption relevance would have to be replaced by more representative outlet types and a quality adjustment would also have to be applied if the quality of the outlet type has been identified as a significant price-determining characteristic.

However, the statement applies that the dynamic of the dimension "model" is usually considerably higher than that of the dimensions "outlet" and "region". Therefore, the scope

of this Handbook is confined to the model dimension. In the following, the term "replaced" and "replacement model" is therefore used instead of "replaced" and "replacement product-offers":

Chart 10
Notation of subsequent models within the remaining text (p = price)

"replaced" model"   "replacement" model

$P_{t=1} \rightarrow P_{t=2} \rightarrow P_{t=3}$ → $P_{t=4} \rightarrow P_{t=5} \rightarrow P_{t=6} \rightarrow P_{t=7}$

4.3 Representativity at any point of time

4.3.1 The problem with sticking to similar or identical models by all means

One way of managing a sample of models over time between two revisions may be to stick to identical or similar models when replacing expiring ones. By replacing unrepresentative models with similar successors, the sample is as far as possible not changed and it is assured that like is compared with like over time. This approach measures what may be called the "pure" price change, undisturbed by quality changes.

But the matching of prices of similar models over time will for a range of product categories lead to the monitoring of a sample of models increasingly unrepresentative of the population of transactions. For some models, it will even not be possible to follow this strategy, because neither the initially chosen nor similar models will after a while any longer be available on the market. To stick to identical or similar models is in particular not appropriate for products with significant technical progress. Aiming at replacing obsolete models by identical or even by similar models in a market with rapid technical progress means that these replacements will soon be obsolete, too. Obsolete models are by their nature at the end of their lifecycle and identical or similar replacement models, to be comparable, must also be near or at the end of their lifecycle.

There is another danger of continuously monitoring similar models of products until they are out-of-time or even no longer supplied in the shops. Such models may exhibit unusual price changes as they near the end of their lifecycle, because of the marketing strategies of the firms. The price development starts to be determined by sell-out prices. Keeping the model in the sample can lead to declining prices which do not reflect the price trend which is true for most of the commonly bought up-to-date models.

Another important problem of sticking to similar or identical models arises when the index is chain linked in the course of the comprehensive revisions. If the sample is only renewed by applying chain linking then an important part of the price development may get lost, namely that part of the price development which comes with the introduction of replacement models (see following box).

Two types of price changes

The HICP aims at measuring the "pure" price change, unbiased by changes in product quality or other factors (e.g. the conditions of sale). However, there are two types of pure price changes and both should be captured. The first occurs when the prices of a non-replaced model simply change (a price change within one uninterrupted price series). For instance, a seller changes the price label of a specific computer model in a specific outlet and location from one period to another. The measurement of this kind of price effect does not cause any trouble because the pure price change is directly observable from one period to another.

However, when for example a modified model is launched by a manufacturer this model may be introduced with a price change, which also needs to be measured. The observed price difference between the preceding and the modified model can in this case be composed of two effects: (1) The price effect which is due to quality differences between the two models and (2) the price effect which comes with the introduction of the newly issued model. It is only the price effect of quality changes that should be excluded in order to calculate the pure price change, not the price effect coming with the model's launch.

Car models can be taken as an example. Suppose a modified car model is introduced which includes improved equipment such as a navigation system as standard feature. Assume that this new equipment has been available before as an option – previously available at an additional cost of about 400 Euros. Assume that business is doing well and the dealer decides to seize the opportunity and to increase the price of the new car model (including the new equipment) by 1 000 Euros compared to the replaced model. So it could be estimated that the price effect, which is due to quality improvements, may be at maximum 400 Euros. The pure price change however comes to at least 600 Euros – the car is more expensive now, even if accounting for the quality improvement.

The price change coming with the introduction of a replacement model *should not be excluded* from the price measurement. It is an important part of the price development to be captured by price statistics. The appropriate way to do this is to replace models which are becoming unrepresentative by more representative ones. Replacement procedures are especially important in the case of technical

Revisions and replacements in the HICP

"Revisions of the HICP sample do not remove the need to introduce replacement product-offers without delay in between two revisions."

Regulation 1749/1996 as amended by 1334/2007, Article 2a (8).

progress, because they allow including the quality adjusted price difference between the replaced and the replacement model into the price measurement and thereby to capture the price development induced by technical improvements.

On the other hand, chain linking of the index is not a problem when the sample of models is (by and large) up-to-date and the models within the sample are reflecting the state of the technology. In this case, price trends due to the technical progress will be captured

well by replacements between the annual revisions and the index will not systematically be biased by "chain linking out" the price development in the course of a revision.

4.3.2 Replacement to ensure representativity

The previous sections showed that, especially for products with technical progress, the sample should be maintained continuously by replacing unrepresentative models. The models in the sample have to be replaced when they have lost their representativity and not only when they cannot be found in the outlets any longer.

The chart illustrates this exemplarily. The first step has been to select a target sample according to the available information on sales volumes. The prices of a selected model can then be traced as long as the model is still representative for the respective consumption segment. This has to be checked at regular intervals.

However, the model distribution which is used in the chart for a regular representativity check is meant to be hypothetical. Usually, information on sales volumes is not available for time intervals shorter than one year. Instead, judgemental estimations (relying on supportive evidence, if available) must be used. For example, the products sold most frequently within an outlet also tend to be chosen. The described procedure may be called "replacement to ensure representativity".

Chart 11
Replacement to ensure representativity
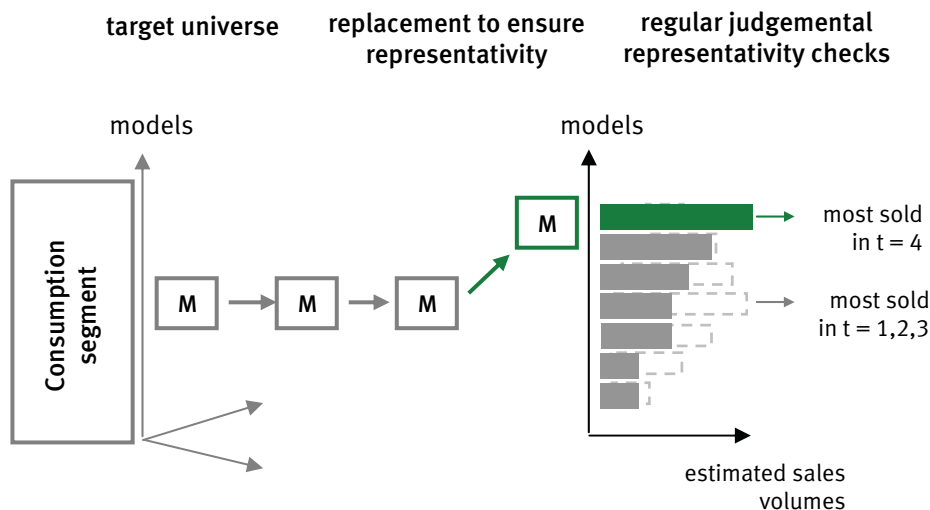
4.4   Product specifications

4.4.1   Tight or loose product specifications

Even when striving for representativity, it does not make sense to only follow represent-ativity with replacement. Every replacement implies a more or less reliable judgement on the quality difference between the replaced and the replacement model. Even if elaborated quality adjustment methods are applied, there are always uncertainties connected to the estimation of the quality difference. Additionally, high frequencies of replacement can cause high costs due to the need of quality adjustment. Therefore, it is meaningful to use the models that were in the sample in the previous month as a starting point for the model selection in the current month in order to keep the share of matched models as high as possible. But if the representativity of an initially chosen model decreases significantly, it should be replaced by a more representative successor as soon as possible. Thus, the main criterion for the selection of replacements should be representativity whereas a sec-ondary criterion could be to avoid unnecessary large changes with the selection of replace-ment models.

A slightly more formal way to account for both criteria would be to define a range of model variants within which replacement is carried between two revisions. For example for TV sets, the replacement strategy could be to choose replacements which are of the same TV type, belong to the same brand cluster and to the same range of screen sizes. A replace-ment model, for example, might be chosen to fit into the description "LCD TV, screen size about 32 inches, higher/medium brand". Those descriptions are often referred to as "product specification".

In this context, different market circumstances may be distinguished:

(a) The market of the product is characterised by continuous quality changes over time that are caused e.g. by technical progress and by which more or less all models are affected that are offered a similar way.

(b) Product variants of different quality are available in the market that show relevance in the market at the same point in time, but there is no significant technical progress which affects the evolution of the product variants in a common way.

In the first case (a), the range of model variants which come into consideration for replace-ment should be defined loosely so that continuous quality changes due to technical pro-gress can be accounted for. For the example of TV sets, this would for example mean that the range of screen sizes should be broad enough so that the trend towards larger TV sets can be reflected in the choice of replacements.

In the second case (b), it would be justifiable to lower the range of model variants coming into consideration for replacement in order to reduce the scale of quality changes connect-ed with the replacement. This corresponds to a tight product specification.

Tight product specifications can have the further advantage that the price collectors re-ceive more guidance for the selection of replacement models whereas loose specifications might demand too much from the price collector.

4.4.2 Several product specifications within one consumption segment

So far, we have assumed that there is only one (tight or loose) product specification for the replacement within one consumption segment which forms the basis for the selection of replacement models for price collectors.

One problem shows in the fact that the tighter these product specifications are defined the smaller is the part of the market which is covered by the range of models of this tight product specification. This problem may already occur for middle tightness of the product specification. Referring to the above mentioned example for TV sets, we find a relatively loose product specification – however, tube and plasma TV sets as well as very small TV sets are not included in the range of models that may be selected as replacement models. This problem can be solved by applying several product specifications in parallel (see following chart 12).

Chart 12
Replacement within several product specifications
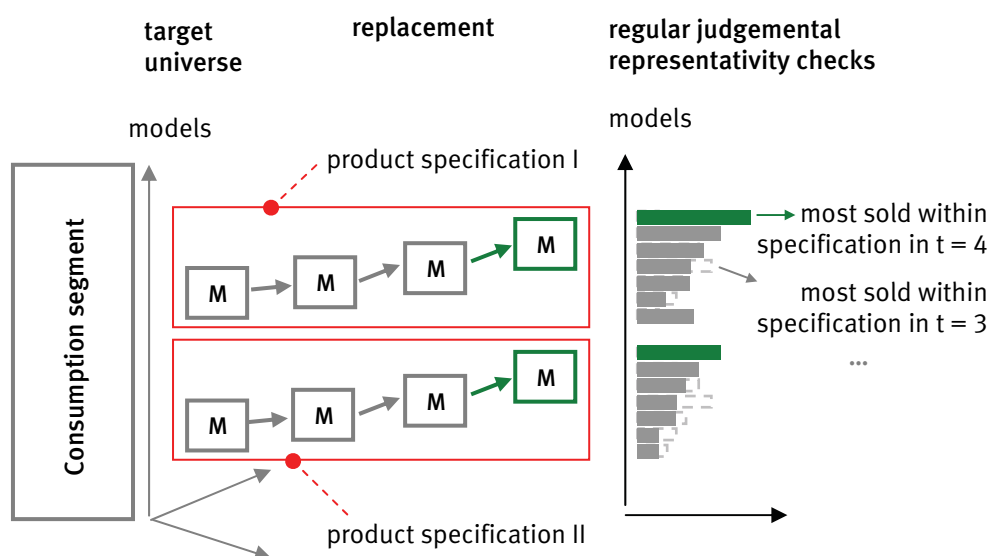
If a stratification has been applied to compile the target sample, then this stratification may serve as a first orientation for the definition of several product descriptions in parallel.

5 Quality adjustment

5.1 Creating continuous price series

The next task after having decided on replacement is to connect the prices of the replaced and the replacement models in order to obtain a continuous series of comparable prices. In the following, two strategies of connecting models are described which should in no case be applied automatically. The two methods are based on simplistic assumptions –

the first assuming that the entire price difference is due to quality changes and the second presuming that non of the price difference arises from quality variations.

5.1.1 Link-to-show-no-price-change

With applying "Link-to-show-no-price change" it is assumed that any price difference between the replacement model and the replaced model is caused by their difference in quality. This strategy should not be used automatically because it rules out any pure price change possibly coming with the introduction of replacement models on the market.

The following chart 13 shows an example where model "a" exists in the market in period 4 and its successor model "b" is introduced in period 5. With *linking* the price development of model "a" to the new one of model "b", it is assumed that the price difference is completely caused by quality improvements of model "b". Thus, the price development of model "b" is directly linked to the one of its predecessor.

Chart 13
Graphical illustration of link-to-show-no-price-change
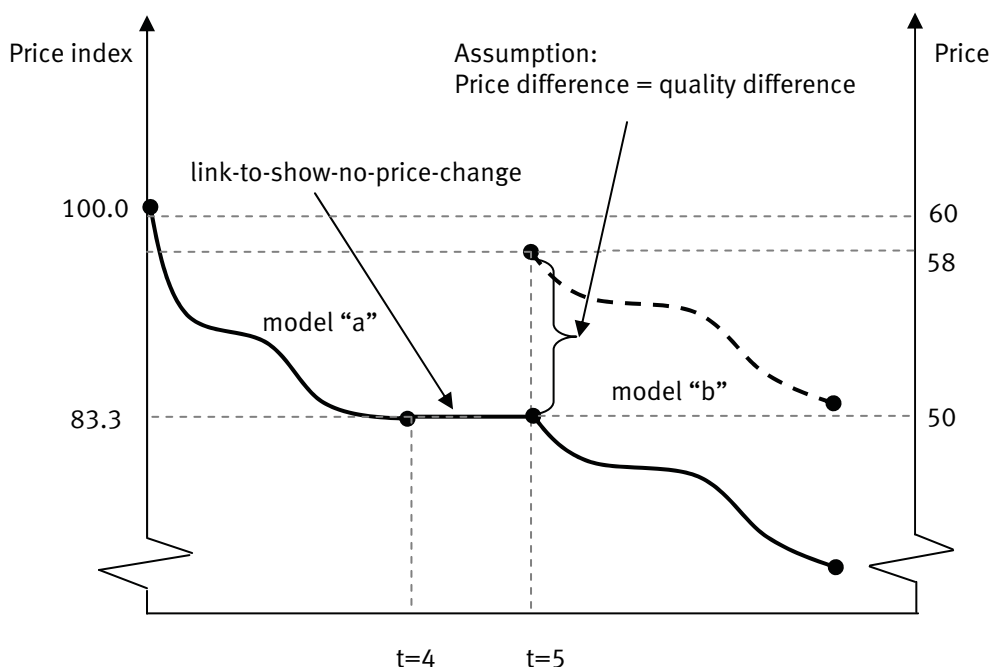
The following example illustrates this strategy numerically. Although an actual price difference of + 16 % is observable between period 4 and 5, this is ruled out by the assumed difference in quality. Thus, a price change of 0 % is assumed between periods 4 and 5 instead of the actual increase of + 16 %.

Chart 14
Numerical illustration of link-to-show-no-price-change

Period	t_1	t_2	t_3	t_4	t_5
Price model a	60	54	53	50	
Price model b					58
Price index	**100.0**	**90.0**	**88.3**	**83.3**	**83.3**
Price change		**– 10.0 %**	**– 1.9 %**	**– 5.7 %**	**0 %**

The main disadvantage of link-to-show-no-price-change is that the real price changes coming with the introduction of replacement models cannot be tackled. Regulation No. 1334/2007 also highlights that the method of link-to-show-no-price change should normally not be applied. Consequentially, for products which improve in quality over

"In no case shall a quality change be estimated as the whole of the difference in price between the two product-offers, unless this can be justified as an appropriate estimate."

Commission Regulation 1749/1996 as amended by 1334/2007, Article 5 (5).

time, the value of quality differences should explicitly be assessed in a replacement situation in order not to miss price changes coming with the introduction of replacement models.

5.1.2 Direct price comparison

A second strategy of connecting the prices of replaced and replacement models is direct comparison. Direct comparison plainly means to assume that there is no relevant quality difference between the replaced model and the replacement. Direct comparison of a replacement's price with the one of its predecessor is thus only an adequate method if both models are essentially equivalent, that means of the same or very similar quality.

If for example the introductory price of the replacement model lies above the exit price of the replaced model, the price difference is interpreted as a full price increase in the period in which the replacement takes place. A price increase occurs within the price-series as shown below.

Chart 15
Graphical illustration of direct comparison
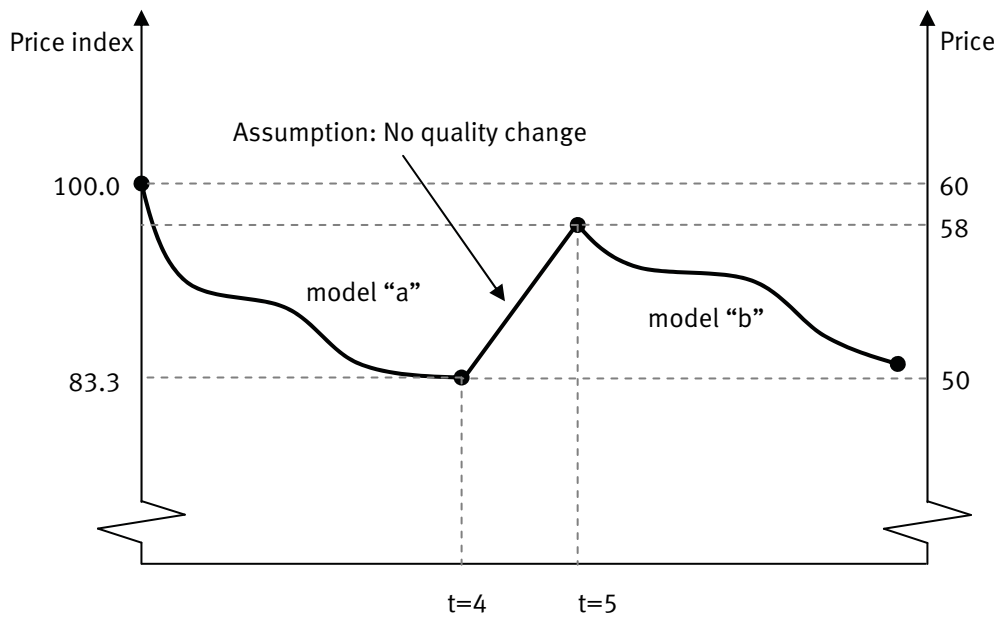
While the price of the replaced model dropped towards its market exit in period 4, the introduction of the replacement model causes a price increase of 16 % from period 4 to period 5. Using direct comparison, it must be assured that this increase is not caused by quality improvements of the replacement model.

Chart 16
Numerical illustration of direct comparison

Period	t_1	t_2	t_3	t_4	t_5
Price model a	60	54	53	50	
Price model b					58
Price index	**100.0**	**90.0**	**88.3**	**83.3**	**96.7**
Price change	− 10.0 %	− 1.9 %	− 5.7 %	+ 16 %	

Direct comparison may in many cases have to be accepted as a convention if there is (with reasonable effort) not enough information available for the estimation of the value of the quality difference between the replaced and the replacement model (see next section). A small excuse for this practice may in some cases be that if the quality difference is difficult to notice for the price statistician it may be difficult to be noticed by consumers as well – a quality difference that is not even valued by consumers should not be considered by statisticians.

> "Where no appropriate estimates are available, price changes shall be estimated as the difference between the replacement price and that of the product-offer it has replaced"
>
> Regulation 1749/1996 as amended by 1334/2007, Article 5 (6).

Direct comparison may in many cases have to be accepted as a convention if there is (with reasonable effort) not enough information available for the estimation of the value of the quality difference between the replaced and the replacement model (see next section). A small excuse for this practice may in some cases be that if the quality difference is difficult to notice for the price statistician it may be difficult to be noticed by consumers as well – a quality difference that is not even valued by consumers should not be considered by statisticians.

5.1.3 Estimating the value of quality differences

How to include the real price effect of changed models' launches, but at the same time exclude the disturbing price effect of quality changes? A consistent solution is to estimate the monetary value of quality changes and to take only this value for the correction of the price comparison between the replaced and the replacement model. This way, only price differences which exceed or fall below the monetary value of quality changes are measured as price changes.

For instance, starting 2004 a certain car model of a certain brand was in Germany offered with different equipment. The car was amongst other things equipped with a new drive unit and a stronger engine and petrol consumption was reduced. The air conditioning was improved, and head airbags were now standard. At the same time, however, the new price of the model increased by roughly 8 %, and it afterwards cost about 20,000 Euros.

What is the value of the additional equipment which turned standard? Many of these equipment items were already available as options. In order to estimate the value of the additional equipment which is now standard, it is possible to use the previous list prices of the equipment items. The quality-adjusted price trends are then calculated as a change in the sales price, while ruling out the value of the improved equipment.

If the price of a replacement model is quality adjusted compared to the replaced model, it is labelled "equivalent by quality adjustment".

5.1.4 Examples

Suppose there is a product with models newly issued in regular time intervals and that the models are very expensive when their lifecycles start. Each replacement model is intro-

duced with improved quality features. The first model that is introduced is called model "a". After a certain time interval, model "a" is replaced by a changed model with improved quality, which is called model "b".

Model "a" was introduced at a relatively high price. After its launch, it is getting increaseingly cheaper until it finally disappears from the market. Model "b" is introduced one month after model "a" has disappeared from the market.

In Chart 17, an artificial example is given with three possibilities of linking the price development of model "a" to that of model "b".

When "direct comparison" is applied the price of replacement model "b" in t_5 is directly compared to the sell-out price of replaced model "a" in the previous period t_4. The price development thus leaps up with the introduction of replacement model "b". In this case, the fact that the quality of replacement model "b" has improved is not accounted for.

If "link-to-show-no-price-change" is used, the introductory price of model "b" is put on one level with the sell-out price of model "a". This way, the price-series of model "b" is tied to the preceding price-series of model "a" and the price increase coming with the introduction of model "b" is eliminated. The price development is therefore continuous and the resulting price index decreases more and more. The price declines measured in this way do not reflect the price trend in the whole market because prices are not really decreasing to that extent. In this case, the "linking" strategy is clearly misleading.

Chart 17
Direct comparison, link-to-show-no-price-change and quality adjusted price
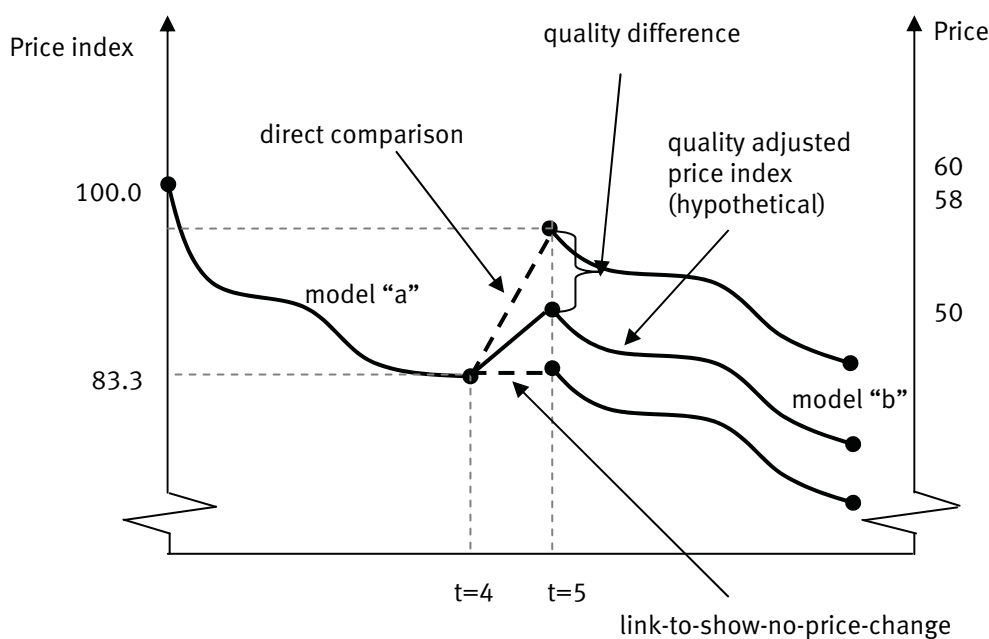
The third solution shown by the chart is a "quality adjusted" price development. For explanation, the graph shows an example where the quality of the replacement model "b" has considerably improved. The replacement model could for example include new useful features. So if the value of the quality difference is considered, the price of the replacement model "b" appears to be lower as when measured by direct comparison.

Chart 18
Numerical illustration of a quality adjusted price

Period	t_1	t_2	t_3	t_4	t_5
Price model a	60	54	53	50	
Price model b					58
Price index	**100.0**	**90.0**	**88.3**	**83.3**	**90.0**
Price change	− 10.0 %	− 1.9 %	− 5.7 %	+ 8 %	

In the above example the index changes by 8 percent from 83.3 to 90.0. In this example it is assumed for illustrative reasons that only half of the observed price increase from 50 to 58 (an increase by 16 percent) is regarded as quality improvement. Therefore, the pure price change amounts to only 8 percent by which the index rises.

The lesson is that "direct comparison" and "link-to-show-no-price-change" can lead to errors in measuring the price trend for the respective product. A consistent solution when facing quality differences is achieved by estimating the value of the quality difference and correcting for this value.

Comparing models' prices with the help of quality adjustment also increases the flexibility of which replacement to choose as a successor model. It enables price statisticians to a certain degree to choose successor models which are currently most representative of the consumption segment as a replacement, regardless of whether they differ in quality from the replaced model or not.

5.2   Applying quality adjustment methods

In this section, methods of esti-
mating the value of quality differ-
ences will be shortly described:
Hedonics, Option Pricing, Supported
Judgement and Bridged Overlap.
Regarding Hedonics, there will be an
extra chapter in this handbook. The
section aims at describing the basic
procedures which apply for most
technical durable goods in more or
less the same way. Detailed product
specific proposals on the application
of the above mentioned methods are
provided in the second chapter.

> **Quality changes in the HICP**
>
> "Concerning quality change, the judgement
> shall be based on due evidence of a differ-
> ence between the specification of a replace-
> ment product-offer and the product-offer it
> replaced in the sample; That is, a difference
> in the product offers' significant price-deter-
> mining characteristics, such as brand, mate-
> rial or make, that are relevant to the con-
> sumer purpose in question."
>
> Regulation 1749/1996 as amended by
> 1334/2007, Article 2a (8).

5.2.1   Explicit quality adjustment methods

Explicit methods serve to identify a so-called monetary value of the quality difference be-
tween a replacement product and its predecessor. This value can then be purged from
the directly observed price difference between the two subsequent products and what
remains is the pure price change, which should finally enter the index calculation.

Quality adjustment methods as hedonic re-pricing, option pricing, and supported expert
judgement estimate the value of the quality difference between a replaced and a replace-
ment product explicitly – contrary to implicit methods. Two steps are necessary for the
quality adjustment:

(1) Estimate the value of the quality difference.

(2) Adjust the price difference between replaced and replacement model by the value of
     the quality difference. This can be done by an additive or multiplicative operation.

The two-steps-structure applies each for hedonic re-pricing, option pricing and supported
expert judgement. Different is the way of estimating the value of the quality difference: In
the case of hedonic re-pricing the estimate of the value of the quality difference is calcu-
lated with the values of the variables according to the regression equation. Regarding op-
tion pricing the estimate of the value of the quality difference is calculated by means of
prices for the respective options. In this case the value of the quality difference corre-
sponds to the prices of additional features (options), which can be taken from price lists.
Regarding supported expert judgement the value of the quality difference is estimated
whereby additional information may be used. The second step consists of deducting the
estimated value of the quality difference from the price difference between replaced and
replacement model. In the case of hedonic re-pricing it is more convenient to calculate the
quality adjusted price directly by multiplying the observed price by a quality adjustment
factor g, $P^{adj}(B)_{t=0} = P(A)_{t=0} \cdot g_{t=0}$. Whereas the quality adjustment factor is the ratio
of the (by means of the determining characteristics) estimated prices of the replaced and
the replacement product.

5.2.2 **Hedonic methods** (see Chapter Three for more details)

The application of hedonic methods is one way to explicitly estimate the value of the quality difference between a replaced and a replacement model. A regression is set up to express the market prices of different products as a function of their characteristics. This gives a market valuation of the quality difference of the models, which is used as the 'monetary value of the change in quality' when comparing prices.

Different variants exist of how to compute the value of changes of characteristics, but all hedonic methods are based on a regression analysis. The functional form of the regression can vary depending on the data. Linear, semi-logarithmic and double log expressions are possible.

The relation between prices and characteristics may change rapidly from month to month (e.g. for computers) or less rapidly, e.g. over a time period of several months (e.g. for TVs). For some products it might therefore be advisable to estimate hedonic regressions on a regular basis.

A general description of hedonic methods will be provided in Chapter Three of this handbook, as well as examples and product specific guidance on the application of hedonics.

5.2.3 **Option pricing**

With option pricing, the estimation of the value of the quality difference between two models is done by using listed prices of their characteristics (options). For most products, option pricing is used when a certain feature of a product, like air conditioning in a car, previously used to be an option but has now become standard. Hence the name "option pricing".

For some other products, e.g. computers, it is used in a slightly different way. Then, option pricing is used to adjust for the price differences of a certain feature, when the replacement model has a different variant of that feature than the replaced model. For example, when the replacement model has a hard disk of 200 GB and the old model one of 100 GB and if the option prices of these features are available, option pricing adjusts for the price difference of these hard disks.

For option pricing, the following aspects need to be considered:

- A specific replaced model has to be linked with a specific replacement model. Replacement models are called successors in this case. The differences between replaced models and their successors need to be determined, both qualitatively and quantitatively.

- The option prices of these particular differences have to be determined.

Given this information, the quality-adjusted price of either the replacement models or the successors can be calculated. For product groups with a high rate of turnover, like computers, it is generally not known beforehand when a model will be replaced. In practice, option prices can then only be collected in the period when the successor is introduced. In that case, the quality adjustment is applied to the price of the successor and this price is compared with the unadjusted price of the replaced item (see following chart). It is also possible to compare the unadjusted price of the replaced item with the adjusted price of the replacement.

Chart 19
Example for the application of option pricing

	Observed price of the replacement
+	Option prices of the characteristics in which the replaced model differs from the replacement
–	Option prices of these characteristics of the replacement
=	Quality adjusted price of the replacement

Or more formally:

$$\hat{p}_{i \in N}^{y,m} = p_{i \in N}^{y,m} + \left(\sum_k b_{kj}^{y,m} - \sum_k b_{ki}^{y,m} \right).$$

Here i is the successor and j the replaced model. Furthermore, $\hat{p}$ denotes the estimated price, p the observed price in year y and month m. The characteristics are denoted by k and their values, as expressed in option prices, are denoted by b_k.

One drawback of option pricing lies in the fact that a monetary value of the characteristics in which replaced and replacement model differ from each other has to be collected. With option pricing, one chooses explicitly to collect additional prices to determine these values. This places a high burden on data collection, as one needs not only information on prices and characteristics of the models in the sample, but also on the prices of these characteristics. Moreover, for some characteristics it will not be possible at all to collect separate prices. Especially for replaced models, the option prices may not be available because these particular options are not available anymore.

Another drawback of option pricing is that one cannot be sure whether the option prices correctly reflect the price differences of these characteristics when sold *as part of a product* as opposed to bought separately. For example possibly only some buyers of a new car want a particular feature that became standard and are willing to pay the full former option price for it. To capture these aspects in some cases a "reduction factor" by which the value of the added or subtracted features is reduced from their observed market values is introduced. In the case of option pricing for cars the HICP standards recommend to apply a reduction factor of 50 per cent.

5.2.4   Supported judgemental quality adjustment

The supported judgemental approach shows many similarities with option pricing. The monetary value of the quality difference between two subsequent products is calculated by using supplementary information sources – beyond the prices and quality features of the products sampled for the price index. Other than for option pricing, the supplementary information is in this case not restricted to the prices for options taken from real existing price lists. The value of the quality difference can rather be calculated in more flexible ways – using a broader source of supplementary information. Three examples are provided here:

First example: Energy consumption

One example of the calculation of the benefit in money's worth is if the replacement model, e.g. an electric appliance, has lower power consumption than its predecessor. The monetary benefit caused by the lower power consumption can be calculated by multiplying a current average price of the energy saved per year by the assumed lifespan of the appliance.

Second example: Comparable models

An example of the use of comparable models to determine the value of the quality change may be the case that a manufacturer offers two models that only differ in one characteristic. This characteristic could, for example, be the net capacity of two otherwise identical freezers. If it can be assumed that prices have been set in a competitive market it would in this case be justified to take the price difference between the two freezers as an estimation of the value of the quality difference – because the price difference can clearly be assigned to the respective characteristic. Thus, the price for a certain amount of additional capacity can be determined. The assumption of a linear relation between capacity and price may be strong but acceptable.

Third example: Fuel efficiency of new cars

A further example of the application of supported judgemental quality adjustment is the calculation of the quality difference regarding fuel efficiency of new cars. In this case hypothetical values of some parameters are assumed: the amount of kilometres driven per year is set to 15,000, the number of years a car will be in operation is set at 5 years. Given this assumption the value of the difference between two in all other characteristics equal cars can be calculated in an easy way. Model A consumes 8.0 l/100 km Model B 7.5 l/100 km. Suppose that the actual fuel price is 1.00 €/l. Then the option price for enhanced fuel efficiency can be calculated as:

$$\frac{(8\,l - 7.5\,l)}{100\ km} \cdot 75{,}000\ km \cdot 1.00\,\frac{€}{l} = 375.00\ €.$$

5.2.5 Implicit quality adjustment – bridged overlap

It has been shown that linking in the form of "link-to-show-no-price-change" is problematic, because the price change coming with the introduction of the replacement product will not be reflected in the measured price development. Bridged overlap now serves to link the price-series of a replacement model to the one of a replaced model in a more meaningful way. The price developments of other models of the same consumption segment, which are not replaced, build the bridge between the replaced and the replacement model. In this way, the average price development of a set of comparable models can be used as an estimation for the price change coming with the introduction of the replacement product. Chart 20 (see p. 40) illustrates this procedure.

Chart 20
Bridged overlap with a real price increase
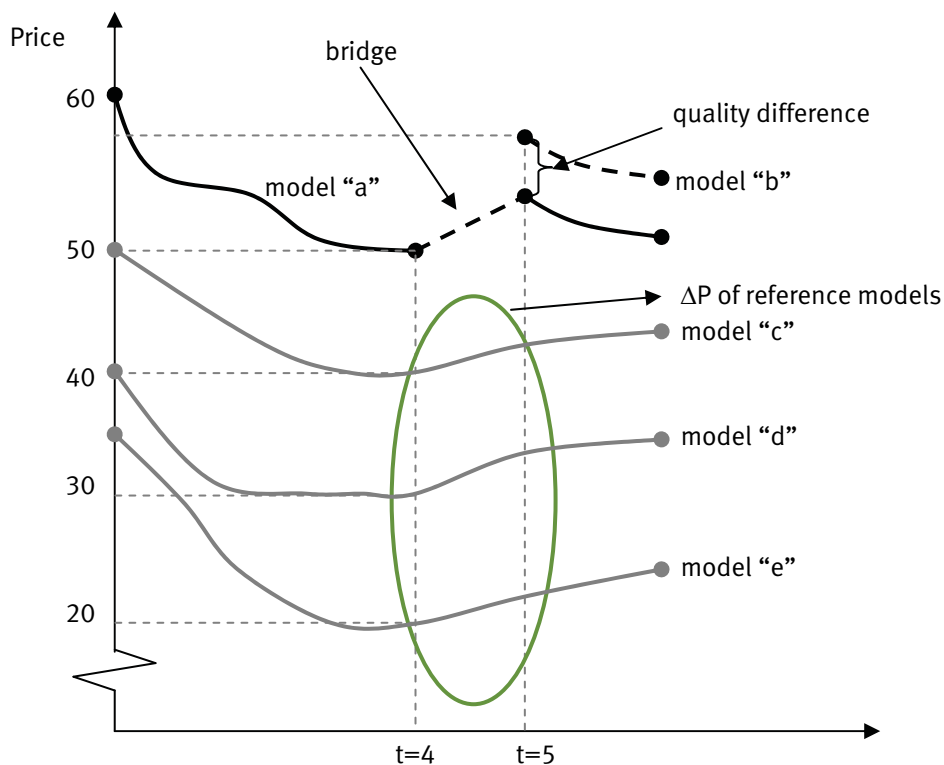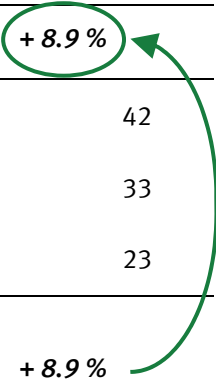
Model "a" disappears from the market and shall be replaced by model "b". Models "c", "d" and "e" are comparable models, that is, models with similar values for their quality characteristics, compared to models "a" and "b". They may be called "reference models" in the context of this method.

When the replacement "b" is introduced to the market, the question arises if the price difference to its predecessor, model "a", is fully due to its improved quality. The average price increase of the comparable models "c", "d" and "e" indicates that this is not the case. Because the price of other models has risen in the period of comparison, it may be the case that also the price difference between replaced and replacement model underlies this trend. With bridged overlap, the same price development is assumed between the replaced and replacement model. The numerical example additionally displays this logic.

The last observed price of model "a" has been 50 in the fourth period, the price of the replacement in the following period is 58. Using bridged overlap, the average price development of the reference models "c", "d" and "e" is taken as a proxy for the missing link between models "a" and "b". As a result, the average price development of + 10 % is used to link the price-series of model "a" to that of the replacement model "b" instead of the actual price increase of + 16 %.

Chart 21
Numerical illustration of bridged overlap

Period	t_1	t_2	t_3	t_4	t_5
Price model "a"	60	54	53	50	
Price model "b"					58
Price change	− 10.0 %	− 1.9 %	− 5.7 %	+ 8.9 %	
Price model "c"	50	45	40	40	42
Price model "d"	40	32	30	30	33
Price model "e"	35	30	25	20	23
Average price change of reference models "c", "d", "e"	− 14.4 %	− 11.2 %	− 5.3 %	+ 8.9 %	

The following Chart 22 provides another example of bridged overlap. It shows a situation, in which the quality adjusted price difference between replaced and replacement model is zero. In contrast to the example given above, the price of the reference models "c", "d" and "e" remained constant during the bridged period. As a result, no real price change is assumed between the replaced and the replacement model.

Chart 22
Bridged overlap
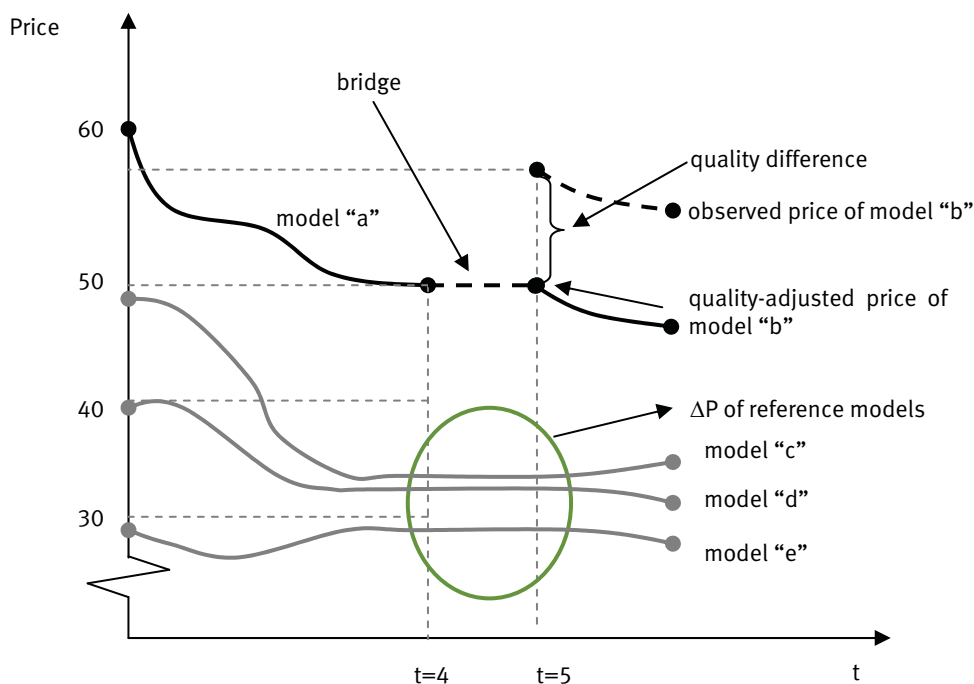
The choice of models which are used as reference models is an important task with this method. Basically, the reference models must compete with the replaced and replacement models. However, competition is difficult to observe empirically. Nevertheless, the following conditions should be met:

First, bridged overlap should only be applied if within the respective market the prices of the products react to each other immediately. This means that the price development of the reference models in the same month should reflect the price development coming with the introduction of the replacement model. In other words, it is presumed that the manufacturers or sellers of the reference models react instantly to the introduction of a new model with price adjustments of their models. Bridged overlap would for instance be senseless in the case of books in Germany. Due to the fixed retail prices of books, sellers can not react to the introduction of new and possibly competing books and adjust prices accordingly.

Second, the price-series of the reference models should not be influenced by unusual price fluctuations, e.g. caused by special price strategies of individual sellers. Such fluctuations can bias the price development of the reference products. Thus, replacement model, replaced model and comparable models should exhibit homogenous price changes not only in the period of comparison, but also prior to it.

5.3   Combining quality adjustment methods

Oftentimes several quality adjustment methods are combined in practice. A frequently used way of distinguishing between the application of two different quality adjustment methods is to make a distinction between minor and major quality changes. For example, there might be a product for which option pricing is applied in the case of minor changes and bridged overlap in the case of major changes. The definition of minor and major changes is product-dependent and will be provided in the product specific proposals (see next chapter).

Chart 23
Combining quality adjustment methods
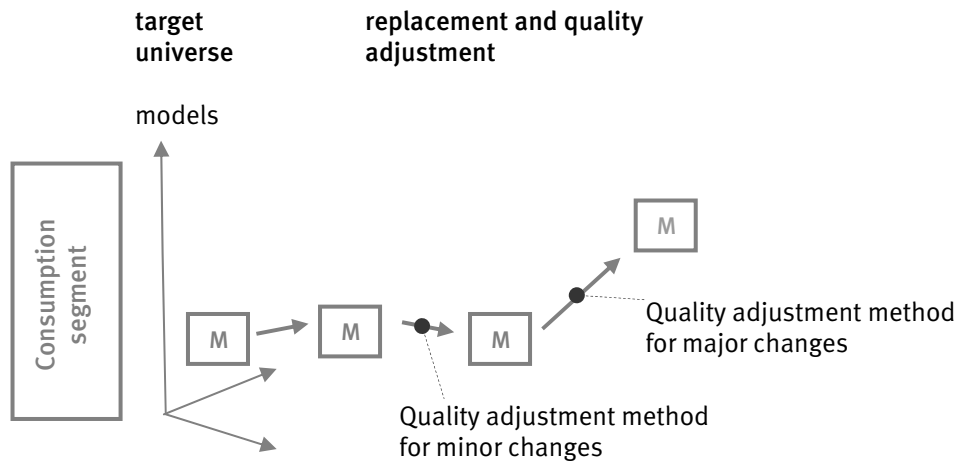
Product-specific guidance and examples not using hedonics

The following table gives an overview of the CENEX products and the quality adjustment methods recommended.

Chart 24
Overview of CENEX products and recommended quality adjustment methods

Product	Non-hedonic methods	Hedonic methods [1]
TV sets	Bridged overlap	Hedonics
New cars	Option pricing	–
Used cars	Combination of direct comparison, bridged overlap and supported judgement	Hedonics
Computers		
• Notebooks	Bridged overlap	Hedonics
• Desktops	Option pricing	Hedonics
Washing machines	Bridged overlap	Hedonics
Books		
• Long-selling market	Combination of direct comparison and expert judgement	–
• Rapidly-changing market	Direct comparison of bestseller lists	Hedonics
Software		
• Applications	Direct comparison with consumer profile approach	–
• Games	Direct comparison	–

———————

1) See next chapter "Hedonic Regression"

All recommendations for quality adjustment are based on the respective Task Force results and HICP standards. Additionally, empirical studies have been performed within the CENEX HICP Quality Adjustment project. The role of these studies was not to assess the suitability of different quality adjustment methods – this was already undertaken by the respective task forces. Rather, the intention was to gain practical experience in the implementation of the suggested methods.

This chapter focuses on the product-specific recommendations not using hedonics. Subsequently, Chapter Three will give a general introduction into the hedonic quality adjustment methods followed by an additional product-specific chapter for TV sets, used cars, computers, washing machines and books.

1   Television sets

- Television sets belong to a market with a low replacement rate and high technological change (e.g. large screen television sets). The Task Force on Quality Adjustment and Sampling assessed explicit methods for this market as A-methods and implicit methods (bridged overlap) as B-methods. Expert judgement is rated as a C-method. For the television market with a low replacement rate and low technological change (e.g. 13 inch television sets) implicit methods (bridged overlap and direct comparison) are rated as A-methods. Unsupported judgement is assessed as a C-method.

- The empirical studies of the CENEX members showed that hedonics and bridged overlap with appropriate stratification yield similar results. Expert judgement is not suitable (even with stratification).

- The following section deals with the application of bridged overlap for television sets.

1.1   Proposal for the identification of consumption segments

- Television sets are covered by COICOP class 09.1.1.

- Regarding the identification of consumption segments, different solutions may be possible.

  – For TV sets the screen size may provide an indication of different consumption purposes. As already mentioned in Chapter One, small TV sets could, for example, be situated in the bedroom or in the children's room or, more generally, be interesting for less-frequent users (e.g. for watching the news), whereas large TV sets tend to be bought for usage in the living room and for watching motion pictures.

  – An alternative approach might be that all television sets serve the same consumption purpose, namely entertainment, so that there would only be one consumption segment.

  – Furthermore, another criterion for the distinction of consumption segments might be the "mobility" of television sets. If, one day, portable television sets become more popular it may be necessary to identify individual consumption segment for them. This criterion is, for example, used for the distinction of desktop and notebook computers.

- For practical reasons only one consumption segment is considered in the following. This pragmatic proposal is, however, not based on convention. For the time being, the issue remains open.

1.2   Proposal for the construction of a target sample

- A stratification of the target universe according to model types is suggested, followed by a pre-selection of the relevant model types. Subsequently, outlets should be chosen which sell models belonging to the pre-selected model types. Market information on the sales figures of models can be obtained either from market research institutes or through a small field survey. In the selected outlets, representative models which belong to the pre-selected model types should be chosen for price observation.

Chart 25
Proposal for the construction of the target sample

> **model types › outlets › models**
>
> (1) Stratify the target universe according to model types.
>
> (2) Pre-select relevant model types.
>
> (3) Choose outlets which are relevant for the type of good, accounting for the regional dimension.
>
> (4) In the outlets, choose representative models which belong to the pre-selected model types.

(1) Stratify the target universe according to model types

- TV sets can be characterised by the type of TV (e.g. LCD, tube, plasma) and by the screen size.

- Carry out an evaluation on which types of TV sets are available (e.g. tube, plasma, LCD TV sets) and on how large their market share is.

- Additionally, evaluate the available screen sizes so that stratification by screen sizes can be applied.

- Stratify for example by

  a) TV type: LCD, plasma, tube (however, in many countries tube TV sets do not play a role anymore.)

  b) Screen size: Identify the market share of the screen sizes available either with the help of data from market research institutes (e.g. Gesellschaft für Konsumforschung International [GfK], AC Nielsen) or with the help of a small field survey. The field survey can either be conducted on the internet or in a few outlets. One example would be to establish three screen size strata: "small" with a screen size of about 14 inches, "medium" with a screen size of about 20 inches, and "large" with a screen size of about 32 inches. The values given in the example might differ for the TV sets available in your national TV market. Choose the significant screen sizes of your national market.

Chart 26
Example of straticfication by screen size and TV type

Overview of TV market	LCD	Tube	Plasma
. . .			
~ 14 inches			
. . .			
~ 20 inches			
. . .			
~ 32 inches			

(2) Pre-select relevant model types

- The strata with the biggest market shares are successively selected until 50 to 80 % of the total market are covered. This means that the strata with a small market share will not be included in the sample (cut-off sampling).

- The result of the pre-selection will be a list containing the pre-selected TV types plus a guiding value for the respective screen size. This list can be passed to the price collector for the selection of concrete models.

Chart 27
Example of pre-selection of strata

Overview of TV market	LCD	Tube	Plasma
. . .			
~ 14 inches		selected	
. . .			
~ 20 inches	selected		
. . .			
~ 32 inches	selected		
. . .			

(3) Choose outlets which are relevant for the type of good, accounting for the regional dimension

- An idea for sampling outlets could be as follows:
  - Distinguish between large/small retailers and mail order/stationary retailers.
  - Include the largest retailers in any case. Check whether or not the large retail chains have the same pricing policy in the entire country. If yes, prices can be centrally observed in big retail chains. If not, prices have to be observed locally taking into account the regional variance of price developments.
  - Include a sample of small retailers. This could be done by probability sampling if data can be obtained from the business register of your respective national statistical office. If information from the business register is not available, choose relevant regions and within the regions select typical outlets (just as you do for other products of the HICP).
  - Prices from small retailers should be observed locally in general (under consideration of regional variations in price development).
  - If mail order selling is relevant in the market it should be taken into account by collecting prices from the internet or catalogues additionally.

(4) In the outlets, choose representative models which belong to the pre-selected model types

- Within the chosen outlets, select TV models which are best sold and correspond to the pre-selected strata.

- Which TV sets are best sold in the respective strata should be determined by the price collector after consulting a shop assistant. If this is not practicable the price collector

can also revert to indicators such as the way the product is advertised or presented in the shop or he might also revert to his experience. A model that is clearly visible in the store could, for example, be judged to be representative.

Minimum size of the target sample

*   A number of 25 to 30 product-offers may be suggested as a normal rough minimum bound for sample size of TV sets, where no more specific indications are present.

1.3   Proposal for the replacement strategy

*   The stratification from the target sample is used to set up the product specification for replacement, i.e. the replacement should be chosen from the same stratum. Additionally, the replacement model should normally be selected from the same brand cluster.

*   A classification of brand clusters for TV sets can be obtained from the PPP statistics (Purchasing Power Parities – price indices comparing the national price levels). The available brand cluster lists of the PPP classify TV sets into high/medium and low brands. In these lists, not all available brands are classified. Missing brands should be assigned to one of the brand clusters by personal judgement.

Chart 28
Extract from the PPP classification for TV sets

Brand cluster	Assigned brands
Higher and Medium	HITACHI, JVC, LG, LOEWE, PANASONIC, PHILIPS, PIONEER, SAMSUNG, SHARP, SONY
Lower	BEKO, BIGA, DAEWOO, DIBOSS, ELEMIS, EVELUX, FUEGO, LENCO, MATRIX, QUADRO, SENCOR, SCHNEIDER, SILVA, VIVAX

Source: Eurostat (Lot C), European Comparison Programme: Consumer price survey E07-1
"House and garden" Particular survey guidelines

*   The result is a product specification that is characterised by three dimensions, namely TV type, screen size and brand cluster. A replacement might, for example, be chosen so that it fits the description "LCD TV, screen size 32 inches, higher/medium brand".

Representativity check within the scope of the monthly price collection in the shop

*   Use the concrete TV models that were in the sample in the previous month as a starting point for the price collection of the current month in order to keep the share of matched models reasonably high. However, the main criterion for the selection of replacements should be representativity.

*   The price collector should check whether or not the models of the previous month are still representative of the corresponding stratum and brand cluster in the current month. The price collector should assess this monthly with the help of the shop assistant. If this is not practicable the price collector can also revert to indicators such as the way the product is advertised or presented in the shop or he might also revert to his experience.

- If the model of the previous month is still representative of the stratum and brand cluster, continue observing the price of this model.

- If the model is no longer representative or if it is no longer available replace it by a representative one from the same stratum and brand cluster – if available. The new model would then be
    - of the same TV type (LCD, plasma, tube),
    - of roughly the same screen size,
    - of the same brand cluster.

- If possible, try to find a replacement that is still representative but is so similar to the replaced model that the changes in the characteristics between replaced and replacement model do not constitute a major change. Those characteristics that cause a major change in quality are for example frequency, aspect ratio, sound system (see section "proposal for quality adjustment").

- If such a replacement cannot be found for lack of representativity, a replacement has to be selected which differs in the characteristics causing a major change within the product specification. The selection of a replacement of the same screen size is thereby more important than selecting a replacement of the same brand.

- If no model is available from the same stratum the replacement has to be chosen from the target universe, making a compromise between representativity and similarity to the replaced model. The replacement could, for example, be of the same TV type but of a clearly different screen size. In this case, the initial product specification must be adjusted by the national statistical office to current developments in the TV market as soon as possible (see below).

Representativity check in the office

- Additionally to the representativity checks conducted by the price collector a representativity check should be conducted regularly in the office, especially for large TV sets.

- Check whether the product specifications are still representative of the market. Therefore, the market has to be observed regularly. This regular observation can also be used to determine general changes (e.g. new equipment, new brands, technological progress, trend towards larger screen size) which are also important for quality adjustment (see next section).

- If the product specifications are still representative, carry on using them.

- If not, adjust the product specifications to the current market circumstances by resampling.

1.4   Proposal for the quality adjustment

- A distinction in minor and major changes helps to decide whether a quality adjustment is necessary. In general, major changes require a quality adjustment whereas minor changes do not.

- Minor quality changes would for example be changes in resolution, brightness, contrast ratio, HD ready, number of scart connectors, station memory, teletext memory, picture in picture. If minor changes occur the prices can be directly compared.

- Major changes within the same product specification would be changes in:
  - Frequency (50 Hz – 100 Hz).
  - Aspect ratio (4:3 – 16:9).
  - Sound system (Mono – Stereo – Surround Sound).
  - Brand cluster (e.g. from medium to low).
  - Small change of the screen size.

  If major changes within the same product specification occur, bridged overlap shall be applied. The price development of the remaining models in the same product specification is used as the bridge. (If the price collector was forced to choose a replacement from outside the product specification because there was no representative model available in the initial product specification, the price development of the models in the initial product specification is used as the bridge. Re-sampling should then be carried out as soon as possible.)

- A major change normally accompanied by re-sampling would be:
  - Big change of the screen size.
  - Change in the TV type (e.g. from tube TV to LCD TV).

Chart 29
Quality adjustment for minor and major changes
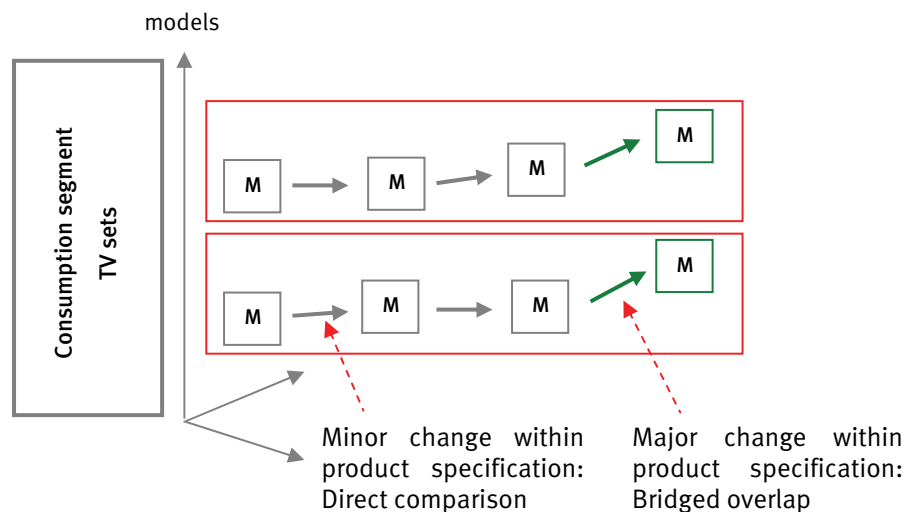
1.5   Cost estimation

One-time effort for the introduction of option pricing for television sets

- The one-time implementation effort amounts to approximately one month.

Current effort of price collection and index calculation

- The monthly operational costs involve approximately 1.5 working days for the product expert.

1.6   Examples

Example of the construction of the target sample

The field survey on available TV types and screen sizes in one exemplary country has yielded the following stratification results:

Chart 30
Market share in percentage of sales volume

Overview of TV market	LCD	Tube	Plasma
. . .		. . .	
~ 14 inches	1	11	‹ 1
. . .		. . .	
~ 20 inches	16	‹ 1	‹ 1
. . .		. . .	
~ 32 inches	33	2	2
. . .		. . .	

The stratum with the largest market share of 33 % is LCD TV sets with a screen size of 32 inches. This is the first stratum to be pre-selected. The second stratum that is pre-selected is LCD TV sets with a screen size of 20 inches. The two strata pre-selected so far add up to 49 % of the total sales. In order to reach the cut-off border of at least 50 %, another stratum has to be selected. The third largest stratum is tube TV sets with a screen size of 14 inches with a market share of 11 %. Finally, three strata are pre-selected, which together cover 60 % of the market:

- Tube TV sets with a screen size of ~ 14 inches,
- LCD TV sets with a screen size of ~ 20 inches,
- LCD TV sets with a screen size of ~ 32 inches.

The pre-selection of model-types is finished. We now have to pre-select outlet types. We distinguish between large and small sellers. Once this distinction is finished we can determine concrete outlets. The distribution of the sales across points of sales might look like this:

Chart 31
Pre-selection of outlet types

Large seller 1	Large seller 2	Small sellers
50 %	30 %	20 %

Two large sellers cover 80 % of the market while the sales by small sellers make up 20 % of the market. Large sellers should be included in any case. Furthermore, a probability sample should be taken from all small sellers.

The next step is to determine how many TV sets will have to be observed in which outlets. First it has to be calculated how large the shares of the three pre-selected segments are in the sample.

Chart 32
Shares of pre-selected strata

Overview of TV market	Share of total sales		Share in the sample
Tube TV (screen size 14 inches)	11%	→	18%
LCD TV (screen size 20 inches)	16%	→	27%
LCD TV (screen size 32 inches)	33%	→	55%
	60%	→	100%

Then, it has to be determined which share of the sample has to be observed in which outlet-types. The following matrix will help to do so. It refers to the tables above.

Chart 33
Matrix of shares

Overview of TV market	Share in the sample	Large seller 1 50 %	Large seller 2 30 %	Small sellers 20 %
Tube (14 inches)	18 %			
LCD (20 inches)	27 %			
LCD (32 inches)	55 %			
Total	100 %			

For example, in order to find out how many tube TV sets with a screen size of 14 inches to observe in the outlet of large seller 1, multiply 18 % by 50 % and you obtain a value of 9 %. The resulting table looks like this:

Chart 34
Completed matrix of shares

Overview of TV market	Share in the sample	Large seller 1 50 %	Large seller 2 30 %	Small sellers 20 %
Tube (14 inches)	18 %	9.0 %	5.4 %	3.6 %
LCD (20 inches)	27 %	13.5 %	8.1 %	5.4 %
LCD (32 inches)	55 %	27.5 %	16.5 %	11.0 %
Total	100 %			

For our example we assume that 30 price observations are required. The following table shows how many TV sets of which screen size have to be observed in which shop (numbers rounded):

Chart 35
Matrix containing numbers of observations to be included

Overview of TV market	Share in the sample	Large seller 1	Large seller 2	Small sellers (prob. sample)
		50 %	*30 %*	*20 %*
Tube (14 inches)	*18 %*	3	2	1
LCD (20 inches)	*27 %*	4	2	2
LCD (32 inches)	*55 %*	8	5	3
Total	*100 %*	15	9	6

In this example it is assumed that both large sellers pursue a pricing strategy that is identical across all regions within one country. Therefore, it is does not matter in which outlets of the large retailers the prices are finally observed.

In a next step the price collector would be instructed to collect prices of e.g. three TV sets of the type "LCD, ~ 32 inches, higher or medium brand" within one outlet of large seller 1. He might be provided with the following price collection form:

Chart 36
Example of a price collection form

Television, screen size ~ 32 inches, LCD, higher or medium brand

Price (€):   929.–

Brand and model description: Sony KDL-32D3000

Screen size (inch):   32

Resolution: 1366 x 768 pixels

Contrast ratio: 8000:1

Reaction time: 8 ms

Brightness: 450 cd/m²

Frequency: ☒ 50 Hz   ☐ 100 Hz

Aspect ratio: ☒ 16:9   ☐ 4:3

Sound system: ☒ Surround   ☐ Stereo   ☐ Mono   ☐ Others:_____

Connectors: ☐ VGA   ☐ DVI   ☒ HDMI   ☒ Others: <u>Scart, PC</u>

☐ Picture in Picture   ☒ HD ready

Shop: _____

Date: _____

In case of bridged overlap being used it may be unnecessary to collect all the mentioned variables from the price collection form above.

Example: Minor change within the same product specification

In month 3, Model 4a was no longer representative and has therefore been replaced by model 4b (see chart 37).

Chart 37
TV sets collected within the product specification "LCD, ~ 20 inches, higher and medium brands" – minor changes

Model	Brand	Type	Screen Size	Price in month 1	Price in month 2	Price in month 3
1	LG	RE20LA30	20	799.–	799.–	699.–
2	PHILIPS	20PF8846	20	599.–	599.–	599.–
3	SEG	MONTECARLO	20	599.–	599.–	599.–
4 a	TOSHIBA	20VL33G	20	810.–	810.–	
4 b	SONY	KLV20SR3	20			710.–
Average price (geometric mean, rounded)				694.–	694.–	650.–
Price change (in %)					0	– 6.4
Index value				100.0	100.0	93.6

The change between models 4 a and 4 b is evaluated as a minor change in the model characteristics, therefore no quality adjustment is necessary. The price of the replacement TV set Sony is compared directly to the price of the replaced Toshiba.

The seventh line of the matrix above shows the average price (geometric mean). The average prices for month 1 and month 2 are the same and therefore the average price change is 0.0 %. In month 3, if prices are compared directly we can see a price decline for the LG from 799.– € to 699.– € and for the Sony replacing the Toshiba from 810.– € to 710.– €. This results in a decrease of the average price from 694.– € to 650.– € and in a price change of – 6.4 %.

Example: Major change within the same product specification

In this example the change in the model specification from model 4 a to model 4 b is assessed to be a major quality change. A quality adjustment should be done. In the following example the Toshiba model is replaced by a larger Sharp TV. A rise in the screen size from 20 to 21 inches is observed. To adjust for this difference bridged overlap is applied.

Chart 38
**TV sets collected within the product specification "LCD, ~ 20 inches,
higher and medium brands" – major changes**

Model	Brand	Type	Screen size	Price in month 1	Price in month 2	Price in month 3
1	LG	RE20LA30	20	799.– €	799.– €	699.– €
2	PHILIPS	20PF8846	20	599.– €	599.– €	599.– €
3	SEG	MONTECARLO	20	599.– €	599.– €	599.– €
Average price of models 1 – 3 without QA (geometric mean)				659.– €	659.– €	631.– €
Average price change of models 1 – 3 without QA (in %)					0.0	– 4.4
4a	TOSHIBA	20VL33G	20	810.– €	810.– €	
4b	SHARP	LC22SV2E	21		680.– €	650.– €
Average of directly observed prices				694.– €	694.– €	635.– €
Quality adjusted average price					664.– €	
Price change (in %)					0.0	– 4.4
Monthly indexes				100.0	100.0	95.6

A bridge is needed to reflect and apply the price change of all unchanged TV models to the new Sharp model. The bridge is taken from the average prices of models 1 to 3. The price change of these models from month 2 to month 3 is – 4.4 %. The Sharp TV has a price of 650.– € and the imputed price for the previous month can now be calculated:

$$650.– € / 0.956 = 680.– € \qquad \text{with } 0.956 = 1 – 0.044$$

The quality adjusted average price in the previous month amounts to 664.– €. The result on the basis of this quality adjusted average price is a quality adjusted price change of – 4.4 % and a decline of the index from 100.0 to 95.6.

2   New cars

- As the first step, the COICOP four-digit-level: 07.1.1 Motor Cars (containing motor cars, passenger vans, station wagons, estate cars and the like with either two-wheel drive or four-wheel drive) is divided into new cars and used cars. This section only deals with new cars.

- The recommended quality adjustment method for new cars is Option Pricing. This is in line with the results of the Task Force on Quality Adjustment and Sampling and the HICP standards which propose option pricing as a B-method. No method was assessed as an A-method for cars.

- The following section deals with the application of option pricing for new cars.

2.1   Proposal for the identification of consumption segments

- It is suggested to divide the universe of new cars into different consumption segments according to the different consumption purposes.

- The official EU car classification system, Euro-NCAP, contains nine market segments and can serve as a starting point for inspiration:

  – Superminis (e.g. Renault Twingo), Small family cars (e.g. Ford Focus), Large Family cars (e.g. VW Passat), Executive cars (e.g. BMW 5 Series), Roadsters (e.g. BMW Z4), Small multi-purpose vehicles (e.g. Opel Meriva), Multi-purpose vehicles (e.g. Toyota Previa), Small off-road vehicles (e.g. Honda CR-V), Large off-road vehicles (e.g. Jeep Grand Cherokee).

  – This Euro-NCAP classification is not exhaustive since luxury cars (e.g. Mercedes-Benz S-class) are excluded.

- According to Regulation 1334/2007 consumption segments are characterised by consumption purposes and pre-dominantly usage in similar situations. Since the consumption purpose of a car can not be measured, the size of the car serves as proxy variable. The Euro-NCAP classification seems to be too tight for a clear distinction of consumption purposes. Therefore it is suggested to aggregate the nine segments into four consumption segments according to the size of the car:

  – small new cars,
  – medium-sized new cars,
  – large new cars,
  – special new cars.

- This consumption segment identification should be done country-specifically in accordance with the national market circumstances.

- Small new cars are predominantly used for short distance rides in urban areas, e.g. for shopping, whereas large new cars may also be appropriate for long distances such as vacation trips. Furthermore the consumption purpose to transport persons and luggage (e.g. family cars) also depends on the size of the car. A further segment of cars serves individual consumption purposes; these are for example convertibles, off-road vehicles and roadsters. For these cars a separate consumption segment should be identified.

Chart 39
Proposal for the identification of consumption segments for new cars

```
                                              ┌─────────────────────────┐
                                              │   "small new cars"      │
                                              └─────────────────────────┘
                                              ┌─────────────────────────┐
                                              │  "medium-sized new cars"│
                              New cars         └─────────────────────────┘
                                              ┌─────────────────────────┐
                                              │   "large new cars"      │
                                              └─────────────────────────┘
      COICOP 07.1.1                            ┌─────────────────────────┐
      Motor cars                               │   "special new cars"    │
                                              └─────────────────────────┘

                              Used cars
```
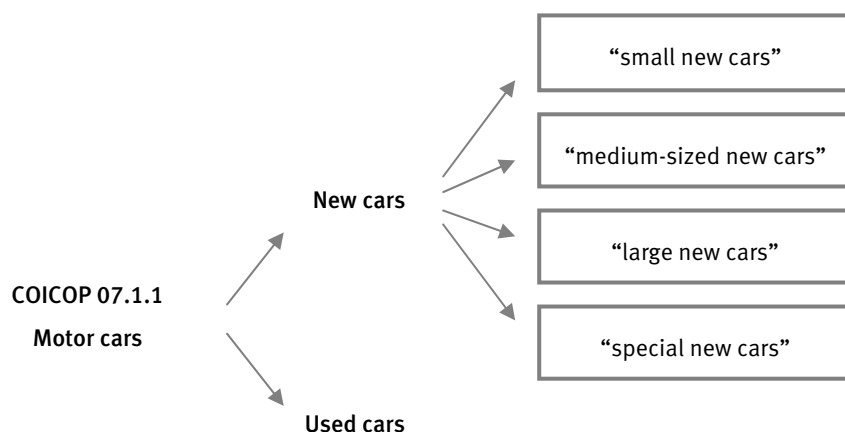
- The next step is to assign the universe of the new car models available in the country to the different consumptions segments.

- This should be done on the basis of primary models. A primary model is an umbrella term for a model of a passenger car (e.g. VW Golf) whereas the term "sub-model" refers to a specific engine – and equipment version of the primary model (e.g. VW Golf V 1.9 TDI Trendline).

- The universe of primary models consists of approximately 300 models for a country. The information which primary models are currently sold in the particular country can be obtained from the national central car register.

- The assignment of primary models to the mentioned consumption segments can be conducted individually by each country and may to a certain degree depend on national circumstances (possibly, the consumption segment "large new cars" contains different primary models in different countries).

Chart 40
Example for the assignment of concrete models to the consumption segments

	Central car register	
	Primary models	Registrations per year
Small new cars	VW Golf	. . .
Medium-sized new cars	Opel Corsa	. . .
Large new cars	Mercedes-Benz SLK	. . .
Special new cars	Mazda 323	. . .
	. . .	. . .
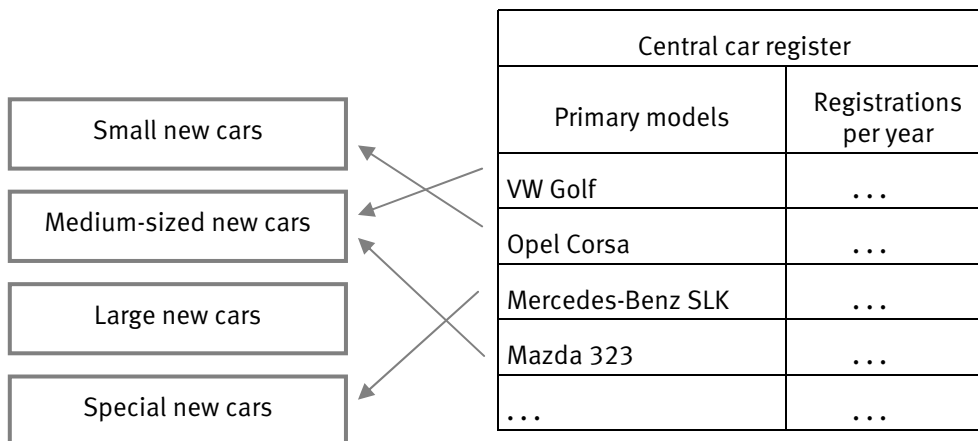
- The central car register may already contain a variable which divides the primary models into different segments. In many cases this segmentation has only to be adjusted to the segmentation of the four consumption segments. Altogether, the assignment to segments is not very extensive. As a result all primary models that are sold in the particular country are assigned to the consumption segments mentioned above.

- The exclusion of business cars:
  - In correspondence to the HICP regulation framework, business cars shall not be covered.
  - The practical feasibility depends on whether the national central car register contains a distinction between business cars and privately used cars.
  - The term "business cars" consists of two types: Company cars (that may also be privately used) and cars of self-employed persons.
  - A complete exclusion of business cars could result in a declined quality of the car sample since such cars are normally concentrated in specific consumption segments and specific brands.
  - The cars of self-employed persons are rarely used for business purposes only and even for company cars, white collar workers may have to finance a significant part of the car which legitimates a private usage of the company car.
  - In case the central car register contains a distinction between business car types, only exclude company cars. If the central car register does not contain any distinction of business cars, it is suggested to keep the business cars in the sample.

Weighting of the consumption segments

- It is suggested to weight the mentioned consumption segments explicitly according to the expenditure shares.

- Generally, the expenditure shares will not be available but could be obtained by multiplying the total number of sales from the previous year by an average price for each consumption segment.

- The total number of sold cars can be derived from the information in the central car register. This contains the number of initial registrations (from the previous year) per primary model which can serve as a proxy for the sales frequencies of the primary models.

- An average price for the consumption segment could be calculated on the basis of the sample of list prices, which are collected anyway. The collection of list prices will be described in the next section.

2.2   Proposal for the construction of a target sample

- It is suggested to first select primary models. After that, precise sub-models for each primary model have to be selected which represent the corresponding primary model. Subsequently, the list prices of these particular cars are observed.

Chart 41
Proposal for the construction of the target sample

> **primary models › sub-models › manufacturer's list prices**
>
> (1) Select primary models by probability or cut-off sampling.
>
> (2) Select sub-models by purposive sampling.
>
> (3) Collect list prices for the chosen sub-models.

(1) Select primary models by probability or cut-off sampling

- Two possible sampling methods can be applied: Probability sampling proportional to size could, in the case of new cars, be applied without much effort because of the limited complexity of the universe of car models (only approximately 300 primary models). Another possibility would be cut-off sampling within the consumption segments. The selection criterion for both sampling methods is the number of initial registrations from the previous year for each particular primary model.

- When applying probability sampling the central car register can serve as a sampling frame. It is likely to be feasible to let the sampling of models be based on the number of initial registrations of car models in the previous year.

- The suggested procedure is similar for cut-off sampling. Here, the models with the highest number of registrations in the previous year according to the car register are selected successively until a defined cumulative market share is reached. However, there is a risk of bias that is caused by the exclusion of primary models in market niches.

- Therefore, probability sampling should be preferred to cut-off sampling because when using probability sampling all primary models available have a chance of being in-

cluded in the sample whereas, when using cut-off sampling, it is accepted right from the beginning that the sample does not mirror the entire market. In the case of cars it cannot be excluded that a significant number of left-out models will have a diverging price development (e.g. expensive luxury models, models that are important in a specific market niche, new models at the start of the life cycle or old models that will soon disappear from the market).

- The risk of bias in the case of cut-off sampling can be alleviated by means of stratification according to consumption segments. In this case however an adequate number of consumption segments should be precisely defined so that they effectively represent the different market niches. A good starting point for this exercise would be the already mentioned Euro-NACP classification plus an extra segment for luxury cars.

(2) Select sub-models by purposive sampling

- After the selection of primary models, sub-models of the selected primary models have to be chosen. For this sampling stage, purposive sampling is suggested.
- The sub-models may be selected according to the following criteria:
  - The sub-model should be well sold (e.g. a well sold engine version such as VW Golf 1.9 TDI).
  - The sub-model might be of the least extensive or a very popular equipment level (e.g. the least extensive equipment level of Volkswagen is called "Trendline").
  - The sub-model must not be a special edition (e.g. VW Golf equipment version "Goal").
- The higher the number of registrations of a primary model, the higher the number of price observations (i.e. implicit weighting). Each collected list price has to refer to one precise sub-model.
- If a high number of list prices is collected, which means that a corresponding high number of sub-models has to be observed, it might be necessary to diverge from the sub-model selection criteria mentioned above. Especially, the restriction on the equipment level could be relaxed.
- For the selection of precise sub-models, consider a representative relation of diesel and petrol engines. It may be determined in advance how many petrol engine and diesel engine cars should be in the sample for each consumption segment.

(3) Collect list prices for the chosen sub-models

- According to the HICP standards for cars and other vehicles, list prices can be used as an approximation of real transaction prices in the case of new cars. The term "list price" in the HICP standard can be interpreted in two ways: either as the recommended retail price of the manufacturer or as the offer price (asking price) of a certain retailer. For ease of expression it is here interpreted as the manufacturer's recommended retail price.
- This allows for a central price collection on the websites of the manufacturers. The regional and outlet dimensions are then be disregarded.

Minimum size of the target sample

- The sample size should be established country-specifically.

- A pragmatic proposal is to apply a minimum sample size of 100 observations monthly for the index of new cars. That means, for four consumption segments a minimum of 25 price observations per consumption segment is sufficient to ensure representativity.

Weighting of the selected primary models

- The primary models which are chosen to represent the consumption segment are weighted implicitly according to the respective number of registrations (see section *(2) Select sub-models*). That means the sample size of approximately 25 price observations is distributed over 25 sub-models which refer to primary models.

2.3 Proposal for the replacement strategy

- The primary models which were selected for the target sample serve as a product specification for the replacement.

- A replacement can be carried out by selecting a new sub model within the range of the corresponding primary model (product specification) or the replacement can be selected by changing the primary model. The decisive criterion for the selection of a replacement is representativity. For practice in the following a distinction is made between replacements within the scope of the monthly price collection and a regular re-sampling.

Replacements within the scope of the monthly price collection

- Use the concrete primary model and the corresponding selected sub-models that were in the sample in the previous month as a starting point for the price collection of the current month in order to keep the share of matched models reasonably high. However, if an observation has to be replaced the main criterion for the selection of the successor model should be representativity.

- If the sub-model *dramatically loses its market share* within the primary model or if the primary model *dramatically loses its market share* within the consumption segment, it has to be replaced by a more representative sub- or primary model that is most similar to the old one (non-forced replacement). In the case of the non-forced replacement of a primary model its successor can belong to the same or to an alternative brand. If the successor belongs to an alternative brand, it should belong to the same "precisely defined" consumption segment (e.g. same Euro-NCAP class). For the newly chosen primary model precise sub-models and their corresponding list prices have to be assigned again. This sub-model selection should correspond to the procedure as mentioned in the preceding section.

- A forced replacement occurs if the sub-model or primary model *disappears*. In this case the same rules apply as in the case of non-forced replacements.

Periodical re-sampling

- The periodical re-sampling should be conducted regularly (e.g. yearly). This periodical re-sampling depends on the publication of the statistics of the initial registrations (e.g. from the previous year) by the central car register.

- Repeat the pre-selection process as described for the compilation of the target sample. Corresponding to the sales figures (or the number of initial registrations) the pre-selection of primary models has to be renewed regularly. This way current trends in characteristics, e.g. towards larger size of the cars within the consumption segments are included.

- Within the scope of the re-sampling the implicit weights of the selected primary models are renewed. Therefore, the number of selected sub-models and the corresponding number of price observations for each primary model can change.

2.4 Proposal for the quality adjustment

- In the case of new cars, minor changes constitute changes in the equipment of an essentially equivalent model which can be adjusted explicitly. Major changes in the quality of new cars are too complex for an explicit quality adjustment. In these cases an implicit method is applied.

- Minor changes in quality can occur in three situations:
    - The equipment of a precise sub-model changes.
    - The replacement of a precise sub-model within the range of the same primary model only contains changes in the equipment.
    - The succession of an old by a new version of a primary model is judged to be essentially equivalent (expert knowledge necessary). That means the only difference between the old and the new version of the same primary model is equipment features. A hint for the essential equivalence of an old and a new version can be that the old version had a rather short life span and the follow-up model looks rather similar.

- Major changes in quality occur in three situations:
    - The primary model is replaced within the scope of monthly price collection.
    - The succession of an old by a new version of a primary model contains too many complex technological modifications.
    - The replacement of a precise sub-model within the range of the same primary model contains too many complex technological modifications.

Quality adjustment in the case of minor changes: Option pricing

- Option pricing should be applied whenever it is possible.

- Minor quality changes could for example be changes in the extension of the standard equipment package, e.g. the inclusion of:
    - automatic bi-zone air-conditioning,
    - parking sensor,
    - . . .

- For the application of option pricing it is important that the considered equipment items were already available as options prior to the inclusion into the standard equipment package. A description of the calculation of a quality adjusted price when applying option pricing can be found in the first chapter of the handbook. The price of the new model is adjusted for 50 % of the value of the changed equipment that was observable as an option in the previous period. The 50 % rule is confirmed by the HICP standards on cars.

- It is possible to adjust the price of the replaced model as well as to adjust the price of the replacement model with regards to the same option prices.

- Option pricing is applied in the case of the extension as well as in the case of a reduction of the equipment level.

- There are two cases where option pricing should be applied even though no particular option price is available. In these cases indirect option prices are calculated.
  - A change in the fuel consumption of a car.
  - A change in the engine power of a car.

- If the presumed fuel consumption of a car changes this could be adjusted by applying supported expert judgement. This expert judgement calculates an indirect option price for a hypothetical amount of mileage. It is suggested to calculate the value of changing fuel consumption for an assumed mileage of 75,000 kilometres. (The car is presumed to be driven 75,000 kilometres in the following 5 years). That means to multiply the difference in fuel consumption with 75,000 kilometres and the current fuel price. This indirect option price should be adjusted for 100 %. Applying this indirect option price aims at adjusting for changing running expenses from the consumer's perception. It is assumed that the consumer evaluates the value of changed fuel consumption for the following five years on the basis of the recent purchase price of petrol or diesel. Furthermore it is assumed that the average consumer might drive 15,000 kilometres per year. NSIs may establish conventions for the assumptions involved.

- If the engine power of a car changes this should be adjusted by applying supported expert judgement calculating an indirect option price. This indirect option price should be based on the former price range of sub-models that only differ with regard to engine power. Suppose a range of three sub-models with an engine power of 80, 100 and 120 hp and that their list price is 12,000, 13,500 and 15,000 €. The new cheapest sub-model has 90 hp and costs 12,500 €. In this case the indirect option price would be based on the difference between the list prices of the former sub-models with 80 and 100 hp. A complication occurs when differences in engine power are coupled with differences in other relevant technical characteristics (e.g. better brakes) or enhanced standard equipment (e.g. ESP is standard in case of the higher engine versions). The price differences between different sub-models with different engine versions can serve as a basis for option pricing if such combinations are taken into account. For example if the sub-model with the higher engine power has some extra equipment standard that costs 1,000 €, then this 1,000 € should be subtracted from the price difference between the two sub-models.

> **Discussion box**
>
> It has to be considered that the application of an indirect option price for engine power is a completely new topic in the field of quality adjustment for new cars. The proposal is based on a convention of the CENEX consortium and was in the focus of discussion. Nevertheless, this proposal should be subject of practical advanced empirical investigations in future.

- The option prices should ideally stem from the particular manufacturer for the particular primary model (from the previous period). If such an option price is not available option price lists of alternative brands for similar primary models from the same consumption segments could also be used.

> **Discussion box**
>
> The price range of identical options over primary models of different brands may differ to a large extent although the respective cars refer to the same consumption segment. In this case it could be more appropriate to use option prices from a different primary model of the same brand, even if the model refers to a different consumption segment.

Quality adjustment in the case of major changes: Bridged overlap

- In the case of major changes in quality, no explicit quality adjustment is possible since the replaced and the replacement product are in principle not comparable at all.
- If major quality changes occur, bridged overlap shall be applied. The price development of all other models of the same consumption segment which were not replaced build the bridge between the replaced and the replacement model. In this way the average price development of a set of comparable models is used.

Discussion box

It might be argued that the assumptions concerning the application of bridged overlap (see Chapter One) might not be entirely met in the case of new cars. Especially, the assumption that manufacturers and sellers react to the introduction of a new model *in the same period* might be questionable. Nevertheless, the HICP standards on cars and other vehicles classify the application of bridged overlap for fundamental changes in quality (major changes) as a B method.

As a bridge the price development of all other models in the same consumption segments is used. To apply an alternative bridge as the price development of models from the same manufacturer is impractical due to the sampling strategy (since it is not secured that other models of the same manufacturer are in the sample).

Explicit quality adjustment methods as option pricing or hedonic methods may fail in the case of fundamental changes between car models which contain too complex technical developments.

In summary, in the case of major changes there might be no alternative to bridge overlap due to practical reasons. This decision was made by convention due to practical reasons since fundamental changes between car models might be too complex for explicit quality adjustment.

The appropriate number of consumption segments in the case of cars depends on the use of such segments. In the case of cut-off sampling, combined with stratification according to consumption segments, the appropriate number would be about 10. The same applies in the case of non-forced replacements where the successor belongs to a different brand.

Chart 42
Regular re-sampling

Re-sampling

Consumption segment "Medium-sized new cars"

Primary model, e.g. VW Golf

M → M → M → M → M

M → M → M → M → M

Primary model, e.g. Opel Astra

M → M → M → M → M

M → M

Primary model, e.g. MB A-class

M → M → M

Primary model is no longer representative

Change to a different primary model:
Bridged overlap
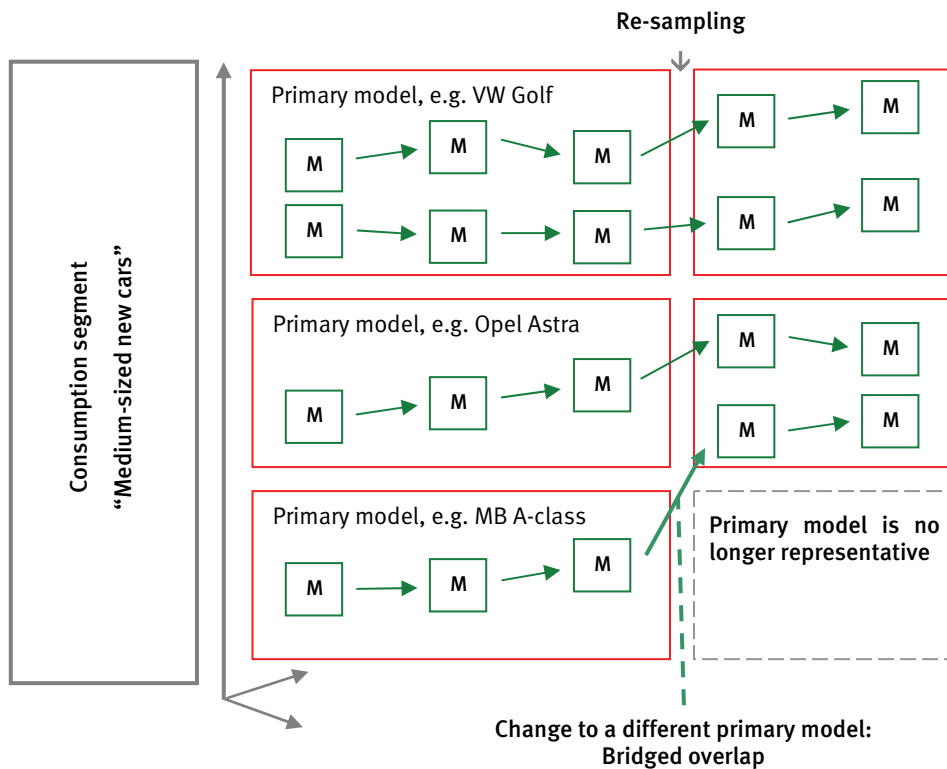
2.5   Cost estimation

One-time effort for the introduction of option pricing for new cars

- The start-up costs stem from the creation a new car index system. This involves:

   (a) the setting up of a sample structure,

   (b) the selection of the data sources and the creation of a documentation system,

   (c) the device of new QA-procedures – option pricing in the case of new cars.

- The setting up of a sample structure involves a thorough investigation of the sample frame, the creation of the sample structure itself and the identification of market segments for all car models. This work can easily involve 15 full working days (mostly of an academic level except for the identification of the market segments).

- The selection of the data sources, the creation of the documentation system and the device of the new QA procedures can be performed by the product expert. All this work should however be tightly supervised – especially the device of the new QA-system.

- The work on parts (a) and (b) amount to approximately 15 full working days.

Current effort of price collection and index calculation

- The monthly operational costs involve approximately 5 full working days for the product expert.

Effort of periodical re-sampling

- The cost of the yearly re-sampling will depend on the thoroughness of the operation. In Belgium, the sample structure is totally overhauled every two years. This process involves up to 10 full working days. In the years in between the sample structure gets a less complete update (the weights and number of observations for each consumption segment will remain constant). A semi-update of the sample structure will cost approximately 5 full working days.

2.6   Examples

Example: Generation of consumption segments

- In the first step, the new car market has to be divided into different consumption segments according to the size of the car. The pragmatic proposal is to define four consumption segments:
  - small new cars,
  - medium-sized new cars,
  - large new cars,
  - special new cars.
- The universe of primary models consists of approximately 300 cars in each country. Each of these primary models has to be assigned to the identified consumption segments. The distinguishing criterion is the size of the car.
  - The data on the particular primary models that are registered in the country can be obtained from the national central car register.

Chart 43
Example for the assignment of concrete models to the consumption segments

Central car register	
Primary models	Registrations per year
VW Golf	. . .
Opel Corsa	. . .
Mercedes Benz SLK	. . .
Mazda 323	. . .
. . .	. . .

Small new cars

Medium-sized new cars

Large new cars
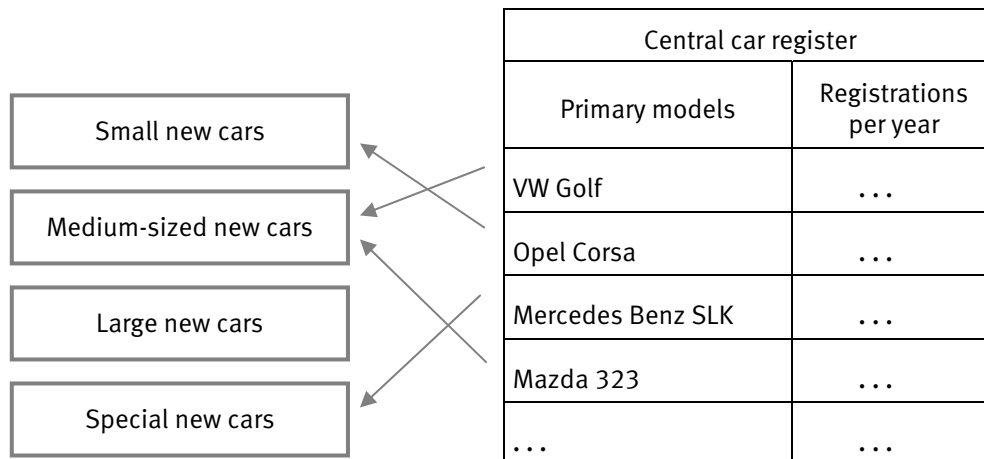
Special new cars

- As a result, each consumption segment consists of precise primary models.

Chart 44
Consumption segments and corresponding primary models

Consumption segments							
Small new cars		Medium-sized new cars		Large new cars		Special new cars	
Primary model	Initial registrations	Primary model	Initial registrations	Primary model	Initial registrations	Primary model	Initial registrations
Opel Corsa	26,082	VW Golf	73,692	Mercedes Benz C class	18,631	Opel Zafira	14,620
VW Polo	16,332	Opel Astra	36,889	BMW 5 series	16,247	VW Caravelle	8,305
Renault Twingo	11,094	Mercedes Benz C class	34,851	Audi A 6	12,937	VW Sharan	7,162
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
sum	192,684	sum	440,878	sum	73,504	sum	124,923

- The consumption segments have to be weighted according to their expenditure share.
- To obtain the total expenditure of a consumption segment, multiply the total number of initial registrations from the previous year for the particular consumption segment by its average price.
  - The total number of initial registrations for each consumption segment can be taken from the central car register. The average price for a consumption segment can be calculated on the basis of the sample of list prices for the selected sub-models (see next section).

Chart 45
Calculation of expenditure weights for the consumption segments

Weighting the consumption segments							
Small new cars		Medium-sized new cars		Large new cars		Special new cars	
Total number of initial registrations	Average price (in €)	Total number of initial registrations	Average price (in €)	Total number of initial registrations	Average price (in €)	Total number of initial registrations	Average price (in €)
192,684	15,000	440,878	20,000	73,504	30,000	124,923	25,000
Total expenditure (in billion €):							
2.89		8.81		2.21		3.12	
Total expenditure of all consumption segments: 17.03 billion €							
Expenditure share (in %):							
17.0		*51.8*		*12.9*		*18.3*	

Example: Construction of a target sample

- Select primary models by probability sampling (cut-off sampling also possible):
  - The primary models are sampled in accordance to their market shares within the consumption segment.
  - An example of sampled primary models within the consumption segment "medium-sized new cars" could look like this:

Chart 46
Exemplary target sample for the consumption segment "medium-sized new cars"

Target sample for "medium-sized new cars"		
Primary model	Initial registrations (from the previous year)	Market share (in %)
VW Golf	73,692	*16.7*
Opel Astra	36,889	*8.4*
Mercedes-Benz C-class	34,851	*7.9*
BMW 3 series	33,548	*7.6*
Ford Focus	32,264	*7.3*
Audi A4	30,123	*6.8*
Audi A3	26,007	*5.8*

  - The selected primary models represented in the table make up 60.5 % of the market for "medium-sized new cars".

- Select sub-models by purposive sampling:
  - The selected primary models have to be implicitly weighted according to the relation of their sales figures. Since in our proposal the decision was made to collect 25 price observations per consumption segment, we have to determine how many price observations to collect for each primary model.
  - The distribution of the price observations might look like this (implicit weighting):

Chart 47
Number of observations to be included

Distribution of price observations				
Primary model	Market share (in %)		Share in the sample (ratio) (in %)	Number of price observations
VW Golf	16.7	→	27.6	7
Opel Astra	8.4	→	13.9	4
Mercedes-Benz C class	7.9	→	13.1	3
BMW 3 series	7.6	→	12.6	3
Ford Focus	7.3	→	12.1	3
Audi A4	6.8	→	11.2	3
Audi A3	5.8	→	9.6	2
Total	*60.5*	→	*100*	25

  - In this example seven sub-models for the primary model VW Golf have to be selected in order to reflect the weight of its market share within the consumption segment "medium-sized new cars".
  - The sub-model selection has to be conducted by purposive sampling according to the following criteria:
    - Should be a well sold sub-model within the range of the corresponding primary model.
    - Should be of the least extensive equipment level.
    - Must not be a special edition.
  - The following chosen sub-models meet these criteria. Additionally, the approximate ratio of diesel and petrol engines is considered.

Chart 48
Precisely selected sub-models for the primary model "VW Golf"

Sub-model selection for VW Golf		
Observation	Sub-model	Manufacturers' list price (in €)
1	Golf V 1.4 Trendline	16,300
2	Golf V 1.6 Trendline	17,600
3	Golf V 1.4 TSI Trendline	18,975
4	Golf V 1.9 TDi Trendline	19,150
5	Golf V 2.0 TDi Trendline	22,000
6	Golf V 1.4 Comfortline	17,800
7	Golf V 1.9 TDi Comfortline	20,650

- Collect list prices for the chosen sub-models:
  - The list prices for the corresponding sub-models are collected on the national website of the manufacturer.

Example: Replacement strategy

- Replacements within the scope of the monthly price collection:
  - The price collector (product expert) should assess whether replacements are called for. Therefore it should be checked:
    - Whether the sub-model is still available. Even if the sub-model can still be found on the manufacturer's website it might in fact not be available anymore because maybe the manufacturer's website is not updated.
    - Whether the introduction of a new sub-model within the range of the corresponding primary model results in declining representativity of the formerly selected sub-models.
    - Whether the considered primary model is followed by a new version: The follow-up model for VW Golf IV is the VW Golf V.
- Representativity check for the periodical re-sampling
  - The target sample should be updated regularly, maybe yearly, depending on the publication of the statistics of the initial registrations by the central car register.
  - The procedure is the same as described in section 2.2.
- The following table (see chart 49) shows the replacement of the sub-model 1.4 TSI Trendline by 1.4 TSI Comfortline.

Chart 49
Exemplary replacement situation for concrete sub-models

Exemplary replacement situation				
Selected sub-models for VW Golf V in period 1	Price in period 1 (in €)		Selected sub-models for VW Golf V in period 2	Price in period 2 (in €)
Golf V 1.4 Trendline	16,300	→	Golf V 1.4 Trendline	16,300
Golf V 1.6 Trendline	17,600	→	Golf V 1.6 Trendline	17,600
Golf V 1.4 TSI Trendline	**18,975**	→	**Golf V 1.4 TSI Comfortline**	**20,475**
Golf V 1.9 TDi Trendline	19,150	→	Golf V 1.9 TDi Trendline	19,150
Golf V 2.0 TDi Trendline	22,000	→	Golf V 2.0 TDi Trendline	22,000
Golf V 1.4 Comfortline	17,800	→	Golf V 1.4 Comfortline	17,800
Golf V 1.9 TDi Comfortline	20,650	→	Golf V 1.9 TDi Comfortline	20,650

Example: Quality adjustment

- Minor changes in quality can occur in three situations:
  - The basic equipment of the sub-model VW Golf V 1.9 TDi Trendline is for instance extended by a parking sensor.
  - The sub-model VW Golf 1.4 TSI Trendline is replaced by the VW Golf 1.4 TSI Comfortline. Caution, the extension of the equipment version is considered to include additional equipment features rather than complex technological modifications.
  - The succession of an old by a new version of the primary model is judged to be a minor change that means it is considered to include changed equipment features rather than complex technological modifications. E.g. the planned succession of the Peugeot 307 by the Peugeot 308. The Peugeot 307 has had a rather short life span and the follow-up version hardly contains technological developments and even looks very similar.

- Major changes in quality can occur in three situations:
  - The primary model is replaced due to the representativity check within the scope of monthly price collection. For example, when the production of the VW Lupo was stopped in 2005 it had to be replaced by another representative primary model.
  - The succession of an old by a new version of a primary model contains many technological modifications. For example, the primary model VW Golf IV was followed by the VW Golf V including technical progress in engine, gearbox and chassis suspension.
  - The replacement of a precise sub-model within the range of the same primary model: This should be an exemption in case the replacement sub-model contains complex technological modifications and no corresponding option prices exist. E.g. The replacement of a VW Golf V 1.9 TDi Trendline by a VW Golf V GTI 2,0 FSI.

- Option pricing for minor changes:
  - Option pricing matches the price of the new observation and the price of the old observation by adjusting for 50 % of the value for all equipment features that differ between the replaced and the replacement product.
  - In the example below (see chart 50), a VW Golf V 1.4 TSI Trendline is replaced by the same model but with the equipment level "Comfortline". These equipment levels differ for instance in three features: an air conditioning, light-alloy wheels and an airbag system.
  - It is possible to adjust the price of the replaced model as well as to adjust the price of the replacement model with regards to the same option prices. In the example provided below the price of the replacement model is adjusted. The price of the new car is adjusted for 50 % of the value of these changed features.

Chart 50
Option pricing for minor changes

Option pricing for minor changes					
Sub-model in period 1	Price in period 1 (in €)		Sub-model in period 2		Price in period 2 (in €)
Golf V 1.4 TSI Trendline	18,975	→	Golf V 1.4 TSI Comfortline [5]		20,475
			Air conditioning	1,610 €	− 805
			Light-alloy wheels	340 €	− 170
			Head-airbag system	800 €	− 400
			Adjusted price		19,100

- Option pricing for fuel efficiency:
  - The information on fuel efficiency can be gained from manufacturer information, which is established in accordance with regulation 1999/94/EG. The fuel efficiency has to be measured by the fuel consumption in the case of "combined drive cycle" (= mix of urban and extra urban drive cycle).
  - To calculate an indirect option price for the fuel consumption one has to presume a precise amount of mileage for which the value of fuel consumption can be calculated. This can be illustrated by the following example:

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5) Fictitious example.

– Sub-model A is replaced by the similar sub-model B. The fuel efficiency has enhanced because the fuel consumption in the case of "combined drive cycle" has diminished from 8.0 to 7.5 l/100 km. Suppose that the actual fuel price is 1.50 € (price of diesel). Then the option price for enhanced fuel efficiency can be calculated as:

(8.0 l – 7.5 l) / 100 km) · 75,000 km · 1.50 €/l = 562.50 €.

– In the case of fuel consumption the indirect option price equals 100 % of the value of the difference in fuel consumption of the presumed mileage.

3 Used cars

- In the first step, the COICOP four-digit-level: 07.1.1 Motor cars (containing motor cars, passenger vans, station wagons, estate cars and the like with either two-wheel drive or four-wheel drive) is divided into new cars and used cars. This section only deals with used cars.

- The Task Force on Quality Adjustment and Sampling did not establish an explicit classification of A, B, C-methods for used cars.

- The recommended quality adjustment methods for used cars depend on the available data source. For data from internet platforms or car magazines it is recommended to apply the regression approach or supported expert judgement and in the case of data from a market research institute a combination of direct comparison and bridged overlap should be applied.

- With regard to the data collected on internet platforms and car magazines, the empirical studies of the CENEX members showed that hedonic re-pricing is more suitable than supported expert judgement. The empirical studies showed that the hedonic re-pricing method yields more reliable results with less effort.

- The following section deals with the application of a combination of direct comparison and bridged overlap for market research data and with supported expert judgement in the case of data from internet platforms and car magazines.

3.1 Proposal for the identification of consumption segments

- The identification of appropriate consumption segments for used cars equals the one for new cars (see section 2.1).

- Therefore, the pragmatic proposal is to divide the used car market into four consumption segments according to the size of the car:

Chart 51
Proposal for the identification of consumption segments for used cars
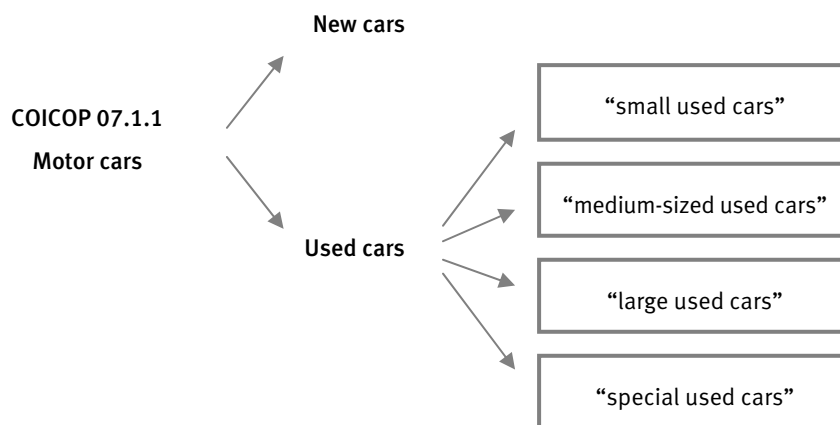
- The next step is to assign the universe of the used car models registered in the country to the different consumptions segments.

- This should be done on the basis of primary models. A primary model is an umbrella term for a model of a passenger car (e.g. VW Golf) whereas the term "sub-model" refers to a specific engine – and equipment version of the primary model (e.g. VW Golf V 1.9 TDI Trendline).

- The universe of primary models within the used car market might be bigger than the new car universe (consisting of approximately 300 models for a country). The larger universe is due to the fact that the used car universe goes back in time and therefore also contains primary models that have been sold years ago. The information which primary models are currently registered in the particular country can be obtained from the national central car register or from a national car seller's association.

- The assignment of primary models to the mentioned consumption segments can be conducted individually by each country and may to a certain degree depend on national circumstances (possibly, the consumption segment "large used cars" contains different primary models in different countries).

Chart 52
Example for the assignment of concrete models to the consumption segments
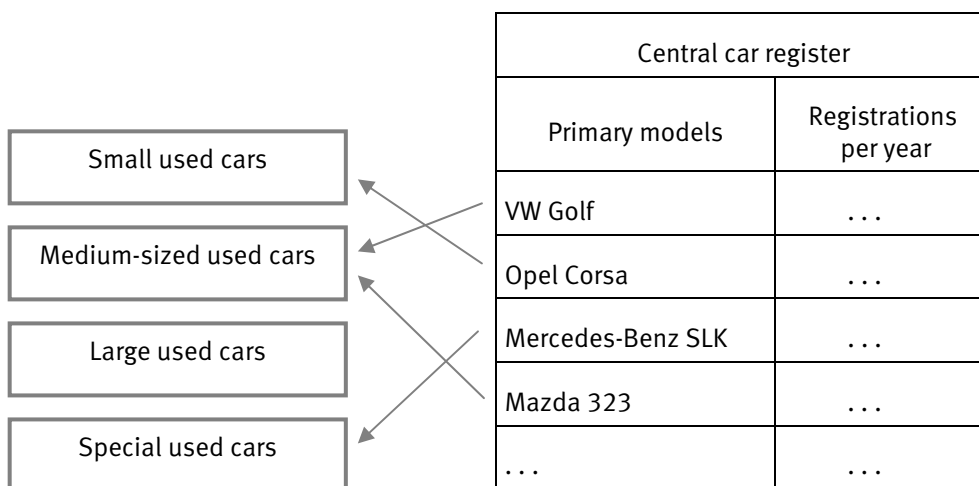
- The central car register (or the national car seller's association) usually already contains a variable which divides the primary models into different segments. In many cases this segmentation has only to be adjusted to the segmentation of the four consumption segments. Altogether, the assignment to segments is not very extensive. As a result all primary models that are registered in the particular country are assigned to the consumption segments.

Weighting of the consumption segments

- The COICOP four-digit-level 07.1.1 Motor cars is divided into new cars and used cars with individual weights. The weight for used cars in general has to conform to the net-principle of the HICP. This net concept takes into account the result of all interaction in purchases between the business sector and the private sector. This means that the weight shall reflect all purchases from business to private households minus the purchases from private households to the business sector – but not transactions between private households.

- As the weight for used cars (on the COICOP five-digit-level) is established, the weight may be split over the consumption segments. It is suggested to weight the mentioned consumption segments explicitly according to the expenditure shares.

- Generally, the expenditure shares will not be available but could be obtained by multiplying the number of ownership changes from the previous year by an average price for the cars of the respective consumption segment.

- The total number of ownership changes for each consumption segment can be obtained from the central car register and should refer to the previous year. In order to ensure the net concept of the HICP, it is important to only consider sales from the business sector to private households. If the central car register contains the information whether the car was registered by a private person or by business cooperation prior to the transaction, only ownership changes from business retailers have to be considered. If the information on the ownership status prior to the transaction is not contained in the central car register, only those ownership changes with a temporary vehicle deregistration prior to the transaction should be considered assuming that only business sales are temporarily deregistered.

- An average price for the consumption segment could be calculated on the basis of the sample of list prices, which are collected anyway. The collection of list prices will be described in the next section.

3.2   Proposal for the construction of a target sample

- It is suggested (for each consumption segment) to first stratify the universe of used cars according to age classes. The second step is to select relevant primary models within these age classes for price observation with the help of information on the market shares from the central car register. The next step is to assign precise sub-models to each primary model. For the price collection, the regional dimension should only be considered roughly. The outlet dimension can be neglected.

Chart 53
Proposal for the construction of a target sample

> **Stratification according to age classes › primary models › sub-models › offer prices**
>
> (1) Stratification by age classes.
> (2) Selection of relevant primary models.
> (3) Assignment of precise sub-models.
> (4) Collection of offer prices.

(1) Stratification by age classes

- The consumption segments should be stratified according to country-specific age classes following "peaks" in the amount of ownership changes in the national used car market. This information can be obtained from the central car register.

- For practical reasons, there should be about three age classes.

- In many European markets these peaks will occur for up to two-year-old cars (which are often formerly leased or rental cars). An age class of ten years and older should be avoided.

- As a pragmatic proposal the used car market could be stratified according to the following age classes:
  - ~ 2 years old cars,
  - ~ 3 years old cars,
  - ~ 4 years old cars.

Chart 54
Visualisation of the stratified used car market

Used cars

CS "small used cars"	CS "medium-sized used cars"	CS "large used cars"	CS "special used cars"
• ~ 2 years	• ~ 2 years	• ~ 2 years	• ~ 2 years
• ~ 3 years	• ~ 3 years	• ~ 3 years	• ~ 3 years
• ~ 4 years	• ~ 4 years	• ~ 4 years	• ~ 4 years
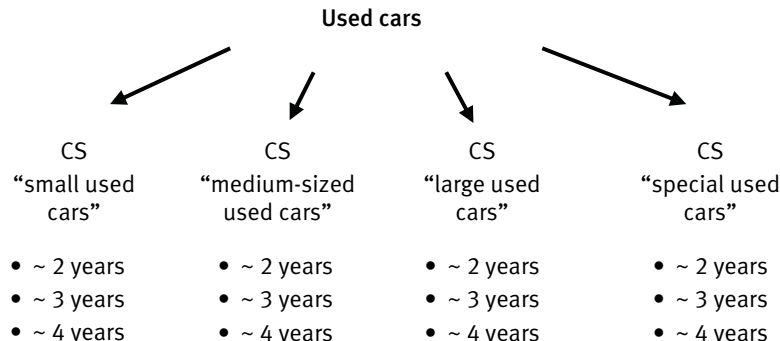
(2) Selection of relevant primary models

- Two possible sampling methods can be applied: The first is to apply cut-off sampling within the consumption segments and age classes. If a small number of models represents a large share of the market this sampling method works well. If, on the other

hand, the market shares are well spread among primary models, probability sampling proportional to size could be a better choice. In general, probability sampling in the case of cars can be applied without much effort because of the limited complexity of the universe of car models (only approximately 300 primary models). The selection criterion for both sampling methods is the number of ownership changes (of the particular primary model) for the considered age class from the previous year. As there is data on model-specific expenditure shares available, those should be applied as the selection criterion.

- When applying probability sampling the central car register can serve as a sampling frame. The sampling of models may be based on the number of ownership changes of car models from the previous year. Please ensure that only ownership changes from business retailers to private households or alternatively with a deregistration prior to the transaction, are considered.

- The procedure is quite similar for cut-off sampling. Here, the models with the highest number of ownership changes in the age class are selected successively until a defined cumulative share of ownership changes is reached.

(3) Assignment of precise sub-models

- After the selection of primary models, sub-models of the selected primary models have to be chosen. For this selection process, purposive sampling is suggested.

- The sub-models may be selected according to the following criteria:
  - The sub-model should be well sold (e.g. a well sold engine power alternative such as VW Golf 1.9 TDI).
  - The sub-model should be of the least extensive equipment level (e.g. the least extensive equipment level of Volkswagen is called "Trendline").
  - The sub-model must not be a special edition (e.g. VW Golf equipment version "Goal").

- The higher the number of ownership changes of a primary model, the higher is the number of price observations (i.e. implicit weighting). Each collected offer price has to refer to one precise sub-model.

- If a high number of offer prices is collected, which means that a corresponding high number of sub-models has to be observed, it might be necessary to diverge from the sub-model selection criteria mentioned above. Especially, the restriction on the equipment level could be relaxed.

- For the selection of precise sub-models, consider a representative relation of diesel and petrol engines. It should therefore be determined in advance how many petrol engine and diesel engine cars should be in the sample for each consumption segment.

- Select sub-models that have similar engine power. That means no engine versions with very high or very low engine performance should be chosen.

(4) Collection of offer prices

- According to the HICP standards for cars and other vehicles, list prices can be used as an approximation of real transaction prices. For used cars, the term "list price" in

the HICP standards can be interpreted as an offer price since it is often not possible to gain information on real transaction prices in the scope of price collection.

- The regional dimension should only be considered roughly since it is not assumed to be a major issue.

- This allows for a central price collection.

- In general, there are three approaches for the price observation:
    - Observation of transaction prices from a market research institute.
    - Observation of offer prices from a market research institute.
    - Observation of offer prices from internet platforms or car magazines.

- The usage of data from a market research institute may often be preferable if available. Generally, market research institutes have available many price observations which they can use as a basis for the calculation of specific used car values. For this reason, the exact used car price for a certain sub-model with exactly presumed age in months and mileage can be observed.

- The first choice is to use data from a market research institute that provides transaction prices if available. In many European countries, transaction prices are provided for example by DAT.

- The second choice is to use data from a market research institute that provides offer prices. In many European countries data is available for example from Eurotax Schwacke.

- If data provided by a market research institute are not available for the national used car market, an own survey on internet platforms, such as www.autoscout24.xx, and car magazines has to be performed. Keep in mind to collect only offer prices from business retailers.
    - In the case of price collection on internet platforms and car magazines, the following issues are of importance:
        - It is most important to refer to the same sub-model over time.
        - The age in months should be held constant as far as possible. In practice, there will be variations in the precise age which have to be adjusted in the following (see section 3.4 "Proposal for the quality adjustment").
        - The mileage should be considered roughly. That means the mileage should be of the same dimension from period to period. The variations in mileage also have to be adjusted in the following.
        - It is very important not to consider product-offers from private persons, cars that have been involved in an accident and cars with a lot of obvious extra equipment or modifications.
        - If there is a large range of product-offers that fit all the mentioned criteria, any concrete product-offer among the price variance may be selected.
    - For used cars, the characteristics which are relevant for the price and thus have to be collected are: Brand, primary model, sub-model, age and mileage.
    - An appropriate price collection form should precisely ask for the considered characteristics and might look like this:

Chart 55
Example of a price collection form

Used car: Consumption segment "medium-sized cars" and age class ~ 3 years	
Brand/Make:	Volkswagen
Primary model:	Golf V
Sub-model (with equipment level):	1.9 TDi Trendline
Price (€):	13,450
Date of initial registration [year and month]:	2005/05
Mileage (km):	42,400
Retailer: ABC retailer	
Date: 2008/07/20	

Minimum size of the target sample

- The sample size should be established country-specifically since the number of observations needed depends on the number of generated consumption segments and age classes.

- A pragmatic proposal may be a minimum bound of normally 100 product-offers monthly for the sample of used cars where no more specific indications are present.

- That means, for four consumption segments a minimum of 25 to 30 price observations are spread over three age classes resulting in a sample size of approximately 8 price observations per age class within the consumption segment.

Chart 56
Distribution of price observations
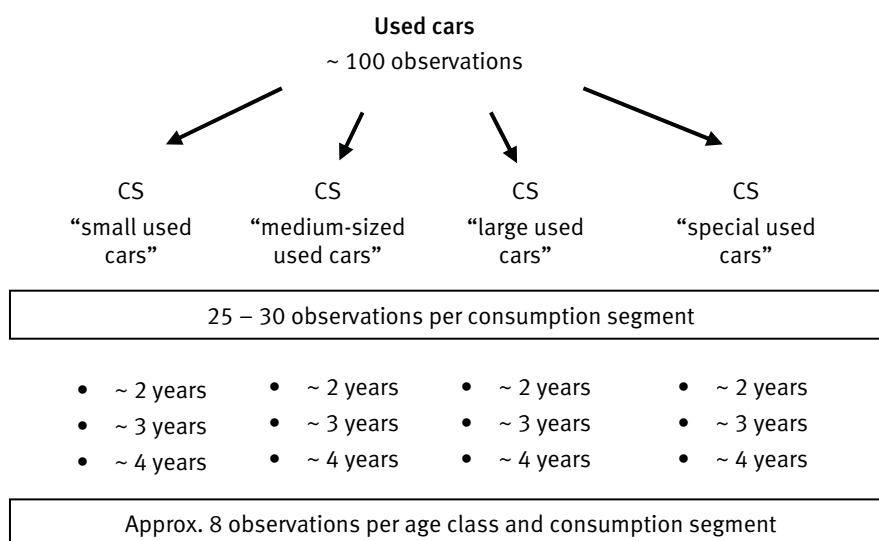
Used cars
~ 100 observations

CS	CS	CS	CS
"small used cars"	"medium-sized used cars"	"large used cars"	"special used cars"

25 – 30 observations per consumption segment

• ~ 2 years	• ~ 2 years	• ~ 2 years	• ~ 2 years
• ~ 3 years	• ~ 3 years	• ~ 3 years	• ~ 3 years
• ~ 4 years	• ~ 4 years	• ~ 4 years	• ~ 4 years

Approx. 8 observations per age class and consumption segment

Weighting of the selected primary models

- The primary models which are chosen to represent the age class in the consumption segment are weighted implicitly according to the respective market share (see sub-section *(3) Assignment of precise sub-models*). The criterion for implicit weighting is the share of ownership changes of the respective primary model within the age class and consumption segment.

Alternative proposal for the construction of a target sample

- As the procedure described above may cause some work load and costs it could be useful to apply a rather simple approach for the target sample: Use the same target sample for used cars as you have used for new cars, for example from two years ago.

- This simple approach might not be recommendable for every country. It is important that the structure of the new car market and the used car market is rather similar. That means, the same primary models which are sold as new cars are also sold as used cars two years later. This assumption could be violated when the used cars are imported to a large extent prior to their purchase.

- If the new car sample from two years ago can be applied, this means there is only one age class: 2-year-old cars. The price development of this age class represents the whole range of ages in the used car market. The relevant primary models have been selected with the help of information on the initial registrations from the central car register. The corresponding sub-models that have been assigned to the primary models could be the same as for new cars again. The price collection would be the same as described above, the regional dimension should only be considered roughly and the outlet dimension can be neglected.

- So, the construction of the target sample consists of only two steps:

Chart 57
Proposal for the construction of a target sample

New car sample from two years ago > offer prices
(1) Use the new car sample from two years ago
(2) Collection of offer prices

- Regarding the minimum size of the target sample, the sample size corresponds to the sample size of new cars two years ago. A sample size of 100 observations monthly should be ensured. That means, for four consumption segments a minimum of 25 price observations per consumption segment is sufficient to ensure representativity.

- The weights of the primary models should correspond to the weights that have been applied in the new car sample two years ago. That means the sample size of approximately 25 price observations is distributed over 25 sub-models which refer to primary models (implicit weighting).

3.3   Proposal for the replacement strategy

- A peculiarity of the used car market is that no observation can be assumed to be identical over time since the characteristics "age" and "mileage" change continuously. Thus, no used car can be considered to be "identical" over periods. This means, in every period each observed used car has to be replaced minimising differences in the particular model (as an approximation for similar equipment), precise age and mileage. Note that this peculiarity is solved in the case that data from a market research institute are used where the characteristics of the specific cars are kept fix. In this case one is comparing an average price of sold cars with the same characteristics in consecutive months.

- The primary models within the age classes which were selected for the target sample serve as a product specification for the replacement. To keep the sample fix means that the replacement model is characterised by the same primary model and exactly the same sub-model with identical age (in months) and mileage. To hold the precise age and mileage constant will only be possible if market research data are used, otherwise the observed sub-models will vary in these characteristics.

- A replacement can be carried out by selecting:
  - the same sub-model (with small variations in age and mileage in case of data collected on internet platforms or in car magazines)
  - a new sub-model within the range of the corresponding primary model (with variations in age and mileage in case of data collected on internet platforms or in car magazines).
  - or the replacement can be selected by changing the primary model.

- In the following a distinction is made for practical reasons between a representativity check within the scope of the monthly price collection and a regular representativity check in the office.

Representativity check within the scope of the monthly price collection

- In the case of used cars it is suggested to evaluate the sample based on yearly figures. This is due to practical reasons like the issue of seasonality and the availability of monthly data from the central car register.

- Use the concrete primary model and the corresponding selected sub-models that were in the sample in the previous month as a starting point for the price collection of the current month in order to keep the share of matched models reasonably high.

- If the sub-model of the previous month is no longer available it should be replaced. The replacement sub-model has to correspond to the same primary model maintaining the basic characteristics so that the effect on the sample characteristics will be minimal. The new sub-model would then be
  - of the same primary model,
  - of the same age class,
  - of the same mileage dimension.

- If the primary model significantly loses its market share within the consumption segment and age class, maybe due to a former production stop, the primary model has

to be replaced by a more representative primary model that is most similar to the old one. To give an example, the production of the VW Lupo was stopped (therefore this primary model became unrepresentative) and it was replaced by the VW Fox. This replacement primary model could be a different primary model (with similar size) of the same or an alternative brand. For the newly chosen primary model precise sub-models in the corresponding age class have to be assigned again as described in the preceding section.

Representativity check in the office for the periodical re-sampling

- Additionally to the representativity checks conducted within the scope of price collection a representativity check should be conducted regularly (e.g. yearly). This periodical renewal depends on the publication of the statistics of the ownership changes (e.g. from the previous year) by the central car register.

- Check whether the pre-selected primary models are still representative of the market in the particular consumption segments and age classes. Therefore, the number of ownership changes has to be observed regularly. This regular observation can also be used to determine general changes in the market, e.g. new primary models, new sub-models, new brands.

- If the selected primary models are still representative, continue the observation of the corresponding sub-models.

- If not, repeat the pre-selection process as described for the compilation of the target sample. Corresponding to the sales figures (number of ownership changes) the pre-selection of primary models has to be renewed regularly (yearly). If the formerly pre-selected primary models are no longer representative they will be replaced by more representative primary models.

3.4   Proposal for the quality adjustment

- A distinction of minor and major changes helps to decide whether an explicit or an implicit quality adjustment is necessary. Both, major and minor changes require a quality adjustment. In general, major changes in the quality of used cars are too complex for an explicit quality adjustment whereas minor changes can be adjusted explicitly.

- Minor changes in quality of used cars can only occur in case of observing the same sub-model over time:
    - changes in the equipment of a precise sub-model,
    - the age of the car [in months] differs,
    - the mileage of the car differs.

- Major changes in the quality of used cars are:
    - the change of the primary model,
    - the introduction of a new generation of the primary model (the old version of the primary model is followed by a new version),
    - the change of the sub-model.

Quality adjustment in the case of major changes: Bridged overlap

- In the case of major changes in quality, no explicit quality adjustment is possible since the replaced and the replacement product are in principle not comparable at all.

- If major quality changes occur, bridged overlap shall be applied. The price development of all other models of the same consumption segment and age class which were not replaced build the bridge between the replaced and the replacement model. In this way the average price development of a set of comparable models is used.

Quality adjustment in the case of minor changes: Supported expert judgement

- Minor quality changes in the equipment of a precise sub-model can not be adjusted explicitly since the value of a singular equipment feature which is a component of the used car is unknown. The depreciation rate of equipment features in a used car is different from the depreciation rate of the whole car itself. Therefore it is not possible to adjust for changed equipment which is already of used condition. In order to alleviate the problem the equipment should not significantly differ from month to month. In practice this means, the observed used car should not contain too many additional equipment features or any modifications. Direct comparison should be applied.

- Changes in the age (in months) or in the mileage of the car should be adjusted by supported expert judgement.

- Note that these changes in age and mileage between two periods can only occur if the used cars prices are collected on internet platforms or in car magazines. If market research data is used, no supported judgement adjustment would be necessary.

- The supported expert judgement approach calculated for each considered primary model in each age class a separate depreciation rate for age and for mileage. These depreciation rates are calculated on a yearly basis.

- That means, for each primary model in each relevant age class two additional samples of approximately 10 observations have to be collected: One sample to calculate a depreciation rate for age and one sample for mileage. The price observations of these two samples should refer to one specific sub-model. The samples should only contain product-offers from business retailers. Cars that have been involved in an accident and cars with a lot of obvious extra equipment or modifications should be skipped.

- To calculate a depreciation rate for the age of a particular primary model and in a particular age class, 10 used car prices should be observed. These 10 price observations consist of 5 pairs, each should be of the same sub-model, very similar mileage and of different ages within the range of the corresponding age class. It is important that the mileage of the observation pairs is very similar (nearly constant) whereas the age in months can vary within the interval of the considered age class.

- The sample for the "age depreciation" might look like this (see following chart 58):

Chart 58
Sample for the calculation of the depreciation rate for age for the "VW Golf V"

Observation	Age	Mileage	Used car price
Primary model: Volkswagen Golf V			
Sub-model: 1.9 TDi Trendline			
Age class ~ 2 years			
	in month	in km	in €
1	18	32,000	15,000
2	26	31,000	14,000
3	17	13,000	14,800
4	24	13,800	14,000
5	15	33,000	16,000
6	29	33,000	13,000
7	19	40,000	15,500
8	24	39,000	14,000
9	20	31,000	15,000
10	26	33,000	14,000

- On the basis of the first sample, a depreciation rate for the age in months can be calculated. Therefore, five depreciation rates for the five observation pairs have to be computed. These depreciation rates are averaged by the arithmetic mean. Thus, the calculation follows the equation:

$$\delta_{Age}^{Model\_A,\,Age\_class} = \frac{1}{5}\left(\frac{(P_1-P_2)}{(Age_2-Age_1)} + \frac{(P_3-P_4)}{(Age_4-Age_3)} + \frac{\dots}{\dots} + \frac{(P_9-P_{10})}{(Age_{10}-Age_9)} \right)$$

- The $\delta_{Age}^{A,\,Age\_class}$ can be interpreted to be the absolute monetary value of one month of age for the considered primary model in the considered age class.

- Analogously, to calculate a depreciation rate for the mileage of a particular primary model and in a particular age class, a second sample of 10 used car prices should be observed. These 10 price observations consist of 5 pairs again, each should be of the same sub-model, identical age in months but of different mileages. Thereby the age between the pairs can differ within the range of the age class.

- On the basis of the second sample, a depreciation rate for the mileage can be calculated following the equation:

$$\delta_{Mileage}^{Model\_A,\,Age\_class} = \frac{1}{5}\left(\frac{(P_1-P_2)}{(Mileage_2-Mileage_1)} + \frac{(P_3-P_4)}{(Mileage_4-Mileage_3)} + \frac{\dots}{\dots} + \right.$$
$$\left. + \frac{(P_9-P_{10})}{(Mileage_{10}-Mileage_9)} \right)$$

The $\delta_{Mileage}^{A,\,Age\_class}$ can be interpreted to be the absolute monetary value of an additional mileage of 1,000 kilometres for the considered primary model in the considered age class.

- These model- and age-class-specific depreciation rates can be used to adjust observed used cars with subsequently different ages and mileages from month to month. This would especially be the case when the data is collected on internet platforms and in car magazines.

Chart 59
Quality adjustment when using data from internet platforms and car magazines
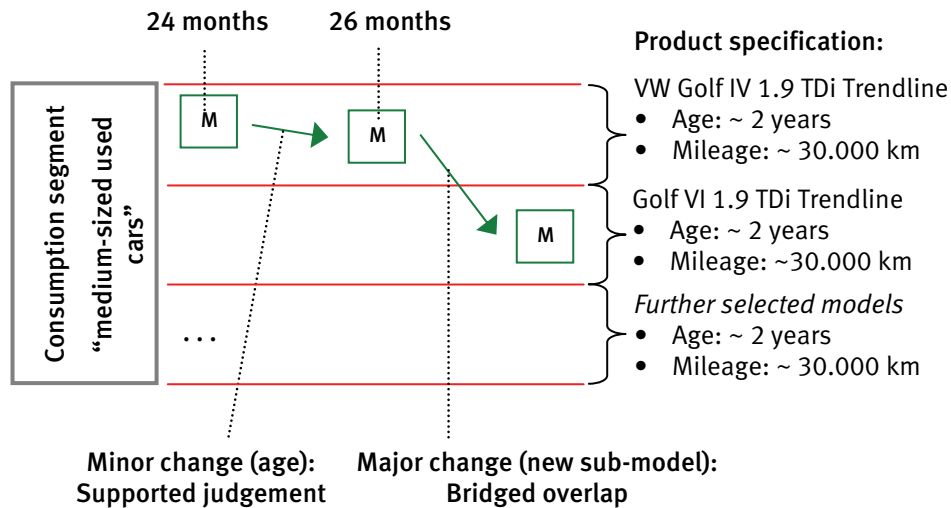
Drawbacks of supported expert judgement

- The empirical study on used cars conducted within the scope of the CENEX project showed that supported expert judgement should be assessed to be the second-best approach for used cars in the case that the hedonic re-pricing approach is not applicable.
- There are several concerns against supported expert judgement:
  - The sub-samples collected for the calculation of the depreciation rates for age and mileage refer to the specific primary model and age class. Therefore these sub-samples are rather small (10 observations) possibly resulting in unreliable depreciation rates. The reason is that the collected offer prices can vary to a large extent even for cars with very similar characteristics.
  - Furthermore, the availability of the observations with precisely defined characteristics (sub-model, equipment version, age and mileage) can cause some difficulties. Especially in small countries there might not be enough observations available.
- In case of data obtained by a market research institute, no variations of the characteristics age and mileage occur. Therefore, no supported expert judgement has to be applied.

Chart 60
Quality adjustment when using data from market research institutes
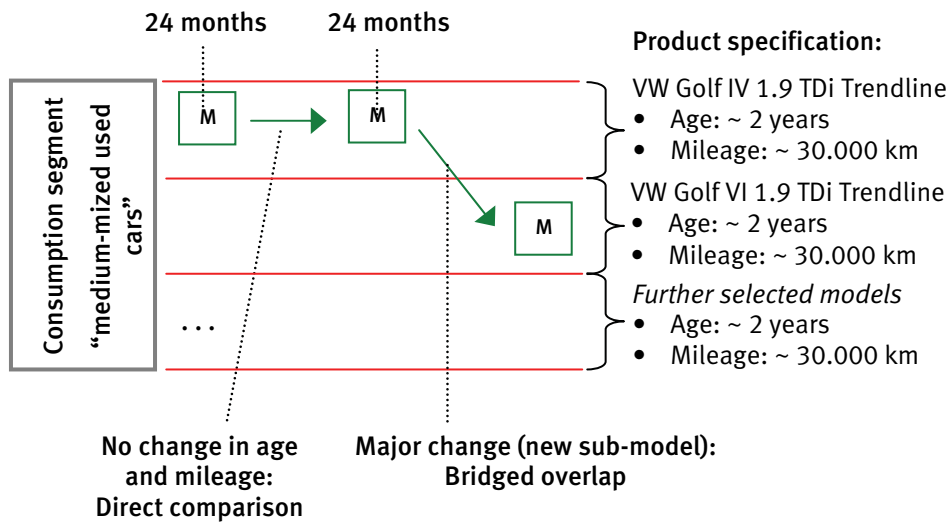
3.5   Cost estimation

One-time effort for the introduction

- For the implementation of the non-hedonic method one staff member with market knowledge and economic expertise is required. Up to three months seem to be necessary to set up an adequate sample and to perform the suggested non-hedonic approach. The time effort also depends on the current practice in use. For example, if there is already an appropriate sampling procedure implemented the time effort for the introduction might be lower. Market research seems to be unnecessary since the used car market is well determined in the statistics of the central car registers.

Current effort of price collection

- The time effort for the price collection depends on the data source that is used. In the case of data provided by a market research institute an own price collection is not required. In the case that the prices are collected by an own central survey on internet platforms and in car magazines, up to 4 man-days seem to be sufficient to collect the observations. To include the observed prices and characteristics into a database might additionally last one day. The price collector should be a trained staff member. There is no need for academic skills or expert knowledge in the used car market.

- In case that the observations have to be collected on internet platforms and in car magazines, for each considered primary model in each age class two additional samples for the calculation of the specific depreciation rates have to be collected. This might be a work load of up to ten days for a non-academic staff member. These depreciation factors are compiled yearly.

Current effort of index calculation

- Regarding the index calculation, the price statistician should have econometric knowledge, especially when the index calculation is conducted manually. In the case of an automatic or semi-automatic process only moderate economic skills are required. The index calculation might be done quickly; an effort of approximately 1 man-day seems to be sufficient.

- The effort of the yearly re-sampling amounts to up to 5 days for a staff member with non-academic qualification.

3.6   Examples

Example: Generation of consumption segments

- In the first step, the used car market has to be divided into different consumption segments in according to the size of the car. This step should correspond to the procedure for new cars where the pragmatic proposal is to define four consumption segments:
  - small used cars,
  - medium-sized used cars,
  - large used cars,
  - special used cars.

- As in the case of new cars, the universe of primary models consists of approximately 300 cars in each country. Each of these primary models has to be assigned to the identified consumption segments. The distinguishing criterion is the size of the car.
  - The data on the particular primary models that are registered in the country can be obtained from the national central car register.

Chart 61
Example for the assignment of concrete models to the consumption segments

Central car register	
Primary models	Registrations per year
VW Golf	. . .
Opel Corsa	. . .
Mercedes-Benz SLK	. . .
Mazda 323	. . .
. . .	. . .

Small used cars

Medium-sized used cars

Large used cars
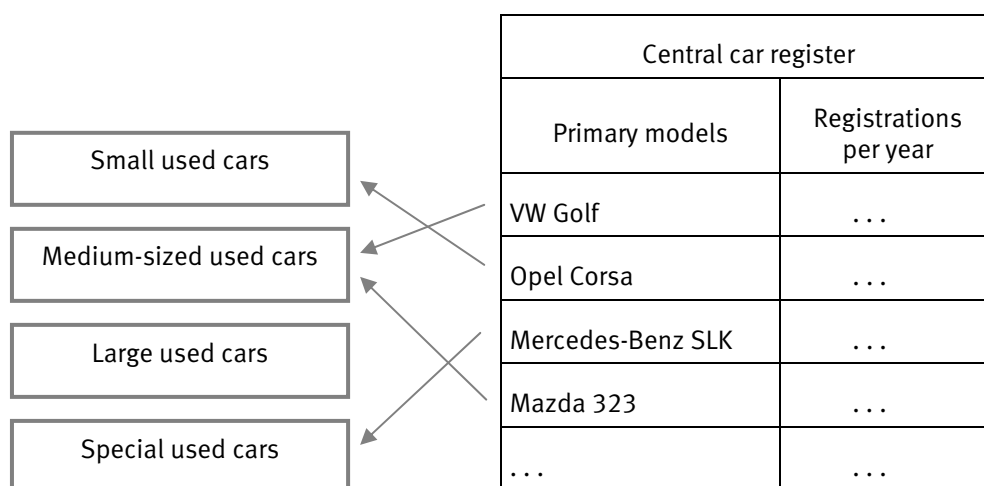
Special used cars

- As a result, each consumption segment consists of precise primary models.

Chart 62
Consumption segments and the corresponding primary models

Consumption segments							
Small used cars		Medium-sized used cars		Large used cars		Special used cars	
Primary model	Ownership changes	Primary model	Ownership changes	Primary model	Ownership changes	Primary model	Ownership changes
Opel Corsa	26,082	VW Golf	73,692	Mercedes-Benz E class	18,631	Opel Zafira	14,620
VW Polo	16,332	Opel Astra	36,889	BMW 5 series	16,247	VW Caravelle	8,305
Renault Twingo	11,094	Mercedes-Benz C class	34,851	Audi A6	12,937	VW Sharan	7,162
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
sum	192,684	sum	440,878	sum	73,504	sum	124,923

- The consumption segments have to be weighted in accordance to their expenditure share.

- To obtain the total expenditure of a consumption segment, multiply the total number of ownership changes from the previous year for the particular consumption segment by its average price.
  - The total number of ownership changes for each consumption segment can be taken from the central car register. The average price for a consumption segment can be obtained from the section on price collection below. It should refer to one specific arbitrary age class which has to be the same for all consumption segments.

Chart 63
Calculation of expenditure weights for the consumption segments

Weighting the consumption segments							
Small used cars		Medium-sized used cars		Large used cars		Special used cars	
Total number of ownership changes	Average price (in €)	Total number of ownership changes	Average price (in €)	Total number of ownership changes	Average price (in €)	Total number of ownership changes	Average price (in €)
192,684	7,500	440,878	10,000	73,504	15,000	124,923	12,500
Total expenditure (in billion €):							
1.44		4.40		1.11		1.56	
Total expenditure of all consumption segments: 8.51 billion €							
Expenditure share (in %):							
17.0		51.8		12.9		18.3	

Example for the construction of a target sample

- (1) Stratify the universe of ownership changes by age classes:
  - Two or three age classes should be generated following "peaks" of ownership changes in the national market. Therefore, the distribution of ownership changes according to the age of the cars should be checked. In the example provided below, the number of ownership changes according to age exhibits three "peaks" in two, three and four-year-old cars.

Chart 64
Number of ownership changes for different ages of the car
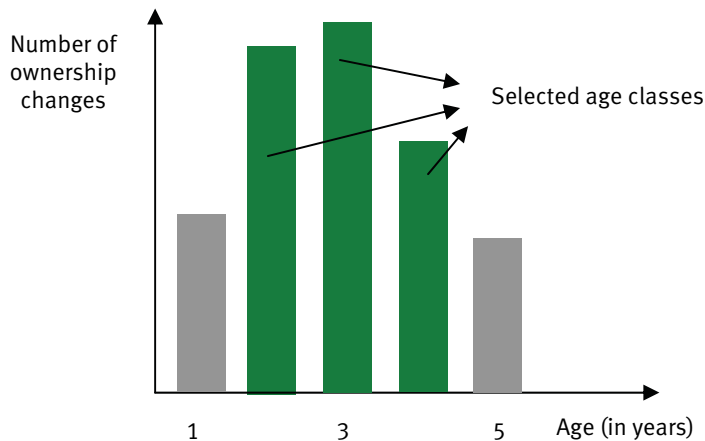
- The pragmatic proposal is to form three age classes: Two-year-old, three-year-old and four-year-old cars within each consumption segment. In the following this recommendation will be considered.
- (2) Select primary models by cut-off sampling (probability sampling is also possible):
  - In each consumption segment and age class, include all primary models until a cumulative market share of 50 % to 60 % is reached.
  - This means to draw a sample for the recommended twelve segments: Four consumption segments each contain three age classes.
  - An example for the consumption segment "medium-sized used cars" and the age class of two-year-old cars (see following chart 65):

Chart 65
Exemplary target sample for the consumption segment "medium-sized used cars"

Target sample for "medium-sized used cars" and two-year age class			
Primary model	Ownership changes (from the previous year)	Market share	Cumulative market share
		in %	
VW Golf	32,040	*16.7*	*16.7*
Opel Astra	16,039	*8.4*	*25.1*
Mercedes-Benz C class	15,153	*7.9*	*33.0*
BMW 3 series	14,586	*7.6*	*40.6*
Ford Focus	14,028	*7.3*	*47.9*
Audi A4	13,097	*6.8*	*54.7*

- The selected primary models represented in the table make up 54.7 % of the market for "medium-sized used cars" within the considered age class.

- Assignment of precise sub-models by purposive sampling
  - The selected primary models have to be implicitly weighted according to the relation of their sales figures. The proposal is collect 25 to 30 price observations per consumption segment which spread over the three age classes. This results in a sample size of approximately 10 per stratum. Now it is to determine how many price observations to collect for each primary model.
  - The distribution of the price observations might look like this (implicit weighting):

Chart 66
Number of observations to be included

Distribution of price observations "medium-sized used cars" and two-year age class				
Primary model	Market share		Share in the sample (ratio)	Number of price observations
	in %		in %	
VW Golf	*16.7*	→	*30.5*	3
Opel Astra	*8.4*	→	*15.4*	1
Mercedes-Benz C class	*7.9*	→	*14.4*	1
BMW 3 series	*7.6*	→	*13.9*	1
Ford Focus	*7.3*	→	*13.3*	1
Audi A4	*6.8*	→	*12.5*	1
Total	***54.7***	→	***100***	**8**

- – In this example, three sub-models for the primary model VW Golf have to be selected in order to reflect its market share of the consumption segment "medium-sized used cars" within the age class of two-year-old cars.
- – The sub-model selection has to be conducted by purposive sampling according to the following criteria:
  - – Should be a well sold sub-model within the range of the corresponding primary model.
  - – Should be of the least extensive equipment level.
  - – Must not be a special edition.
- – The following chosen sub-models meet these criteria. Additionally, the approximate ratio of diesel and petrol engines is considered.

Chart 67
Precisely selected sub-models for the primary model "VW Golf"

Sub-model selection for VW Golf V	
Observation	Sub-model
1	Golf V 1.6 Trendline
2	Golf V 1.9 TDi Trendline
3	Golf V 2.0 TDi Trendline

- Collect offer prices for the chosen sub-models
  - – The prices for the selected sub-models can ideally be obtained from market research institutes. Otherwise, collect prices on internet platforms and in car magazines.

Example: Replacement strategy

- Representativity check within the scope of the monthly price collection:
  - – The price collector (product expert) should refer to the selected sub-models of the previous month. In the case that a specific sub-model of a precise age is no longer observable it should be replaced. Maybe, the considered primary model is followed by a new version: For example, the follow-up model for VW Golf IV is the VW Golf V.
- Representativity check for the periodical renewal of the sample
  - – The target sample should be updated regularly, maybe yearly, depending on the publication of the statistics of the ownership changes by the central car register.

Example: Quality adjustment

- It is important to distinguish between minor and major changes
- Major changes can occur in three situations:
  - – Change of the primary model due to a former production stop.

- – The old version of a primary model is followed up by a new generation: e.g. VW Golf IV is followed by a VW Golf V.
  - – The sub-model is replaced since it is no longer available.
- Minor changes:
  - – The equipment of a particular sub-model is, for example, extended by a parking sensor.
  - – The product observations of a particular sub-model differ in age and/or in mileage.
- Differences in the equipment of the used cars are not adjusted.
- As regards data from market research institutes: Minor changes due to variations in age and/or mileage do not occur. Therefore, direct comparison is applied in the case of changed equipment and bridged overlap in case of major changes.
- When prices are observed on internet platforms or car magazines, differences in age and/or mileage can occur. In this case, supported expert judgement is applied.
- For each considered primary model in each relevant age class two additional samples of approximately 10 observations have to be collected yearly.
- Collect a first sample with (nearly) constant mileages and varying age in months within the range of the age class:

Chart 68
Sample for the calculation of the depreciation rate for age for the "VW Golf V"

Primary model: Volkswagen Golf V Sub-model: 1.9 TDi Trendline			
Age class ~ 2 years			
Observation	Age	Mileage	Used car price
	(in months)	(in km)	(in €)
1	18	32,000	15,000
2	26	31,000	14,000
3	17	29,000	14,800
4	24	30,000	14,000
5	15	33,000	16,000
6	29	33,000	13,000
7	19	32,000	15,500
8	24	30,000	14,000
9	20	31,000	15,000
10	26	33,000	14,000

- The depreciation rate for age in months for the VW Golf V 1.9 TDi Trendline in the age class of ~ 2 years can be calculated as follows:

$$\delta_{Age}^{Model\_A,\ Age\_class} = \frac{1}{5}\left(\frac{(P_1 - P_2)}{(Age_2 - Age_1)} + \frac{(P_3 - P_4)}{(Age_4 - Age_3)} + \frac{\cdots}{\cdots} + \frac{(P_9 - P_{10})}{(Age_{10} - Age_9)} \right)$$

$$\delta_{Age}^{VWGolf,\sim 2years} = \frac{1}{5}\left(\frac{(1,000€)}{(8)} + \frac{(800€)}{(7)} + \frac{(3000€)}{(14)} + \frac{(1500€)}{(5)} + \frac{(1000€)}{(6)} \right) = 184.05\ €$$

- The $\delta_{Age}^{A,\ Age\_class}$ can be interpreted as follows: If a replacement is chosen that is 1 month older, the price of the replacement car has to be adjusted for 184.05 €. The applied depreciation rate corresponds to the primary model and the considered age class.

- Analogously, to calculate a depreciation rate for the mileage of a particular primary model and in a particular age class, a second sample of 10 used car prices should be observed. These 10 price observations consist of 5 pairs again, each should be of the same sub-model, identical age in months but of different mileages.

Chart 69
Sample for the calculation of the depreciation rate for mileage for the "VW Golf V"

Primary model: Volkswagen Golf V Sub-model: 1.9 TDi Trendline			
Age class ~ 2 years			
Observation	Age	Mileage	Used car price
	in months	in 1,000 km	in €
1	24	15	15,000
2	24	45	13,500
3	22	20	14,500
4	22	30	14,800
5	25	20	15,500
6	25	60	13,200
7	20	15	15,500
8	20	35	14,000
9	26	30	14,500
10	26	50	13,800

- On the basis of the second sample, a depreciation rate for the mileage in kilometres can be calculated following the equation:

$$\delta_{Mileage}^{Model\_A,\ Age\_class} = \frac{1}{5}\left(\frac{(P_1 - P_2)}{(Mileage_2 - Mileage_1)} + \frac{(P_3 - P_4)}{(Mileage_4 - Mileage_3)} + \frac{\cdots}{\cdots} + \right.$$
$$\left. + \frac{(P_9 - P_{10})}{(Mileage_{10} - Mileage_9)} \right)$$

$$\delta_{Mileage}^{VWGolf,\sim 2years} = \frac{1}{5}\left(\frac{(1,500€)}{(30)} + \frac{(-300€)}{(10)} + \frac{(2.300€)}{(40)} + \frac{(1,500€)}{(20)} + \frac{(700€)}{(20)} \right) = 37.50€$$

- The $\delta_{Mileage}^{A,\,Age\_class}$ can be interpreted as follows: If a replacement is chosen that exhibits a mileage of 1,000 kilometres more, the price of the replacement car has to be adjusted for 37.50 €. The applied depreciation rate corresponds to the primary model and the considered age class.

- In case of data collection on internet platforms and in car magazines, variations of the characteristics age and mileage of two subsequent product observations are adjusted by applying the model-specific depreciation values.

Chart 70
Example of quality adjustment for minor and major changes
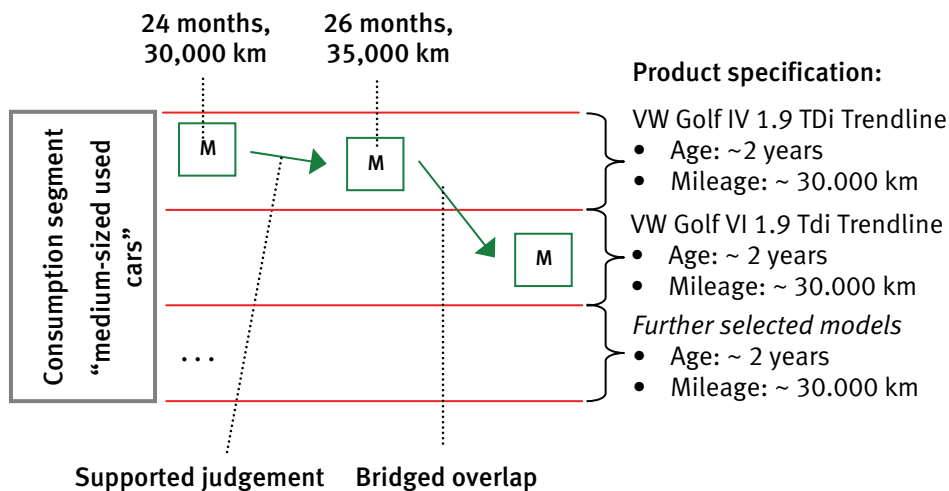
- Assume that the observed used car in the first period (24 months old and 30,000 km) has a price of 16,000 € and the observed used car in the second period (26 months old and 35,000 km) has a price of 15,000 €.

- Since the two product offers differ in age and mileage the calculated model-specific and age class-specific depreciation rates for age and mileage have to be applied to match the price observations.
  - Price observation in the first period: $P^1_{24\ months,\ 30,000\ km}$ = 16,000 €.
  - Price observation in the second period: $P^2_{26\ months,\ 35,000\ km}$ = 15.000 €.
  - The price of the second observation has to be adjusted for 2 months and 5,000 kilometres:
  - $P^2_{adj} = P^2 + \delta_{Age}^{A,\,Age\_class} \cdot (age^2 - age^1) + \delta_{Mileage}^{A,\,Age\_class} \cdot (mileage^2 - mileage^1)$
    = 15,000 € + (184.05 €) (26 mo. − 24 mo.) + (37.50 €) · (35 km − 30 km)
    = 15,555.60 €.

Discussion box

For various reasons used cars is a tricky topic in the price index and may have deceptive pitfalls. Reservation must therefore be made that optimal advice may not yet have been found.

4 Computers

- The Task Force on Quality Adjustment and Sampling rated hedonics as an A-method. 100 % option pricing (for desktops), supported judgement as a proxy to 100 % option pricing, and bridged overlap (applied under certain conditions) were assessed as B-methods.

- The empirical studies of the CENEX members showed that hedonic re-pricing is more suitable than bridged overlap for desktop computers, whereas both methods yield similar results for notebooks. Furthermore, the empirical studies showed some difficulties regarding the application of 100 % option pricing for both desktops and notebooks.

- The following section deals with the application of bridged overlap for notebooks and 100% option pricing for desktops.

4.1 Proposal for the identification of consumption segments

- Computers are covered by COICOP class 09.1.3. The proposal is to form two consumption segments:
  - "desktops" and
  - "notebooks".

- Reason: If the criterion of mobility is applied, desktops and notebooks serve two different consumption purposes. Desktops are used mostly at home whereas notebooks can be used anywhere. Another criterion stated in Regulation (EC) No. 1334/2007 is that a consumption segment is formed by product-offers which "can largely be described by a common specification". This can be applied in the case of computers to form the consumption segments: notebooks combine display and computer, desktops do not.

- This identification is also in alignment with the Draft Report of the Task Force Classification COICOP/HICP (November 2005).

Weighting of the consumption segments

- The consumption segments should be explicitly weighted. Weights should ideally be based on the relative expenditure shares of desktops and notebooks. Information about the expenditure share can be obtained for example from market research institutes, from retail trade organisations or by an own (internet) survey. Another source could be the regular official survey based on Regulation (EC) No. 808/2004 concerning the Community statistics on the information society.

- If only sales frequencies are available the expenditure share could be obtained by multiplying the respective sales figures by a roughly estimated average price of both desktops and notebooks. A roughly estimated average price could stem from a small market survey from the collected prices of preceding periods.

4.2 Proposal for the construction of a target sample

- It is suggested to first select outlets, since usually information on the sales frequencies of specific models is either not available or changes too fast to be used as a starting point. Subsequently, representative models are chosen within the outlets.

Chart 71
Proposal for the construction of a target sample

> **outlets › models**
>
> (1) Choose outlets which are relevant for computers, accounting for the regional dimension.
>
> (2) Choose representative models in the outlets.

- In the following it will be described how to proceed with these two steps for computers.

(1) Choose outlets which are relevant for computers, accounting for the regional dimension

- In the case of computers it is likely that in such a highly competitive market the price development is identical across the country. Generally, regional market power of a certain outlet is not given. The market is highly transparent as consumers can use the internet for price comparisons. Computers are standardised products which are available from different outlet types. A central price collection may therefore be suitable.

- Online price collection is suggested as this is a very efficient way of collecting prices and characteristics. Computer stores, especially the larger ones, usually have websites advertising the computers they have on sale. Internet is also the only available source for computer sellers that operate online through their websites such as Dell. A practical way is to choose outlets first and then to check whether the prices in these outlets can be observed online. In each outlet, several observations should be made in order to increase efficiency.

- If not enough models can be observed using online sources, additional price collection in physical stores is necessary. In that case, again several observations should be made in individual outlets.

- If, in a certain country, in spite of the transparent market price developments should differ significantly throughout regions prices should be collected locally: A procedure like the following may be used.
  - Distinguish between large/small retailers and mail order/stationary retailers.
  - Include the largest retailers in any case. Check whether or not the large retail chains have the same pricing policy in the entire country. If yes, prices can be centrally observed in big retail chains. If not, prices have to be observed locally taking into account the regional variance of price developments.
  - Include a sample of small retailers. This could be done by probability sampling if data can be obtained from the business register of your respective national statistical office. If information from the business register is not available, choose relevant regions and within the regions select typical outlets (just as you do for other products of the HICP).
  - If prices are collected locally check whether mail order selling is relevant in the market. If this is the case prices should be collected from the internet or catalogues additionally.

(2) Choose representative models in the outlets

- For the target sample, those models should be observed that are representative of the sales of the outlet where they are observed. A good rule of thumb is that any model that is fairly new or clearly visible in the outlet (on display or on its webpage) is very likely representative. Sales staff can also help select the most sold computers.

Minimum size of the target sample

- A number of 25 to 30 product-offers may be suggested as a normal rough minimum bound for sample size of computers, where no more specific indications are present.

Additional aspects when applying option pricing (desktops only)

- When applying option pricing it is necessary to collect not only the prices of models. Additionally, characteristics of the chosen models and their respective prices (= option prices) have to be collected in order to apply option pricing.

- The following characteristics are may be suggested for observation. (These characteristics are examples resulting from the empirical studies by the CENEX members.)
  - Processor type (e.g. Celeron, Pentium IV, . . .).
  - Processor speed (in MHz).
  - Hard disk capacity (in MB/GB).
  - Working memory (in MB/GB).
  - Operating system (Windows XP, Linux, none, . . .).
  - Other software (MS Office, . . .).
  - Type of drive (CD-rewriter, DVD player/rewriter, . . .).

- Other characteristics may be relevant as well.

4.3   Proposal for the replacement strategy

General remarks

- Given the rapid technological change of computers, replacing old models will be a frequent task. Many of the replacements will be voluntary: when a model is judged not to be representative anymore it should be replaced, even if it is still available. Forced replacements will probably be frequent as well.

- A replacement model should be observed in the same outlet as the replaced model and it should be representative of computer sales in that outlet. A model that is a suitable replacement in one outlet may not be suitable in another one, because not every outlet will have the same models available.

- Note that similarity of the replacement model with the old model is not relevant. Only its representativity for the sales of the outlet where it is selected is important. Also, the reason for its disappearance is not relevant.

- Similarity may only play a role when there are several equally representative replacement models available.

- In the case of online price collection the price statistician from the office will often also be the one who collects the prices. The price statistician will thus be constantly up to

date regarding current developments in the computer market. A representativity check in the office is therefore not explicitly mentioned here. Additionally, when using bridged overlap for notebooks it is not relevant to explicitly observe characteristics.

Representativity check within the scope of the monthly price collection

- Ideally, there could be reason to have the sample refreshed every month. As it would not be desirable to have no or only a few models with a match in the previous month it is suggested to use the models that were in the sample in the previous month as a starting point for the price collection of the current month in order to keep the share of matched models reasonably high.

- During the collection process, the price collector should ask him or herself for each model that was observed in the previous month, whether this model is still representative. If the model is still available, the answer will usually be "yes", as models that are out of date will disappear very quickly.

- If the answer is "yes", the collector should quote the current price. If the answer is "no", the collector should select a new model that is judged to be representative. No effort should be made to try to find a replacement model that is similar to the old one. Similarity to disappearing models is of no relevance at all. This is a very important point.

- Similarity to the predecessor may only play a role when the price collector can choose between multiple equally representative replacements.

Additional aspects when applying option pricing

- Given the rapid technological change of computers, new features are included with certain regularity. This is not so frequent that it would be necessary to select a new set of relevant characteristics every month, but the price statistician should be aware of the possibility. Whenever a new characteristic (say, a new kind of processor or a new drive) is introduced, the price statistician should judge whether the new characteristic is important enough to be included. Ideally, this would happen only a few times each year.

- Of course, a new characteristic can only be considered for quality adjustment if this characteristic is collected in both the previous and the current month.

4.4   Proposal for the quality adjustment

I.   Bridged overlap (notebooks only)

- Matched models can be directly compared.

- If an old model is replaced by a new one bridged overlap shall be applied. The price development of all other (matched) notebooks is used as the bridge.

Replacement to ensure representativity

Chart 72
Replacement to ensure representativity

target universe   replacement to ensure   regular judgemental
representativity   representativity checks
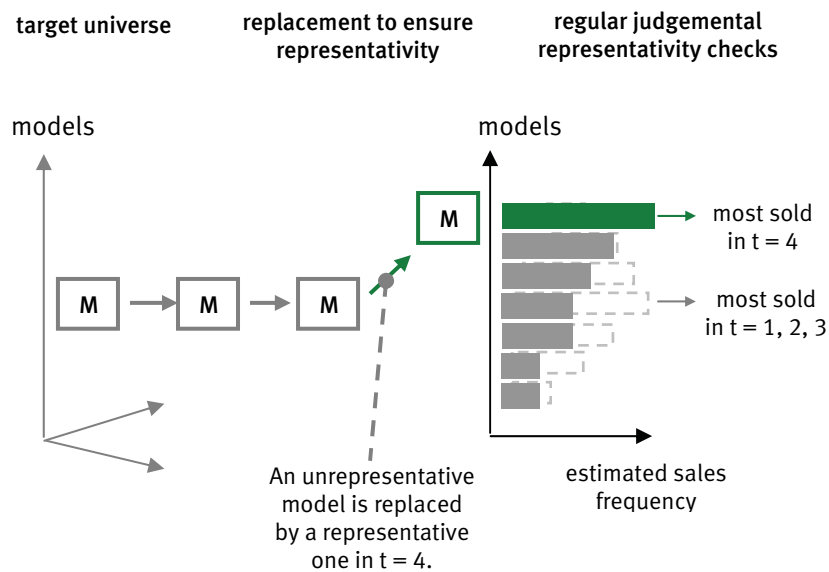
- In order to adjust for the quality change between replaced and replacement model the price development of all other observed models is used as bridge (see below).

Chart 73
Bridged overlap with a real price increase
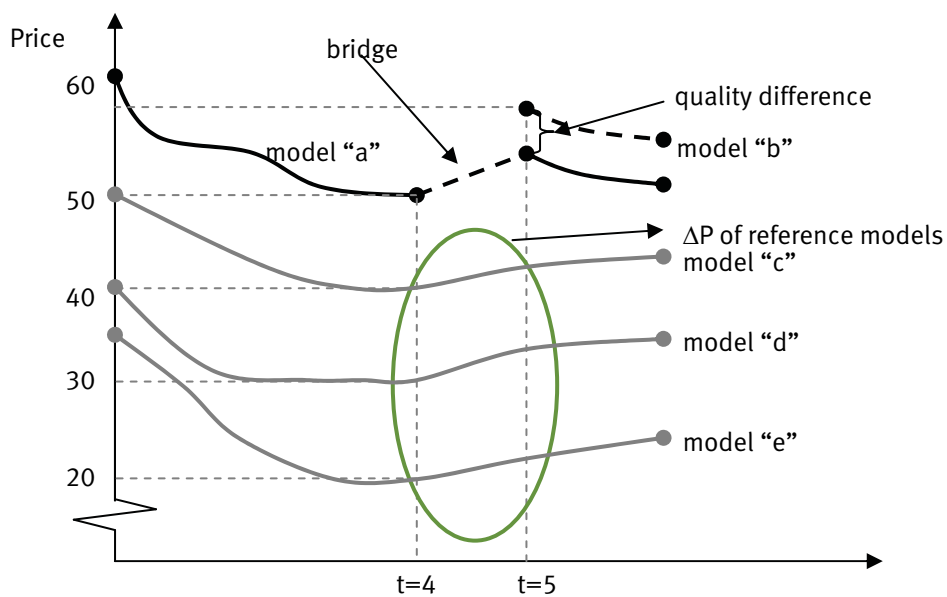
II. Option pricing (desktops only)

- For most products, option pricing is used when a certain feature of a product, like air conditioning in a car, used to be an option but has now become standard. Hence the name "option pricing". For computers, it is used in a slightly different way. Here, we use option pricing to adjust for the price differences of a certain feature, when the replacement model has a different variant of that feature than the old model. For example, when the replacement model has a hard disk of 200 GB and the old model one of 100 GB, option pricing adjusts for the price difference of these hard disks.

- The following characteristics are suggested for observation:
    - Processor type (e.g. Celeron, Pentium IV, . . .).
    - Processor speed (in MHz).
    - Hard disk capacity (in MB/GB).
    - Working memory (in MB/GB).
    - Operating system (Windows XP, Linux, none, . . .).
    - Other software (MS Office, . . .).
    - Type of monitor, including size (TFT or not, . . .).
    - Type of drive (CD-rewriter, DVD player/rewriter, . . .).

- If a model can be observed in two subsequent periods (matched model) the prices of the previous and the current period can be directly compared.

- If a change in one of the characteristics above occurs option pricing shall be applied. For desktops, 100 % option pricing is suggested. Let us assume that an optional hard disk capacity of 100 GB is available at a price of 40 Euros. For the above mentioned example, this means that the price of the replacement model is adjusted by 40 Euros.

- For option pricing, we need information on three aspects:
    - We need to link specific replaced models with specific replacement models. Replacement models are called successors in this case.
    - We need to know the differences between replaced models and their successors, both qualitatively and quantitatively.
    - We need to know the option prices of these particular differences.

- Given this information, we can calculate the quality-adjusted price of either the replaced models or the successors. For product groups with a high rate of turnover, like computers, we generally do not know beforehand when a model will be replaced. In practice, option prices can then only be collected in the period when the successor is introduced. It is possible to adjust the price of the replaced model as well as to adjust the price of the replacement model with regards to the same option prices.

- In the example provided below the price of the replacement model is adjusted. In that case, the quality adjustment is applied to the price of the successor and this price is compared with the unadjusted price of the replaced item.

- Therefore:

  Observed price of the replacement
  - \+ Option prices of the characteristics in which the replaced model differs from the replacement
  - − Option prices of these characteristics of the replacement
  _____
  - = Quality adjusted price of the replacement

- Or more formally:

$$\hat{p}_{i\in N}^{y,m} = p_{i\in N}^{y,m} + \left(\sum_{k} b_{kj}^{y,m} - \sum_{k} b_{ki}^{y,m} \right)$$

  Here i is the successor and j the replaced model. Furthermore, $\hat{p}$ denotes the estimated price, p the observed price in year y and month m. The characteristics are denoted by k and their values, as expressed in option prices, are denoted by b_k.

- Example of the calculation:

  Suppose i and j are two desktops that are identical in every aspect except for their hard disk. Computer I has a hard disk of 200 GB and computer j a hard disk of 100 GB. When bought separately in the current month, a 200 GB hard disk would cost 100 €, whereas a 100 GB hard disk would cost 40 €.

  Observed price of the replacement
  - \+ 40 €
  - − 100 €
  _____
  - = Quality adjusted price of the replacement

  - → Subtract 60 € from the observed price of the successor to obtain the quality ad justed price of the replacement.

Drawbacks of 100 % option pricing for desktops

- The empirical study on computers conducted within the scope of the CENEX project did not necessarily yield reliable results for option pricing.

- There are several other problems with option pricing:
  - We need to be able to determine in which respects the replacement and the successor differ.
  - We need a monetary value of the characteristics in which these models differ from each other. With option pricing, one chooses explicitly to collect additional prices to determine these values. This places a huge burden on data collection, as one needs not only information on prices and characteristics of the models in the sample, but also on the prices of these characteristics.

- The biggest problem with the option pricing method is that one cannot be sure whether the option prices correctly reflect the price differences of these characteristics when sold as part of a computer as opposed to bought separately. Moreover, on some char-

acteristics it will not be possible at all to collect these separate prices. Especially for replaced models, the option prices may not be available because these particular options are not available anymore.

- Since we lack any information on the reliability of these additional option prices, we cannot assume that option pricing leads to a reliable quality adjustment in the case of computers. In that case, an implicit quality-adjustment method like bridged overlap may result in an index that is as good as an index that was quality-adjusted using option pricing.

4.5   Cost estimation

One-time effort for the introduction

- With regard to bridged overlap and option pricing, there is no more effort than setting up an initial sample (which should be done anyway, regardless of quality adjustment).

Current effort of price collection

- With regard to bridged overlap, there is the same effort as for other product groups or segments without explicit quality adjustment.

- With regard to option pricing, besides the prices of the product-offers, also characteristics need to be observed. This effort is the same as for the hedonic approach and requires the same expertise. In the month where a model is replaced, the option prices for the features in which the new and old models differ need to be collected in the same store. This may be the task of the price collector and therefore requires some technical expertise. The amount of extra time depends on the number of replacements and thus on the sample size.

Current effort of index calculation

- With regard to bridged overlap, there is the same effort as for other product groups or segments without explicit quality adjustment.

- With regard to option pricing, price changes of replacements are adjusted using option prices. This requires knowledge about the option price method. Since this method is fairly widespread among NSIs, this probably does not require additional expertise from the price statistician. The amount of extra time necessary for quality adjustment depends on the number of replacements and thus on the sample size. It should not exceed one day.

4.6   Examples

- In the following an example for the application of bridged overlap is described which is only relevant for notebooks.

Example of the construction of the target sample

- For the pre-selection of outlets where relevant notebooks are sold we distinguish between large and small sellers. Once this distinction is finished we can determine concrete outlets. The distribution of the sales across point of sales might look like this:

Chart 74
Pre-selection of outlet types

Large seller 1	Large seller 2	Small sellers
40 %	40 %	20 %

- Two large sellers cover 80 % of the market while the sales by small sellers make up 20 % of the market. Large sellers should be included in any case. Furthermore, a probability sample should be taken from all small sellers. The regional dimension has to be considered.

- Then, it has to be determined which share of the sample has to be observed in which outlet types. The following table will help to do so. For our example we assume that 30 price observations are required. The following table shows how many notebooks have to be observed in which shop (numbers rounded):

Chart 75
Matrix containing numbers of observations to be included

	Large seller 1	Large seller 2	Small sellers (prob. sample)
	40 %	*40 %*	*20 %*
Notebooks	12	12	6

- In a next step the price collector would be instructed to collect prices in an outlet of large seller 1. He might be provided with the following price collection form:

Chart 76
Price collection form

Notebook in outlet x of large seller 1

Price (€):	799.–
Processor type:	Intel Core2 Duo T8100
Processor speed (GHz):	2,200
Hard disk drive capacity (GB):	60
Working memory (MB):	1,024
Operating system:	Windows XP
Other software:	–
Type of display:	LCD
Size of display (inch):	15.4
Type of drive:	DVD writer
Graphic card:	nVidia GeForce 8000M GS
Brand and model description:	xxx
Other features:	–
Shop: _____	
Date: _____	

Example for quality adjustment

In this example model D1 is replaced by model D2 in month 3. Therefore, a quality adjustment should be done by applying bridged overlap.

Chart 77
Bridged overlap for notebooks

Model	Brand	Price in month 1	Price in month 2	Price in month 3
A	DELL	799.– €	799.– €	699.– €
B	DELL	599.– €	599.– €	599.– €
C	DELL	599.– €	599.– €	599.– €
Average price of models 1 – 3 without quality adjustment (geometric mean)		659.– €	659.– €	631.– €
Average price change of models 1 – 3 without qualitiy adjustment (in %)			0.0	– 4.4
D1	DELL	810.– €	810.– €	
D2	DELL		680.– €	650.– €
Average of directly observed prices		694.– €	694.– €	635.– €
Quality adjusted average price			664.– €	
Price change (in %)			0.0	– 4.4
Monthly indexes		*100.0*	*100.0*	*95.6*

A bridge is needed to reflect and apply the price change of all unchanged notebooks to the new model D2. The bridge is taken from the average prices of models A to C. The price change of these models from month 2 to month 3 is – 4.4 %. Model D2 has a price of 650.– € in month 3 and the imputed price for the previous month can now be calculated:

650.– € / 0.956 = 680.– €   with 0.956 = 1 – 0.044

The quality adjusted average price in the previous month amounts to 664.– €. The result on the basis of this quality adjusted average price is a quality adjusted price change of – 4.4 % and a decline of the index from 100.0 to 95.6.

5   Washing machines

- For washing machine market, the Task Force on Quality Adjustment and Sampling rated explicit methods (hedonics and option pricing) as A-methods. Implicit methods (bridged overlap) are assessed as B-methods.

- The following section deals with the application of bridged overlap for washing machines.

5.1   Proposal for the identification of consumption segments

- Household appliances are covered by COICOP group 05.3. Among others, washing machines are one major item in this category.

- One consumption segment should be built for each of the products relevant in the category household appliances (e.g. fridge, freezer, cooker, microwave, [vacuum] cleaner, washer-dryer etc.). In the following a detailed guidance for washing machines is described.

- One consumption segment named "washing machines" is suggested, including all washing machines but excluding washer-dryers, which should be treated separately in another consumption segment.

- Reason: All washing machines are marketed for predominant use in similar situations, serving the same consumption purpose. Washer-dryers have an additional purpose (drying).

5.2   Proposal for the construction of a target sample

- A stratification of the target universe according to model types is suggested, followed by a pre-selection of the relevant model types. Subsequently, outlets should be chosen which are relevant for the type of good. Market information on the sales figures of models can be obtained either from market research institutes or through a small field survey. In the selected outlets, representative models which belong to the pre-selected model types should be chosen for price observation.

Chart 78
Proposal for the construction of a target sample

model types › outlets › models
(1)   Stratify the target universe according to model types.
(2)   Pre-select relevant model types.
(3)   Choose outlets which are relevant for the type of good, accounting for the regional dimension.
(4)   In the outlets, choose representative models which belong to the pre-selected model types.

(1) Stratify the target universe according to model types

- For washing machines, model types might be characterised by the type of washing machine (e.g. front or top loader) and by their capacity.

- Carry out an evaluation on which types of washing machines are available (e.g. front loader, top loader) and on how large their market share is.

- Additionally, evaluate the available capacities so that stratification by capacity classes can be applied.

- Stratify for example by
  - a) Washing machine type: top loader – front loader.
  - b) Capacity: up to 5 kg – between 5 kg and 7 kg – more than 7 kg.

Chart 79
Example of stratification: Market shares in percentage of sales volume

Overview of washing machine market	Front loader	Top loader
Capacity: up to 5 kg	22	8
Capacity: 5 – 7 kg	53	7
Capacity: more than 7 kg	10	0

(2) Pre-select relevant model types

- The strata with the biggest market shares are successively selected until 50 to 80 % of the total market are covered. This means that the strata with a small market share will not be included in the sample (cut-off sampling).

- Another possibility to pre-select model types would be probability sampling. In this case the market shares of all strata are reflected by the number of observations of the respective strata.

- The result of the pre-selection will be a list containing the pre-selected washing machine types plus a guiding value for the respective capacity class. This list can be passed to the price collector for the selection of concrete models.

(3) Choose outlets which are relevant for this type of good, considering the regional dimension

- An idea for sampling outlets could be as follows.
  - Distinguish between large/small retailers and mail order/stationary retailers.
  - Include the largest retailers in any case. Check whether or not the large retail chains have the same pricing policy in the entire country. If yes, prices can be centrally observed in big retail chains. If not, prices have to be observed locally taking into account the regional variance of price developments.
  - Include a sample of small retailers. This could be done by probability sampling if data can be obtained from the business register of your respective national statis-

tical office. If information from the business register is not available, choose relevant regions and within the regions select typical outlets (just as you do for other products of the HICP).

– Prices from small retailers should be observed locally in general (under consideration of regional variations in price development).

– If mail order selling is relevant in the market it should be covered by collecting prices from the internet or catalogues additionally.

(4) In the outlets, choose representative models which belong to the pre-selected model types

• Within the chosen outlets, select washing machines which are best sold corresponding to the pre-selected strata.

• Which washing machines are best sold in the respective strata should be determined by the price collector after consulting a shop assistant. If this is not practicable the price collector can also revert to indicators such as the way the product is advertised or presented in the shop or he might also revert to his experience. A model that is clearly visible in the store could, for example, be judged to be representative.

Minimum size of the target sample

• A number of 25 to 30 models seems reasonable to represent the consumption segment. Large countries may, however, need a higher number of price observations depending on their regional variance of price development.

5.3   Proposal for the replacement strategy

• The stratification from the target sample is used to set up the product specification for replacement, i.e. the replacement should be chosen from the same stratum. Additionally, the replacement model should always be selected from the same brand cluster.

• A classification of brand clusters for washing machines can be obtained from the PPP statistics (Purchasing Power Parities – price indices comparing the national price levels). The available brand cluster lists of the PPP classify washing machines into higher, medium, and lower brands. In these lists, not all available brands are classified. Missing brands should be assigned by personal judgement.

Chart 80
Extract from the PPP classification (adapted for washing machines)

Brand cluster	Assigned brands
Higher	AEG-ELECTROLUX, BOSCH, DYSON, MIELE, SIEMENS
Medium	ARISTON, BAUKNECHT, CANDY, ELEKTRA BREGENZ, ELECTROLUX, EUDORA, GORENJE/KÖRTING/MORA, HOOVER, LG, SAMSUNG, WHIRLPOOL, ZANUSSI
Lower	BEKO, BRANDT, DAEWOO, EUROTECH, FAGOR, KONCAR, HOTPOINT, INDESIT, SANYO

Source: Eurostat (Lot C), European Comparison Programme: Consumer price survey E07-1
"House and garden" Particular survey guidelines

- The result is a product specification that is characterised by three dimensions, namely washing machine type, capacity and brand cluster. A replacement might, for example, be chosen so that it fits the description "front loader, 6 kg capacity, higher brand".

Representativity check within the scope of the monthly price collection in the shop

- Use the concrete washing machine models that were in the sample in the previous month as a starting point for the price collection of the current month in order to keep the share of matched models reasonably high. However, the main criterion for the selection of replacements should be representativity.

- The price collector should check whether or not the models of the previous month are still representative of the corresponding stratum and brand cluster in the current month. The price collector should assess this with the help of the shop assistant. If this is not practicable the price collector can also revert to indicators such as the way the product is advertised or presented in the shop or he might also revert to his experience.

- If the model of the previous month is still representative of the stratum and brand cluster, continue to observe the price for this model.

- If the model is no longer representative or if it is no longer available replace it by a representative one from the same stratum and brand cluster – if available. The new model would then be
    - of the same washing machine type (front loader, top loader),
    - of the same capacity (up to 5 kg – between 5 and 7 kg, more than 7 kg),
    - of the same brand cluster (higher – lower brand).

- If possible, try to find a replacement that is still representative but is so similar to the replaced model that the changes in the characteristics between replaced and replacement model do not constitute a major change. Those characteristics that cause a major change in quality are for example changes in brand cluster, waterproofing, energy label, revolutions per minute (see section "proposal for quality adjustment").

- If such a replacement cannot be found for lack of representativity, a replacement has to be selected which differs in the characteristics causing a major change within the product specification.

- If no model is available from the same stratum the replacement has to be chosen from the target universe, making a compromise between representativity and similarity to the replaced model. The replacement could, for example, be of the same washing machine type but of a different capacity. In this case, the initial product specification must be adjusted by the national statistical office to the current developments in the washing machine market as soon as possible.

Representativity check in the office

- As the market for washing machine is relatively stable with regards to technological progress, a yearly representativity check might be sufficient. Nevertheless, the market should be observed for general changes such as new equipment features, new brands, and technological trends in general.

- If the pre-selected strata and product specifications are still representative, carry on using them. If not, adjust the product specifications to the current market circumstances by the annual re-sampling.

5.4 Proposal for the quality adjustment

- A distinction in minor and major changes helps decide whether a quality adjustment is necessary. In general, major changes require a quality adjustment whereas minor changes do not.
- Minor quality changes could for example be:
  - construction type (freestanding – built-in possibility),
  - display of remaining time (yes – no),
  - time manager (yes – no).

  If minor changes occur the prices can be directly compared.

- Major changes within the same product specification would be changes in:
  - change in the brand cluster (e.g. from medium to low),
  - waterproofing (high – low),
  - energy label (high – low, with respect to power consumption, water consumption, spin efficiency),
  - revolutions per minute (e.g. up to 1400 rpm – more than 1400 rpm).

  If major changes within the same product specification occur, bridged overlap shall be applied. The price development of the remaining models in the same product specification is used as the bridge. (If the price collector was forced to choose a replacement from outside the product specification because there was no representative model available in the initial product specification, the price development of the models in the initial product specification is used as the bridge. Re-sampling should then be carried out as soon as possible.)

- Major changes normally accompanied by re-sampling would be:
  - change of the capacity class,
  - change in the washing machine type (e.g. from top loader to front loader).

Chart 81
Quality adjustment for minor and major changes
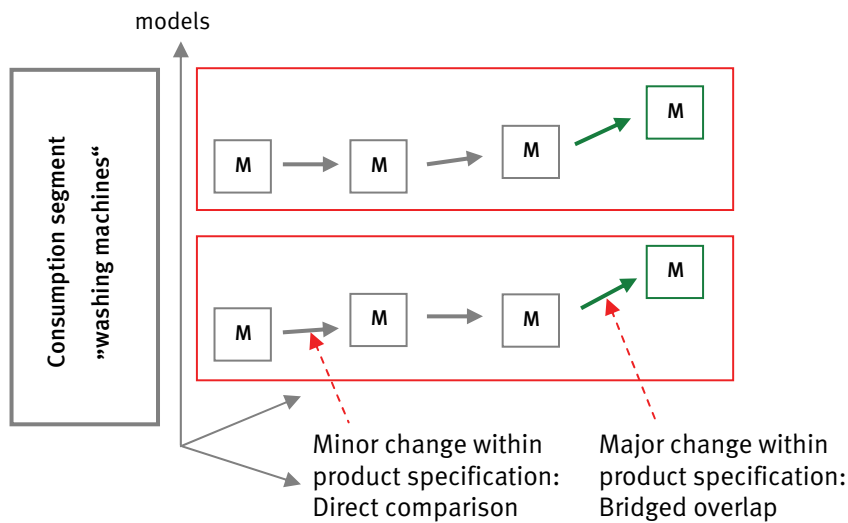
5.5 Cost estimation

One-time effort for the introduction

- There is no more effort than setting up an initial sample (which should be done anyway, regardless of quality adjustment). Up to three months seem necessary to perform an initial design study on data requirements and market research as well as testing new price collector forms etc. in order to set up an initial sample.

Current effort of price collection

- No expert knowledge necessary, instruction with concrete guidelines is sufficient.
- Monthly collection of prices and characteristics: 2 days.
- Entry of prices and quality-adjusted prices into database: 1 hour.

Current effort of index calculation

- Qualification: market knowledge and economic expertise
- Index calculation: 1 hour per month

5.6 Examples

Example of the construction of the target sample

The field survey on available washing machine types and capacities in one exemplary country has yielded the following stratification results:

Chart 82
Example of stratification: Market shares in percentage of sales volume

Overview of washing machine market	Front loader	Top loader
Capacity: up to 5 kg	**22 %**	8 %
Capacity: 5 – 7 kg	**53 %**	7 %
Capacity: more than 7 kg	10 %	0 %

The stratum with the largest market share of 53 % is front loaders with a capacity of 5 – 7 kg. This is the first stratum to be pre-selected. The second stratum that is pre-selected is front loaders with a capacity of up to 5 kg. The two strata pre-selected so far add up to 75 % of the total sales. This is sufficient. Only these two strata are considered in the following.

The pre-selection of model-types is finished. We now have to pre-select outlet types. We distinguish between large and small sellers. Once this distinction is finished we can determine concrete outlets. The distribution of the sales across points of sales might look like this:

Chart 83
Pre-selection of outlet types

Large seller 1	Large seller 2	Small sellers
40 %	40 %	20 %

Two large sellers cover 80 % of the market while the sales by small sellers make up 20 % of the market. Large sellers should be included in any case. Furthermore, a probability sample should be taken from all small sellers.

The next step is to determine how many washing machines will have to be observed in which outlets. First it has to be calculated how large the shares of the two pre-selected segments are in the sample.

Chart 84
Shares of pre-selection strata

Overview of washing machine market	Share of total sales (in %)		Share in the sample (in %)
Front loader (capacity up to 5 kg)	22	→	29
Front loader (capacity 5 – 7 kg)	53	→	71
Total	**75**	→	**100**

Then, it has to be determined which share of the sample has to be observed in which outlet-types. The following matrix will help to do so. It refers to the tables above.

Chart 85
Shares matrix

	Share in the sample (in %)	Large seller 1	Large seller 2	Small sellers
		in %		
		40	40	20
Front loader (up to 5 kg)	29			
Front loader (5 – 7 kg)	71			
Total	100			

For example, in order to find out how many front loaders with a capacity of 5 – 7kg to observe in the outlet of large seller 1, multiply 71 % by 40 % and you obtain a value of 28.4 %. The resulting table looks like this:

Chart 86
Completed shares matrix

	Share in the sample (in %)	Large seller 1	Large seller 2	Small sellers
		in %		
		40	40	20
Front loader (up to 5 kg)	29	11.6	11.6	5.8
Front loader (5 – 7 kg)	71	28.4	28.4	14.2
Total	100			

For our example we assume that 30 price observations are required. The following table shows how many front loaders of which capacity class have to be observed in which shop (numbers rounded):

Chart 87
Matrix containing numbers of observations to be included

	Share in the sample (in %)	Large seller 1	Large seller 2	Small sellers
		in %		
		40	40	20
Front loader (up to 5 kg)	29	3	3	2
Front loader (5 – 7 kg)	71	9	9	4
Total	100	12	12	6

In this example it is assumed that both large sellers pursue a pricing strategy that is identical across all regions within one country. Therefore, it is does not matter in which outlets of the large retailers the prices are finally observed.

In a next step the price collector would be instructed to collect prices of e.g. four washing machines of the type "Front loader, capacity of 5 – 7 kg, higher or medium brand" within one outlet of large seller 1. He might be provided with the following price collection form:

Chart 88
Price collection form

Washing machine, front loader, capacity of 5 – 7 kg, higher brand	
Price (€):	649.–
Brand and model description:	Bosch WAS 28440
Capacity (kg):	7
Waterproofing:	☒Yes　　☐ No
Maximum spin speed (rpm):	1400
Shop: _____	
Date: _____	

Example: Minor change within the same product specification

In month 3, Model 3a was no longer representative and has therefore been replaced by model 3b (see chart 89).

Chart 89
Washing machines collected within the product specification
"front loader, 5 – 7 kg, higher brands" – minor changes

Model	Brand	Type	Capacity	Price in month 1	Price in month 2	Price in month 3
1	Bosch	WAS 28440	7 kg	649.– €	649.– €	629.– €
2	Miele	W1614	6 kg	819.– €	819.– €	819.– €
3a	AEG-Electrolux	Lavamat 64840	6 kg	599.– €	599.– €	
3b	Siemens	WM 14 E 421	7 kg			499.– €
Average price (geometric mean, rounded)				683.– €	683.– €	636.– €
Price change (in%)					0	– 6.9
Index value				100.0	100.0	93.1

The change between models 3a and 3b is evaluated as a minor change in the model characteristics as the only difference is, for example, the existence of a time manager. Therefore no quality adjustment is necessary. The price of the replacement washing machine Siemens is compared directly to the price of the replaced AEG-Electrolux.

The sixth line of the matrix above shows the average price (geometric mean). The average prices for month 1 and month 2 are the same and therefore the average price change is 0.0 %. In month 3, if prices are compared directly we can see a price decline for the Bosch from 649.– € to 629.– € and for the Siemens replacing the AEG-Electrolux from 599.– € to 499.– €. This results in a decrease of the average price from 683.– € to 636.– € and thus in a price change of − 6.9 %.

Example: Major change within the same product specification

In this example the change in the model specification from model 3a to model 3b is assessed to be a major quality change. A quality adjustment should be done. In the following example the AEG-Electrolux model is replaced by a Samsung which is assigned to the medium brand cluster. To adjust for this difference in brand class cluster bridged overlap is applied.

Chart 90
Washing machines collected within the product specification
"front loader, 5 – 7 kg, higher brands" – major changes

Model	Brand	Type	Capacity	Price in month 1	Price in month 2	Price in month 3
1	Bosch	WAS 28440	7 kg	649.– €	649.– €	629.– €
2	Miele	W1614	6 kg	819.– €	819.– €	819.– €
Average price of models 1 − 2 without quality adjustment (geometric mean)				729.– €	729.– €	718.– €
Average price change of models 1 − 2 without quality adjustment (in %)					0.0	− 1.6
3a	AEG-Electrolux	Lavamat 64840	6 kg	599.– €	599.– €	
3b	Samsung	WFB 146 NV White	6 kg		456.– €	449.– €
Average of directly observed prices				683.– €	683.– €	614.– €
Quality adjusted average price					624.– €	
Price change (in %)					0.0	− 1.6
Monthly indexes				100.0	100.0	98.4

A bridge is needed to reflect and apply the price change of all unchanged washing machine models to the new Samsung model. The bridge is taken from the average prices of models 1 and 2. The price change of these models from month 2 to month 3 is − 1.6 %. The Samsung washing machine has a price of 449.– € and the imputed price for the previous month can now be calculated:

$$449.– € / 0.984 = 456.– € \qquad \text{with } 0.984 = 1 − 0.016$$

The quality adjusted average price in the previous month amounts to 624.– €. The result on the basis of this quality adjusted average price is a quality adjusted price change of − 1.6 % and a decline of the index from 100.0 to 98.4.

6   Books

- As a first step the COICOP four-digit-level 09.5.1 Books is divided into two headlines: "rapidly-changing market" and "long-selling market". In the following, both headlines are treated separately as they require different approaches:
  - Rapidly-changing market ("changing-product principle"): Applicable to products which have relatively short commercial life-spans and high rates of introduction of new products (books for children, books for leisure and culture including recently published books).
  - Long-selling market ("constant product principle"): Applicable to products that have relatively long commercial life-spans and low rates of introduction of new products (schoolbooks, dictionaries, encyclopaedias, evergreens and the like).

- The HICP standards rate hedonics as an A-method in the rapidly-changing market. Direct comparison and single variable adjustment (using the logarithm or square root of the number of pages) are rated as B-methods. For the long-selling market direct comparison is rated as an A-method, whereas a careful application of overlap and bridged overlap is rated as a B-method. If applied automatically, overlap and bridged overlap must be regarded as C-methods.

- For the rapidly-changing market the empirical studies of the CENEX showed that the index with hedonic adjustment exhibits the smallest volatility followed by the index with adjustment by the natural logarithm of the number of pages and an index based on average prices. The index with linear adjustment by the number of pages exhibits the highest volatility. This result stresses once more that a single variable adjustment has to be treated with some caution. The assumption that the price of one page of a small book is equal to the price of one page of a thick book does not seem to hold. Therefore, an adjustment with the natural logarithm is more sensible.

- The following section deals with the application of
  - direct comparison of bestseller lists in the rapidly-changing market, and
  - a combination of direct comparison and expert judgement in the long-selling market.

6.1   Rapidly-changing market

- In the rapidly-changing market, the price collection should be focused on individual titles that are representative in a given time frame. In the case of individual titles such a time frame is rather short. Therefore the subset of individual book titles that is relevant for price collection can be very unstable. Suppose that, in the book market, the universe of price movements could be followed directly. Even then it would not be easy to make an objective assessment of the price movements in a very volatile market where most of the products have a very short life cycle. The reason is that in such a market the detection of price movements will probably be more a matter of comparison between different books in subsequent points of time, than instead a matter of observing the price evolution of the same book during a certain time span. The strategy of price collection should take account of this.

6.1.1 Proposal for the identification of consumption segments

- Consumption segments can be built following the Task Force "Classification COICOP/ HICP" (2005) with slight modifications:

Chart 91
Consumption segments following the Task Force Classification COICOP/HICP
for the rapidly-changing market

09.5.1	Books
09.5.1.1	Rapidly-changing market
09.5.1.1.1	*Fiction*
09.5.1.1.2	*Non-fiction (including biographies)*
	Children's books

- Alternatively, a different identification of consumption segments is possible. The required information could stem from a research study, which might be available at a national bookstore association or at a market research institute.

- Note: The application of a bestseller approach is may be more suitable if a bestseller list exists. Thus, if a bestseller list is available for children's books this consumption segment should be included in the rapidly-changing market. Otherwise it is part of the long-selling market.

Weighting of the consumption segments

- Explicit weights are assigned to the consumption segments. Information about weights can be obtained from the national association of bookstores, market research institutes (e.g. Media Control GfK International) or a big book store. Either detailed data can be provided or at least purposive weights can be assigned to the consumption segment based on the experience of the booksellers.

6.1.2 Proposal for the construction of a target sample

- The suggested sampling method is a bestseller approach.

- The way best known of keeping in touch with the most dynamic parts of the book market is the mirroring of readily available bestseller lists. Bestseller lists can take several specific forms. The price collector will have to decide if a specific bestseller list is suitable for the task. In any case, check the reliability of the bestseller list provider.

- The following chart shows the different possibilities for the construction of a target sample for books in the rapidly-changing market. The choice of the procedure thereby depends on the availability of bestseller lists at a national or local level.

- Please note that national bestseller lists are not generally preferred to local bestseller lists. Both approaches can be used depending on the index to be published. If only

a nationwide index is to be published then a national bestseller list of all book sales may be the more appropriate choice. If additionally regional indexes are to be published regional bestseller lists may the better choice.

Chart 92
Different forms of bestseller lists at several levels

bestseller

central

regional

List at a national level

shops

shops

Shop ➔ list of bestselling books
Shop ➔ list of bestselling books

Shop ➔ information provided by shop employees

Shop ➔ books placed prominently (space)

approximation
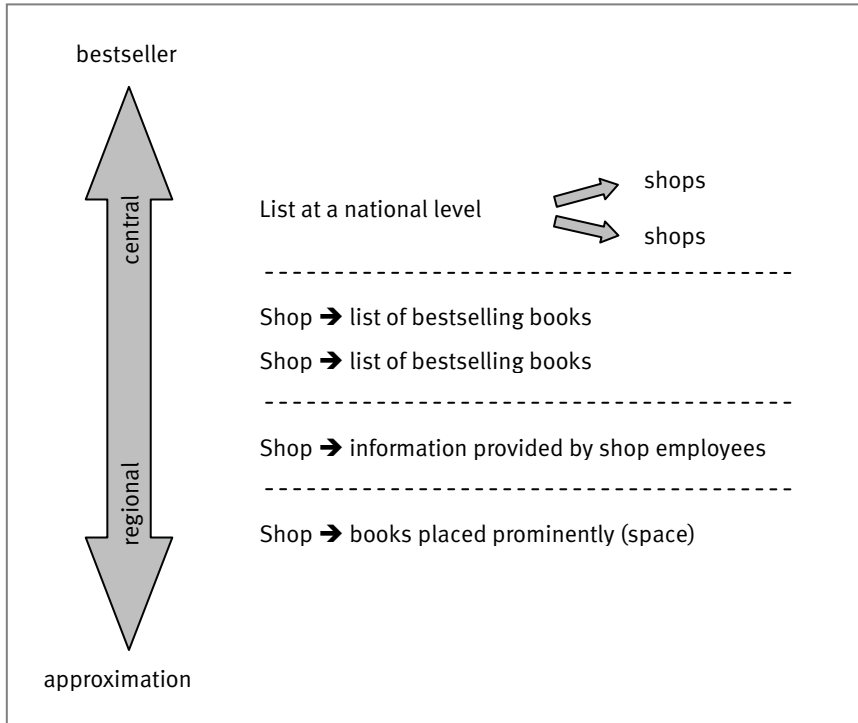
If a national bestseller list is used

- First, relevant models have to be chosen. If there is a national bestseller list available for the rapidly-changing market then the relevant models are known. Representative outlet types and particular outlets have to be identified under consideration of the regional dimension in the next step.

Chart 93
When using a national bestseller list

> **models › outlets**
>
> (1) Choose relevant models.
> (2) Choose representative outlets, accounting for the regional dimension.

(1) Choose relevant models

- Select the specific book titles from the national bestseller list by selecting the first *n* bestsellers from the list.

(2) Choose representative outlets, accounting for the regional dimension

- An idea for sampling outlets could be as follows.
  - Distinguish between large/small retailers and mail order/stationary retailers.
  - Include the largest retailers in any case. Check whether or not the large retail chains have the same pricing policy in the entire country. If yes, prices can be centrally observed in big retail chains. If not, prices have to be observed locally taking into account the regional variance of price developments.
  - Include a sample of small retailers. This could be done by probability sampling if data can be obtained from the business register of your respective national statistical office. If information from the business register is not available, choose relevant regions and within the regions select typical outlets (just as you do for other products of the HICP).
  - Prices from small retailers should be observed locally in general (under consideration of regional variations in price development).
  - If mail order selling is relevant in the market it should be taken into account by collecting prices from the internet or catalogues additionally.
  - In several countries, the prices for books are fixed. In these cases a central price collection is suitable and it is sufficient to select one outlet. The situation may, of course, differ from country to country so that a country-specific evaluation should be conducted before deciding on whether to collect prices centrally or locally.

Chart 94
Decision on central or local price collection

Fixed book prices
or similar price development throughout regions

Yes   No

Central price collection   Local price collection
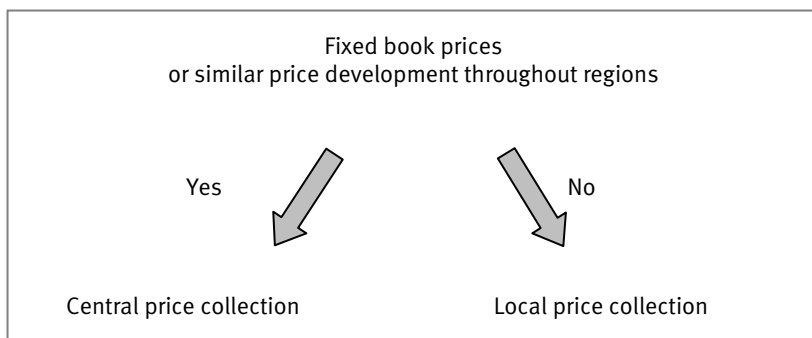
If a national bestseller list is not used

- If there is no national bestseller list available proceed in reversed order. First, select representative outlet types as well as particular outlets under consideration of the regional dimension. In these outlets, the most representative books have to be chosen.

Chart 95
When a national bestseller list is unavailable

> **outlets › models**
>
> (1) Choose representative outlets, accounting for the regional dimension.
> (2) Choose representative models in the outlets.

(1) Choose representative outlets, accounting for the regional dimension

- An idea for sampling outlets could be as follows.
    - Distinguish between large/small retailers and mail order/stationary retailers.
    - Include the largest retailers in any case. Check whether or not the large retail chains have the same pricing policy in the entire country. If yes, prices can be centrally observed in big retail chains. If not, prices have to be observed locally taking into account the regional variance of price developments.
    - Include a sample of small retailers. This could be done by probability sampling if data can be obtained from the business register of your respective national statistical office. If information from the business register is not available, choose relevant regions and within the regions select typical outlets (just as you do for other products of the HICP).
    - Prices from small retailers should be observed locally in general (under consideration of regional variations in price development).
    - If mail order selling is relevant in the market it should be taken into account by collecting prices from the internet or catalogues additionally.

(2) Choose representative models in the outlets

- Within the shop, the selection of specific book titles may be carried out in three different ways, depending on the availability of information:
    - In some cases shops provide local bestseller lists. The specific book titles can then be selected according to these local bestseller lists by choosing the first n bestsellers.
    - In other cases information can be obtained from shop employees.
    - Alternatively, prominently placed books (e.g. books placed on tables) can serve as an indicator for how well these books are sold. The rationale for this is that only the most recent titles with a significant market share are placed prominently. However, please be careful not to select special offers.

Minimum size of the target sample

- In the rapidly-changing market, a relatively high number of price observations is required in order to cope with the relatively high variance.

Chart 96
Rough guidance for the minimum size of the target sample

National bestseller list	Fixed book prices throughout the country	No fixed book prices
available	one small sample in one outlet is sufficient *small sample size*	the same items from the bestseller list are collected in different outlets *large sample size*
unavailable	different bestselling items have to be collected in different outlets *large sample size*	different bestselling items have to be collected in different outlets *large sample size*

Additional aspects

- The application of bestseller lists can have problematic aspects of its own.
  - Firstly, there is the fact that particular bestseller lists can be very heterogeneous. You may experience an inherent matching problem of individual items caused, e.g., by different size, prestige or covering of the books. This may, however, not be a problem on the aggregate level.
  - Secondly, particular bestseller lists are representative of a specific sub-sector of the market. Sometimes such a sub-sector will be representative of the wider general book market, otherwise it will not. For instance it is clear that one has to be careful in the case that a bestseller list originates from a not well-known internet-bookstore.
- There are some possibilities to solve the variance problem. Please remember that they need to be handled with care under consideration of their inherent disadvantages:
  - Use bestseller lists with a relatively large number of items. A larger sample can decrease variability. The number of observed prices depends on different national circumstances. For example in the case of countries with regulated prices, less price observations are needed compared to countries with a fully competitive market.
  - Apply appropriate stratification procedures and create several less heterogeneous sub-samples. Homogenise the bestseller list by applying certain criteria (e.g. hardcover/paperback, pocket/non-pocket, page intervals). This strategy can of course in principle reduce the representativeness of the sample. Therefore one should be careful. The following chart shows some possibilities for stratification of the rapidly-changing market:

Chart 97
**Examples for product descriptions for different consumption segments
with stratification**

Rapidly changing market	
Soft covered books, between 300 and 500 pages of a "normal" size	
Bestseller Fiction; belonging to 5 most sold books, Novels, several types *a: Paperback, b: Hardback, c: Special edition* No. of pages; Length in cm	Bestseller Non-fiction; belonging to 5 most sold books *a: Paperback, b: Hardback, c: Special edition* No. of pages; Length in cm
Bestseller Children's Book; belonging to 4 most sold books, several types *a: Paperback, b: Hardback, c: Special edition* No. of pages; Length in cm	

- Apply simple quality adjustment formulas (e.g. division of the price through logarithm of number of pages). Although such strategy can be effective in some cases, it is in general not as effective as the application of hedonic QA-procedures.
- The stability could be further enhanced through the systematic exclusion of outliers. This strategy is however even more risky (can create bias) than the artificial homogenisation of bestseller lists, and is therefore not advisable.

• In case that stratification is used and that local price collection is necessary, the local price collectors need to be carefully instructed. They need information on the concrete product specifications for their observations and on the amount of bestsellers and prices that need to be observed.

• In order to gain information on characteristics of a certain book the ISBN is a unique identifier. It can be used to centrally collect the characteristics of a certain book title in databases rather than locally in the stores. They can, for example, be found on the internet (e.g. at *www.amazon.xx*).

6.1.3   Proposal for the replacement strategy

• Replacements occur quite often – sometimes so often that the sample has been completely renewed after a relatively short time span. The vast majority of replacements will therefore have an unforced character which means that in most cases the replaced book is still available in the market but no longer a representative bestseller.

• In the case of bestseller lists one can not speak of one-to-one replacements. Instead, each month the first *n* books are chosen from the same bestseller list that was already considered in the previous month.

- If no bestseller lists are available the price collectors have to check every month whether the books of the previous month are still representative by applying the same criteria as in the previous month (e.g. books placed prominently in the outlet). If they are no longer representative they have to be replaced by representative ones.

Chart 98
Monthly replacement of bestseller lists (with stratification)
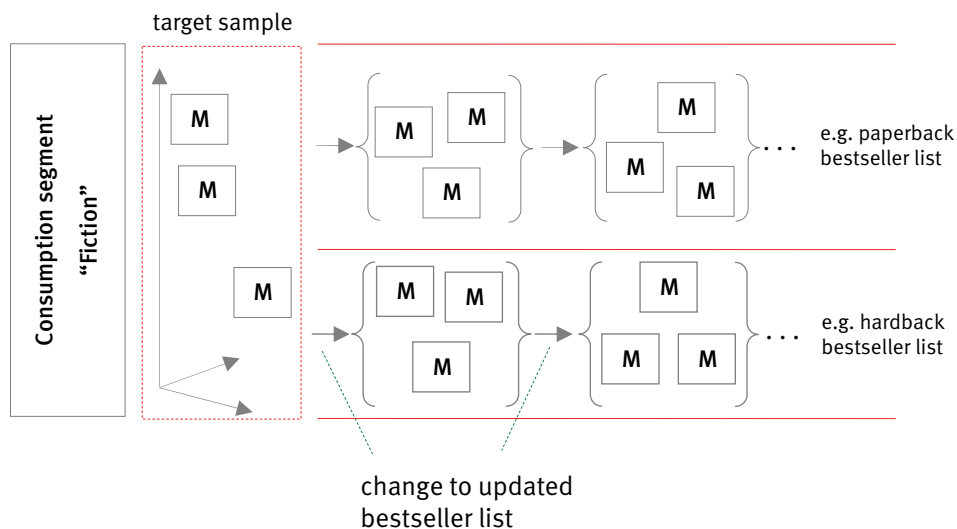
6.1.4   Proposal for quality adjustment

Direct comparison of bestseller lists

- The prices of the books from the same bestseller list are directly compared.
- Calculate the arithmetic or geometric mean of all prices monthly.
- Compare the arithmetic or geometric mean values over time to calculate the index.
- The choice between a Jevons- or Dutot-Index is left to the national NSI, since both formulas are allowable and allowed.

6.1.5   Cost estimation

One-time effort for the introduction

- Approximately one month may be sufficient for the implementation of the method.

Current effort of price collection

- One to two man-days may be sufficient to collect prices.

Current effort of index calculation

- The index calculation should not take more than one day.

6.1.6 Examples for the rapidly-changing market

Example for the identification of consumption segments

- Identify the relevant consumption segments for your country. Use the recommendation of the Task Force on "Classification COICOP/HICP" as a starting point.

- It is assumed that three consumption segments are relevant for your country:
  - fiction books,
  - non-fiction books,
  - children's books.

- In the following, the focus lies on fiction books. In order to deal with the two remaining consumption segments you would need to proceed analogously.

Example for the construction of the target sample

- In a first step, check whether a national bestseller list is available for fiction books for your country. If a bestseller list is unavailable, please proceed as described above in the section on sampling.

- For this example, a homogeneous bestseller list for fiction books is available. It is, furthermore, assumed that prices are fixed throughout the country.

- The top five fiction titles are exemplarily considered from the bestseller list for price collection.

- As the price development is similar throughout regions due to fixed prices, the prices can be collected centrally, for example from a big bookstore.

Chart 99
Fictitious example of the sample of bestseller fiction books
in the base period

Position	Author	Titel	Price
1	Danielle Steel	Roque	17.95 €
2	Paulo Coelho	The Witch of Portobello	20.99 €
3	Robert Menasse	Don Juan de la Mancha	20.99 €
4	Catherine Coulter	Tailspin	16.45 €
5	Henning Mankell	Italian Shoes	24.99 €

Digression on stratification

- In case that there is no (homogeneous) bestseller list, stratification should be applied in order to avoid high volatility. The following chart shows some possibilities for stratification of the rapidly-changing market:

Chart 100
Examples for product descriptions for different consumption segments with stratification

| Rapidly changing market	
Soft covered books, between 300 and 500 pages of a "normal" size	
Bestseller Fiction; belonging to 5 most sold books, Novels, several types *a: Paperback, b: Hardback, c: Special edition* No. of pages; Length in cm	Bestseller Non-fiction; belonging to 5 most sold books *a: Paperback, b: Hardback, c: Special edition* No. of pages; Length in cm
Bestseller Children's Book; belonging to 4 most sold books, several types *a: Paperback, b: Hardback, c: Special edition* No. of pages; Length in cm	

- In case that stratification is used and that local price collection is necessary, the local price collectors need to be carefully instructed. They need information on the concrete product specifications for their observations and on the amount of bestsellers and prices that need to be observed. The price collectors might be provided with the following price collection form:

Chart 101
Example of a price collection form

Fiction book, hardback, 300 – 500 pages			
Author: Paulo Coelho			
Title: The Witch of Portobello			
ISBN: 978-0007251865	Price: 20.99 €		
Number of pages: 320	length: 21.6 cm		
Binding:	☐ binds in board	☒ hardback	☐ special binding
Shop: _____ Date: _____			

- The ISBN is needed for a clear identification of different book titles and its respective editions.

Example for the replacement strategy

- In the case of bestseller lists one can not speak of one-to-one replacements. Instead, for our example, in each month the first five books are chosen from the bestseller list originating from the same source that was already considered in the previous month. This way, the sample remains representative over time.

Chart 102
Fictitious example of the sample of bestseller fiction books
in three sequent months

Posi-tion	Month 1		Month 2		Month 3	
	Author / Title	Price	*Author* / Title	Price	*Author* / Title	Price
1	*Danielle Steel* Rogue	17.95 €	*Joanne K. Rowling* Harry Potter and the deathly hallows	18.95 €	*Joanne K. Rowling* Harry Potter and the deathly hallows	18.95 €
2	*Paulo Coelho* The Witch of Portobello	20.99 €	*Paulo Coelho* The Witch of Portobello	20.99 €	*Paulo Coelho* The Witch of Portobello	20.99 €
3	*Robert Menasse* Don Juan de la Mancha	20.99 €	*Danielle Steel* Rogue	17.95 €	*Danielle Steel* Rogue	17.95 €
4	*Catherine Coulter* Tailspin	16.45 €	*Cornelia Funke* Inkdeath	17.99 €	*Stephenie Meyer* The Host	18.95 €
5	*Henning Mankell* Italian Shoes	19.99 €	*Stephenie Meyer* The Host	18.95 €	*Henning Mankell* Italian Shoes	19.99 €

- The chart above demonstrates the dynamics of bestseller lists:
  - Two books remain in the sample in all three months: Rogue by *Danielle Steel* and The Witch of Portobello by *Paulo Coelho*.
  - The book Italian Shoes by *Henning Mankell* is in the sample in the first month, loses representativity in the second month so that it needs to be excluded and re-gains representativity in the third month when it is again among the five top selling books and therefore re-included in the sample.
  - The remaining books stayed in the sample either only for one month or for two sequent months.

Example for quality adjustment

- For the calculation of the index for fiction books the prices from the fiction bestseller list are directly compared.
  - In a first step the arithmetic mean is calculated for months one, two, and three as follows:

Chart 103
Calculation of arithmetic mean prices, month 1 – 3

Month 1:	$\dfrac{17.95 + 20.99 + 20.99 + 16.45 + 19.99}{5}$ = 19.27 €
Month 2:	$\dfrac{18.95 + 20.99 + 17.95 + 17.99 + 18.95}{5}$ = 18.97 €
Month 3:	$\dfrac{18.95 + 20.99 + 17.95 + 18.95 + 19.99}{5}$ = 19.37 €

– In the next step, the arithmetic mean values are directly compared to calculate the sub-index for fiction books for month one, two, andf three:

Chart 104
Direct comparison of arithmetic means for months 1 – 3

Index $_{month\ 1}$	(= base period)	=	100.0
Index $_{month\ 2}$	= 18.97/19.27	=	98.4
Index $_{month\ 3}$	= 19.37/19.27	=	100.5

6.2 Long-selling market

6.2.1 Proposal for the identification of consumption segments

• Consumption segments can be built following the Task Force "Classification COICOP/ HICP" (2005) with slight modifications:

Chart 105
**Consumption segments following the Task Force Classification COICOP/HICP
for the long-selling market**

09.5.1	**Books**
09.5.1.2	Long-selling market
09.5.1.2.1	*Dictionaries*
09.5.1.2.2	*Schoolbooks*
09.5.1.2.3	*Children's books (including scrapbooks and albums for children)*
09.5.1.2.4	*Art books*
09.5.1.2.5	*Travel guides, reference books*
09.5.1.2.6	*Other books (includes book binding)*
	Book series

- Alternatively, a different identification of consumption segments is possible. The required information could stem from a research study, which might be available at a national bookstore association or at a market research institute.

- In practice, not all consumption segments need to be equally relevant in all countries. For example, in countries with governmental subsidies for schoolbooks the consumption segment "schoolbooks" might be empty due to low relevance for private consumption.

- Note: The application of a bestseller approach may be more suitable if a bestseller list exists. Thus, if a bestseller list is available for children's books this consumption segment should be included in the rapidly-changing market. Otherwise it is part of the long-selling market.

Weighting of the consumption segments

- Explicit weights are assigned to the consumption segments. Information about weights can be obtained from the national association of bookstores, market research institutes (e.g. Media Control GfK International) or a big book store. Either detailed data can be provided or at least purposive weights can be assigned to the consumption segment based on the experience of the booksellers.

6.2.2   Proposal for the construction of a target sample

- Usually, bestseller lists do not exist for books of the long-selling market. As a consequence, in a first step outlets should be chosen which are relevant for the long-selling market under consideration of the regional dimension. Subsequently, representative models should be chosen within the outlets for price collection.

Chart 106
Proposal for the construction of a target sample

> **outlets › models**
>
> (1) Choose outlets which are relevant for the long-selling market, accounting for the regional dimension.
> (2) Choose representative models in the outlets.

(1) Choose outlets which are relevant for the long-selling market, considering the regional dimension

- Distinguish between large/small retailers and mail order/stationary retailers.

- Include the largest retailers in any case. Check whether or not the large retail chains have the same pricing policy in the entire country. If yes, prices can be centrally observed in big retail chains. If not, prices have to be observed locally taking into account the regional variance of price developments.

- Include a sample of small retailers. This could be done by probability sampling if data can be obtained from the business register of your respective national statistical of-

fice. If information from the business register is not available, choose relevant regions and within the regions select typical outlets (just as you do for other products of the HICP).

- Prices from small retailers should be observed locally in general (under consideration of regional variations in price development).
- If mail order selling is relevant in the market it should be taken into account by collecting prices from the internet or catalogues additionally.

(2) Choose representative models in the outlets

- For the long-selling market, the "matched model approach" is suitable. This means that price collection is not focused on e.g. one specific book title but rather on a representative of a particular series or edition. These representatives are deemed interchangeable. This means that the series or edition may serve as product specification for replacements. The criterion for inclusion in the sample is that the market share is stable and relevant.
- The matched model approach is especially suitable for:
  - Book series: Series are a numbered sequence of books of the same publisher that, except for their particular content, have most or all of their objective characteristics in common. Series can be defined around a specific author (Karl May, Agatha Christie) or around a specific theme (SF-stories, the French science pocket series *Que sais-je?*).
  - Dictionaries,
  - schoolbooks,
  - children's books,
  - art books,
  - travel guides,
  - . . . and the like.
- Within the shop, the selection of specific book titles may be carried out in different ways, depending on the availability of information. In most cases, information on long-sellers can be obtained from shop employees. In the following, the selection of specific book titles is exemplified:
  - For the observation of a book series, select one specific representative of the series. From the point of view of price statistics different titles of the same series are normally interchangeable: they are (quasi-)perfect substitutes. As long as the market share of the series is stable and relevant, it will be a good candidate to be included in a book (sub-)index. It can be expected that pockets have a higher probability to be included in series than normal paper- or hardbacks.
  - For travel guides, for example, select the most sold travel guides. If possible (i.e. if information is available) use the most recent representatives of a large and well sold series as for example guides from the *Rough Guide Travel Guides* series or the *Lonely Planet Country Guides* series. If there is no information about this matter then travel guides of those countries could be selected which are most visited by the citizens of your country.

- Concerning art books evaluate relevant and stable series, for example the *Taschen Basic Art Series*. The latest edition in a series could be considered for price observation.

- The selection of price representatives is done in the base period. Once selected the sample is kept constant for one year or longer – if the chosen books are still representative. In each reporting period, the price of the latest edition or issue shall be reported.

Minimum size of the target sample

- The sample for the long-selling market can be smaller than the one for the rapidly-changing market as in the latter a bigger sample is needed to reduce variance of the index numbers.

- For each consumption segment around three models might be observed in each selected outlet.

Additional aspects

- If the books selected for one consumption segment within the long-selling market are very heterogeneous then it may be necessary to stratify the market for example according to their binding. The following chart shows some possibilities for stratification:

Chart 107
Examples for product descriptions for different consumption segments
with stratification

Long selling market	
Textbook; German dictionary, best sold *a: Paperback, b: Hardback, c: Special edition* No. of pages; Length in cm	Textbook; English-German dictionary, best sold *a: Paperback, b: Hardback, c: Special edition* No. of pages; Length in cm
Textbook; Travel guide,best sold *a: Paperback, b: Hardback, c: Special edition* No. of pages; Length in cm	Textbook; Cookbook,best sold *a: Paperback, b: Hardback, c: Special edition* No. of pages; Length in cm

6.2.3   Proposal for the replacement strategy

- The sample will be kept constant during a fixed period (for instance a full calendar year). During this period the sample is considered to be representative.

- As already mentioned the latest edition or issue of a book series should be observed; sequent editions or issues are considered interchangeable. By definition, unforced replacements (a certain book that has lost too much market share to remain representative) do not occur.

- Forced replacements (the book has disappeared from the market) are possible, but are not expected to happen very often. A replacement situation occurs only in the case that a model disappears from the market during the fixed period.

- Especially for series an update to new series has to be made on a regular basis, approximately once a year. Series or editions of books that are no longer representative are then replaced by representative ones.

Chart 108
Forced replacement – long selling market

Forced replacement
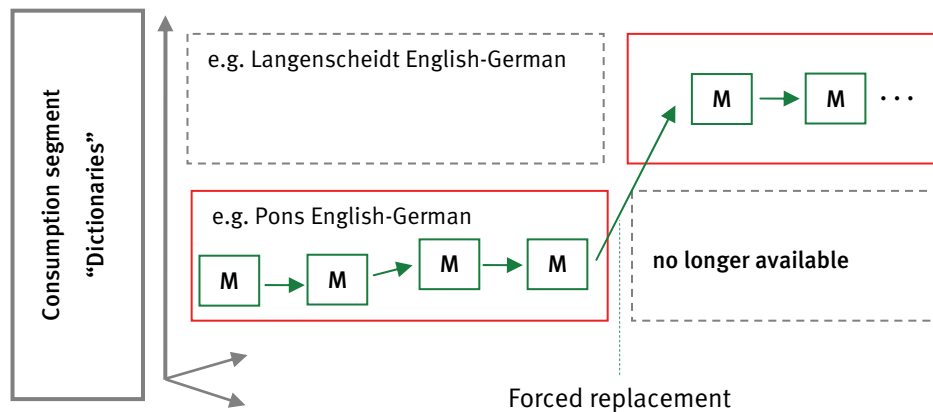
6.2.4   Proposal for the quality adjustment

- Within the matched model approach, different titles of the same series and different editions are deemed interchangeable. In this case, the prices of the different titles are directly compared.

- In case of forced replacements two types of changes can occur within the matched model approach:
  - Minor changes: If there is a forced replacement the obvious strategy would be to search for a replacement that can be deemed comparable with the disappeared item and to apply the direct comparison procedure in this case. For example, one English-German dictionary is replaced by a new edition of the same quality. As the dictionaries are of the same quality they are deemed interchangeable and direct comparison may be applied.
  - Major changes: Only in those cases where the incomparability between the disappeared item and its replacement is obvious an automatic application of direct comparison cannot be maintained. In this case, expert judgement needs to be applied, meaning here that by expert judgement an appropriate quality adjustment has to be chosen.
    - Suppose that the sample of a book sub-index contains the cheap paperback version of a vocabulary. At a certain moment this paperback version isn't available any more in the market and therefore has to be replaced in the sample, e.g. by a hardcover version. Other publishers still offer paperback versions,

but due to practical reasons these items will not be used as a replacement (suppose that the local price collection is based on one of the three book stores in town and that this book store sells vocabularies of only one publisher). In this case it is obvious that the most appropriate quality adjustment procedure would be bridged overlap.

– Suppose that the only cheap paperback version of a vocabulary on the market isn't available any more and therefore all consumers have no choice but to buy a significantly more expensive hardback version. The application of a bridged overlap is not straightforward in this situation. After all a significant part of the consumers would have preferred the cheaper paperback version that has disappeared from the market. At first sight a direct comparison is not straightforward either: The more expensive version has (at least in some dimensions) more quality than the cheaper version (e.g. it is more suitable to give it a prominent place in the bookcase in the living room or it can serve as a nice present) and a relevant part of the consumers will value this. However in this case one should adopt a pragmatic perspective. Since the consumers have no choice in the matter, direct comparison is still a sound quality adjustment strategy in this case.

Chart 109
Quality adjustment – long-selling market
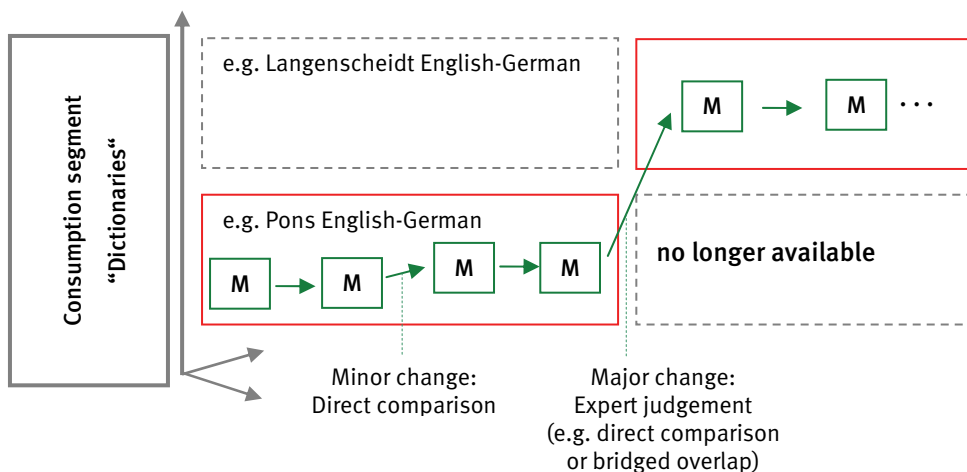
6.2.5 Cost estimation

One-time effort for the introduction

• Approximately one month may be sufficient for the implementation of the method.

Current effort of price collection

• One to two man-days may be sufficient to collect prices.

Current effort of index calculation

• The index calculation should not take more than one day.

7 Software

- Software appears in two COICOP-classes:
  - Application programs belong to COICOP 09.1.3 "Information processing equipment".
  - Video games belong to COICOP 09.3.1 "Games, toys, and hobbies".
- Therefore, the approaches for application programs and video games will be described separately in the following.
- Regarding application programs, the Task Force results are only tentative recommendations proposing a monthly chaining and re-sampling approach.
- Concerning video games, the HICP standards rate direct comparison in combination with bestseller lists as a B-method. No method is classified as an A-method.
- In the following only pre-packaged software is considered. Pre-packaged software products are purchased ready-made and not customised. Additionally, programs which are pre-installed on the hardware are not considered, since there are different pricing strategies of the producers for pre-installed and separately purchased software. As a general rule, pre-installed software is regarded to be a component of the computer hardware package.
- The following section deals with the application of
  - direct comparison of bestsellers within "consumer profiles" for application programs,
  - direct comparison of bestseller lists for video games.

7.1 Application programs

7.1.1 Proposal for the identification of consumption segments

- The term "application program" comprises a large variety of computer programs for different consumption purposes. For the HICP only those application programs should be considered that are relevant for the private consumer. The relevance of the different application programs for private consumption can differ from country to country. Hence, the decision on which application programs to consider should be made individually by each NSI, following the circumstances of the national market.
- The relevant consumption segments can differ from country to country. Information on which consumption segments are relevant in a country can be obtained from market research institutes or by performing a small own survey in relevant outlets. As a pragmatic proposal, approximately four groups of software applications could be considered. For example, the following consumption segments could be included:
  - home office applications (e.g. MS Office),
  - security software (e.g. anti-virus programs),
  - education (e.g. language learning software),
  - personal finance (e.g. tax preparation programs),
  - . . .

- Consumption segments are identified according to the consumption purpose of the application programs. For example, the consumption segment "home office applications" includes word processing, spreadsheet applications and the like for managing a household's private affairs. Security software serves the protection of the computer system.

- Operating systems are not considered as a separate application since the hardware does not work without an appropriate operating system which is in most cases pre-installed on the computer. Therefore, operating systems are regarded as a part of the computer hardware package.

7.1.2   Proposal for the construction of a target sample

- As a sampling method a bestseller approach is suggested as this is a suitable method to select representative application programs for the target sample.

- For the compilation of the target sample two approaches are possible, depending on whether national bestseller lists are used:
  - choose application programs first (according to a bestseller list), then sample outlets, or
  - sample outlets first, then choose representative application programs in the chosen outlets.

Chart 110
Different forms of bestseller lists at several levels
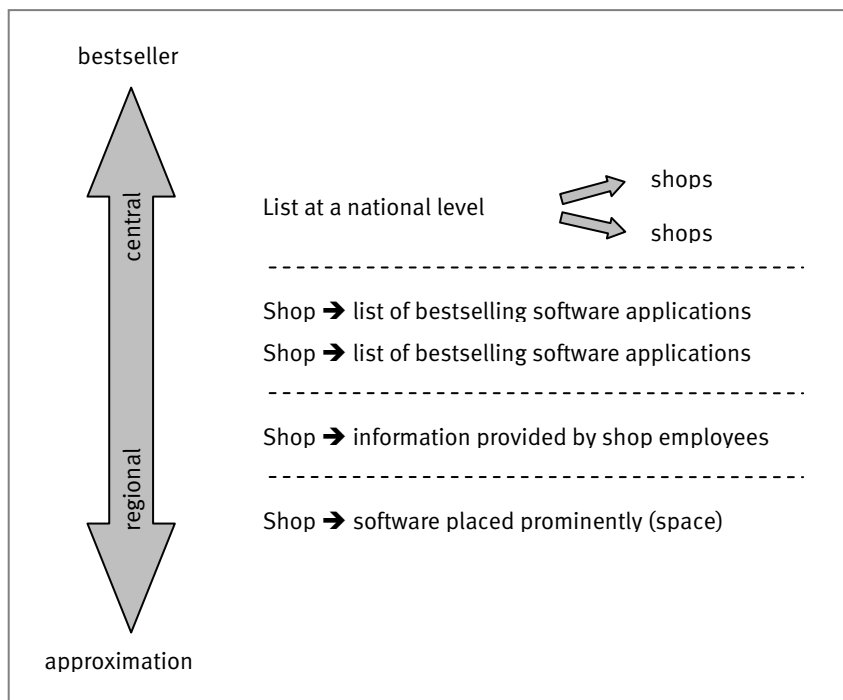
- In the following, both sampling approaches are described in more detail.

If national bestseller lists are used

- If there are national bestseller lists available then the relevant application programs are known. Representative outlet types and particular outlets have to be identified in consideration of the regional dimension in the next step.

Chart 111
When using a national bestseller list

> **models › outlets**
>
> (1) Choose relevant application programs.
> (2) Choose representative outlets, accounting for the regional dimension.

(1) Choose relevant application programs

- Depending on the kind of available bestseller lists, application programs have to be chosen.
    - If there are bestseller lists for each considered consumption segment select the first *n* bestsellers from the list.
    - If there is a heterogeneous bestseller list containing models of different consumption segments the models from the bestseller list have to be assigned to the respective consumption segments first.
- Bestseller lists are compiled and published by market research institutes and/or by computer magazines.

(2) Choose relevant outlets, accounting for the regional dimension

- Distinguish between large/small retailers and mail order/stationary retailers.
- Include the largest retailers in any case. Check whether or not the large retail chains have the same pricing policy in the entire country. If yes, prices can be centrally observed in big retail chains. If not, prices have to be observed locally taking into account the regional variance of price developments.
- Include a sample of small retailers. This could be done by probability sampling if data can be obtained from the business register of your respective national statistical office. If information from the business register is not available, choose relevant regions and within the regions select typical outlets (just as you do for other products of the HICP).
- Prices from small retailers should be observed locally in general (under consideration of regional variations in price development).
- If mail order selling is relevant in the market it should be taken into account by collecting prices from the internet shops or catalogues of the particular retailers additionally.

If a national bestseller list is not used

- If no national bestseller list is used proceed in reversed order. First, select representative outlet types as well as particular outlets under consideration of the regional dimension. In these outlets, the most representative application programs have to be chosen.

Chart 112
When a national bestseller list is not used

> **outlets › models**
>
> (1) Choose representative outlets, accounting for the regional dimension.
> (2) Choose representative application programs in the outlets.

(1) Choose representative outlets, accounting for the regional dimension, as described directly above

(2) Choose representative application programs in the outlets

- Within the shop, the selection of specific application programs may be carried out in three different ways, depending on the availability of information:
  - In some cases shops provide local bestseller lists. The specific application programs can then be selected according to these local bestseller lists by choosing the first *n* bestsellers.
  - In other cases information can be obtained from shop employees.
  - Alternatively, prominently placed application programs can serve as an indicator of how well these application programs are sold. The rationale for this is that only the most recent programs with a significant market share are placed prominently. However, please be careful not to select special offers.

Minimum size of the target sample

- Regardless of the chosen approach, the number of relevant bestsellers might be country-specific. However, in general we can assume that a few models per consumption segment (e.g. the top two or the top three bestsellers) in each selected outlet are sufficient since the software market in general has an oligopolistic structure and thus the products within the bestseller lists exhibit a relatively high market share.

7.1.3   Proposal for the replacement strategy

- A bestseller list (whether a national one or one from a local shop) was used to select initially relevant products. Those products that are still available and on the bestseller list in the following month are not replaced. Those products that are not available anymore or have become clearly unrepresentative have to be replaced. Each month comparable replacements of these products have to be found. For this purpose – *and only for this purpose* – consumer profiles are introduced.

- The consumer profiles are based on different levels of the consumers' consumption purpose within one consumption segment. In other words, the consumer profiles divide the universe of software *users* in different sub-categories according to the range of use of the programs. For example, regarding home office applications the overall consumption purpose is managing the household's correspondence and expenses. But not every household needs a database management system which could be included in a premium version for managing the household's private affairs. However, some households want to exploit the whole range of an application program bundle. Consumer profiles are introduced in order to catch the different "quality levels" in a developing market.

- Two consumer profiles are suggested in the following:
  - Occasional user: This user is interested in the basic feature(s) of a product.
  - Power user: This user is interested in the full scope of a program or software bundle (or product bundle).

- These consumer profiles are only relevant for replacement, not for the target sample. Therefore, the distribution of the market over the profiles does not play a role. The representativity of the sample is ensured by the bestseller list, not by the consumer profiles.

- As a general rule, the replacement should be chosen so that it fits the consumer profile. By this, the comparability of replaced and replacement model is ensured. In order to also ensure representativity, the first product on the bestseller list fitting into the consumer profile should be chosen as a replacement.

- In a replacement situation the following question has to be answered: "Which product would the respective user buy instead of the one to be replaced?" Usually manufacturers offer an overview which can help assign the different versions to the respective consumer profiles. The program's name extensions like "plus", "premium", "extended version", "ultimate", "standard", "home", "deluxe", "pro", etc. can be used as hints for the assignment.

- However, specific product knowledge is necessary, since name extensions are only hints that are not used in a systematic way. Each manufacturer uses different strategies to mark different software bundles. In some cases the "power user"-package may consist not only of a program (bundle), but of a bundle that offers additional services such as free online support, free updates etc. Information on the disposable versions or editions is available on the internet sites of the respective manufacturers.

- For example: An unrepresentative deluxe version of an anti-virus program is replaced by a now representative deluxe version of another anti-virus program. The replacement is chosen by answering the question "Which program would the respective consumer buy instead of the one to be replaced?". This new program should again be chosen from a bestseller list in order to maintain representativity of the models in the sample.

7.1.4 Proposal for the quality adjustment

- With regard to quality adjustment several reasons suggest that the following quality adjustment methods are not applicable for software:

- – Hedonics: The quality of application programs is not measurable in physical units, e.g. measuring operator convenience or the value of a single (new) software feature.
- – Bridged overlap: The assumption of a competitive market is violated in the field of software. The small number of suppliers with extensive market shares results in an oligopolistic market structure.
- – Option pricing: In general, options are not available in the field of application programs.
- – Expert judgement: The quality of application programs is difficult to capture. Comprehensive estimations of quality changes would be highly subjective and complex.

- Since the above mentioned methods are not applicable in the field of application programs, direct comparison of bestsellers is suggested. The prices of the selected products are directly compared since none of the above mentioned quality adjustment methods are adequate. In order to compare more or less homogenous models direct comparison is applied within the consumer profiles. When applying this approach, the price of a replaced basic version is directly compared with the price of a now representative replacement basic version.

Chart 113
Replacement within consumer profiles according to bestseller lists
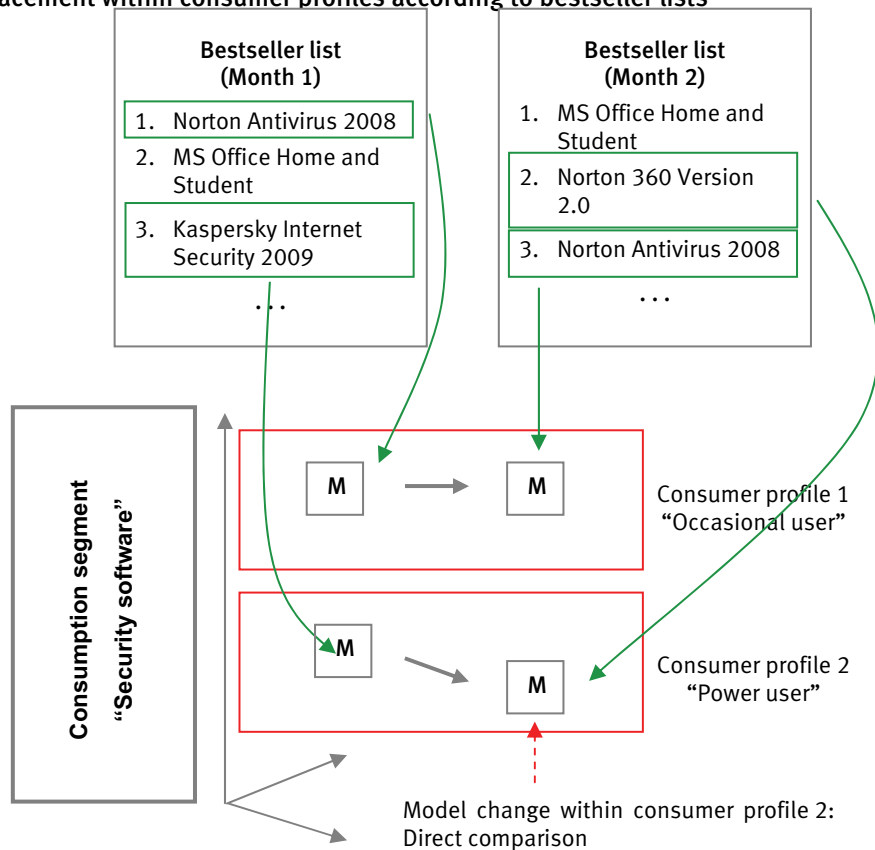
7.1.5 Cost estimation

One-time effort for the introduction

- For the implementation of the method one staff member with some market expertise is required.

- One month seems to be necessary to set up an adequate sample and to perform the suggested method.

Current effort of price collection

- The price collector should be a trained staff member. There is no need for academic skills. However, the price collector should have some market expertise.

- One to three man-days may be sufficient to collect prices.

Current effort of index calculation

- Regarding the index calculation, the price statistician does not necessarily need broad econometric knowledge, only moderate skills are required.

- The index calculation might be done quickly; an effort of approximately 1 man-day seems to be sufficient.

7.2 Video games

7.2.1 Proposal for the identification of consumption segments

- Two consumption segments of video games are suggested, according to the required hardware systems:
  - PC games,
  - console games.

- The consumption purpose of all video games is the same, namely entertainment. However, different specifications according to different hardware systems exist, which can be used as a segmentation criterion. Regulation 1334/2007 states that consumption segments can be formed around models that are largely described by the same specifications. (For console games a further stratification is suggested [see below]. However, it is not suitable to identify consumption segments by a particular console such as Xbox or Playstation since the market changes quite rapidly.)

- An explicit weighting for the two consumption segments is suggested. Information about market shares is available from market research institutes, game magazines or from a small own survey.

7.2.2 Proposal for the construction of a target sample

- As a sampling method a bestseller approach is suggested as this is a suitable method to select representative models each month. As for application programs, the construction of the target sample depends on whether or not national bestseller lists are available.

Chart 114
Different forms of bestseller lists at several levels

```
bestseller


                         List at a national level        →  shops
     central
                                                          →  shops
                         - - - - - - - - - - - - - - - - - - - - - - -

                         Shop → list of bestselling games
                         Shop → list of bestselling games
                         - - - - - - - - - - - - - - - - - - - - - - -

                         Shop → information provided by shop employees
     regional
                         - - - - - - - - - - - - - - - - - - - - - - -

                         Shop → games placed prominently (space)


approximation
```
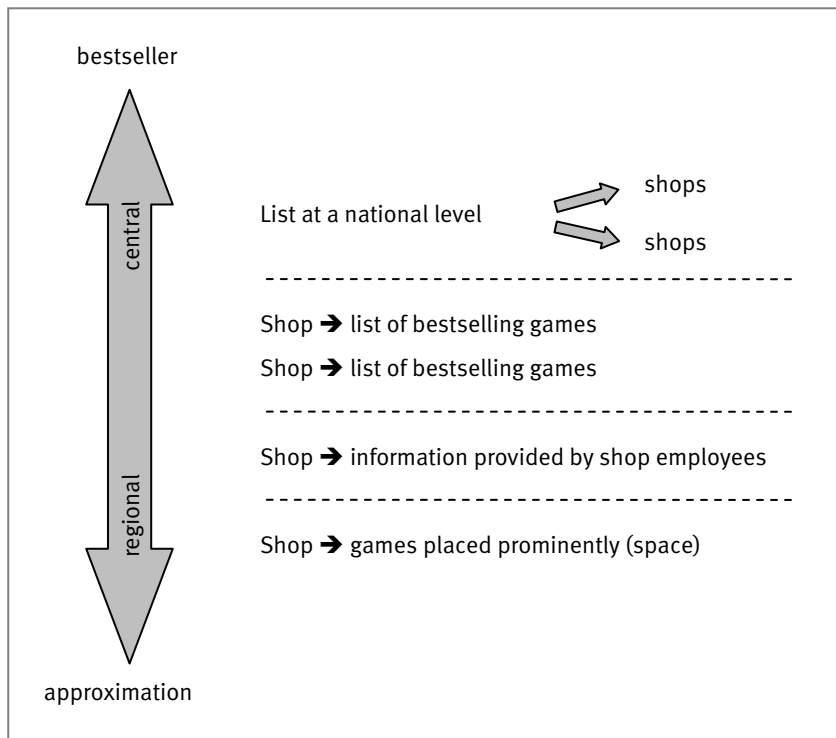
If national bestseller lists are used

- First, relevant games have to be chosen. If there are national bestseller lists available then the respective relevant games are known. Representative outlet types and particular outlets have to be identified in consideration of the regional dimension in the next step.

Chart 115
When using national bestseller lists

> **models › outlets**
>
> (1) Choose relevant video games.
> (2) Choose representative outlets, accounting for the regional dimension.

(1) Choose relevant video games

- Depending on the kind of available bestseller lists, video games have to be chosen.
  - If there are bestseller lists for each considered consumption segment select the first *n* bestsellers from the lists.

> – If there is a heterogeneous bestseller list containing models of different consumption segments the models from the bestseller list have to be assigned to the respective consumption segments first.

- Bestseller lists are compiled and published by market research institutes and/or by computer magazines.

(2) Choose relevant outlets, accounting for the regional dimension

- Distinguish between large/small retailers and mail order/stationary retailers.

- Include the largest retailers in any case. Check whether or not the large retail chains have the same pricing policy in the entire country. If yes, prices can be centrally observed in big retail chains. If not, prices have to be observed locally taking into account the regional variance of price developments.

- Include a sample of small retailers. This could be done by probability sampling if data can be obtained from the business register of your respective national statistical office. If information from the business register is not available, choose relevant regions and within the regions select typical outlets (just as you do for other products of the HICP).

- Prices from small retailers should be observed locally in general (under consideration of regional variations in price development).

- If mail order selling is relevant in the market it should be taken into account by collecting prices from the internet shops or catalogues of the particular retailers additionally.

If national bestseller lists are not used

- If no national bestseller list used proceed in reversed order. First, select representative outlet types as well as particular outlets under consideration of the regional dimension. In these outlets, the most representative video games have to be chosen.

Chart 116
When national bestseller lists are not used

---

outlets › models

(1) Choose representative outlets, accounting for the regional dimension.

(2) Choose representative video games in the outlets.

---

(1) Choose representative outlets, accounting for the regional dimension, as described directly above

(2) Choose representative video games in the outlets

- Within the shop, the selection of specific video games may be carried out in three different ways, depending on the availability of information:
  - In some cases shops provide local bestseller lists. The specific video games can then be selected according to these local bestseller lists by choosing the first *n* bestsellers.

- In other cases information can be obtained from shop employees.
- Alternatively, prominently placed PC and console games can serve as an indicator of how well these games are sold. The rationale for this is that only the most recent games with a significant market share are placed prominently. Please be careful not to select special offers.

Minimum size of the target sample

- The number of relevant bestsellers might be country-specific. However, in general we can assume that a few models per consumption segment and stratum (e.g. the top two or the top three bestsellers) in each selected outlet should be sufficient.

Additional aspects concerning console games

- Concerning console games it is appropriate to further stratify according to the particular console:
    - GameCube,
    - Xbox,
    - Playstation.
- This stratification should be adjusted when the market circumstances change, e.g. a new popular console is introduced in the market. The stratification has to be adapted when new consoles (as for example "Wii") are gaining relevant market shares.
- If available, bestseller lists of console games according to the type of console can be used for sampling. Bestseller lists according to console types can often be found in magazines or in large outlets. For example, in a specific outlet games available for the Xbox may be sorted according to their respective sales rank in that outlet. If there is only an overall bestseller list for all console games the bestsellers have to be assigned to the respective strata.
- The console strata are roughly weighted according to their market shares. The weighting information is available from market research institutes, game magazines or has to be obtained from an own small survey.
- For PC games no further stratification is suggested.

7.2.3 Proposal for the replacement strategy

- When using a bestseller list, choose each month the first (approximately) two to three games for console games from the same bestseller list in each stratum (depending on the particular market structure in the specific country). Regarding PC games choose the two to three bestsellers from the bestseller list. Due to this procedure, there is no exact one-to-one replacement.
- If no bestseller lists are available the price collectors have to check every month whether the games observed in the previous month are still representative by applying the same criteria as in the previous month (e.g. games placed prominently in the outlet). If they are no longer representative they have to be replaced by representative ones. In this case, the console strata from the target sample should be used as product specification so that a Playstation game is replaced by another Playstation game and not by an Xbox game.

7.2.4   Proposal for the quality adjustment

- Calculate the arithmetic or geometric mean of the prices from one bestseller list or from the compiled list of the outlets.

- Directly compare the arithmetic or geometric means over time. The weighted mean price changes are forming the index.

Chart 117
Replacement within strata according to bestseller lists

Bestseller list of stratum 1
(e.g. Game Cube)

Bestseller list of stratum 2
(e.g. Playstation)

New game within stratum 2:
Direct comparison
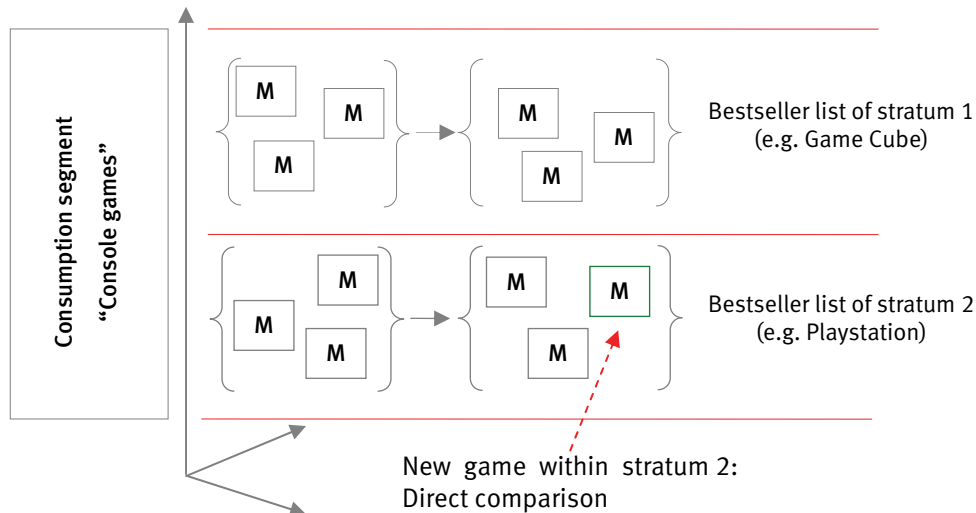
7.2.5   Cost estimation

One-time effort for the introduction

- For the implementation of the method one staff member with some market expertise is required.

- Up to one month seems to suffice to set up the sample and to perform the suggested method.

Current effort of price collection

- The price collector should be a trained staff member. There is no need for academic skills or comprehensive market expertise.

- One to two man-days should be sufficient to collect prices.

Current effort of index calculation

- Regarding the index calculation, the price statistician does not necessarily need broad econometric knowledge, only moderate skills are required.

- The index calculation might be done quickly; an effort of approximately 1 man-day seems to be sufficient.

Hedonic regression

1 Applying hedonic regression – concepts and guidance for use

The hedonic approach has basically the same aim as other approaches to quality adjustment. That is, the quality adjustment aims at making the price index show pure price change, unaffected by quality change. The hedonic methods handle this task by using statistical regression analysis. A simple example will show how it works.

1.1 An introductory example

Consider a product group with a sample of 6 models. For times t = 1 and t = 2, prices for each of the 6 models have been collected as in the following table.

Chart 118

t = 1			t = 2		
Price	Size	Trait_A	Price	Size	Trait_A
390	23	0	290	23	0
480	39	0	519	39	0
700	51	1	700	51	1
550	39	0	550	39	0
520	35	1	520	35	1
490	43	0	698	53	1

Here "Size" is a size measure, while "Trait_A" is a variable with values 1 = "yes" and 0 = "no", telling whether the model has a particular feature. "Size" and "Trait_A" are called characteristics variables, as they express characteristics of the models.

In the last line of the table, the model was replaced between time t = 1 and t = 2, as the model disappeared or became unimportant. By the replacement, the characteristics variables changed, as you can see.

Hedonic regression equation and hedonic function

We make a computer run with statistical analysis software, to fit a *regression equation* to the data for time t = 1. The result is this equation:

(1) $\quad \ln Price = 5.604 + 0.0155 \cdot Size + 0.1331 \cdot Trait\_A + \varepsilon$

Here "ln" stands for natural logarithm. This equation is known as a *hedonic regression equation*, and it expresses how the prices of the models depend on characteristics for the models. The last term ε is called the *residual term* and is needed as prices are not exactly determined by characteristics.

The hedonic regression equation may be re-written in this form:

(2)
$$Price = h\left(Size, Trait\_A\right) + r$$
$$= e^{5.604 + 0.0155 \cdot Size + 0.1331 \cdot Trait\_A} + r$$

Here h is a mathematical function, known as *hedonic function*, which expresses price as a function of characteristics variables. Further $e \approx 2.718$ is the base of the natural logarithm. Again, the last term r is a residual term, with a role similar to that of ε in Eq. (1).

Index calculation – concluding the example

Without quality adjustment, a price index with reference period $t = 1$ and current period $t = 2$ is calculated from the prices in the table as:

$$(3) \qquad I = \left(\frac{290}{390} \cdot \frac{519}{480} \cdot \frac{700}{700} \cdot \frac{550}{550} \cdot \frac{520}{520} \cdot \frac{698}{490} \right)^{1/6} \cdot 100 = \mathbf{102.29}$$

Here the Jevons index formula, or geometric mean index, was used.

Now to apply hedonic quality adjustment, consider the replacement shown in the last line of the table. We shall use the hedonic function h to compute a *quality adjustment factor* as

$$(4) \qquad g = \frac{h\,(Size\,of\,replacement\,model, Trait\_A\,of\,replacement\,model)}{h\,(Size\,of\,replaced\,model, Trait\_A\,of\,replaced\,model)}$$

Here plug in the computed expression Eq. (2) for h, and values from the table, to get

$$(5) \qquad g = e^{\,0.0155 \cdot (53 - 43)\ +\ 0.1331 \cdot (1 - 0)} = 1.3339$$

The *price index with quality adjustment by hedonics* is calculated similarly to that without quality adjustment in Eq. (3). But this time, multiply the reference price in the replacement by the quality adjustment factor $g = 1.3339$. The calculation thus becomes:

$$(6) \qquad I = \left(\frac{290}{390} \cdot \frac{519}{480} \cdot \frac{700}{700} \cdot \frac{550}{550} \cdot \frac{520}{520} \cdot \frac{698}{490 \cdot 1.3339} \right)^{1/6} \cdot 100 = \mathbf{97.49}$$

This completes the example.

Characteristics variables – continuous variables and dummy variables

As is seen in the example, characteristics variables play a crucial role in hedonics. These variables serve to express quality of the models, so that quality change can be mathematically adjusted for. The idea of hedonics is to quality adjust the price index, so that the index shows price change corresponding to unchanged characteristics.

The example demonstrates that characteristics variables may be of two main types:

- "Size" is a *continuous variable*, that is, a measure of some kind which may take various numerical values. Example: Screen size of a TV set.

- "Trait_A" is a *dummy variable*, that is, a variable with only two possible values, 0 or 1, indicating "no" or "yes". Such a variable typically tells whether or not the product model in question has some particular feature. Example: Stereo sound in a TV set, yes or no.

Some more terminology

The numbers 0.0155 and 0.1331 on the right of Eq. (1) are known as *regression coefficients*. They express the impact of the characteristics variables on the price. This will be further described in Section 1.3.3, subsection "Assess the hedonic function at design stage – plausibility of results".

The characteristics variables used in hedonic regression are *regressors*, in the wording of general regression analysis textbooks. Alternatively they are often called *explanatory variables*, as the regression equation "explains" price variations in terms of their variations.

In general regression theory, a regression equation is usually said to express a "regression model". However, in this handbook the expression *regression equation* will be preferred, and "regression model" will be avoided. This is in order not to confuse with the priced product models considered all the time, such as TV models, dishwasher models etc.

A synonym for "residual term" is "error term", not to be confused with other uses of the word "error" in statistics.

Role and meaning of the hedonic function

To summarise the above example in one sentence: The procedure is that first a hedonic function h is computed from collected data, and then the computed hedonic function is used for quality adjustment in the index calculation.

The hedonic function h thus serves as an intermediary step in the process, to yield the quality adjustment factor g as defined by Eq. (4). It may be mentioned that the hedonic function h also has an independent meaning in itself. As is shown by Eq. (2) the hedonic function h reproduces the prices up to an "error", measured by the residual term r.

The value of the hedonic function h for a given set of characteristics may then itself be interpreted as a price. This is a theoretically expected, or "predicted", price for a model with that set of characteristics. However, in using the type of hedonic method used in the example (hedonic re-pricing, cf. Section 1.2 below), we actually do not have to think much about this fact in the practical calculations.

It should also be noted that the fictitious example given here is simplified, to demonstrate the basic principles of hedonics. In actual applications of hedonics one uses considerably larger sample sizes than just 6 models as in the example. Also, mostly more than two characteristics variables are used, although sometimes in actual practice using just two is relevant.

An authentic example of a hedonic regression equation

The following regression equation is an authentic example, expressing how prices P of computer models depend on the characteristics "speed" and "memory":

$$(7) \qquad \ln P = a + 0.783 \ln(speed) + 0.219 \ln(memory) + \varepsilon$$

The interpretation of this equation is similar to that of Eq. (1) in the example above. The computer example is a simplified form of the hedonic regression equation found by Dulberger (1989) and cited by Triplett (2006).

1.2 Types of hedonic methods

There are several technically different possible ways to use hedonic functions for quality adjustment. The basic aim is the same for the types of hedonic methods, namely, to give an index for price change at unchanged quality in terms of product characteristics. However the methods differ technically in the way they accomplish this.

Four main types of hedonic methods can be identified, namely the following (Triplett 2006; cf. National Research Council 2002):

- The hedonic time dummy variable method.
- The hedonic characteristics price index method.
- The hedonic price imputation method.
- The hedonic re-pricing method.

In practice it should mostly be suitable to try to keep to one of the methods throughout.

The hedonic re-pricing method is here suggested first choice among the four methods. This is the method used in the introductory example above. This method works by modifying observed prices in proportion to a hedonic function. Important advantages of the Hedonic re-pricing method are that it works transparently, and that it can be applied flexibly to meet practical conditions.

The four types of hedonic methods and the choice between them are described and discussed more in detail in Annex 1.

1.3 Topics for consideration in applying hedonic methods

To apply the hedonic approach, one needs to consider and decide on several issues. Those issues may be grouped into five topics:

- Topic 1 – Data needed.
- Topic 2 – Data editing.
- Topic 3 – Creating the hedonic function.
- Topic 4 – Index calculation.
- Topic 5 – Refreshing the hedonic function.

In the following these five topics will be dealt with one by one. It is assumed that Hedonic re-pricing is the method to be used.

Design stage and operative stage

Normally one should at least attempt to distinguish between design stage and operative stage of the work. The design stage comes before the operative stage. It is at the design stage that decisions are made on methods, variables etc. The work at the design stage results in a plan and process instruction for the work at the operative stage. The operative stage is when index numbers for presentation are actually produced from currently or recently collected price data.

The considerations according to the five topics should as far as possible be completed at the design stage. The plan produced at the design stage should be thoroughly considered and tested, so that it can be followed without problems at the operative stage.

A distinction between design stage and operative stage is essential not least to the credibility of the index. There should be no room for suspicion that the choice of methods was unduly influenced by desirability of results. Statistical theory is largely valid under the condition that methods are fixed before one encounters actual data on which statistical results are to be based.

1.3.1 Topic 1 – Data needed

Data are needed for two uses:

- fitting the hedonic regression equation,
- monthly index calculation.

Data needed for fitting the regression equation – price and characteristics variables

For fitting the hedonic regression equation, data on both price and characteristics variables are needed for a sufficiently large set of models of the product in question. This set of data is to be used in a statistical regression analysis which yields the estimated hedonic regression equation. The result is a hedonic function which is to be used in monthly index calculation.

The regression analysis and re-computation of the hedonic function is typically not performed monthly but with longer time intervals in between. In the periods when this is to be done, a larger sample may have to be used than in regular monthly index calculation, due to the requirements of the regression analysis.

Data needed for monthly index calculation – price and characteristics variables

Also in the monthly data collection for index calculation, values of the characteristics variables have to be collected along with prices. Specifically, values of characteristics variables have to be collected when product models are replaced in the price collection, such as when a model in the sample is no longer for sale or is no longer chosen by many consumers. In such replacement situations, characteristics of the replacement model are collected for use in the quality adjustment by hedonics.

How to select characteristics variables

A crucial question is what characteristics variables to collect and use in the hedonic function. Some initial selection is called for, to avoid overambitious data collection which would be unnecessarily costly to the index producer and to respondents. Notably, not all kinds of variables would be relevant anyhow.

The selection of characteristics variables has to be considered with regard to the features of the particular product area and market in question. Differences in market conditions could potentially lead to differences between countries regarding what choice is most adequate.

However, generally the following criteria are relevant for the characteristics variables to be selected:

- They should reflect quality in a consumer perspective.
- They should be perceived by consumers.
- They should be related to the price.
- They should not reflect fashion.
- They should not reflect production cost not giving consumer value.

To keep fashion variables out is necessary to avoid a long-term bias. Fashion features such as skirt length can oscillate forth and back over time, and changes in both directions cannot be considered lasting quality improvements (cf. Guédès 2007). The borderline between quality and fashion may not always be entirely clear, so here again some sound judgement is required. To take another example, if the colours of laptop computers change over time, this should probably be seen as due to fashion – unless it can really be shown that certain colours have a lasting higher value to consumers.

It is not the aim to find variables to account for all price differences. It is only the quality-related differences that are to be captured by the characteristics variables.

Variables expressing production cost

Variables expressing production cost do not necessarily reflect quality to the consumer. Where they do not, they should not be quality adjusted for, even if they may influence the price. For instance transport of raw materials needed for a product may influence the price but does not constitute quality to the consumer.

Nevertheless it may occur that variables related to production cost are also related to quality to the consumer, such as the kind of material in a garment. Such variables should of course be considered to be quality adjusted for. Some support for sometimes using production cost variables is supplied by Gordon (1990, Sect. 2.5). He shows theoretically that under certain conditions, the user-value and resource-cost criteria will tend to give equivalent results.

Omitted variables bias

The set of characteristics variables should be complete enough to reasonably fully account for occurring quality differences between models. An incomplete set of variable may entail *omitted variables bias*.

An example could occur for computers. Suppose the hedonic function accounts for clock rate in gigahertz (GHz) but not for processor type. Now, a computer with a processor of more advanced type may have higher performance than a computer with a processor of less advanced type, even if the clock rate is not higher. Not recognising this, and then omitting indication of processor type, can make the quality adjustment go wrong.

Knowledge about products and market conditions may generally be essential to avoid omitted variables bias. Relevant product features are often likely to be announced in advertising etc. which should be followed.

Intangible product properties corresponding to "subjective" consumer value may present some difficulty. They may be essential to consumer perception of quality, but they may not so easily be measured by some characteristics variables.

Brand dummy variables

In some cases it may be motivated to include dummy variables for groups of brands as characteristics variables. This could be the case if one of these conditions applies:

- Brand may be a proxy for intangible aspects of quality, related to "subjective" consumer perception.

- It may sometimes be necessary to control for brand to make the effect of other variables show up correctly.

Use of dummy variables for brands is somewhat controversial among experts. An argument against such use is that brand does not in itself express useful quality, and then accounting for brand may disturb the impact of other variables. However, a conclusion for HICP practice is that dummy variables for brand groups may be motivated under each of the two conditions just mentioned.

The price variable

There is a somewhat fine point on the price variable, regarding the treatment of price reductions. The ideal requirements on the price variable are slightly different between the use for fitting the hedonic regression equation and the use in monthly price calculation.

For the monthly index calculation, there are rules for the treatment of reduced prices in the Regulation on price reductions (Commission of the European Communities 2000). The rules there state that the prices used shall be as after deduction of such price reductions that are available to all consumers. This applies to prices reduced due to sales, stock clearances etc.

For fitting the hedonic regression equation, the matter is somewhat different. It could reasonably be argued that here it might be preferable to take prices as they are before such short-lasting price reductions that are due to temporary promotion offers, stock clearances, going out of season or out of fashion, or similarly. The reason is that in order to accurately reflect market value of quality, prices should reflect a state of equilibrium, that is, a state of balance between supply and demand. Stock clearance prices etc. do not.

Or to put it in other words, retailers and producers occasionally have logistic reasons (aging overstock, large deliveries etc.) to speed up business by offering bargains, with prices considerably below a sustainable market value. It may then be preferable to exclude those bargain prices, as it seems at least questionable if they duly reflect the quality of the products.

However this may be a somewhat subtle point, and there may be special cases depending on the kind of price reduction. Also, in practice there may be limitations on what can be done in price collection here. Nevertheless it may under some conditions be possible to collect the desired information on causes of price reductions.

Number of price observations needed

Typically more price observations are needed for fitting the hedonic regression equation than for the monthly index calculation. In the index calculation the law of large numbers ensures that sampling errors tend to cancel out on higher levels of aggregation. In the regression analysis one cannot be sure it works quite that way. If the sample for the regression analysis is too small, the hedonic function will be dominated by noise and cannot reflect quality differences.

A general rule of thumb may be stated as:

For regression analysis use a sample so large that there are at least some 15 to 20 price observations per characteristics variable in the regression equation.

This rule of thumb assumes that the sample is statistically fairly efficient, as would be the case for a simple random sample in a homogenous stratum of models. If the sample is less efficient a correspondingly larger sample is called for.

There is some basis in statistical theory for the rule of thumb; cf. Annex 2.

1.3.2   Topic 2 – Data editing

Data have to be edited and prepared in some ways to be rendered suitable for use in the computations: Fitting the hedonic regression equation, and calculating the index.

Identify spurious outliers (as usual)

The usual data cleaning procedures used in index calculations apply as well when the hedonic approach is used, of course. Indeed the data cleaning should in principle be performed at least as carefully as otherwise.

This applies to the treatment of outliers, in the sense of observations with unusually high or low prices or price changes. Usually in index calculation, such outliers are picked out for verification, as they may be due to mistake or error in observation or recording. This cleaning is essential not least before fitting the hedonic regression equation, as regression analysis in its usual form is notably sensitive to outliers.

Transform variables by logarithm

The hedonic regression equation usually contains the logarithm of the price. Sometimes it may also contain the logarithm of other variables. For that reason the price, and possibly other variables, have to be transformed by logarithm before the regression analysis.

Transform category variables into dummy variables

The original data sets are likely to contain variables expressing category or type in some respect. Examples are type of screen on a TV set, and type of cd-rom or dvd drive in a computer.

To facilitate the application in the hedonic approach, it is convenient to transform such category variables into sets of dummy variables. Then define one dummy variable for each category except one of them. The excluded category serves as a reference to which the other categories are compared.

Example: Type of drive on a computer. If there are *n* drive types occurring in current data, then define *n* − 1 dummy variables: One dummy variable for each drive type, except for one drive type. Each dummy variable indicates presence of the drive type in question.

Tricks to edit down the number of characteristics variables

It is often a good idea to try to have relatively few characteristics variables in the hedonic regression equation. Some tricks for achieving this by data preparation are:

- *Group together* alternative features into groups with one dummy variable per group, instead of having one dummy variable for each single alternative.

  Example: Brands. There may be tens or hundreds of brands, so normally do not define individual dummy variables for single brands. Instead define a few broad brand groups. Perhaps it could suffice with just three brand groups, such as brands of low, medium or high status, respectively.

- *Select among or take average of* variables that are closely related to each other.

  Example: Size measures. The size of a book could be measured in several ways, such as number of pages, physical weight, height of cover, width of cover, area of cover, physical volume etc. Do not use all those variables in the hedonic regression equation, but instead choose perhaps two of them, or perhaps the geometric mean of two of them.

- *Consider representing the rank of ordered categories as one continuous variable*, instead of using separate dummy variables.

  Example: Energy economy rating for appliances. Instead of defining dummy variables for rating categories, consider treating the rank of the rating category as one single continuous variable. Some care should be taken to check by judgement that the step-size does not become vastly varying over the range.

Generally, do not include variables that are actually constant or practically constant.

The desirable feature of using few variables is sometimes known as *parsimony*. This may enhance the accuracy and keep down the necessary number of observations in the estimation of the hedonic function.

Missing values in fitting the hedonic regression equation

In practice it may occur that for some of the product models in the sample, information is not available on all of the characteristics variables. For instance, a cheap TV set sold in a hypermarket might not be accompanied by a full technical specification with all details such as screen resolution etc. Hence some values of characteristics variables may be missing. However, regression analysis in its usual form can use only observations that have values on all the variables occurring in the regression equation.

Dropping all observations (product models) with some value missing is of course a potential way to deal with the problem. This could perhaps do if observations with missing values occur only exceptionally. But usually this is not a desirable solution, as it may lead to selection bias and bad precision.

Imputation in a simple pragmatic form should mostly be a better practice. It could be carried out in this way:

- For each *continuous variable* that may have missing values, take two actions: (a) Define a dummy variable indicating whether or not the value is missing; and (b) For the continuous variable itself, impute (insert) a constant for all missing values. (*Note 1*: The choice of the constant is not critical but should be in the natural range of the variable. *Note 2*: If there are two or more continuous variables which can be missing only together, use just one dummy variable for their joint missingness.)

- For each *dummy variable* that may have missing values: Impute a default value for all missing values. (*Note*: The default value chosen for imputation should normally correspond to a "plain" model of the product, without more luxurious or unusual features.)

- Optionally, one may consider defining dummy variables indicating missing values also in sets of dummy variables. Example: Brand groups. A separate dummy variable could be defined to indicate "no brand".

This simple approach may often be adequate. An advantage is that the process is fairly transparent, and one has some common sense control of what happens here. The choice of default values for dummy variables should be done using product knowledge.

Imputation by more advanced statistical techniques may also be considered, although they are probably not yet so much corroborated for use in hedonic regression. Such techniques may rely on assumptions which the potential implementer should be well aware of and should then assess in the light of product knowledge.

Missing values in index calculation

In the monthly index calculation, missing values for characteristics variables may often be less of a problem than in fitting the hedonic regression equation. In the index calculation characteristics variables are used for quality adjustment when models are replaced.

Thus imputation should often not need to be considered in index calculation. Nevertheless, under some conditions the same imputation as for the regression may have to be used also in index calculation.

Remember to update the editing process

The development in the markets alters the conditions also for the data editing process. For instance, category variables may take more possible values than before, as models with newly developed features show up on the market. Then one has to decide on how to handle this in the transformation to dummy variables. New dummy variables may have to be created, while others may have become obsolete and can be dropped. Or perhaps new features may be grouped together with existing ones, and be represented by the same dummy variable.

Brand groups (cf. Section 1.3.1, subsection "Brand dummy variables") are likely to deserve particular attention, if they are used. In some markets new brands emerge all the time, and then the new brands have to be classified into appropriate brand groups. This classification is a judgemental task which requires knowledge of markets and products.

1.3.3 Topic 3 – Creating the hedonic function

Creating the hedonic function is naturally a key issue. The hedonic function has to be designed and assessed to ensure that it can adequately reflect quality differences. In this work it is essential to have a reasonably thorough understanding of statistical regression theory, as it is treated in textbooks such as those by Ryan (1997); Draper & Smith (1998); Kutner et al. (2004). The following treatment can only highlight a few essential points, and for further advice and explanations the reader is referred to the textbooks.

Again – how to choose characteristics variables

Again, the choice of characteristics variables is a crucial issue. In the treatment of Topic 1 in Section 1.3.1 above, principles for choosing characteristics variables were discussed. And in the treatment of Topic 2, it was shown how the characteristics variables may be modified by editing.

For the design of the hedonic function it has to be more definitely decided on which variables to include in the hedonic function, and in which form. And again a primary concern should be to select the variables so that they reflect essential quality differences between product models.

These important considerations must to a large extent rely on knowledge of the product area. Also, specific advice for such considerations has to be given separately for each product area and take account of the particular product aspects there. Nevertheless, the view should be that of consumers rather than that of product engineers. Thus the characteristics variables in the hedonic function should at least indirectly reflect quality as it makes sense to consumers.

Choosing the function form – normally choose a log-linear form

The choice of function form for the hedonic regression equation is usually likely to be less critical than the choice of characteristics variables. A standard choice should mostly be adequate.

A *semi-logarithmic* hedonic regression equation looks like this:

(8) $\ln P = b_0 + b_1 \cdot z_1 + b_2 \cdot z_2 + ... + b_k \cdot z_k + \varepsilon$.

Here ln stands for natural logarithm, P is the price, and z_1, z_2, ..., z_k are characteristics variables, which may each be either continuous or a dummy variable. Further b_1, b_2, ..., b_k are regression coefficients to be estimated by fitting of the regression equation to observed data, and ε is a residual term.

A *double-logarithmic* hedonic regression equation is similar and can alternatively be used when the characteristics variables are continuous. In this form logarithms are used also for the characteristics variables, so the equation looks like:

(9) $\ln P = b_0 + b_1 \cdot \ln z_1 + b_2 \cdot \ln z_2 + ... + b_k \cdot \ln z_k + \varepsilon$.

The double-logarithmic form has to be modified if dummy variables are present, as the logarithm is then not taken for dummy variables. For example, with two continuous characteristics variables and one dummy variable, the hedonic regression equation would be like:

$$(10) \qquad \ln P \,=\, b_0 + b_1 \cdot \ln z_1 + b_2 \cdot \ln z_2 + b_3 \cdot z_3 + \varepsilon \; .$$

The *semi-logarithmic* and the *double-logarithmic* forms, together known as *log-linear* forms, may generally both be seen as recommended choices. They seem to be the forms most commonly used in hedonic regression, and there seems to be good reasons for this, for instance considering the behaviour of the residual term (cf. end of next subsection).

The semi-logarithmic and double-logarithmic forms both yield regression coefficients that have meaningful independent interpretations. This is an advantage for transparency and in assessment of the performance in practice.

A further notable property of the semi-logarithmic and double-logarithmic forms is this: If all prices are multiplied by the same constant factor, then all the regression coefficients $b_1, ..., b_k$ are unaffected, and only the constant term b_0 changes. This should be a desirable property, as the relative impact of quality characteristics on the price should not have anything to do with the purchasing power of the Euro.

The choice between the semi-logarithmic and double-logarithmic forms may be made case by case. The *semi-logarithmic* form may have a slight transparency advantage, in treating continuous variables and dummy variables equally (cf. ILO et al. 2004, Sect. 7.98).

On the other hand, the *double-logarithmic* form may be more suitable when continuous variables may vary over wide ranges, with high ratios between upper and lower bounds. In use of the double-logarithmic form, be careful if some continuous characteristics variables may assume zero value, as logarithm of zero is undefined. A possible remedy is then to do as suggested for missing values above (Section 1.3.2, subsection "Missing values in fitting the hedonic regression equation"): For each continuous variable where zeros may occur, define a dummy variable to indicate zeros, and impute a positive constant for the zeros.

Other function forms

As the log-linear function forms just described should be adequate in most cases, other function forms should not often need to be considered. However potentially several alternatives would be possible.

In a *plain linear* hedonic regression equation, logarithms are not used, and it looks like:

$$(11) \qquad P \,=\, b_0 + b_1 \cdot z_1 + b_2 \cdot z_2 + ... + b_k \cdot z_k + \varepsilon \; .$$

This form has found some use, but it may generally be seen as less adequate than the log-linear forms described above. An indication of inadequacy is that the hedonic function may here turn out to predict negative prices, which does not make sense.

Using a *Box-Cox transformation* for the price on the left-hand side could be seen as a generalisation of the semi-logarithmic and plain linear forms. This transformation is defined by a control parameter λ as:

$$(12) \quad \begin{cases} \dfrac{P^{\lambda}-1}{\lambda} & \text{for } \lambda > 0 \\[2em] \ln P & \text{for } \lambda = 0 \, . \end{cases}$$

For $\lambda = 0$ using this transformation would give the semi-logarithmic form, and for $\lambda = 1$ essentially the plain linear form. Those two alternatives now appear as opposite extremes of a continuous range of alternative function forms, obtained by varying λ. On transformations, cf. further Ryan (1997), Ch. 6; Davidson & MacKinnon (1993), Ch. 14; and Emerson & Stoto (1983).

Box-Cox transformations are probably of at most secondary relevance for hedonics, although the control parameter λ could be optimised for best fit to data. A reason is that on intervals of relevant length, correlations tend to be high even between functions of notably different form. Then probably not so much is to be gained by fine-tuned transformations.

In other applications of regression analysis than hedonics, such as econometrics, different criteria are in use for choosing function form (cf. Kennedy 2008). One such criterion is to stabilise the variance of the residual term, or in other words, to eliminate heteroskedasticity; see subsection "Residual analysis – interpretation" a few pages below. In practice it may be difficult to formally apply such criteria to hedonic applications, and normally this should not be urgently needed. Nevertheless, it may be noted that from general theoretical plausibility arguments, the log-linear function forms should often be expected to be suitable for hedonics also in view of the mentioned criterion.

Estimating the hedonic function

The actual fitting of the hedonic regression equation, yielding the estimated hedonic function, is carried out by a computer run using some standard software package for statistical analysis. Regression analysis is available in several well-known such program packages, such as Minitab, R, SAS, SPSS, STATA, and SYSTAT.

In practice this means the following. For example, suppose that the hedonic regression equation to be fitted is of the semi-logarithmic form,

$$(8) \qquad \ln P = b_0 + b_1 \cdot z_1 + b_2 \cdot z_2 + \ldots + b_k \cdot z_k + \varepsilon \, .$$

A data table (computer file) is prepared containing one row for each product model in the sample. The table has columns containing the values of $\ln P$ and the values of the characteristics variables z_1, z_2, $\ldots$, z_k. The computer program is set up to perform a linear regression analysis on the data in the table, with the column containing $\ln P$ as "dependent" variable and" z_1, z_2, $\ldots$, z_k as "independent" variables. The output of the computer run consists in the estimated values of the regression coefficients b_1, b_2, $\ldots$, b_k. And along with them there is usually a lot of additional information produced.

The computer run for the regression analysis is in a way the easiest part of it all. The user just has to feed in the data, and the computer does the work. The more difficult part consists in the considerations needed before and after, as is described in this chapter, to ensure that it all makes sense.

The computational method used by the computer program is normally a classical method known as *ordinary least squares (OLS)*. The guiding principle of that method is to determine the regression coefficients so that the sum of squares of the values of the residual term becomes as small as possible (cf. e.g. Ryan 1997, Sect. 1.4). But that all takes place inside the computer. For deeper views on the estimation theory, see McCullagh & Nelder (1989).

Weighted regression?

Occasionally some kind of weighting information may be available for the product models. For instance sales volumes may be known for the individual models. In index calculation it is often seen as advantageous to use such weighting information where it is available.

On the other hand, for the regression analysis the first choice should be not to use weighting information.

Some explanation is called for. There are forms of regression analysis that can use weighting information for the observations, available in standard software packages. The question is whether to use this option or not.

A basic fact from the classical Gauss-Markov theorem (Wilks 1962, Sect. 10.3; Davidson & MacKinnon 1993, Sect. 5.5; Kutner et al. 2004) is this: Under the condition that the regression equation is "correct" in the sense that prices truly tend to follow a law of the same form (but with unknown true coefficient values), then un-weighted estimation of the regression coefficients is unbiased. So under that condition weighting is not needed to yield unbiased coefficient estimates.

A regression equation is never perfectly correct in the mentioned sense. But if it has been deemed correct enough to be applied at all, it may be correct enough also for un-weighted coefficient estimation. Furthermore it follows from theoretical work by Nordberg (1989) that un-weighted estimation of regression coefficients is unbiased also under somewhat more general conditions. Essentially such a condition is zero correlation between residuals and weights.

Regarding precision, again the Gauss-Markov theorem just mentioned asserts that under the condition of the regression equation being correct, un-weighted regression gives the best precision. An intuitive way to realise this is to note that in a weighted analysis, a few observations with large weights may dominate, so that the sample size becomes effectively small there.

But there is still an issue of robustness. Sometimes observations with small weights may be likely to be exceptional outliers. Those may disturb unduly if they are used without account for their low weights.

A conclusion could be this: Normally do not use weights. However, if models with very low weights are likely to be exceptional (outliers in price), then possibly consider using

weights with a suitably chosen low upper limit. In the latter case, retain weights below the limit, and replace those above the limit by a constant equal to the limit.

It should be mentioned that this advice may not be quite uncontroversial, as some experts advocate use of weighting. Also, the advice given here to avoid weighting is restricted to the hedonic re-pricing method. For the Hedonic time-dummy variable method (cf. Annex 1), probably available weights should normally be used.

Assess the hedonic function at design stage – principles

At the design stage one should perform test runs of the regression analysis, using available data from previous periods, from pilot surveys or so. This should be done to assess whether the hedonic regression equation can be considered to work adequately: whether it fairly fits data, is not disrupted by disturbances, etc.

A lot of information is usually produced in regression runs. In the test runs, this information should be examined carefully, as it could reveal possible problems with the choice of variables, impurities in data, or other design aspects. Some primary issues on this will be discussed in the following.

The assessment should essentially be completed at the design stage. Nevertheless some monitoring should be in place also at the operative stage, in the production of actual indices to be presented. The latter efforts may be seen as a complement to data editing, to ensure that unexpected deficiencies in data or processing do not go undetected.

The R-square (R^2)

The R-square, or R^2, is a number produced in the regression analysis, along with the regression coefficients. R-square is a number between 0 and 1. A high R-square indicates that the regression equation fits closely to the data, as then the residual term is generally small. Then the hedonic function closely follows the prices.

An R-square equal to 0 would mean that the hedonic function is constant. Then the chosen characteristics variables are not at all related to the price, and so the hedonic function can say nothing about price variation. The opposite extreme, an R-square equal to 1, would mean that the hedonic function is always equal to the price. This would be as if one monopolist sets all prices according to one simple tariff, and it should normally not happen in real markets.

The R-square is among the first things to look at to assess a regression run. The R-square should be fairly high, to indicate that the hedonic application may work properly. How high R-square should be expected may vary between product areas, and this has to some extent to be based on experience. General rules of thumb could hardly be given. In some cases even an R-square as low as 0.25 may be adequate, while in other cases one would rather expect a figure around perhaps 0.75.

It should be stressed that a higher R-square is not always better than a lower R-square. For instance, it may in some cases be more adequate to run separate regressions for each of two strata, rather than one regression on both strata pooled together, even if the R-squares then become substantially lower.

Which R-square – take the "adjusted" one

Actually two R-square numbers are presented in parallel: The "unadjusted" R-square, and the lower "adjusted" one (see, e.g., Ryan 1997, Sect. 7.4.1).

Suggestion: Mainly use the adjusted R-square, rather than the unadjusted one. The adjustment corrects for the fact that due to finiteness of the sample, the "raw" R-square tends to be higher than what would be expected for a very large sample. The adjusted R-square may potentially even become negative, and just like a zero or very low R-square, that outcome indicates that the characteristics are practically unrelated to the price.

Nevertheless, one may quickly glance at the unadjusted R-square as well, just to check that it is not unexpectedly extremely close to 1, with a value of 0.99 or so. Such a high value could possibly indicate some kind of degeneracy in data, leading to invalid results.

Assess the hedonic function at design stage – plausibility of results

Assess the plausibility of the regression coefficients. The regression coefficients have an independent interpretation and could thus be assessed in view of product knowledge and common sense.

Consider again the hedonic regression equation obtained in the introductory example above.

(1) $\ln Price = 5.604 + 0.0155 \cdot Size + 0.1331 \cdot Trait\_A + \varepsilon$.

This hedonic regression equation is of semi-logarithmic form (as defined above). For such an equation, the regression coefficients can be interpreted in the following simplified approximate way:

- The regression coefficient 0.0155 for the continuous variable Size means this: If Size increases by one unit, then the expected price increases by approximately $0.0155 \cdot 100 = 1.55\ \%$.

- The regression coefficient 0.1331 for the dummy variable Trait_A means this: If the feature indicated by Trait_A is added, then the expected price increases by approximately $0.1331 \cdot 100 = 13.31\ \%$.

So it is possible to assess whether the results make sense from a point of view of product knowledge. However some estimation error must be allowed for; see next subsection.

Particularly, beware of coefficients with "wrong sign". If increment in a variable should mean higher quality and higher expected price, then the estimated coefficient should be larger than zero. If instead it has a minus sign in front of it and is thus smaller than zero, then this should be taken as a warning. Possibly there could be some disturbance from omitted variables bias (cf. Section 1.3.1, subsection "Omitted variables bias"), or from multicollinearity (cf. subsection "Use diagnostics for multicollinearity", shortly below), etc. For further discussion, see Kennedy (2008, Sect. 22.3 [with Notes]).

It may be noted that the interpretation of coefficients just described involves rather rough approximations, with the limited aim of facilitating quick assessments of plausibility. For a closer discussion on interpretation of coefficients of dummy variables, see Kennedy (2008, Sect. 15.1 [with Notes]).

Test statistics – use with care

The regression run usually also provides estimated standard errors for the estimated regression coefficients. There may as well be "t-values" which are in principle ratios between the regression coefficients and their standard errors.

The standard errors indicate the uncertainty or "estimation error" in the estimation of the regression coefficients. A "margin of error" by usual standards corresponds to a double standard error. Thus under certain conditions, the true coefficient should mostly lie within the interval given by the estimated coefficient plus/minus two times the standard error.

The t-values are used to test whether the coefficients are significantly distinct from zero; that is, whether the variable in question is significantly related to the price. Very simply stated, by usual standards the variable in question is deemed to be significantly related to the price if the t-value is either below − 2 or above + 2.

However, it should be stressed that one should be a little careful here and perhaps take the standard errors and t-values as merely indicative, not too literally.

The reason is that the computations rely on a mathematical theory using assumptions that may be problematic in the price statistics context. There are assumptions of stochastic mutual independence between observations, and these may in price-statistics be disrupted as observations are clustered by manufacturer etc.

If a weighted regression is used, standard errors and t-values may be grossly invalid and should not be used at all, unless particular precautions are taken.

Criteria for variable selection

There are actually several criteria for variable selection, and for instance the adjusted R-square can be useful here. It may turn out that some variables could be omitted from the regression equation without diminishing the adjusted R-square very much. Then it could be worth considering doing so – even if the t-values suggest that the variables are "significant".

Other criteria are for instance the "information criteria" AIC and BIC (see e.g. Kennedy 2008, Notes to Sect. 6.2). Like the adjusted R-square these can be used to compare the fit of models with fewer or more variables. In doing so they put a penalty on the number of variables, so as to somewhat favour having fewer variables in the regression equation.

Data-driven variable selection?

It is sometimes suggested that decisions on design issues such as variable selection should be data-driven. The idea is then to let decisions on variable selection be guided by assessment on data, usually aiming at a regression equation with good fit to the data.

However, there may be reasons to be a little careful here. A primary concern should always be that the characteristics variables chosen have to be relevant from points of view of consumer perception and product knowledge. A too automatic hunt for optimal fit could then be misleading, for instance by the difficulty to identify variables reflecting fashion which should not be quality adjusted for.

In the regression equation, should one exclude variables with regression coefficients not significantly distinct from zero in test runs? (Cf. preceding subsection.) Often this may be the right thing to do, as those "insignificant" variables do not prove to be important. An appealing reason for excluding such variables is that their coefficients may be likely to occasionally come out with the "wrong sign" just by chance, which may not seem to make good sense (cf. subsection "Assess the hedonic function at design stage – plausibility of results", recently above).

However there is some reason to think twice here. There may be a possibility that separately insignificant variables may be significant together. There may also be a possibility that an insignificant variable would have turned up as significant if the sample had been larger. Thus occasionally insignificant variables should perhaps not be thrown out immediately, as they may have a role to play in the larger picture.

Another complication is that significance tests should be taken as merely indicative, as was mentioned in the preceding subsection. Further, when a lot of significance tests are considered simultaneously there is a problem of "mass significance" or "multiple comparisons" which would have to be tackled so that control is not lost.

However, even if one should be a little careful in interpreting the t-values and significance tests, one should of course not ignore them. Their message is indeed important. A particular issue may be noted here. It may occur that a variable turns out to be persistently insignificant, although it would be believed to be important from a perspective of market knowledge. This would seem to indicate that the variables are actually too many, for the regression analysis to fully sort out their impacts, at least in the sample used (due to "collinearity", or co-variation of variables; cf. the subsection "Use diagnostics for multicollinearity" shortly below). Then some variable should be excluded, probably the persistently insignificant one.

It may be advisable to use a compromise approach, and take guidance from both market knowledge and outcomes of test runs. The process could be roughly as follows:

Start with an initial idea from product knowledge. Then assess the initial idea in view of test runs, but be a little conservative. Do not modify the variable set immediately after a single test run. Instead modify it if a persistent pattern suggesting this emerges after several test runs and informed interpretation of their outcome.

More in passing it may be noted that modern statistical theory provides more systematic approaches to variable selection and multiple testing, as developed by Miller (2002), Miller (1981) and Savin (1984). Possible application of such techniques to hedonics may need more methodological research.

Use diagnostics for influential observations

The software for regression analysis usually produces a lot of further information, "regression diagnostics" which may give useful indications on potential problems; see, e.g., Atkinson & Riani (2000); Belsley et al. (1980); Donald & Maddala (1993); Kennedy (2008); Ryan (1997); SAS (2004); cf. also Bartlett & Lewis (1994).

Some of these diagnostics warn about "influential observations". There are several such diagnostics, known as leverage, Cook's distance, DFFITS etc. "Influential observations" are

observations with particularly strong impact on the estimated regression coefficients. The diagnostics show if there are single observations which on their own have a notable impact on the regression coefficients or on the hedonic function. If this is the case, it may indicate a too great sensitivity to disturbances.

Solving such a problem, if it turns up, may need some consideration. One could have to re-consider variable selection, sample size, the process of data editing etc. But do not arbitrarily use these tools in the operative index production just to throw away problematic observations, as that could be bias-prone.

Use diagnostics for multicollinearity

Multicollinearity is said to occur when there is some close relationship between characteristics variables. When multicollinearity occurs that may be problematic, as the regression equation then becomes unstable and the regression coefficients uncertain.

There are regression diagnostics to detect multicollinearity. For instance, one can use variance inflation factors (VIF), eigenvalues and condition number of the covariance matrix, and correlations between variables and between estimated regression coefficients. It should be good practice to take a quick look at those diagnostics, although, as Triplett (2006) notes, the problem of multicollinearity should perhaps not be exaggerated for hedonic regression.

The variance inflation factors (VIF) are computed for each characteristics variable. They are factors by which the variance of the coefficient estimates are inflated due to collinearity. It has been suggested that a VIF of 10 or above may be taken as a warning (cf. Kutner et al. 2004).

The condition number of the matrix $X^T X$ (see Annex 2) is equal to the ratio between the largest and the smallest eigenvalues of that matrix. Normally exclude the constant column (corresponding to the intercept) of the X matrix in this consideration; this is achieved by for instance option COLLINOINT of the usual regression procedure PROC REG in the SAS System (cf. SAS 2004). Limits between 10 and 100 have been suggested for considering the condition number "high" (Belsey et al. 1980; SAS 2004).

When multicollinearity occurs in hedonic applications, it may often be expected in advance, by the nature of the products in question. For instance, for some kinds of products such as cars and books, there are different variables that are each strongly related to the size of the model. Then diagnostics may not have much to add. The problem should then preferably be handled upfront in selection of variables, rather than by trying to cope with too many variables as long as diagnostics remain just modestly alarming.

Examine residuals

Consider again the hedonic regression equation, for instance in the semi-logarithmic form,

$$(8) \qquad \ln P = b_0 + b_1 \cdot z_1 + b_2 \cdot z_2 + \ldots + b_k \cdot z_k + \varepsilon \; .$$

The last term ε on the right-hand side here, known as residual term (or error term), may be seen as a little more interesting than just a disturbance. The behaviour of the residuals could reveal a little more than the R-square about how well the regression equation fits to the data.

When the regression equation is designed to fit observed data, it may therefore be useful to examine the values of the residual term. The residuals are then computed for each of the observations used to fit the regression equation, and this can often be practically accomplished by the software used to fit the regression equation.

The residuals may be plotted against characteristics variables or background variables, or they could be analysed in statistical tables; see, e.g., Goodall (1983); Ryan (1997); Kutner et al. (2004). Such plots or tables could reveal presence of outliers, skewed outlier distributions, deviating outlier distributions in some cells, etc. This in turn could indicate risk of omitted variable bias, need of enhanced data editing etc.

Residual analysis – an example of setup

The following Chart 119 shows an example of a residual analysis. A hedonic regression was run on a set of German price data for notebook computers in April 2006. The regression equation was of semi-logarithmic type, with continuous characteristics variables for clock rate ("speed"), RAM capacity and screen resolutions, and four dummy variables for processor types and one for type of screen. The number of observations was 199, and the adjusted R-square was 0.59.

The chart is a scatter plot, where the computer models in the sample are plotted by residual on the vertical axis and clock rate in megahertz (MHz) on the horizontal axis. Each "x" or "c" denotes one or more computer models, and the models denoted by "c" are those of a particular brand. The scatter plot was produced by the regression program (here PROC REG of the SAS System; cf. SAS 2004).

The scale of the vertical axis refers to differences in the natural logarithm of the price. This so since the regression equation is of the semi-logarithmic form like Eq. (8). This means that for instance a residual value of 0.1 corresponds to an observed price that is roughly 10 % higher than the price given by the hedonic function (as $0.1 \cdot 100 = 10$).

The idea of the scatter plot is to give a useful impression how the residuals are distributed. Particularly it can be seen how the distribution of residuals depends on the clock rate, which was chosen for the horizontal axis as it is a key characteristics variable for computers. Namely, the x's and c's along a given vertical line correspond to computer models with a given clock rate.

Chart 119
Scatter plot of residuals by clock rate (MHz) for a sample of notebook computers
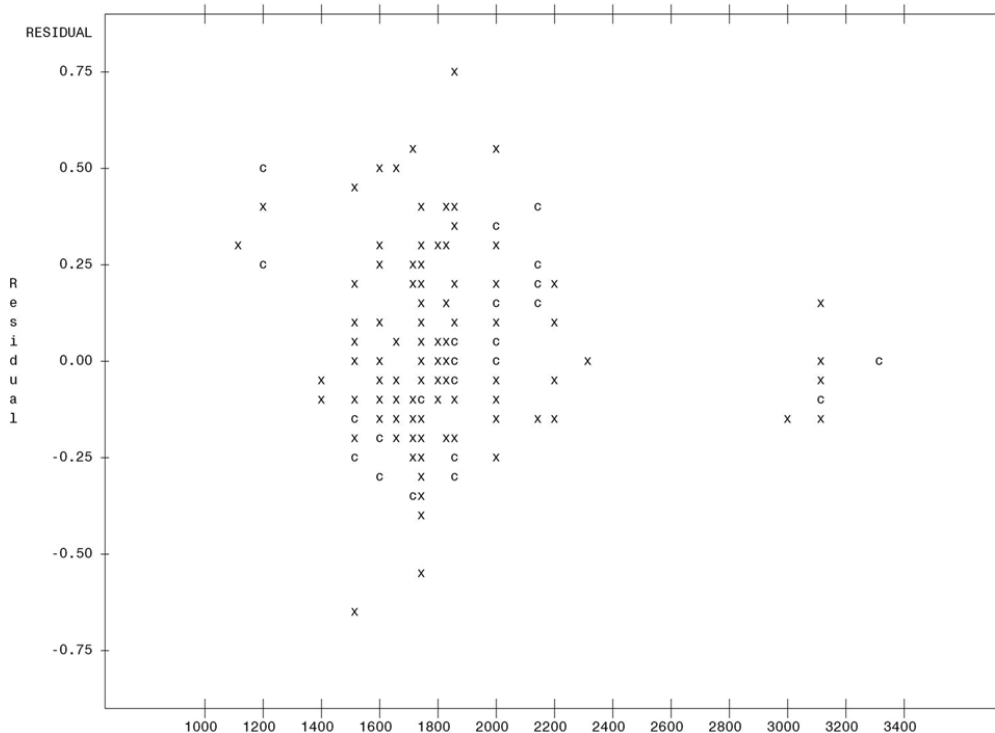
Residual analysis – interpretation

A residual analysis such as the one just shown (Chart 118) can be interpreted as follows. What one would like to find here, if the regression equation works as assumed, is fulfilment of these conditions:

(1) The residuals should be fairly symmetrically distributed around the zero level, everywhere along the horizontal axis.

(2) The residuals should be fairly symmetrically distributed around the zero level, also for important subgroups of observations, such as brand "c" in this example.

(3) The dispersion of the residuals should not vary much between different values on the horizontal axis.

(4) There should essentially not be exceptional outliers among residuals.

If conditions (1) or (2) would be violated, then this could indicate that there are some essential characteristics variables that have been omitted and would have to be included in the regression equation. Not doing so could result in omitted variables bias (cf. Section 1.3.1, subsection "Omitted variables bias"). Violations of condition (3), known as heteroskedasticity, may normally be a little less worrying in hedonic regression. It should

normally not lead to bias but is likely to affect precision and significance tests (cf. Davidson & MacKinnon 1993, Sect. 16.5). In exceptional cases, the function form of the hedonic equation might have to be re-considered, or weighting considered, in order to deal with heteroskedasticity. Outliers (condition [4]) could be disturbing if they are prevalent, and thus they then need consideration.

The scatter plot could be supplemented by computations, such as computation of the mean residuals for chosen subgroups. Those means should be close to zero, to verify condition (2).

For the actual data shown in Chart 119, it is seen that there is not so much to worry about regarding conditions (1) – (4). It is seen that the residuals are indeed fairly symmetrically distributed around the zero level. There is no clear evidence of heteroskedasticity, as the variation in dispersion does not seem clearly larger than may correspond to variation in number of observations. There are some outliers but they seem notably few, in this example.

Particularly, the residuals for models of brand "c" are also seen to be symmetrically distributed around zero. Actually a computation shows that the residuals for brand "c" have mean – 0.02, thus close enough to zero, and standard deviation 0.20.

Potential of advanced regression methods

Nowadays there are several more advanced methods for regression analysis. Far from all of them, but some of them may be of potential value for hedonic regression, for instance in handling outliers, or interdependence between observations. The latter might make statistical significance testing better valid. Examples could be "forward search" (of observations), and generalised linear models, both described by e.g. Atkinson & Riani (2000), and further robust regression, as described by e.g. Maronna et al. (2006). Here further methodological research would be called for.

1.3.4   Topic 4 – Index calculation

When the method of hedonic re-pricing is used, the index calculation is basically carried out as it is without quality adjustment, except that a hedonic function is used to modify prices.

Index calculation usually straightforward

The monthly current index calculation is usually straightforward when the method of hedonic re-pricing is used. The hedonic function h (.) should usually have been computed earlier, so it can be assumed to be available for use in the index computation.

Then the monthly process for index calculation is as follows:

1. For each product-offer with a model replacement since the preceding month, compute a quality adjustment factor as:

(13) $$g = \frac{h\,(\text{Characteristics of replacement model})}{h\,(\text{Characteristics of replaced model})}$$

2. For each of the mentioned product-offers, modify the reference price by multiplying it with the quality adjustment factor *g*, computed for that product-offer.

3. Calculate the index by the usual index formula.

Hedonic function form vs index formula – don't worry

Normally one should not have to worry whether the hedonic function form and the index formula go together well. In practice a log-linear hedonic function form should be useful irrespectively of which elementary index formula is used: geometric mean index (Jevons index), or ratio of mean prices (Dutot index). The approximation possibly involved should usually be quite harmless.

The process just described for monthly index calculation applies to both index formulas. The quality adjustment factor *g* in each replacement is computed in the same way for both cases, and in both cases the reference price is multiplied by it.

Application for non-matched replacement

The hedonic re-pricing method can be used also when model replacements in the price collection are not made one-to-one.

In the usual price-collection practice, there is a one-to-one matching between observed product-offers in the price reference period and those in the comparison period. Many of the product-offers are the same in both periods, while some may be replaced one-to-one as they have gone out of the market or become unimportant.

In some cases such one-to-one matching between the periods is not possible or not suitable. For instance, novels or newly built houses are more or less individual objects and cannot suitably be matched between periods.

To apply hedonic re-pricing to such a situation without matching, modify all prices of both periods, by multiplying them with a quality adjustment factor obtained as:

$$(14) \qquad g = \frac{h \,(\text{Standard set of characteristics})}{h \,(\text{Characteristics of actual model})}$$

The numerator here is the value of the hedonic function for some hypothetical "standard" model with given characteristics.

The idea is that all prices, of both the price reference period and the current period, are modified so as to correspond to the same standard quality.

Choice of domains for hedonic functions

A decision to be made at the design stage is to determine the domains of products that shall have their own hedonic functions, that is, their own hedonic regression equations. A probably often useful default is to choose consumptions segments as domains for the hedonic functions, and thus use separate hedonic functions throughout separate consumption segments. There are conceptual reasons for this choice, as according to the Regulation (1334/2007) consumption segments shall form the fixed objects of the index basket to be followed.

However, the default idea of having one hedonic function per consumption segment should not be taken as a strict rule. In some cases the accuracy of the index might be deemed to be better served by some other choice. It could occur either that one common hedonic function could be used for two or more consumption segments, or conversely that separate hedonic functions could be used for different strata within the same consumption segment.

Using one hedonic function over two or more consumption segments could be applicable under some conditions: First, the relevant characteristics variables should in principle be the same in the consumption segments in question. Second, these characteristics variables should also have a similar role for the quality in the different consumption segments.

If one hedonic function is used over two or more consumption segments, a dummy variable should be used to indicate the consumption segment. A potential advantage of the approach could be better accuracy, by better precision in the estimated regression coefficients.

On the other hand, using separate hedonic functions for different strata within a consumption segment could be motivated if different strata have very different sets of relevant characteristics variables. This could occur in a technology shift, such as that from tube TV sets to flat-screen TV sets. However, an alternative way of handling such a situation could be using the same hedonic function throughout the consumption segment anyhow, and allowing for missing values by the imputation technique described in Section 1.3.2.

1.3.5 Topic 5 – Refreshing the hedonic function

The hedonic function has to be re-computed, that is "refreshed", often enough to stay up-to-date.

Need of frequent refreshing due to product development

Product development causes a need to refresh the hedonic function. Product characteristics get changed valuation, and newly developed features become important. Then the hedonic function needs to be re-computed to stay adequate.

Example: Assume computer producers benefit from a sharp drop in prices of processor chips used in computers. Then prices of computers are likely to become less strongly dependent on the processor clock rate. If yet the existing hedonic function continues to be used, this will lead to an over-adjustment for improvements in clock rate. For the retained coefficient for clock rate in the hedonic function is higher than it currently should be.

Frequent enough refreshing of the hedonic functions should be most urgent in areas with rapid technological development, such as computers and video cameras.

How about other areas, with less rapid technological development, should frequent refreshing be considered urgent there too? Here there is a lack of clear evidence, and views differ somewhat. It does not seem quite as evident to what extent frequent refreshing may be urgent for e.g. TV sets, where the consumer visible technology is relatively more stable.

A trade-off

There may be some trade-off to be made here. There may be some danger in refreshing more frequently than as is motivated, as it may then be more problematic to prevent fashion from getting an undue influence.

Example: If, say, metallic blue TV sets would become fashionable, they may get a higher price than other TV sets. But when they go out of fashion next year or so, they get a lower price than other TV sets. Now, suppose that metallic blue colour becomes accounted for in a frequently refreshed hedonic function. Then metallic blue colour would be accounted for first as good quality when it comes in, and then as bad quality when it goes out.

And so, in the end TV sets would be treated as having become permanently better just by having been metallic blue for a while. Of course that would not make sense and would produce a long-term bias in the index.

This hypothetical example may seem somewhat extreme. A feature such as colour of a TV set would likely be recognised from start as a fashion feature and thus not considered for quality adjustment. But the point is that the borderline between quality and fashion may not always be very clear. Some new feature highly valued today may or may not be highly valued tomorrow, perhaps no-one knows yet. To complicate further, possibly some new features may at start have both a temporary fashion value and a lasting quality value. The difficulty to recognise fashion features vs quality features may entail a risk that frequent refreshing of the hedonic function leads to bias as in the example.

When to refresh – monitor the market and run control regressions

Usually it is probably not feasible to refresh the hedonic function every month. So there is need for some indications on when refreshing is called for. Two main possibilities here are:

* Monitoring the market for information on changes in product features and their valuation.
* Control regressions to check for change in regression coefficients.

Probably a combination of these two approaches is advisable. A fully automatic criterion based on control regressions may not be feasible, as the tools provided by statistical theory may not fully comply with the conditions here. There is not a full consensus on this matter. For evaluation of the suggested control regressions, significance tests on regression coefficients can be used as indicative evidence whether the impact on the price of the characteristics variables has changed (cf. Section 1.3.3, Subsection "Test statistics – use with care"). A suitable option could be a form of Chow test as described by Kennedy (2008, Notes to Sect. 15.4).

By the latter approach one would, just for the sake of the control regression, formally apply the computations of the hedonic time dummy variable method (see Section 7.1.1) in two versions: In one version the coefficients for the characteristics variables are the same for both periods compared (as in Eq. [15]), and in the other they are allowed to differ between the periods. It can then be tested by an *F* test whether the latter regression equation fits the data significantly better than the former does. (It may be noted that the second regression equation mentioned would be useless for directly computing an index, and it is of interest only for the comparison of fit described.)

Suggested convention

In the lack of clear evidence on appropriate frequency of refreshing the hedonic function, the following convention may be suggested:

- Perform scheduled control regressions to check the constancy of the regression coefficients.

- Switch to using re-estimated regression coefficients if they deviate significantly from those in use.

- Assign a person or a group with product knowledge, to monitor the market for signs of need of refreshing.

1.4   Cost aspects

Applying hedonic regression in index production incurs costs due to:

- competence needs,

- data processing amendment,

- extended data collection.

Competence needs

In the index computation staff, competence is needed both on the markets, product areas in question, and on the statistical theory and practice of regression analysis. This competence is needed to provide a sound basis for decisions on design of process details, including variable selection, stratification, refreshing plan, etc., as has been discussed in this chapter. In the staff there should be persons with a thorough background in statistical theory of regression analysis.

The competence needs are most prominent at the design stage. But to a notable extent they are needed also at the operative stage, to monitor diagnostics etc. in re-computations of the hedonic function.

Data processing amendment

Some effort of system design is probably needed. The data processing environment for the index production has to be enhanced to provide for:

- Flexible management of characteristics variables.

- Smooth extraction and transfer of data needed for hedonic regression by standard software for statistical analysis.

- Management (storage and presentation) of hedonic coefficients etc.

- Automatic process in monthly index production, for modifying prices by hedonic function.

- For monthly index production also enhanced tools for data editing, particularly for micro-level tracing of impact of quality change.

These enhancements should primarily be a one-time effort when the system is (re-)designed for hedonics.

Extended data collection

Data collection has to be extended to include the characteristics variables needed. Also, the sample size may have to be increased in periods of refreshing the hedonic function.

The need to collect characteristics values of course increases the demand on monthly price collection. There may also be an increased demand on manual efforts in monthly data editing, as more suspected measurement errors may be found and have to be followed up for verification of the measurements.

As far as the data needed can be collected from web sites, that should be a cost advantage. For representativity, monthly price collection may still have to be made in conventional shops, and then characteristics variables have to be included. But for refreshing the hedonic function, it might possibly suffice to use web sources. These considerations have to be carried out in a skilled way for each situation, in view of relevant conditions regarding index accuracy, market features and cost.

2 Television sets

- Television sets belong to a market with a low replacement rate and high technological change (e.g. large screen television sets). The Task Force on Quality Adjustment and Sampling concluded that the hedonic method is highly recommended for television sets (A-method) besides some implicit methods like bridged overlap which are subject of Chapter Two.

- The empirical studies of the CENEX members showed that hedonics and bridged overlap with appropriate stratification yield similar results.

- The following section deals with the application of hedonic re-pricing for television sets.

2.1 Proposal for the identification of consumption segments

- The suggested consumption segments are identified as described in the non-hedonic section for television sets.

2.2 Proposal for the construction of a target sample

- For the application of hedonic re-pricing, usually two samples have to be collected. The first sample is called "regression sample" which serves the calculation of the hedonic regression equation. The second sample is called "index sample" and is used to calculate the price index for TV sets. The sampling procedure for the index sample is described in non-hedonic section for television sets. The index sample may or may not be a sub-sample of the regression sample.

The regression sample

- To apply the hedonic method, a regression sample has to be collected. This sample is needed for the calculation of a systematic relationship between the prices of the TV sets and their particular characteristics. Resulting from this relationship the hedonic equation can be established.

- In the case that different types of TV sets are considered it is suggested to collect separate regression samples which might be used to run separate regressions.

- The regression sample can be collected according to the same procedure as the index sample. The index sample may also be a sub-sample of the regression sample or it can be independent from the regression sample.

- To find out which characteristics are relevant to quality adjust TV sets for, if possible try several approaches:
  - Use publicly available information from advertising, shop displays, TV market magazines etc.
  - Use experience from other national statistical offices, which may be further ahead in implementation of hedonics for TV sets, or from other research.
  - Consult product experts in the TV set business – but remember that the consumer perspective is what is relevant, not engineering effort or so as such.

- A more ambitious approach could be to conduct a pilot study with a rather broad-minded collection of characteristics. But do not do that if you do not already have a rather clear mind about what you are looking for, as else you would likely just waste your and respondents' resources.

- The same set of characteristics needs to be collected for each television set, regardless of whether it belongs to the regression sample or to the index sample. Since there are different TV types (LCD, tube, plasma – see below) which differ in their characteristics different sets of characteristics need to be collected for each TV type.

- It is important not to consider those variables that reflect fashion. This could be for example the colour of the TV set.

- The following characteristics may serve as orientation for LCD TVs:
  - brand cluster,
  - TV type,
  - screen size,
  - number of pixels,
  - brightness,
  - contrast ratio,
  - reaction time,
  - frequency,
  - picture format (aspect ratio),
  - sound system,
  - picture in picture,
  - types and number of connectors (scart, HDMI, etc.),
  - outlet type,
  - . . .

- The following characteristics may serve as orientation for tube TVs:
  - brand cluster,
  - screen size,
  - picture format (aspect ratio),
  - sound system,
  - types and number of connectors (scart, HDMI, etc.),
  - outlet type,
  - frame rate,
  - . . .

- The brands of the selected TV sets should normally be assigned to brand clusters. A classification of brand clusters can be obtained from the PPP statistics (Purchasing Power Parities – price indices comparing the national price levels). The available brand cluster lists of the PPP classify brands into high/medium and low brands. In these lists, not all available brands are classified. Missing brands should be assigned to one of the brand clusters by informed judgement.

Chart 120
Extract from the PPP classification (adjusted for TV sets)

Brand cluster	Assigned brands
Higher and Medium	HITACHI, JVC, LG, LOEWE, PANASONIC, PHILIPS, PIONEER, SAMSUNG, SHARP, SONY
Lower	BEKO, BIGA, DAEWOO, DIBOSS, ELEMIS, EVELUX, FUEGO, LENCO, MATRIX, QUADRO, SENCOR, SCHNEIDER, SILVA, VIVAX

Source: Eurostat (Lot C), European Comparison Programme: Consumer price survey E07-1
"House and garden" Particular survey guidelines

- Given the technological change of TV sets, new features should be included regularly. This is not so frequent that it would be necessary to select a new set of relevant characteristics every month, but the price statistician should be aware of the possibility.

- Whenever a new characteristic is introduced, the price statistician should judge whether the new characteristic is important enough to be included. Therefore, a continuous market observation is necessary.

- Of course, new characteristics can only be used to adjust for quality differences if this characteristic is collected in both the price reference month and the current month.

- An appropriate form which could be distributed to the price collectors should precisely ask for the considered characteristics and might look like this:

Chart 121
Example of a price collection form

Television, screen size ~ 32 inches, LCD, higher or medium brand

Price (€):   929.–

Brand and model description: Sony KDL-32D3000

Screen size (inch):   32

Resolution: 1366 x 768 pixels

Contrast ratio: 8000:1

Reaction time: 8 ms

Brightness: 450 cd/m²

Frequency: ☒ 50 Hz   ☐ 100 Hz

Aspect ratio: ☒ 16:9   ☐ 4:3

Sound system: ☒ Surround   ☐ Stereo   ☐ Mono   ☐ Others:_____

Connectors: ☐ VGA   ☐ DVI   ☒ HDMI   ☒ Others: Scart, PC

☐ Picture in Picture   ☒ HD ready

Shop: _____

Date: _____

- For the estimation of the regression equation it is desirable that price observations used reflect a state of equilibrium (balance between supply and demand). That means that if it is practically possible, it would normally be preferable that temporarily reduced prices due to promotion offers or stock clearances can be identified in the price collection and not used for estimating the regression equation. (However, note that in the index calculation, on the other hand, reduced prices shall not be excluded.)

Minimum size of the regression sample and the index sample

- The regression sample should contain 100 to 300 observations depending on the number of characteristics that are used in the regression equation (see section on quality adjustment). As a rule of thumb, 15 to 20 observations per characteristic which is finally included in the regression equation should be collected.

2.3   Proposal for the replacement strategy

General remarks

- The general remarks for the replacement strategy are the same as described in the non-hedonic section for television sets. Please consider that the replacement strategy only refers to the index sample. The regression sample is a cross-sectional sample where no "replacements" can occur.

- In order to check whether the chosen products are still representative of the market the market has to be observed regularly. This regular observation can also be used to determine general changes (e.g. new equipment, new brands, technological progress, new characteristics) which might have to be included into the regression equation (see section on quality adjustment below).

- If a model is no longer available or no longer well sold it should be replaced. The successor model should be best sold and representative.

- It is necessary to observe the market in order to account for general changes. Therefore, the representativity of the models in the index sample should be checked within the scope of monthly price collection and on a regular basis in the central office.

Representativity check within the scope of the monthly price collection in the shop

- Use the concrete TV models that were in the sample in the previous month as a starting point for the price collection of the current month in order to keep the share of matched models reasonably high. However, the main criterion for the selection of replacements should be representativity.

- The price collector should check whether or not the models of the previous month are still representative. The price collector should assess this each month with the help of the shop assistant. If this is not practicable the price collector can also revert to indicators such as the way the product is advertised or presented in the shop or he might also revert to his experience.

- If the model of the previous month is still representative continue observing the price of this model. If the model is no longer representative or if it is no longer available replace it by a representative one.

Representativity check in the office

- Additionally to the representativity checks conducted by the price collector a representativity check should be conducted regularly in the office.

- Check whether the chosen products are still representative of the market. Therefore, the market has to be observed regularly. This regular observation can also be used to determine general changes (e.g. new equipment, new brands, technological progress, new characteristics, trend towards larger screen size) which might have to be included into the regression equation (see section on quality adjustment below).

2.4   Proposal for the quality adjustment

- As stated in the section on the construction of the target sample, for the application of hedonic re-pricing it is necessary to collect two data sets. In order to calculate the hedonic equation a comprehensive database is necessary which is called "regression sample". The hedonic equation is used to apply quality adjustment in the case of replacement situations which can only occur in the index sample. In the following sections the individual steps are described in great detail.

Topic 1: Data needed

Collection of quality characteristics

- The compilation of the regression sample as well as of the index sample is described in the section on the target sample.

- The regression sample could look like this:

Chart 122
Example of a data base of a regression sample for LCD TV sets

t	Model	Brand	Version	Price	Brand cluster	Size (cm)	Brightness	Picture format	Contrast ratio	Sound	Number of pixels	...
1	A	LG	RE20LA30	799	High	51	450	4:3	450:1	Stereo	640x480	...
1	B	Philips	20PF8846	599	High	51	450	4:3	350:1	Virtual Sound	640x480	...
...	...	...	...	...	...	...	...	...	...	...	...	...

- The variable "Version" is not needed for the calculation but makes the identification of individual TV models easier.

Topic 2: Data editing

- After the regression sample is established, the data should be put in shape. That means, the variables should be defined as numerical or dummy variables.

- Reformat category variables to dummy variables. These can only take values of 0 or 1 depending on whether the model is equipped with a specific feature or not.

- Numeric variables like the price or the screen size are transformed by logarithm prior to the regression.

Chart 123
Example for the modified data base of the regression sample for LCD TV sets

t	Model	Price (ln)	Brand	Size (ln)	Picture format	Brightness (ln)	Picture format	Contrast ratio (ln)	Surround Sound	Stereo sound	...
1	LG	6.6834	1	3.9318	0	6.1092	0	6.1092	1	0	...
1	Philips	6.3953	1	3.9318	0	6.1092	0	5.8579	0	1	...
...	...	...	...	...	...	...	...	...	...	...	...

Topic 3: Creating the hedonic function

- After the data has been arranged, the hedonic regression equation can be set up. In this regard, the price (as dependent variable) should be explained as a function of the model's characteristics (independent variables).

- Statistical programs like SPSS, Stata or SAS are helpful to calculate the regression. The computer program is set up to perform a linear regression analysis on the data of the regression sample. The price is to be considered as the "dependent" variable and the characteristics (brand dummies, screen size, etc.) are considered as "independent" variables.

- With regard to the general function form of the hedonic regression equation a double-logarithmic function form is suggested. For dummy variables the logarithm is not taken whereas continuous variables have to be transformed by logarithms.

$$\ln P = b_0 + b_1 \cdot \ln (screen\ size) + b_2 \cdot picture\ format + b_3 \cdot specialised\ store +$$
$$+ b_4 \cdot warehouse + b_5 \cdot brand\ cluster + \ldots + \varepsilon$$

- The hedonic regression equation contains dummy variables (brand, picture format, specialised store, warehouse) and continuous variables (screen size). For each dummy variable, one characteristic value has to be defined as default (reference) value, e.g. the reference value for picture format may be "4:3" and for brand cluster it may be "lower brands".

- The statistical program computes the coefficients (corresponding to the particular characteristics) and further statistical values which contain information on the significance of the variables.

- The result of the regression analysis could look like this:

Chart 124
Example for the results of the hedonic regression

N = 91			$R^2 = 0.8172$	
Regression coefficients			t-value	Variance inflation
b_0	Constant	1.01320	1.75	2.2574
b_1	ln (screen size)	1.4052	9.29	2.26994
b_2	Picture format	0.3111	3.91	1.14571
b_3	Specialised store	0.2986	3.94	1.22207
b_4	Warehouse	0.1783	2.76	1.24657
b_5	Brand cluster "high"	0.2338	3.15	1.17197

- The variables that were deemed relevant to quality adjust for have been collected as discussed under *Topic 1*. These were included into the regression equation. Potentially, some of the considered variables might not be significantly related to the price. Those "insignificant" variables could be identified by their t-values. At the design stage when the regression equation is tested, variables with t-values tending to be within the interval of − 2 to + 2 could be considered for skipping from the regression equation to be used operatively. One may have to be a little careful here, and some skilled judgement is called for. It should be noted that the t-test is approximate, as strictly seen it depends on assumptions that are usually not under perfect control.

- Particularly in the testing of the regression equation at the design stage, it should be checked whether the algebraic signs of the coefficients are as expected in view of the meaning of these. If a "wrong" sign occurs, the possible cause should be searched: Whether it is just expected random variation, or a misspecification of the variable, or contaminated data, or something else. Possibly a variable may then be identified as problematic and ultimately have to be skipped from the regression equation. But DON'T skip a variable automatically as soon as a "wrong" sign turns up, as doing so may just sweep problems under the carpet and produce invalid results.

- The particular regression coefficients can be interpreted as follows: The coefficient for a continuous variable like screen size ($b_1 = 1.4052$) indicates that a larger screen size of one percent results in an expected price increase of approximately 1.4052 %. The coefficient for a dummy variable like picture format ($b_2 = 0.3111$) means the inclusion of that feature (from 4:3 to 16:9) results in an expected price increase of approximately 31.11 %.

- In order to assess the adequacy of the regression estimation, consider the adjusted R² value. For TV sets this value should probably be expected to be around 0.5 − 0.6

or higher, as in principle a persistent relation of technological characteristics and the price should be expected. An R² very close to 1 should not normally occur and may indicate severely contaminated data. On the other hand, an adjusted R² considerably below 0.5 indicates a relatively low explanatory ability of the regression equation. A possible cause may be that the sample is taken from a fairly narrow and homogeneous stratum, where large characteristics differences do not occur. If so, the results may possibly be useful anyhow, in spite of the low R²; here some skilled judgement may be called for. Another possible cause for a low R² may be that some essential characteristics variable has been left out and would have to be included in the regression equation.

Topic 4: Index calculation

- In the following the index sample is considered which contains 25 to 30 price observations for TV sets.

- At first those situations where a replacement takes place have to be detected. In these cases the sampled TV models change from one month to the next which implies different characteristic values and thus different quality levels of the two products. Those quality differences have to be adjusted as described in the following.

- In each replacement situation the values of the hedonic function h for the replaced and the replacement model has to be calculated. Therefore, insert the variable values of the respective model in the hedonic equation.

- The coefficients of the hedonic equation have been calculated in *Topic 3* and the variable values of the respective models are collected within the scope of price collection. In the example, the regression coefficients are:

Chart 125
Example of the regression coefficients

	Regression coefficients	
b_0	Constant	1.01320
b_1	ln (screen size)	1.4052
b_2	Picture format	0.3111
b_3	Specialised store	0.2986
b_4	Warehouse	0.1783
b_5	Brand cluster "high"	0.2338

- In the next step, the quality adjustment factor has to be computed. The quality adjustment factor ("g") is the relation of the values of the hedonic function h of replaced and replacement model. In other words, it is the mathematical ratio of quality for the new and the old model and refers to only this particular replacement situation:

$$g = \frac{h(X_t^B)}{h(X_{t-1}^A)} = \frac{\text{Market value of the replacement}}{\text{Market value of the replaced model}}$$

- This quality adjustment factor is used to adjust the quality of the replaced model by multiplying its price with the quality adjustment factor:

$$P_{t-1}^A \cdot g = quality\ adjusted\ price\ of\ the\ replaced\ model$$

- To calculate the quality adjusted price development, divide the price of the replacement product by the quality adjusted price of the replaced product:

$$\frac{P_t^B}{P_{t-1}^A \cdot g} = \frac{observed\ price\ of\ the\ replacement}{observed\ price\ of\ the\ replaced\ model \cdot g}$$

- For the index calculation, insert the quality adjusted price development in cases of replacements instead of the normal term. Here model A has been replaced by model B:

$$I = \left(\frac{P_{t=1}^B}{P_{t=0}^A \cdot g} \cdot \frac{P_{t=1}^C}{P_{t=0}^C} \cdot \frac{P_{t=1}^D}{P_{t=0}^D} \cdot \frac{P_{t=1}^E}{P_{t=0}^E} \cdot \frac{P_{t=1}^F}{P_{t=0}^F} \right)^{1/5} , \text{with } \frac{P_{t=1}^B}{P_{t=0}^A} \text{ being replaced by } \frac{P_{t=1}^B}{P_{t=0}^A \cdot g}$$

Topic 5: Refreshing the hedonic function

- Monitor the market in order to consider technological progress and market changes.

- As the product-specific market develops the validity of the calculated linear regression can change. Especially the significance of the variables as well as the regression coefficients themselves can change since the product undergoes technological progress. In order to reflect those technological changes, the regression equation has to be updated regularly. The empirical studies conducted within the scope of the CENEX showed that the regression equation for TV sets stayed valid for two to three months. That means every two or three months a new regression has to be calculated. Therefore, a new regression sample may have to be collected every three months, following the procedure described for the target sample.

- Update the regression coefficients when significant changes appear.

2.5 Cost estimation

One-time effort for the introduction

- The following steps are required for the introduction: Initial design study on data requirements; market research; reading, understanding and contemplating Handbook advice; cognitive testing etc. of new price collector forms; initial construction with testing and assessment of regression equation; methodology reporting, approval and documentation; systems design for smooth regular production. If an initial pilot study with extended data collection is needed, this of course requires additional resources.

- The following steps are necessary for the operative introduction: Collection of data for the estimation of the regression equation (incl. price collection in the shop, entry into data sheet, online collection of characteristics).

- All in all up to four months may be necessary for the introduction.

Current effort of price collection and index calculation

- Qualification for price collection: No expert knowledge necessary, instruction with concrete guidelines is sufficient.

- Qualification for index calculation: academic.

- Approximately four days may be necessary for price collection and index calculation.

2.6   Examples

Example for the identification of consumption segments:

- In this example we assume that only one consumption segment exists.

Example for the construction of a target sample:

- As described for the compilation of the target sample a market evaluation yielded that three screen size strata are important to be considered:
    - Tube TV sets with a screen size of ~ 14 inches (~ 36 cm).
    - LCD TV sets with a screen size of ~ 20 inches (~ 51 cm).
    - LCD TV sets with a screen size of ~ 32 inches (~ 81 cm).

- In the following example, the screen size is given in centimetres. Only the proceeding for LCD TV sets with a screen size of ~ 51 cm is described. For other TV sets proceed analogously.

- In the first step representative outlets have to be chosen. In our example, let us assume that there is no difference in the price development throughout regions, so that the regional dimension is no major issue.

- The next step is to select representative models in the chosen outlets. For the index sample, at least 25 prices should be collected from the retailers. For the regression sample, 100 to 300 observations are necessary.

- Besides the price a set of characteristics has to be collected for each TV set model. The price collection form below shows some exemplary characteristics that are deemed to impact the price of LCD TV sets. The set of variables could be different in reality, of course.

Chart 126
Example of a price collection form

Television, screen size ~ 51 cm, LCD, higher or medium brand			
Price (€):	799.–		
Brand and model description:	LG RE20LA30		
Screen size (cm):	51		
Resolution:	640 x 480 pixels		
Contrast ratio:	45:1		
Reaction time:	8 ms		
Brightness:	450 cd/m²		
Frequency:	☒ 50 Hz	☐ 100 Hz	
Aspect ratio:	☐ 16:9	☒ 4:3	
Sound system:	☐ Surround	☒ Stereo	☐ Mono ☐ Others:_____
Connectors:	☐ VGA	☐ DVI	☐ HDMI ☒ Others: Scart, S-video, RCA
☐ Picture in Picture		☐ HD ready	
Shop: _____			
Date: _____			

- Consider in month 1, the price collector collects a number of representative TV models for the stratum LCD TV with a screen size of ~ 32 inches. The price collection table could look like this:

Chart 127
Example of a price collection table for the index sample for LCD TV sets

t	Model	Brand	Version	Price	Brand cluster	Size (cm)	Brightness	Picture format	Contrast ratio	Sound	Number of pixels	...
1	A	LG	RE20LA30	799	High	51	450	4:3	450:1	Stereo	640x480	...
1	B	Philips	20PF8846	599	High	51	450	4:3	350:1	Virtual Surround	640x480	...
...	...	...	...	...	...	...	...	...	...	...	...	...

Example for the replacement strategy:

- The following replacement situation refers to the index sample only.
- Suppose that in month 3 model "D" is no longer available or no longer well sold and it is replaced by model "E" (see next chart).
- Those replacement situations are marked with a "Q" in the price collection table.

Chart 128
Example of the price collection table

Model	Brand	Version	Screen size (cm)	...	Price in month 1	Q	Price in month 2	Q	Price in month 3
A	LG	RE20LA30	51	...	799.– €		799.– €		699.– €
B	PHILIPS	20PF8846	51	...	599.– €		599.– €		599.– €
C	TOSHIBA	20VL33G	51	...	999.– €		999.– €		999.– €
D	SEG	MONTECARLO	51	...	999.– €		799.– €	Q	
E	THOMSON	27LCDB03B	67	...				Q	899.– €

- The different models exhibit different characteristics with inherent different qualities. To match the products quality adjustment has to be applied.

Example for quality adjustment by applying hedonic re-pricing:

Topic 1: Data needed

- The compilation of the regression sample is described in the section on the target sample.

- The regression sample could look like this:

Chart 129
Example of a data base for the regression sample for LCD TV sets

t	Model	Brand	Version	Price	Brand cluster	Size (cm)	Brightness	Picture format	Contrast ratio	Sound	Number of pixels	...
1	A	LG	RE20LA30	799	High	51	450	4:3	450:1	Stereo	640x480	...
1	B	Philips	20PF8846	599	High	51	450	4:3	350:1	Virtual Surround	640x480	...
...	...	...	...	...	...	...	...	...	...	...	...	...

Topic 2: Data editing

- After the regression sample is established, the data should be put in shape. That means, the variables should be defined as numerical or dummy variables.

- Since a double-logarithmic function form is suggested, the price, number of pixels, contrast ratio, brightness, and the screen size are transformed by logarithm.

- The category variables brand, connectors, picture format, sound system, outlet type are transformed into dummy variables. These can only take values of 0 or 1 (depending on whether the model is equipped with a specific feature or not).
- Now, one characteristic value has to be chosen as reference value for each dummy variable.
  - The reference value for the brand dummy variables is lower brand. That means, in the case of lower brand LCD TV sets, the alternative brand dummy (higher) brand has a value of 0.
  - The reference value for the connectors variable is "scart". That means, in a case of a LCD TV set equipped with only a scart connector, the alternative connector dummies are 0.
  - The reference value for the picture format variable is 4:3. That means, in the case of LCD TV set equipped with a 16:9 picture format, the dummy has a value of 1.
  - The reference value for the sound system variable is mono sound. That means, in the case of LCD TV set equipped with a surround sound system, the surround sound system dummy has a value of 1; if it is equipped with stereo sound system, the stereo sound system dummy has a value of 1.
  - The reference value for the store type variable is self service store. That means, in the case of a LCD TV set observed in a self service store, the alternative dummies have a value of 0.

Chart 130
Example of the modified data base of the regression sample for LCD TV sets

t	Model	Price (ln)	Brand	Size (ln)	Picture format	Brightness (ln)	Picture format	Contrast ratio (ln)	Surround Sound	Stereo sound	...
1	LG	6.6834	1	3.9318	0	6.1092	0	6.1092	1	0	...
1	Philips	6.3953	1	3.9318	0	6.1092	0	5.8579	0	1	...
...	...	...	...	...	...	...	...	...	...	...	...

Topic 3: Creating the hedonic function

- The procedure of data collection for the regression sample and the subsequent creation of the hedonic function are exemplarily described in the section on quality adjustment. The coefficients of the hedonic equation can be seen in the table below.
- In this example, all the characteristics in the table below impact the price significantly. All other characteristics as described in the example construction of a target sample impact the price insignificantly and are not used to calculate the values of the hedonic function.

Chart 131
Example of the regression coefficients

Regression coefficients		
b_0	Constant	1.01320
b_1	ln (screen size)	1.4052
b_2	Picture format	0.3111
b_3	Specialised store	0.2986
b_4	Warehouse	0.1783
b_5	Brand cluster "high"	0.2338

Topic 4: Index calculation

- In the following table you can find four price series for three periods containing the data that is required for the index calculation. At first, all replacement situations have to be marked since only in those cases quality adjustment has to be applied. In this example from month 2 to month 3 there is one replacement situation.

Chart 132
Example of the price collection table

Model	Brand	Version	Screen size (cm)	...	Price in month 1	Q	Price in month 2	Q	Price in month 3
A	LG	RE20LA30	51	...	799.– €		799.– €		699.– €
B	PHILIPS	20PF8846	51	...	599.– €		599.– €		599.– €
C	TOSHIBA	20VL33G	51	...	999.– €		999.– €		999.– €
D	SEG	MONTECARLO	51	...	999.– €		799.– €	Q	
E	THOMSON	27LCDB03B	67	...				Q	899.– €

- The index calculation from month 1 to month 2 follows the usual formula:

$$I_2 = \left(\frac{P_{t=2}^A}{P_{t=1}^A} \cdot \frac{P_{t=2}^B}{P_{t=1}^B} \cdot \frac{P_{t=2}^C}{P_{t=1}^C} \cdot \frac{P_{t=2}^D}{P_{t=1}^D} \right)^{1/4} = \left(\frac{799\,€}{799\,€} \cdot \frac{599\,€}{599\,€} \cdot \frac{999\,€}{999\,€} \cdot \frac{799\,€}{999\,€} \right)^{1/4} = 0.946$$

- The index from month 2 to month 3 contains a replacement situation. Model "D" is replaced by model "E". For both price observations, the replaced and the replacement model, the values of the hedonic function have to be calculated. As you know the hedonic regression equation is a double-logarithmic function. Hence, the exponential function is needed to obtain the values of the hedonic function which are needed for

the quality adjusted price. This is done by taking the anti-log of the sum of the constant and the respective products of characteristics (or logs of the respective characteristics) and coefficients:

$$h_t = e^{(b_0 + b_1 \cdot v_1 + \ldots + b_5 \cdot v_5)}$$

- To calculate the values of the hedonic function h for both models, it is necessary to know the particular characteristics, which can be seen in the chart below:

Chart 133
Example of the characteristics of replaced and replacement models

Model	Brand	Model	Screen Size (ln)	Aspect Ratio 16:9	Specialised store	Warehouse	Brand cluster
D	SEG	MONTECARLO	3.9318	0	1	0	0
E	THOMSON	27LCDB03B	4.2047	1	0	1	0

- Inserting the variables into the hedonic equation yields the values of the hedonic function h for the particular models:

$$h\,(Model\,D)_{t=2} = e^{(1.0132 + 1.4052 \cdot 3.9318 + 0.3111 \cdot 0 + 0.2986 \cdot 1 + 0.1783 \cdot 0 + 0.2338 \cdot 0)} = 931.47 \,€$$

$$h\,(Model\,E)_{t=3} = e^{(1.0132 + 1.4052 \cdot 4.2047 + 0.3111 \cdot 1 + 0.2986 \cdot 0 + 0.1783 \cdot 1 + 0.2338 \cdot 0)} = 1{,}654.15 \,€$$

- The mathematical ratio of the values of the hedonic function from the replacement and the replaced model yields the quality adjustment factor "g" which can be calculated as followed (the subscript $r = 1$ indicates that the regression was run in month 1):

$$g_{r=1}^{D,E} = \frac{h\,(replacement)_{t=3}}{h\,(replaced\,model)_{t=2}} = \frac{h\,(Model\,E)_{t=3}}{h\,(Model\,D)_{t=2}} = \frac{1{,}654.15\,€}{931.47\,€} = 1.7758$$

- To calculate the index from month 2 to month 3 the following formula is applied again:

$$I_3 = \left(\frac{P_{t=3}^A}{P_{t=2}^A} \cdot \frac{P_{t=3}^B}{P_{t=2}^B} \cdot \frac{P_{t=3}^C}{P_{t=2}^C} \cdot \frac{P_{t=3}^E}{P_{t=2}^D} \right)^{1/4}$$

- The index contains one replacement from model "D" in month 2 to model "E" in month 3. As hedonic re-pricing is used for quality adjustment

$$\frac{P_{t=3}^E}{P_{t=2}^D} \text{ is replaced by } \frac{P_{t=3}^E}{P_{t=2}^D \cdot g_{r=1}^{D,E}}$$

• The index for month 3 is calculated in the following (including the application of hedonic re-pricing):

$$I_3 = \left(\frac{P_{t=3}^A}{P_{t=2}^A} \cdot \frac{P_{t=3}^B}{P_{t=2}^B} \cdot \frac{P_{t=3}^C}{P_{t=2}^C} \cdot \frac{P_{t=3}^D}{P_{t=2}^D \cdot g_{r=1}^{D,E}} \right)^{1/4}$$

$$= \left(\frac{699\ \text{€}}{799\ \text{€}} \cdot \frac{599\ \text{€}}{599\ \text{€}} \cdot \frac{999\ \text{€}}{999\ \text{€}} \cdot \frac{899\ \text{€}}{799\ \text{€} \cdot 1.7758} \right)^{1/4}$$

$$= 0.863$$

Chart 134
Monthly indexes

Model	Brand	Type	Screen Size (in cm)	Price in month 1	Price in month 2	Q	Price in month 3
A	LG	RE20LA30	51	799.– €	799.– €		699.– €
B	PHILIPS	20PF8846	51	599.– €	599.– €		599.– €
C	TOSHIBA	20VL33G	51	999.– €	999.– €		999.– €
D	SEG	MONTECARLO	51	999.– €	799.– €	Q	
E	THOMSON	27LCDB03B	67			Q	899.– €
Quality adjusted prices							
D	SEG	MONTECARLO	67		1 418.86 €		
Monthly indexes				*100.0*	*94.6*		*86.3*

3 Used cars

- As the first step, the COICOP four-digit-level: 07.1.1 Motor cars (containing motor cars, passenger vans, station wagons, estate cars and the like with either two-wheel drive or four-wheel drive) is divided into new cars and used cars. This section only deals with used cars.

- The Task Force on Quality Adjustment and Sampling did not establish an explicit classification of A-, B-, C-methods for used cars.

- The following section deals with the application of hedonic re-pricing for used cars. This approach is recommended for the case that no appropriate market research data is available and the data hat to be collected on internet platforms and in car magazines.

3.1 Proposal for the identification of consumption segments

- The identification of consumption segments is described in the non-hedonic section for used cars.

3.2 Proposal for the construction of a target sample

- For the application of hedonic re-pricing, usually two samples have to be collected. The first sample is called "regression sample" which serves the calculation of the hedonic regression equation.

- The second sample is called "index sample" and is used to calculate the price index for used cars. The proposal for the construction of an index sample can be found in the non-hedonic section for used cars. The index sample may or may not be a sub-sample of the regression sample.

- Unlike the non-hedonic approach for used cars, only two data sources could be used:
  - Offer prices on internet platforms.
  - Offer prices from car magazines.

- If data provided from market research institutes are available, it is not necessary to apply the hedonic approach for used cars since the observed cars do not differ in age and mileage from month to month.

- The recommended data source for the sample collection (regarding the index sample as well as the regression sample) is internet platforms. By entering the criteria of a precise primary and sub-model in the screen mask the used car prices are easily observable. Besides the price further important characteristics can be collected, especialy "age" and "mileage". The product-offers also contain additional explicit information. Keep in mind to collect only offer prices from business retailers from your own national market. A possible internet platform for used cars is for example *www.autoscout24.xx* which is available in several European countries. If no internet platform is available, the prices and characteristics of used cars should be collected in car magazines.

- In the case of price collection on internet platforms and car magazines, the following issues are of importance:

- It is most important to refer to the same sub-model over time.
- The age in months should be held constant as far as possible. In practice, there will be variations in the precise age which have to be adjusted in the following (see section 3.4 Proposal on quality adjustment).
- The mileage should be considered roughly. That means the mileage should be of the same dimension from period to period. The variations in mileage also have to be adjusted in the following.
- It is very important not to consider product-offers from private persons, cars that have been involved in an accident and cars with a lot of obvious extra equipment or modifications.
- If there is a large range of product-offers that fit all the mentioned criteria, any concrete product-offer among the price variance may be selected.

The regression sample

- To apply the hedonic method, a regression sample has to be collected. This sample is needed for the calculation of a systematic relationship between the prices of the used cars and their particular characteristics. Resulting from this relationship the hedonic equation can be established.
- The regression sample can be collected according to the same procedure as the index sample. In the regression period, the index sample may also be a sub-sample of the regression sample or it can be independent from the regression sample.

Discussion box

Regarding the regression sample, it is suggested that the data refer to one particular month only.

Alternatively, a regression sample with pooled data which refer to observations from several previous months might be possible. An advantage is that seasonal effects are avoided which otherwise might appear on the estimates. Furthermore pooling the data alleviates the burden of data collection in order to have enough reliable observations for the regression. Besides that, the "depreciation factor" one is estimating can be seen as an average one, not specific to a particular month.

However there are some counter arguments against the approach to use pooled data. Especially the assumptions that there is no price change over time and the parameters are constant over periods might be a serious issue.

Minimum size of the regression sample

- The sample sizes of the regression and the index sample should be established country-specifically since the number of observations depends on the number of generated consumption segments and age classes.

- The regression sample should contain at minimum 135 observations. This minimum sample size results from the number of characteristics that are used in the regression equation (see section on quality adjustment). As a rule of thumb, 15 to 20 observations per characteristic which is finally included in the regression equation should be collected.

- The regression sample should contain all the selected primary models from the different consumption segments. There is only one regression sample for all consumption segments.

3.3 Proposal for the replacement strategy

General remarks

- Please consider that the replacement strategy only refers to the index sample. The regression sample is a cross-sectional sample where no "replacements" can occur.

- The proposal for the replacement strategy is the same as for the non-hedonic approach which is already described in the non-hedonic section for used cars. Only regarding the selection of the replacement model, the restriction holding the characteristic values age and mileage constant can be relaxed.

3.4 Proposal for the quality adjustment

- A distinction of minor and major changes helps to decide whether an explicit or an implicit quality adjustment is necessary. Both, major and minor changes require a quality adjustment. In general, major changes in the quality of used cars are too complex for an explicit quality adjustment whereas minor changes can be adjusted explicitly.

- Minor changes in quality of used cars can only occur in case of observing the same sub-model over time:
  – changes in the equipment of a precise sub-model,
  – the age of the car (in months) differs,
  – the mileage of the car differs.

- Major changes in the quality of used cars are:
  – the change of the primary model,
  – the introduction of a new generation of the primary model (the old version of the primary model is followed by a new version),
  – the change of the sub-model.

Quality adjustment in the case of major changes: Bridged overlap

- In the case of major changes in quality, no explicit quality adjustment is possible since the replaced and the replacement product are in principle not comparable at all.

- If major quality changes occur, bridged overlap shall be applied. The price development of all other models of the same consumption segment and age class which were not replaced build the bridge between the replaced and the replacement model. In this way the average price development of a set of comparable models is used.

Quality adjustment in the case of minor changes: Hedonic re-pricing

- Minor quality changes in the equipment of a precise sub-model can not be adjusted explicitly since the value of a singular equipment feature which is a component of the used car is unknown. The depreciation rate of equipment features in a used car is different of the depreciation rate of the whole car itself. Therefore it is not possible to adjust for changed equipment which exhibits a used condition. In order to alleviate the problem the equipment should not significantly differ from month to month. In practice this means, the observed used car should not contain an amount of additional equipment features or any modifications. Direct comparison should be applied.

- Changes in the age (in months) or in the mileage (in kilometres) of the car should be adjusted by hedonic re-pricing.

- Note that those variations in age and mileage between two periods can only occur if the used cars prices are collected on internet platforms or in car magazines.

Chart 135
Example for replacement situations
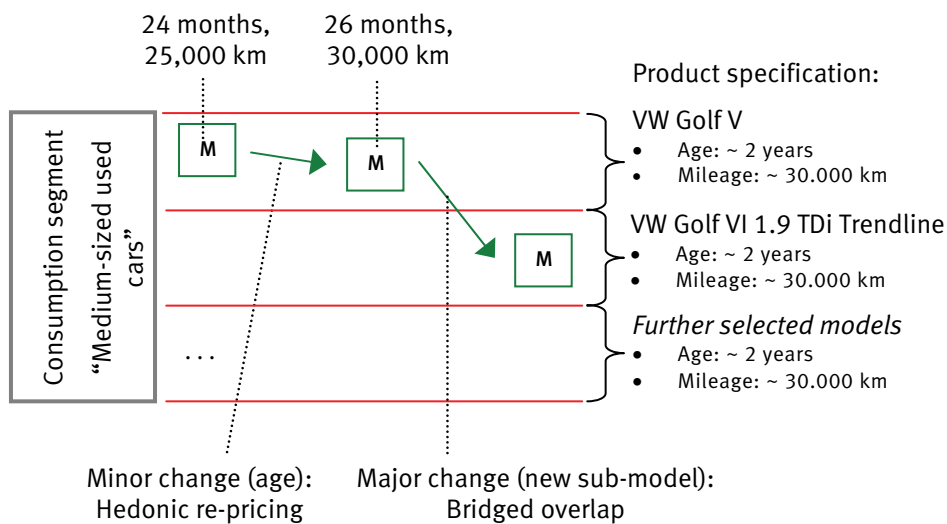
Discussion box

It might seem paradox that minor changes are treated with explicit quality adjustment whereas major changes are treated implicitly. However, the car market implicates very complex technological developments which complicate the explicit measurement of quality changes over time. This applies especially to used cars, where the constitution of the product appears as a further dimension of quality.

It may be argued that applying bridged overlap for major changes implicate the risk of a so-called „vintage effect": Cars of older model types tend to decrease in price more than models which are at the beginning of their product-life-circle. This is especially relevant for the case that an old version of a primary model is followed up by a new version (generation). This could result in a downward bias when indexes for these models are just linked in using bridged overlap.

But it seems that the assumptions of bridged overlap are met very well in the case of used cars since the used car market is very competitive, transparent and the transaction prices are (nearly) equilibrium prices. Therefore, the risk of vintage effects may be small.

- As stated in the section on the construction of the target sample, for the application of hedonic re-pricing it is necessary to collect two data sets. In order to calculate the hedonic equation a comprehensive database is necessary which is called "regression sample". The hedonic equation is used to apply quality adjustment in the case of replacement situations which can only occur in the index sample. In the following sections the individual steps are described in detail.

Topic 1: Data needed

- The compilation of the regression sample as well as of the index sample is described in the section on the target sample.
- In order to ensure a reliable regression, additional variables have to be added which specify the selected primary models:
  - brand dummies (for brand cluster),
  - size dummies (for size cluster).
- The variable "brand cluster" can exhibit a value of 1, 2 or 3 and divides the selected primary models according to the prestige or image of the corresponding make. This variable serves as a proxy variable for the overall quality and the prestige of the models in order to reflect the difference between makes, like Citroën (brand cluster = 3), Ford (2) and Mercedes-Benz (1).
- The variable "size class" can exhibit a value of 1, 2 or 3 and divides the selected primary models within one consumption segment according to the size of corresponding the cars. This variable is important since the models within one consumption segment are still heterogeneous with regards to their size. This variable should reflect the relation of the sizes of the considered primary models within the consumption segment. For orientation the length of the car can serve which can be obtained from

www.wikipedia.com for each primary model. In the consumption segment "small used cars", this variable serves for the distinction of e.g. a VW Lupo (size class = 1) and a VW Polo (size class = 3). In the consumption segment "large cars", this variable serves for the distinction of e.g. a VW Passat (size class = 1) and a BMW 7 series (size class = 3). The variable CS is a dummy variable that indicates the consumption segment.

- The regression sample could look like this:

Chart 136
Example of a data base of a regression sample for used cars

Month	Brand/Make	Primary model	Sub-model	CS	Brand cluster	Size cluster	Mileage (1,000 km)	Age (months)	Price (€)
7-2008	VW	Golf V	1.9 TDi Trendline	Med.	2	2	42,400	26	13,400
5-2008	Mercedes-Benz	C-class	180 classic	Med.	1	3	45,800	22	18,790
. . .	. . .	. . .					. . .	. . .	. . .

Topic 2: Data editing

- After the regression sample is established, the data should be put in shape. That means, the variables should be defined as numerical or dummy variables.

- Reformat category variables to dummy variables. These can only take values of 0 or 1 depending on whether the model contains the characteristic value or not. This is relevant for the variables "CS", "brand_cluster" and "size_cluster".

- As a semi-logarithmic function form is applied. Therefore, the numeric variable price is transformed by logarithm prior to the regression.

- The variable mileage should be transformed into a relative mileage per year.

Chart 137
Example for the modified data base of the regression sample for used cars

⋮	Primary model	Sub-model	CS 1	CS 2	CS 3	CS 4	Brand cluster 1	⋮	ln Price	Age (months)	Relative mileage (1,000 km p.a.)
...	Golf V	1.9 TDi Trendline	0	1	0	0	0	...	9.503	26	19.570
...	C-class	180 classic	0	1	0	0	1	...	9.841	22	24.981
...	...	...	...	...	...	...	...	...	...	...	...

Topic 3: Creating the hedonic function

- After the data has been arranged, the hedonic regression equation can be set up. In this regard, the price (as dependent variable) should be explained as a function of the model's characteristics (independent variables).

- Statistical programs like SPSS, Stata or SAS are helpful to calculate the regression. The computer program is set up to perform a linear regression analysis on the data of the regression sample. The price is to be considered as the "dependent" variable and the characteristics (age, brand dummies, size dummies, etc.) are considered as "independent" variables.

- With regard to the general function form of the hedonic regression equation a semi-logarithmic function form is suggested. Only the logarithm of the price is taken. If all the mentioned variables are considered the hedonic regression equation would look like this:

$$\ln P = b_0 + b_1 \cdot age + b_2 \cdot rel.\,mileage + b_3 \cdot size\_2 + b_4 \cdot size\_3 + b_5 \cdot brand\_2 +$$
$$+ b_6 \cdot brand\_3 + b_7 \cdot CS2 + b_8 \cdot CS3 + b_9 \cdot CS4 + \varepsilon$$

- The hedonic regression equation contains two continuous variables, age and mileage, and dummy variables for the consumption segments, the brand clusters and the size clusters.

- The category variables brand_cluster and size_cluster might alternatively be treated as continuous variables since it is possible to treat an "ordinal scale" as if it was an "interval scale". The advantage might be to bring down the number of coefficients to be estimated. The assumption is that there exists an (hypothetical) linear relationship between the different states of each one of the two categorical variables. For the brand_cluster, for example, this means, one is assuming the difference between brands 1 and 2 is exactly the same as the difference between brands 2 and 3.

- The reference size class is size class 1, the reference brand cluster is brand cluster 1 and the reference consumption segment is consumption segment 1.

- There should be only one common regression equation for the complete used car regression sample (containing all different consumption segments).

- The computational method used by the computer program should be the *ordinary least squares* (OLS).

- The statistical program computes the coefficients (corresponding to the particular characteristics) and further statistical values which contain information on the significance of the variables.

- The regression may yield the following coefficients:

Chart 138
Example for the results of the hedonic regression (fictitious)

	Regression coefficients		Adj. R^2 = 0.70
			t-value
b_0	Constant	9.646	› 2
b_1	Age	− 0.010	‹ − 2
b_2	Relative mileage	− 0.008	‹ − 2
b_3	Size class 2	0.130	› 2
b_4	Size class 3	0.205	› 2
b_5	Brand cluster 2	− 0.060	‹ − 2
b_6	Brand cluster 3	− 0.217	‹ − 2
b_7	CS2	0.229	› 2
b_8	CS3	0.494	› 2
b_9	CS4	0.424	› 2

- The variables that were deemed relevant to quality adjust for have been collected as discussed under *Topic 1*. These were included into the regression equation. Potentially, some of the considered variables might not be significantly related to the price. Those "insignificant" variables could be identified by their t-values. At the design stage when the regression equation is tested, variables with t-values tending to be within the interval of − 2 to + 2 could be considered for skipping from the regression equation to be used operatively. One may have to be a little careful here, and some skilled judgement is called for. It should be noted that the t-test is approximate, as strictly seen it depends on assumptions that are usually not under perfect control.

- Particularly in the testing of the regression equation at the design stage, it should be checked whether the algebraic signs of the coefficients are as expected in view of the meaning of these. If a "wrong" sign occurs, the possible cause should be searched: Whether it is just expected random variation, or a misspecification of the variable, or contaminated data, or something else. Possibly a variable may then be identified as problematic and ultimately have to be skipped from the regression equation. But DON'T skip a variable automatically as soon as a "wrong" sign turns up, as doing so may just sweep problems under the carpet and produce invalid results.

- In the table presented above, the variables age and relative mileage have a negative impact on the price. This seems to be highly reasonable. The size class variable exhibits a positive coefficient. This also seems to be reasonable since this indicates a higher price for larger cars. The negative algebraic sign of the coefficient for brand clusters also meets the expectations since prestigious brands are indicated with a variable value of one and other brands with values of two or three.

- The particular regression coefficients can be interpreted as follows: The coefficient for a continuous variable like age ($b_1 = -0.010$) indicates that increasing age of one month results in an expected price decrease of approximately -1.0%.

- In order to assess the adequacy of the regression estimation, consider the adjusted R^2 value. For used cars this value should probably be expected to be around $0.5 - 0.6$ or higher, as in principle a persistent relation of technological characteristics and the price should be expected. An R^2 very close to 1 should not normally occur and may indicate severely contaminated data. On the other hand, an adjusted R^2 considerably below 0.5 indicates a relatively low explanatory ability of the regression equation. A possible cause may be that the sample is taken from a fairly narrow and homogeneous stratum, where large characteristics differences do not occur. If so, the results may possibly be useful anyhow, in spite of the low R^2; here some skilled judgement may be called for. Another possible cause for a low R^2 may be that some essential characteristics variable has been left out and would have to be included in the regression equation.

Topic 4: Index calculation

- In the following the index sample is considered.

- At first those situations where a replacement takes place including a change in the precise age or mileage have to be detected. Those changes in the characteristic values constitute quality differences have to be adjusted as described in the following. In the case of used cars which are observed on internet platforms and car magazines this will be the usual case since the variables age and mileage might change from observation to observation.

- In each replacement situation the values of the hedonic function h for the replaced and the replacement model has to be calculated. Therefore, insert the variable values of the respective model in the hedonic equation.

- The coefficients of the hedonic equation have been calculated in Topic 3 and the variable values of the respective models are collected within the scope of price collection.

- In the next step, the quality adjustment factor has to be computed. The quality adjustment factor ("g") is the relation of the values of the hedonic function of replaced and replacement model. In other words, it is the mathematical ratio of quality for the replacement and the replaced model and refers to only this particular replacement situation:

$$g = \frac{h(X_t^B)}{h(X_{t-1}^A)} = \frac{Market\ value\ of\ the\ replacement}{Market\ value\ of\ the\ replaced\ model}$$

- This quality adjustment factor is used to adjust the quality of the replaced model by multiplying its price with the quality adjustment factor:

$$P_{t-1}^A \cdot g = quality\ adjusted\ price\ of\ the\ replaced\ model$$

- To calculate the quality adjusted price development, divide the price of the replacement product by the quality adjusted price of the replaced product:

$$\frac{P_t^B}{P_{t-1}^A \cdot g} = \frac{observed\ price\ of\ the\ replacement}{observed\ price\ of\ the\ replaced\ model \cdot g}$$

- For the index calculation, insert the quality adjusted price development in cases of replacements instead of the normal term. Here model A has been replaced by model B:

$$I = \left(\frac{P_{t=1}^B}{P_{t=0}^A \cdot g} \cdot \frac{P_{t=1}^C}{P_{t=0}^C} \cdot \frac{P_{t=1}^D}{P_{t=0}^D} \cdot \frac{P_{t=1}^E}{P_{t=0}^E} \cdot \frac{P_{t=1}^F}{P_{t=0}^F} \right)^{1/5} , \text{with } \frac{P_{t=1}^B}{P_{t=0}^A} \text{ being replaced by } \frac{P_{t=1}^B}{P_{t=0}^A \cdot g}$$

Topic 5: Refreshing the hedonic function

- Regarding the periodical refreshing of the hedonic function, no general rule can be recommended.

- As a pragmatic proposal it seems to be sufficient to re-estimate the hedonic equation yearly as there is no rapid technological development from month to month in existing old cars. This proposal has a practical component since many data bases (e.g. the figures of the ownership changes) might be updated yearly.

- Furthermore a person or a group with product knowledge should be assigned, to monitor the market for signs of the necessity for updating the hedonic function. In the case that there are hints for a need to refresh the hedonic function, a new regressions should be compiled. Otherwise, an annual re-estimation seems to be sufficient.

3.5 Cost estimation

One-time effort for the introduction

- A staff member with moderate knowledge of econometric methods is required to implement the method. Specification of the regression equation is basically standard procedure in this particular market and not much can be changed or tested. Most work will be in software development and creation (if needed) and management of new databases.

- Collection of data for the estimation of the regression equation: about 1 to 3 manmonths, depending on the quality and availability (or access to) of the new databases. An independent survey on European NSI was conducted and, on average, 4 manmonths are generally suggested as necessary to implement the method. If there are members with econometric skills, the estimated time needed drops to 2 months; on the contrary, if there is none expert on the methods, the estimated time needed increases to 6 months.

Current effort of price collection

- No expert knowledge seems necessary. Price collection is still an issue to be discussed regarding this particular market, especially due to wide cultural differences among European countries. Also, no transaction prices are usually available so the quality of proxy variables should be thoroughly checked and only when deemed good should they be used.

- It depends primarily on data sources. Price collection can be done either centrally or by standard procedures. Central collection can be done quite rapidly, 1 man-day should be enough. In what concerns standard price collection, 3 man-days seems a good estimate. These estimates are based on a survey.

Current effort of index calculation

- The price statistician should have moderate econometric knowledge when setting up the system. On a regular production system, any price statistician is able to handle it (under an automatic or semi-automatic process). If the index calculation is done manually, then the price statistician should have some econometric skills.

- As long as the databases are available, the index calculation is quite fast. Around 4 to 8 man-hours in an automatic environment (in order to check inputs and results) might be sufficient. Multiply by a factor of 3 if done manually.

3.6   Examples

Example: Generation of consumption segments

- In the first step, the used car market has to be divided into different consumption segments according to the size of the car. This step should correspond to the procedure for new cars where the pragmatic proposal is to define four consumption segments:
    - small used cars,
    - medium-sized used cars,
    - large used cars,
    - special used cars.

- As in the case of new cars, the universe of primary models consists of approximately 300 cars in each country. Each of these primary models has to be assigned to the identified consumption segments. The distinguishing criterion is the size of the car.
    - The data on the particular primary models that are registered in the country can be obtained from the national central car register.

Chart 139
Example for the assignment of concrete models to the consumption segments

Central car register	
Primary models	Registrations per year
VW Golf	. . .
Opel Corsa	. . .
Mercedes-Benz SLK	. . .
Mazda 323	. . .
. . .	. . .

Small used cars

Medium-sized used cars

Large used cars
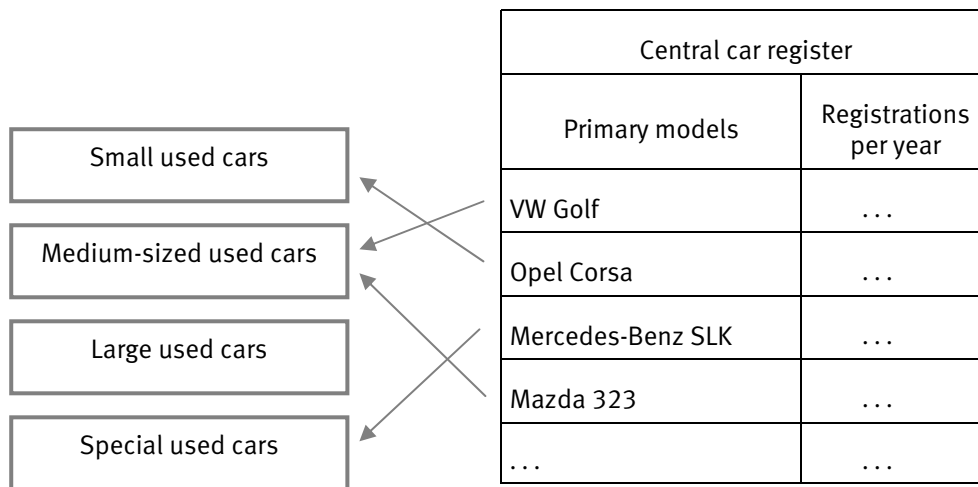
Special used cars

- As a result, each consumption segment consists of precise primary models.

Chart 140
Consumption segments and the corresponding primary models

Consumption Segments							
Small used cars		Medium-sized used cars		Large used cars		Special used cars	
Primary model	Ownership changes	Primary model	Ownership changes	Primary model	Ownership changes	Primary model	Ownership changes
Opel Corsa	26,082	VW Golf	73,692	Mercedes-Benz C-class	18,631	Opel Zafira	14,620
VW Polo	16,332	Opel Astra	36,889	BMW 5 series	16,247	VW Caravelle	8,305
Renault Twingo	11,094	Mercedes-Benz C-class	34,851	Audi A6	12,937	VW Sharan	7,162
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
sum	**192,684**	**sum**	**440,878**	**sum**	**73,504**	**sum**	**124,923**

- The consumption segments have to be weighted in accordance to their expenditure share.
- To obtain the total expenditure of a consumption segment, multiply the total number of ownership changes from the previous year for the particular consumption segment by its average price.

–   The total number of ownership changes for each consumption segment can be taken from the central car register. The average price for a consumption segment can be obtained from the section on price collection below. It should refer to one specific arbitrary age class which has to be the same for all consumption segments.

Chart 141
Calculation of expenditure weights for the consumption segments

Weighting the consumption segments							
Small used cars		Medium-sized used cars		Large used cars		Special used cars	
Total number of ownership changes	Average price (in €)	Total number of ownership changes	Average price (in €)	Total number of ownership changes	Average price (in €)	Total number of ownership changes	Average price (in €)
192,684	7,500	440,878	10,000	73,504	15,000	124,923	12,500
Total expenditure (in billion €):							
1.44		4.40		1.11		1.56	
Total expenditure of all consumption segments: 8.51 billion €							
Expenditure share (in %):							
17.0		51.8		12.9		18.3	

Example for the construction of a target sample

• The following example refers to the index sample.

• (1) Stratify the universe of ownership changes by age classes:

–   Two or three age classes should be generated following "peaks" of ownership changes in the national market. Therefore, the distribution of ownership changes according to the age of the cars should be checked. In Germany, the number of ownership changes according to age exhibits two specific "peaks" in one- and three-year-old cars. For the German market, it would be recommendable to generate these two age classes.

Chart 142
Number of ownership changes for different ages of the car
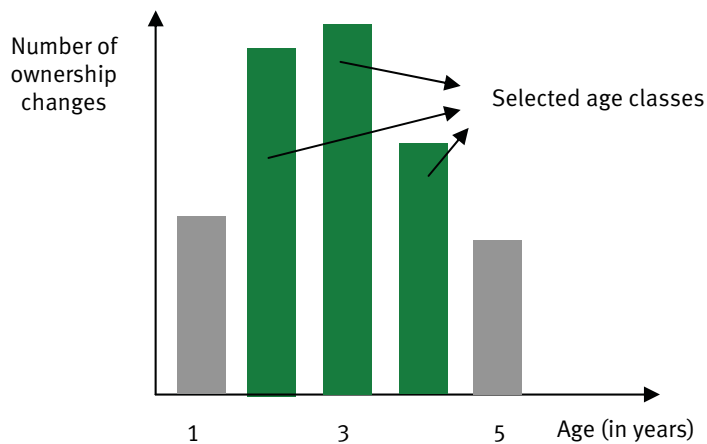
– The more general pragmatic proposal is to form three age classes: Two-year-old, three-year-old and four-year-old cars within each consumption segment. In the following this recommendation will be considered.

- (2) Select primary models by cut-off sampling (probability sampling is also possible):
  – In each consumption segment and age class, include all primary models until a cumulative market share of 50 % to 60 % is reached.
  – This means to draw a sample for the recommended twelve segments: Four consumption segments each contain three age classes.
  – An example for the consumption segment "medium-sized used cars" and the age class of two-year-old cars:

Chart 143
Exemplary target sample for the consumption segment "medium-sized used cars"

Target sample for "medium-sized used cars"and two-year age class			
Primary model	Ownership changes (from the previous year)	Market share	Cumulative market share
		in %	
VW Golf	32,040	*16.7*	*16.7*
Opel Astra	16,039	*8.4*	*25.1*
Mercedes-Benz C-class	15,153	*7.9*	*33.0*
BMW 3 series	14,586	*7.6*	*40.6*
Ford Focus	14,028	*7.3*	*47.9*
Audi A4	13,097	*6.8*	*54.7*

- The selected primary models represented in the table make up 54.7 % of the market for "medium-sized used cars" within the considered age class. In this example quantity shares are applied for sampling, but if available it would be better to apply expenditure shares.

- Assignment of precise sub-models by purposive sampling
    - The selected primary models have to be implicitly weighted according to the relation of their sales figures. The proposal is collect 25 to 30 price observations per consumption segment which spread over the three age classes. This results in a sample size of approximately 10 per stratum. Now it is to determine how many price observations to collect for each primary model.
    - The distribution of the price observations might look like this (implicit weighting):

Chart 144
Number of observations to be included

Distribution of price observations "medium-sized used cars" and two-year age class				
Primary model	Market share		Share in the sample (ratio)	Number of price observations
	in %		in %	
VW Golf	16.7	→	30.5	3
Opel Astra	8.4	→	15.4	1
Mercedes-Benz C-class	7.9	→	14.4	1
BMW 3 series	7.6	→	13.9	1
Ford Focus	7.3	→	13.3	1
Audi A4	6.8	→	12.5	1
Total	54.7	→	100	8

- In this example, three sub-models for the primary model VW Golf have to be selected in order to reflect its market share of the consumption segment "medium-sized used cars" within the age class of two-year-old cars.
- The sub-model selection has to be conducted by purposive sampling according to the following criteria:
    - Should be a well sold sub-model within the range of the corresponding primary model.
    - Should be of the least extensive equipment level.
    - Must not be a special edition.
- The following chosen sub-models meet these criteria. Additionally, the approximate ratio of diesel and petrol engines is considered.

Chart 145
Precisely selected sub-models for the primary model "VW Golf"

Sub-model selection for VW Golf V	
Observation	Sub-model
1	Golf V 1.6 Trendline
2	Golf V 1.9 TDi Trendline
3	Golf V 2.0 TDi Trendline

- Collect offer prices for the chosen sub-models on internet platforms and in car magazines. The price collection is described in the section on the *construction of the target sample.*

Example: Replacement strategy

- Representativity check within the scope of the monthly price collection:
    - The price collector (product expert) should refer to the selected sub-models of the previous month. In the case that a specific sub-model of a precise age is no longer observable it should be replaced. Maybe, the considered primary model is followed by a new version: For example, the follow-up model for VW Golf IV is the VW Golf V.
- Representativity check for the periodical renewal of the sample.

    - The target sample should be updated regularly, maybe yearly, depending on the publication of the statistics of the ownership changes by the central car register.

Example: Quality adjustment applying hedonic re-pricing

- It is important to distinguish between minor and major changes
- Major changes can occur in three situations:
    - Change of the primary model due to a former production stop.
    - The old version of a primary model is followed up by a new generation: e.g. VW Golf IV is followed by a VW Golf V.
    - The sub-model is replaced since it is no longer available.
- Minor changes:
    - Small variations in the equipment of the used cars.
    - The product observations of a particular sub-model differ in age and/or in mileage.
- Differences in the equipment of the used cars can not be considered.
- Variations in age and mileage of the corresponding used cars might be the usual case since prices are observed on internet platforms or car magazines. In this case, hedonic re-pricing is applied.

Example for quality adjustment by applying hedonic re-pricing:

Topic 1: Data needed

- The compilation of the regression sample is described in the section on the target sample.
- The regression sample could look like this:

Chart 146
Example of a data base of a regression sample for used cars

Month	Brand/Make	Primary model	Sub-model	CS	Brand cluster	Size cluster	Mileage (1,000 km)	Age (months)	Price (€)
7-2008	VW	Golf V	1.9 TDi Trendline	Med.	2	2	42,400	26	13,400
5-2008	Mercedes-Benz	C-class	180 classic	Med.	1	3	45,800	22	18,790
. . .	. . .	. . .					. . .	. . .	. . .

Topic 2: Data editing

- After the regression sample is established, the data should be put in shape. That means, the variables should be defined as numerical or dummy variables.
- Since a semi-logarithmic function form is applied, the price is transformed by logarithm.
- The category (alphanumerical) variable consumption segment is transformed into dummy variables. It can only take values of 0 or 1 depending on whether the model fulfils the characteristic or not.

Chart 147
Example for the modified data base of the regression sample for used cars

:	Primary model	Sub-model	CS 1	CS 2	CS 3	CS 4	Brand cluster 1	:	ln Price	Age (months)	Relative mileage (1,000 km p.a.)
. . .	Golf V	1.9 TDi Trendline	0	1	0	0	0	. . .	9.503	26	19.570
. . .	C-class	180 classic	0	1	0	0	1	. . .	9.841	22	24.981
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .

Topic 3: Creating the hedonic function

- The procedure of data collection for the regression sample and the subsequent creation of the hedonic function is exemplarily described in the section on quality adjustment. The coefficients of the recent hedonic equation can be seen in the table below again:

Chart 148
Example for the results of the hedonic regression (fictitious)

Regression coefficients			Adj. R^2 = 0.70
			t-value
b_0	Constant	9.646	› 2
b_1	Age	− 0.010	‹ − 2
b_2	Relative mileage	− 0.008	‹ − 2
b_3	Size class 2	0.130	› 2
b_4	Size class 3	0.205	› 2
b_5	Brand cluster 2	− 0.060	‹ − 2
b_6	Brand cluster 3	− 0.217	‹ − 2
b_7	CS2	0.229	› 2
b_8	CS3	0.494	› 2
b_9	CS4	0.424	› 2

- All the characteristics in the table above are deemed to impact the price signifycantly.

Topic 4: Index calculation

- The example provided here focuses on the index calculation.

- The following chart shows a replacement situation from the month 1 to the month 2 which includes a change in the characteristics age and mileage. In those cases quality adjustment should be applied. The replacement situation from a VW Golf V to the VW Golf VI constitutes a future case where the next generation of the primary model is becomes relevant. In this case, bridged overlap should be applied.

Chart 149
Example for replacement situations
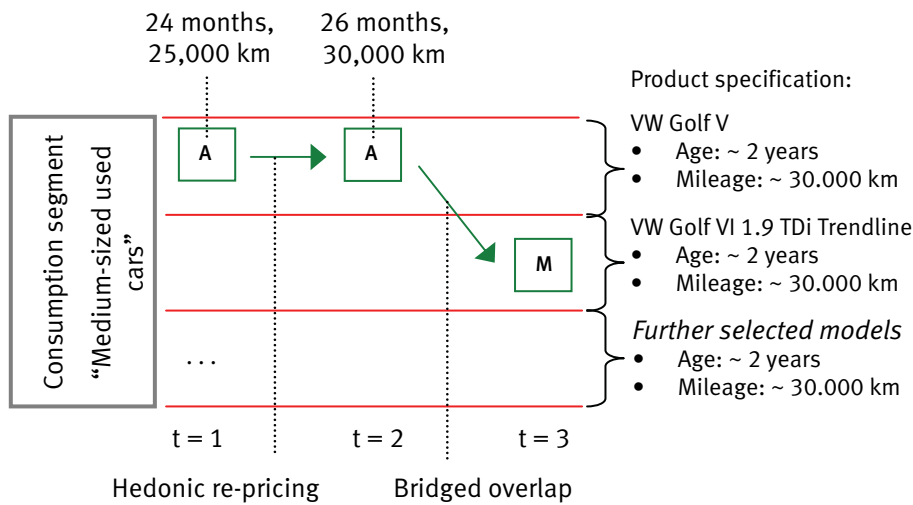
- Regarding the replacement from month 1 to month 2, the values of the hedonic function have to be calculated by applying the recent hedonic function for the observations, both, the replaced and the replacement model. As you know the hedonic regression equation is a semi-logarithmic function. Hence, the exponential function is needed to obtain the values of the hedonic function which are needed for the calculation of the quality adjusted price. This is done by taking the anti-log of the sum of the constant and the respective products of characteristics and coefficients:

$$h_t = e^{(b_0 + b_1 \cdot v_1 + \dots + b_9 \cdot v_9)}$$

- To calculate the values of the hedonic function for both models, it is necessary to know the particular characteristics, which can be seen in the following table.

Chart 150
Example of the index sample

t	Brand/Make	Primary model	Sub-model	CS	Brand cluster	Size cluster	Mileage (1,000 km)	Age (months)	Price (€)
1	VW	Golf V	1.9 TDi Trendline	Med.	2	2	30,000	24	13,000
1	Opel	Astra H	1.6		2	2	33,000	25	11,200
1	Mercedes-Benz	C-class	180 edition	Med.	1	3	28,000	23	16,000
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
2	VW	Golf V	1.9 TDi Trendline	Med.	2	2	38,000	26	12,000
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .

- The table containing the transformed characteristics might look like this:

Chart 151
Example of the characteristics of replaced and replacement model

t	Primary model	Sub-model	CS 1	CS 2	CS 3	CS 4	Brand cluster	Size cluster	Relative mileage (1,000 km p.a.)	Age (months)	ln Price
1	Golf V	1.9 TDi Trendline	0	1	0	0	2	2	15	24	9.4727
2	Golf V	1.9 TDi Trendline	0	1	0	0	2	2	17.538	26	9.3927
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .

- Inserting the variable values into the recent hedonic equation yields the values of the hedonic function for the particular models:

$$h_{t=1}^{A} = e^{(9.646 + (-0.010) \cdot 24 + (-0.008) \cdot 15 + 0.130 - 0.060 + 0.229)} = 14,544.92 \,€$$

$$h_{t=2}^{A} = e^{(9.646 + (-0.010) \cdot 26 + (-0.008) \cdot 17.538 + 0.130 - 0.060 + 0.229)} = 13,974.61 \,€$$

- The mathematical ratio of the values of the hedonic function h of the replacement and the replaced model yields the quality adjustment factor "g" which can be calculated as follows (the subscript r = 1 indicates that the regression was run in month 1):

$$g_{r=1}^{A,t=2} = \frac{h_{t=2}^A}{h_{t=1}^A} = \frac{13{,}974.61\,€}{14{,}544.92\,€} = 0.9608$$

- To calculate the index from month 1 to month 2 the following formula is applied:

$$I_2 = \left(\frac{P_{t=2}^A}{P_{t=1}^A} \cdot \frac{P_{t=2}^B}{P_{t=1}^B} \cdot \frac{P_{t=2}^C}{P_{t=1}^C} \right)^{1/3}$$

- Suppose, for each observed model the variables age and relative mileage change from month to month. As hedonic re-pricing is applied for quality adjustment, for each model the price development has to be calculated adjusting for the difference in the particular variable values. For the price development of the model A (VW Golf 1.9 TDi Trendline) this means:

$$\frac{P_{t=2}^A}{P_{t=1}^A} \text{ is replaced by } \frac{P_{t=2}^A}{P_{t=1}^A \cdot g_{r=1}^{A,t=2}}$$

- The price index for the particular sub-model would be calculated as:

$$I_{t=2}^A = \frac{P_{t=2}^A}{P_{t=1}^A \cdot g_{r=1}^{A,t=2}} = \frac{12{,}000.00\,€}{13{,}000.00\,€ \cdot 0.9608} = 0.9607$$

- The index for month 2 is calculated in the following (including the application of hedonic re-pricing):

$$I_2 = \left(\frac{P_{t=2}^A}{P_{t=1}^A \cdot g_{r=1}^{A,t=2}} \cdot \frac{P_{t=2}^B}{P_{t=1}^B \cdot g_{r=1}^{B,t=2}} \cdot \frac{P_{t=2}^C}{P_{t=1}^C \cdot g_{r=1}^{C,t=2}} \right)^{1/3}$$

Discussion box

For various reasons used cars is a tricky topic in the price index and may have deceptive pitfalls. Reservation must therefore be made that optimal advice may not yet have been found.

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4 Computers

- The Task Force on Quality Adjustment and Sampling rated hedonics as an A-method. 100 % option pricing (for desktops), supported judgement as a proxy to 100 % option pricing, and bridged overlap (applied under certain conditions) were assessed as B-methods.

- The empirical studies of the CENEX members showed that hedonic re-pricing is more suitable than bridged overlap for desktop computers, whereas both methods yield similar results for notebooks.

- The following section deals with the application of hedonic re-pricing for both desktops and notebooks.

4.1 Proposal for the identification of consumption segments

- The suggested consumption segments are described in the non-hedonic section for computers.

4.2 Proposal for the construction of a target sample

- The proposal for the sampling procedure is valid for both the regression and the index sample. It is already described in the non-hedonic section for computers.

- For the application of hedonic re-pricing, usually two samples have to be collected. The first sample is called "regression sample" which serves the calculation of the hedonic regression equation. The second sample is called "index sample" and is used to calculate the price index. These two samples need to be collected for each desktops and notebooks separately.

- For each of desktops and notebooks, it is suggested to compile one (representative) regression sample every month. Therefore, there is no reason to compile a separate index sample. In this case, the regression sample can also be used as index sample using all collected information cost effectively.

The regression sample

- To apply the hedonic method, a regression sample has to be collected. This sample is needed for the calculation of a systematic relationship between the prices of the desktops and notebooks respectively and their particular characteristics. Resulting from this relationship the hedonic equation can be established.

- The regression sample can be collected according to the same procedure as the index sample which is described in the non-hedonic part. The index sample may also be a sub-sample of the regression sample or it can be independent from the regression sample.

- To find out which characteristics are relevant to quality adjust computers for, if possible try several approaches:
  - Use publicly available information from advertising, shop displays, computer magazines etc.

- Use experience from other national statistical offices, which may be further ahead in implementation of hedonics for computers, or from other research.
- Consult product experts in the computer business – but remember that the consumer perspective is what is relevant, not engineering effort or so as such.
- A more ambitious approach could be to conduct a pilot study with a rather broad-minded collection of characteristics. But do not do that if you do not already have a rather clear mind about what you are looking for, as else you would likely just waste your and respondents' resources.

- For desktops and notebooks different sets of characteristics need to be collected. However, the same set of characteristics needs to be collected for each desktop, regardless of whether it belongs to the regression sample or to the index sample. Also for each notebook the same set of characteristics has to be collected regardless of which sample it belongs to.

- It is important not to consider those variables that reflect fashion. This could be for example the colour of a notebook.

- The following characteristics may serve as orientation for desktops:
  - Brand (e.g. Dell, LG, none, . . .).
  - Processor type (e.g. Intel Pentium4, AMD Athlon, . . .).
  - Processor speed (in GHz).
  - Hard-disk drive capacity, abbreviated: HDD (in GB).
  - Working memory, abbreviated: RAM (in GB).
  - Operating system (Windows XP, Linux, none, . . .).
  - Other software (MS Office, . . .).
  - Type of drive (CD-rewriter, DVD player/rewriter, . . .).
  - Graphical card.
  - . . .

- The above mentioned characteristics only serve as orientation. More variables may be important, such as soundcards or TV cards which may be included in the desktop computer.

- For notebooks, the same set of characteristics can be collected. Additionally, two very important characteristics are the size and type of the display, as the display of a notebook is one of the most price-determining characteristics. Therefore, the following characteristics may serve as orientation for notebooks:
  - Type of display (SVGA, VXA, . . .).
  - Size of the display.
  - Brand (e.g. Dell, LG, none, . . .).
  - Processor type (e.g. Intel Pentium4, AMD Athlon, . . .).
  - Processor speed (in GHz).
  - Hard-disk drive capacity, abbreviated: HDD (in GB).
  - Working memory, abbreviated: RAM (in GB).
  - Operating system (Windows XP, Linux, none, . . .).
  - Other software (MS Office, . . .).

- – Type of drive (CD-rewriter, DVD player/rewriter, . . .).
- – Graphical card.
- – . . .

- Given the rapid technological change of computers, new features are included with certain regularity. This is not so frequent that it would be necessary to select a new set of relevant characteristics every month, but the price statistician should be aware of the possibility and at least check this once a year.

- Whenever a new characteristic (say, a new kind of processor or a new drive) is introduced, the price statistician should judge whether the new characteristic is important enough to be included. Therefore, a continuous market observation is necessary.

- Of course, new characteristics can only be used to adjust for quality differences if this characteristic is collected in both the price reference month and the current month.

- An appropriate form which could be distributed to the price collectors should precisely ask for the considered characteristics and might look like this:

Chart 152
Example of a price collection form

Desktop Computer	
Price (€):	299.–
Brand and model description:	M&M Value HD
Processor type	AMD AM2 Athlon64X2 5200 + EE
Processor speed (GHz):	2.6
HDD capacity (GB):	320
Working memory (GB):	2.048
Type of working memory	DDR2
Operating system	Windows Vista
Further pre-installed software	Antivirus
Type of drive	Dual Format DVD writer
Number of USB interfaces	6
Graphic card	ASUS EAH 3450 HTP
Graphic memory (MB):	256
TV card	X
Sound card	X
Shop: _____	
Date: _____	

- For the estimation of the regression equation it is desirable that price observations used reflect a state of equilibrium (balance between supply and demand). That means that if it is practically possible, it would normally be preferable that temporarily re-

duced prices due to promotion offers or stock clearances can be identified in the price collection and not used for estimating the regression equation. (However, note that in the index calculation, on the other hand, reduced prices shall not be excluded.)

Minimum size of the target sample

- The regression samples should contain 100 to 300 observations for each desktops and notebooks, depending on the number of characteristics that are used in the regression equation (see section on quality adjustment). As a rule of thumb, 15 to 20 observations per characteristic which is finally included in the regression equation should be collected.

- The empirical studies conducted within the *CENEX HICP Quality adjustment* showed that for each index sample, i.e. one for desktops and one for notebooks, a number of around 25 observations seems to be reasonable as long as representativity is ensured. The index sample may or may not be a sub-sample of the regression sample. The size of the index sample needs to remain constant.

4.3 Proposal for the replacement strategy

General remarks

- The general remarks for the replacement strategy are the same as described in the non-hedonic section for computers. Please consider that the replacement strategy only refers to the index sample. The regression sample is a cross-sectional sample where no "replacements" can occur.

- In order to check whether the chosen products are still representative of the market the market has to be observed regularly. This regular observation can also be used to determine general changes (e.g. new equipment, new brands, technological progress, new characteristics) which might have to be included into the regression equation (see section on quality adjustment below).

4.4 Proposal for the quality adjustment

- As stated in the section on the construction of the target sample, for the application of hedonic re-pricing it may be necessary to collect two data sets for each desktops and notebooks. That means that there is one regression sample and one index sample for desktops, and one regression sample and one index sample for notebooks. If a regression is carried out monthly the regression sample and the respective index sample may be identical. In order to calculate the hedonic equation a comprehensive database is necessary which is called "regression sample". The hedonic equation is used to apply quality adjustment in the case of replacement situations which can only occur in the index sample. In the following sections the individual steps are described in great detail.

Topic 1: Data needed

- The compilation of the regression sample as well of the index sample is described in the section on the target sample.

- The regression sample could look like this:

Chart 153
Example of a data base of a regression sample for desktops

t	Model	Price (in €)	Brand	Processor type	Processor speed (GHz)	RAM (GB)	HDD (GB)	OS	Type of drive	...
1	A	599.–	DELL	ATH	2.200	1.024	60	WinXP	AA	...
1	B	799.–	DELL	ATH	3.000	2.048	80	WinXP	AA	...
1	C	599.–	DELL	P4	1.900	1.024	40	WinXP	AA	...
...	...	...	...		...	...	...	...	...	...

- The variable "Model" is not needed for the calculation but makes the identification of individual desktop models easier.

Topic 2: Data editing

- After the regression sample is established, the data should be put in shape. That means, the variables should be defined as numerical or dummy variables.
- Also for computers, brands might be "catch-all" variables that contain price effects not included in the other variables. If the number of different brands in the sample is not too big, they might each get a separate dummy. But if the number of brands is big, grouping them might be better, as that would keep the number of variables lower.
- Reformat category variables to dummy variables. These can only take values of 0 or 1 depending on whether the model is equipped with a specific feature or not.
- As a semi-logarithmic function form is applied, only the price is transformed by logarithm prior to the regression.

Chart 154
Example of the modified data base of a regression sample for desktops

t	Model	Price (ln)	Brand A	Brand C	Processor type ATH	Processor type Cel	Processor speed (GHz)	RAM	HDD (GB)	OS: Win2000	...
1	A	6.3953	0	0	1	0	2.200	1.024	60	0	...
1	B	6.6834	0	0	1	0	3.000	2.048	80	0	...
1	C	6.3953	0	0	0	0	1.900	1.024	40	0	...
...	...	...	...	...	...	...	...	...	...	...	...

Topic 3: Creating the hedonic function

- After the data has been arranged, the hedonic regression equation can be set up. In this regard, the price (as dependent variable) should be explained as a function of the model's characteristics (independent variables).

- Statistical programs like SPSS, Stata or SAS are helpful to calculate the regression. The computer program is set up to perform a linear regression analysis on the data of the regression sample. The price is to be considered as the "dependent" variable and the characteristics (brand dummies, processor speed, etc.) are considered as "independent" variables.

- With regard to the general function form of the hedonic regression equation, for computers a semi-logarithmic function form is suggested. Only the logarithm of the price is taken. The hedonic regression equation could, for example, look like this:

$$\ln P = b_0 + b_1 \cdot brand\ a + b_2 \cdot brand\ c + b_3 \cdot processor\ ATH + b_4 \cdot processor\ Cel +$$
$$+ b_5 \cdot processor\ speed + b_6 \cdot RAM + b_7 \cdot HDD + b_8 \cdot OS + \varepsilon\ .$$

Since the computer market is developing very rapidly, this regression equation contains only exemplary variables which are relevant at the time being.

- The hedonic regression equation contains dummy variables – brand a, brand c, processor ATH, processor Cel and operating system (OS) – and continuous variables – processor speed, working memory (RAM), hard disk drive capacity (HDD). For each dummy variable, one characteristic value has to be defined as default (reference) value. In the example above, for the brands, Brand b serves as the default value, for the processor types, the P4 processor serves as a reference, and for the operating systems, Windows XP serves as default value. No dummies are included in the regression equation for the default values.

- The statistical program computes the coefficients (corresponding to the particular characteristics) and further statistical values which contain information on the significance of the variables.

- The regression may yield the following coefficients:

Chart 155
Example of the regression coefficients

Regression coefficients *		
b_0	Constant	3.5115
b_1	Brand a	− 0.3100
b_2	Brand c	− 0.3141
b_3	Processor: Athlon	− 0.1440
b_4	Processor: Celeron	− 0.3488
b_5	Processor speed	0.1439
b_6	Working memory	0.0732
b_7	Hard disk drive capacity	0.0650
b_8	Operating system: Windows 2000	− 0.7930

* Default values: brand b, P4 processor, Windows XP.

- The variables that were deemed relevant to quality adjust for have been collected as discussed under *Topic 1*. These were included into the regression equation. Potentially, some of the considered variables might not be significantly related to the price. Those "insignificant" variables could be identified by their t-values. At the design stage when the regression equation is tested, variables with t-values tending to be within the interval of − 2 to + 2 could be considered for skipping from the regression equation to be used operatively. One may have to be a little careful here, and some skilled judgement is called for. It should be noted that the t-test is approximate, as strictly seen it depends on assumptions that are usually not under perfect control.

- Particularly in the testing of the regression equation at the design stage, it should be checked whether the algebraic signs of the coefficients are as expected in view of the meaning of these. If a "wrong" sign occurs, the possible cause should be searched: Whether it is just expected random variation, or a misspecification of the variable, or contaminated data, or something else. Possibly a variable may then be identified as problematic and ultimately have to be skipped from the regression equation. But DON'T skip a variable automatically as soon as a "wrong" sign turns up, as doing so may just sweep problems under the carpet and produce invalid results.

- The particular regression coefficients can be interpreted as follows: The coefficient for a continuous variable like processor speed ($b_5 = 0.1439$) indicates that a faster processor of 1 GHz results in an expected price increase of approximately 14.39 %. The coefficient for a dummy variable like "Brand a" ($b_1 = − 0.3100$) means that the price difference of "Brand b" (as reference brand) and "Brand a" is approximately − 31.00 %. That means, a replacement of a "Brand b" computer by a "Brand a" computer inherits a price decline of approximately 31.00 %.

- In order to assess the adequacy of the regression estimation, consider the adjusted R^2 value. For computers this value should probably be expected to be around 0.5 − 0.6 or higher, as in principle a persistent relation of technological characteristics and the price should be expected. An R^2 very close to 1 should not normally occur and may indicate severely contaminated data. On the other hand, an adjusted R^2 con-

siderably below 0.5 indicates a relatively low explanatory ability of the regression equation. A possible cause may be that the sample is taken from a fairly narrow and homogeneous stratum, where large characteristics differences do not occur. If so, the results may possibly be useful anyhow, in spite of the low R²; here some skilled judgement may be called for. Another possible cause for a low R² may be that some essential characteristics variable has been left out and would have to be included in the regression equation.

Topic 4: Index calculation

- In the following the index sample is considered which contains at least around 25 price observations for each desktops and notebooks.

- At first those situations where a replacement takes place have to be detected. In these cases the sampled models change from one month to the next which implies different characteristic values and thus different quality levels of the two products. Those quality differences have to be adjusted as described in the following.

- In each replacement situation the values of the hedonic function h for the replaced and the replacement model has to be calculated. Therefore, insert the variable values of the respective model in the hedonic equation. The coefficients of the hedonic equation have been calculated in *Topic 3* and the variable values of the respective models are collected within the scope of price collection.

- In the next step, the quality adjustment factor has to be computed. The quality adjustment factor ("g") is the relation of the values of the hedonic function h of replaced and replacement model. In other words, it is the mathematical ratio of quality for the new and the old model and refers to only this particular replacement situation:

$$g = \frac{h(X_t^B)}{h(X_{t-1}^A)} = \frac{Market\ value\ of\ the\ replacement}{Market\ value\ of\ the\ replaced\ model}$$

- This quality adjustment factor is used to adjust the quality of the replaced model by multiplying its price with the quality adjustment factor:

$$P_{t-1}^A \cdot g = quality\ adjusted\ price\ of\ the\ replaced\ model$$

- To calculate the quality adjusted price development, divide the price of the replacement product by the quality adjusted price of the replaced product:

$$\frac{P_t^B}{P_{t-1}^A \cdot g} = \frac{observed\ price\ of\ the\ replacement}{observed\ price\ of\ the\ replaced\ model \cdot g}$$

- For the index calculation, insert the quality adjusted price development in cases of replacements instead of the normal term. Here model A has been replaced by model B:

$$I = \left(\frac{P_{t=1}^B}{P_{t=0}^A \cdot g} \cdot \frac{P_{t=1}^C}{P_{t=0}^C} \cdot \frac{P_{t=1}^D}{P_{t=0}^D} \cdot \frac{P_{t=1}^E}{P_{t=0}^E} \cdot \frac{P_{t=1}^F}{P_{t=0}^F} \right)^{1/5} ,\ with\ \frac{P_{t=1}^B}{P_{t=0}^A}\ being\ replaced\ by\ \frac{P_{t=1}^B}{P_{t=0}^A \cdot g}$$

Topic 5: Refreshing the hedonic function

- Monitor the market in order to consider technological progress and market changes.

- As the product-specific market develops the validity of the calculated linear regression can change. Especially the significance of the variables as well as the regression coefficients themselves can change since the product undergoes technological progress. In order to reflect those technological changes, the regression equation has to be updated regularly. The empirical studies conducted within the scope of the CENEX showed that for computers the relation between prices and characteristics changes rapidly from month to month. That means every month a new regression has to be calculated. Therefore, a new regression sample has to be collected monthly, following the procedure described for the target sample. In this case, the same characteristics variables are used as before, only their respective coefficients are updated.

- Approximately once a year, the set of relevant characteristics should be reviewed and possibly adjusted. After that, the same set of characteristics is used in the monthly regressions.

4.5   Cost estimation

One time effort for introduction

- The introduction of the hedonic method requires more effort and expertise than up-keeping it. The introduction requires:
    - setting up a sample and determining where and how many models should be observed,
    - setting up a system of smoothly processing collected data on prices and characteristics,
    - setting up a system that automatically calculates the hedonic regression and the resulting indices.

- Both require expertise in statistical analysis methods or econometrics for the specification of the regression function, product expertise for the selection of the relevant characteristics and the setting up of the sample and IT-expertise to design a system to process the data to yield the index. The monthly calculation of the index does not require much econometric or IT-expertise, barring potential catastrophes. Only when the set of characteristics is re-examined once each year, additional econometric and IT-expertise is required to some extent.

- Definition of a sample and determination of relevant characteristics: ca. 2 man-months with statistical/econometric expertise. Setting up a system of efficiently processing data and calculating the index: ca. 3 man-months with adequate programming expertise.

Current effort of price collection

- Ideally, the price collector should have sufficient knowledge of computers to be able to determine which computers should be included in the sample (e.g. those that are representative). In the case of observation through the internet, the price statistician

will often also be the one who collects prices. In that case, expert knowledge should be guaranteed.

- If the price collector does not have much technical expertise on computers, clear guidelines for selecting replacement items are necessary. The ONS currently uses a clear and exhaustive step-by-step procedure, so this approach can work in practice.

- Based on Dutch experience, where computer prices and characteristics are only collected online, the collection of prices and characteristics of 100 observations takes about two days. Having two samples (desktops and notebooks) of 150 models each would thus take about one week each month for price collection. This includes both collecting and processing the data on prices and characteristics.

Current effort of index calculation

- Once the systems for processing observed prices and characteristics and for the calculation of the index have been implemented, the monthly index calculation should not take too much time and expertise. Software skills (MS Access, MS Excel, SPSS or any other statistical application) are sufficient.

- Even if the index calculation takes place using a less advanced system, a price statistician with adequate skills in the relevant applications should be able to perform the index calculation.

- If a system has been developed to calculate the index automatically, the index calculation is a matter of seconds. When done manually using e.g. SPSS and Excel, one day should be enough for the index calculation (data processing is already included in the above section).

4.6   Examples

Weighting of consumption segments:

- Explicit weights of the consumption segments should stem from a reliable data source. For example, an external agency could report the following relative expenditure shares of desktops and notebooks:
  - desktops: 40 %,
  - notebooks: 60 %.
- In the following, we will only refer to desktops.

Example for the construction of a target sample:

- In the first step representative outlets have to be chosen. In our example, let us assume that there is no difference in the price development throughout regions, so that the regional dimension is no major issue.

- The next step is to select representative models on the internet sites of the chosen computer stores where the prices can be collected centrally. For the index sample, at least 25 prices should be collected from the retailers for each desktops and notebooks. For the regression sample, 100 to 300 observations are necessary.

- Besides the price a set of characteristics has to be collected for each computer model. The table below shows some exemplary characteristics that are deemed to impact the price of desktop computers. The set of variables could be different in reality, of course.

- Consider in month 1, the price collector collects a number of representative desktop computers. The data collection table for desktop computers could look like this:

Chart 156
Example of the price collection table for the index sample for desktops (t = 1)

Model	Brand	Processor type	Processor speed (GHz)	RAM (GB)	HDD (GB)	OS	Type of drive	Price in t = 1	...
A	DELL	ATH	2.200	1.024	60	WinXP	AA	599.– €	...
B	DELL	ATH	3.000	2.048	80	WinXP	AA	799.– €	...
C	DELL	P4	1.900	1.024	40	WinXP	AA	599.– €	...
...	...	...	...	...	...	...	...	...	...

Example for the replacement strategy:

- The following replacement situation refers to the index sample only.

- Suppose that in month 2 the selected desktop computer model "C" is no longer available or no longer well sold and it is replaced by a more representative alternative desktop model "D".

Chart 157
Example of the price collection table for the index sample for desktops (t = 2)

Model	Brand	Proessor type	Processor speed (GHz)	RAM (GB)	HDD (GB)	OS	Type of drive	Price in t = 1	Price in t = 2
A	DELL	ATH	2.200	1.024	60	WinXP	AA	599.– €	599.– €
B	DELL	ATH	3.000	2.048	80	WinXP	AA	799.– €	749.– €
C	DELL	P4	1.900	1.024	40	WinXP	AA	599.– €	
D	DELL	P4	2.660	1.024	40	WinXP	AA		649.– €

- The different models exhibit different characteristics with inherent different qualities. To match the products quality adjustment has to be applied.

Example for quality adjustment by applying hedonic re-pricing:

Topic 1: Data needed

- The compilation of the regression sample is described in the section on the target sample.

- The regression sample could look like this:

Chart 158
Example of a data base of a regression sample for desktops

t	Model	Price (in €)	Brand	Processor type	Processor speed (GHz)	RAM (GB)	HDD (GB)	OS	Type of drive	...
1	A	599.–	DELL	ATH	2.200	1.024	60	WinXP	AA	...
1	B	799.–	DELL	ATH	3.000	2.048	80	WinXP	AA	...
1	C	599.–	DELL	P4	1.900	1.024	40	WinXP	AA	...
...	...	...	...		...	...	...	...	...	...

Topic 2: Data editing

- After the regression sample is established, the data should be put in shape. That means, the variables should be defined as numerical or dummy variables.

- Since a semi-logarithmic function form is applied, the price is transformed by logarithm.

- The category variables brand, processor type and operating system are transformed into dummy variables. These can only take values of 0 or 1 depending on whether the model is equipped with a specific feature or not.

- Now, one characteristic value has to be chosen as reference value for each dummy variable.
    - The reference value for the brand dummy variables is DELL. That means, in the case of DELL computers, the alternative brand dummies have a value of 0.
    - The reference value for the processor type variable is P4 (indicating Intel Pentium4). That means, in the case of a P4 processor, the alternative processor dummies have a value of 0.
    - The reference value for the operating system variable is WinXP (indicating Windows XP). That means, in the case of computer equipped with a Windows XP operating system the OS dummy has a value of 0 and in the case of a computer equipped with a Windows2000, the OS dummy has a value of 1.

Chart 159
Example of the modified data base of the regression sample for desktops

t	Model	Price (ln)	Brand A	Brand C	Processor type ATH	Processor type Cel	Processor speed (GHz)	RAM	HDD (GB)	OS: Win2000	...
1	A	6.3953	0	0	1	0	2.200	1.024	60	0	...
1	B	6.6834	0	0	1	0	3.000	2.048	80	0	...
1	C	6.3953	0	0	0	0	1.900	1.024	40	0	...
...	...	...	...	...	...	...	...	...	...	...	...

Topic 3: Creating the hedonic function

- The procedure of data collection for the regression sample and the subsequent creation of the hedonic function is exemplarily described in the section on quality adjustment. The coefficients of the recent hedonic equation can be seen in the chart below again:

Chart 160
Example of the regression coefficients

Regression coefficients		
b_0	Constant	3.5115
b_1	Brand a	− 0.3100
b_2	Brand c	− 0.3141
b_3	Processor: ATH	− 0.1440
b_4	Processor: Celeron	− 0.3488
b_5	Processor speed	0.1439
b_6	Working memory (RAM)	0.0732
b_7	HDD capacity	0.0650
b_8	Operating system	− 0.7930

- All the characteristics in the chart above are deemed to impact the price signifycantly.

- The reference brand is DELL, the reference processor type is P4, the reference operating system is Windows XP.

Topic 4: Index calculation

- The index from month 1 to month 2 contains a replacement situation. Model "C" is replaced by model "D". For both price observations, the replaced and the replacement model, the values of the hedonic function h have to be calculated by applying the recent hedonic function. As you know the hedonic regression equation is a semi-logarithmic function. Hence, the exponential function is needed to obtain the values of the hedonic function which are needed for the calculation of the quality adjusted price. This is done by taking the anti-log of the sum of the constant and the respective products of characteristics and coefficients:

$$h_t = e^{(b_0 + b_1 \cdot v_1 + \ldots + b_8 \cdot v_8)}$$

- To calculate the values of the hedonic function for both models, it is necessary to know the particular characteristics, which can be seen in the chart below:

Chart 161
Example of the characteristics of replaced and replacement model

t	Model	Brand A	Brand C	Processor type ATH	Processor type Cel	Processor speed (GHz)	RAM	HDD (GB)	OS: Win2000
1	C	0	0	0	0	1.900	1.024	40	0
2	D	0	0	0	0	2.660	1.024	40	0

- Inserting the variable values into the recent hedonic equation yields the values of the hedonic function for the particular models:

$$h(Model\_C)_{t=2} = e^{(3.5115 + 0.1439 \cdot 1.900 + 0.0732 \cdot 1.024 + 0.0650 \cdot 40)} = 638.98 \, €$$
$$h(Model\_D)_{t=2} = e^{(3.5115 + 0.1439 \cdot 2.660 + 0.0732 \cdot 1.024 + 0.0650 \cdot 40)} = 712.82 \, €$$

- The mathematical ratio of the values of the hedonic function h of the replacement and the replaced model yields the quality adjustment factor "g" which can be calculated as follows (the subscript r = 2 indicates that the regression was run in month 2):

$$g_{r=2}^{C,D} = \frac{h(Model\_D)_{t=3}}{h(Model\_C)_{t=3}} = \frac{712.82 \, €}{638.98 \, €} = 1.1156$$

- To calculate the index from month 1 to month 2 the following formula is applied:

$$I_2 = \left(\frac{P_{t=2}^A}{P_{t=1}^A} \cdot \frac{P_{t=2}^B}{P_{t=1}^B} \cdot \frac{P_{t=2}^D}{P_{t=1}^C} \right)^{1/3}$$

- The index contains one replacement from model C in month 1 to model D in month 2. As hedonic re-pricing is used for quality adjustment

$\dfrac{P^D_{t=2}}{P^C_{t=1}}$ is replaced by $\dfrac{P^D_{t=2}}{P^C_{t=1} \cdot g^{C,D}_{r=2}}$

- The index for month 2 is calculated in the following (including the application of hedonic re-pricing):

$$I_2 = \left(\frac{P^A_{t=2}}{P^A_{t=1}} \cdot \frac{P^B_{t=2}}{P^B_{t=1}} \cdot \frac{P^D_{t=2}}{P^C_{t=1} \cdot g^{C,D}_{r=2}} \right)^{1/3}$$

$$= \left(\frac{599\ €}{599\ €} \cdot \frac{749\ €}{799\ €} \cdot \frac{649\ €}{599\ € \cdot 1.1156} \right)^{1/3}$$

$$= 0.969$$

Chart 162
Monthly indexes

Model	Brand	Price in month 1		Price in month 2
A	DELL	599.– €		599.– €
B	DELL	799.– €		749.– €
C	DELL	599.– €	Q	
D	DELL		Q	649.– €
Quality adjusted price				
C	DELL	668.24 €		
Monthly indexes		*100.0*		*96.9*

5 Washing machines

- For washing machines, the Task Force on Quality Adjustment and Sampling rated explicit methods (hedonics and option pricing) as A-methods. Implicit methods (bridged overlap) are assessed as B-methods.

- The following section deals with the application of hedonic re-pricing for washing machines.

5.1 Proposal for the identification of consumption segments

- The suggested consumption segments are identified as described in the non-hedonic section for washing machines.

5.2 Proposal for the construction of a target sample

- For the application of hedonic re-pricing, usually two samples have to be collected. The first sample is called "regression sample" which serves the calculation of the hedonic regression equation. The second sample is called "index sample" and is used to calculate the price index for washing machines.

The regression sample

- To apply the hedonic method, a regression sample has to be collected. This sample is needed for the calculation of a systematic relationship between the prices of the washing machines and their particular characteristics. Resulting from this relationship the hedonic equation can be established.

- The regression sample can be collected according to the same procedure as the index sample which is described in the non-hedonic part. In the regression period, the index sample may also be a sub-sample of the regression sample or it can be independent from the regression sample.

- To find out which characteristics are relevant to quality adjust washing machines for, if possible try several approaches:
    - Use publicly available information from advertising, shop displays, magazines etc.
    - Use experience from other national statistical offices, which may be further ahead in implementation of hedonics for washing machines, or from other research.
    - Consult ptoduct experts in washing machine business – but remember that the consumer perspective is what is relevant, not engineering effort or so as such.
    - A more ambitious approach could be to conduct a pilot study with a rather broad-minded collection of characteristics. But do not do that if you do not already have a rather clear mind about what you are looking for, as else you would likely just waste your and respondents' resources.

- The same set of characteristics needs to be collected for each washing machine, regardless of whether it belongs to the regression sample or to the index sample.

- It is important not to consider those variables that reflect fashion. This could be for example the colour of the washing machine.

- The following characteristics may serve as orientation for washing machines:
  - brand cluster,
  - washing machine type (front loader, top loader),
  - electricity consumption (in kWh),
  - maximum spin speed (in rpm),
  - water consumption (in litres),
  - capacity (in kg),
  - built-in possibility,
  - switch-on delay,
  - waterproof systems (aqua-stop, . . .),
  - . . .
- The brands of the selected washing machines should normally be assigned to brand clusters. A classification of brand clusters can be obtained from the PPP statistics (Purchasing Power Parities – price indices comparing the national price levels). The available brand cluster lists of the PPP classify brands into high, medium and low brands. In these lists, not all available brands are classified. Missing brands should be assigned to one of the brand clusters by informed judgement.

Chart 163
Extract from the PPP classification (adapted for washing machines)

Brand cluster	Assigned brands
Higher	AEG-ELECTROLUX, BOSCH, DYSON, MIELE, SIEMENS
Medium	ARISTON, BAUKNECHT, CANDY, ELEKTRA BREGENZ, ELECTROLUX, EUDORA, GORENJE/KÖRTING/MORA, HOOVER, LG, SAMSUNG, WHIRLPOOL, ZANUSSI
Lower	BEKO, BRANDT, DAEWOO, EUROTECH, FAGOR, KONCAR, HOTPOINT, INDESIT, SANYO

Source: Eurostat (Lot C), European Comparison Programme: Consumer price survey E07-1
"House and garden" Particular survey guidelines

- Given the technological change of washing machines, new features appear from time to time. This is not so frequent that it would be necessary to select a new set of relevant characteristics every month, but the price statistician should be aware of the possibility.
- Whenever a new characteristic is introduced, the price statistician should judge whether the new characteristic is important enough to be included. Therefore, a continuous market observation is necessary.
- Of course, new characteristics can only be used to adjust for quality differences if this characteristic is collected in both the price reference month and the current month.
- An appropriate form which could be distributed to the price collectors should precisely ask for the considered characteristics and might look like this:

Chart 164
Price collection form

Washing machine, front loader, capacity of 5 – 7 kg, higher brand		
Price (€):	649.–	
Brand and model description:	Bosch WAS 28440	
Capacity (kg):	7	
Electricity consumption (kWh):	1.19	
Water consumption (litres):	49	
Maximum spin speed (rpm):	1400	
Waterproofing:	Aqua-Stop	
Built-in possibility:	☒ Yes	☐ No
Switch-on delay:	☒ Yes	☐ No
Shop: _____		
Date: _____		

- In practice it would be more convenient to collect only the respective prices as well as the brand and model descriptions in the shop. The characteristics of the particular washing machines can be collected from internet sites.

- For the estimation of the regression equation it is desirable that price observations used reflect a state of equilibrium (balance between supply and demand). That means that if it is practically possible, it would normally be preferable that temporarily reduced prices due to promotion offers or stock clearances can be identified in the price collection and not used for estimating the regression equation. (However, note that in the index calculation, on the other hand, reduced prices shall not be excluded.)

Minimum size of the target sample

- The regression sample should contain 100 to 300 observations depending on the number of characteristics that are used in the regression equation (see section on quality adjustment). As a rule of thumb, 15 to 20 observations per characteristic which is finally included in the regression equation should be collected.

- In the empirical studies conducted within the CENEX project a relatively large index sample was necessary to yield reliable results. Conclusions on a concrete value for the minimum sample size of the index sample could not be drawn.

- In the regression period, the index sample may or may not be a sub-sample of the regression sample.

5.3   Proposal for the replacement strategy

General remarks

- The general remarks for the replacement strategy are the same as described in the non-hedonic section for washing machines. Please consider that the replacement strategy only refers to the index sample. The regression sample is a cross-sectional sample where no "replacements" can occur.

- If a model is no longer available or no longer well sold it should be replaced. The successor model should be best sold and representative.

- It is necessary to observe the market in order to account for general changes. Therefore, the representativity of the models in the index sample should be checked within the scope of monthly price collection and on a regular basis in the central office.

Representativity check within the scope of the monthly price collection in the shop

- Use the concrete washing machine models that were in the sample in the previous month as a starting point for the price collection of the current month in order to keep the share of matched models reasonably high. However, the main criterion for the selection of replacements should be representativity.

- The price collector should check whether or not the models of the previous month are still representative. The price collector should assess this each month with the help of the shop assistant. If this is not practicable the price collector can also revert to indicators such as the way the product is advertised or presented in the shop or he might also revert to his experience.

- If the model of the previous month is still representative continue observing the price of this model. If the model is no longer representative or if it is no longer available replace it by a representative one.

Representativity check in the office

- As the market for washing machine is relatively stable with regards to technological progress, a yearly representativity check might be sufficient. Nevertheless, the market should be observed for general changes such as new equipment features, new brands, and technological trends in general.

- If the pre-selected strata and product specifications are still representative, carry on using them. If not, adjust the product specifications to the current market circumstances by the annual re-sampling.

5.4   Proposal for the quality adjustment

- As stated in the section on the construction of the target sample, for the application of hedonic re-pricing it may be necessary to collect two data sets. In order to calculate the hedonic equation a comprehensive database is necessary which is called "regression sample". The hedonic equation is used to apply quality adjustment in the case of replacement situations which can only occur in the index sample. In the following sections the individual steps are described in great detail.

Topic 1: Data needed

- The compilation of the regression sample as well as of the index sample is described in the section on the target sample.

- The regression sample could look like this:

Chart 165
Example of a data base of a regression sample for washing machines

t	Model	Price (in €)	Brand	Maximum spin speed	Waterproofing	Capacity (kg)	Type	Water consumption (l)	Electricity consumption (kWh)	Built-in possibility	Switch-on delay
1	A	649.–	Bosch	1400	High	7	Top	49	1.19	Yes	Yes
1	B	819.–	Miele	1400	High	6	Top	49	1.02	Yes	Yes
1	C	699.–	AEG-Electrolux	1400	High	6	Top	49	1.02	Yes	Yes
...	...	...	...	...	...	...	...	...	...	...	...

Topic 2: Data editing

- After the regression sample is established, the data should be put in shape. That means, the variables should be defined as numerical or dummy variables.

- Reformat category variables to dummy variables. These can only take values of 0 or 1 depending on whether the model is equipped with a specific feature or not.

- As a semi-logarithmic function is applied only the price is transformed by logarithm prior to the regression.

Chart 166
Example of a modified data base of a regression sample for washing machines

t	Model	Price (ln)	Brand cluster (high)	Brand cluster (low)	Maximum spin speed	Waterproofing (high)	Capacity (kg)	Top loader	Water consumption (l)	Electricity consumption (kWh)	Built-in possibility	Switch-on delay
1	A	6.475	1	0	1400	1	7	0	49	1.19	1	1
1	B	6.708	1	0	1400	1	6	0	49	1.02	1	1
1	C	6.550	1	0	1400	1	6	0	49	1.02	1	1
...	...	...	...	...	...	...	...	...	...	...	...	...

Topic 3: Creating the hedonic function

- After the data has been arranged, the hedonic regression equation can be set up. In this regard, the price (as dependent variable) should be explained as a function of the model's characteristics (independent variables).

- Statistical programs like SPSS, Stata or SAS are helpful to calculate the regression. The computer program is set up to perform a linear regression analysis on the data of the regression sample. The price is to be considered as the "dependent" variable and the characteristics (brand dummies, maximum spin speed, etc.) are considered as "independent" variables.

- With regard to the general function form of the hedonic regression equation, for washing machines a semi-logarithmic function form is suggested. Only the logarithm of the price is taken. The hedonic regression equation could, for example, look like this:

$$\ln P = b_0 + b_1 \cdot \textit{brand cluster high} + b_2 \cdot \textit{brand cluster low} + b_3 \cdot \textit{top loader} +$$
$$+ b_4 \cdot \textit{electricity consumption} + b_5 \cdot \textit{water consumption} + \ldots + \varepsilon$$

- The hedonic regression equation contains dummy variables (here: brand cluster a, brand cluster c, washing machine type) and continuous variables (here: electricity consumption, water consumption). For each dummy variable, one characteristic value has to be defined as default (reference) value. In the example above, for the brand clusters, brand cluster "medium" serves as the default value. For the washing machine type, front loaders were chosen as default value.

- The statistical program computes the coefficients (corresponding to the particular characteristics) and further statistical values which contain information on the significance of the variables.

- The regression may yield the following significant coefficients:

Chart 167
Example of the regression coefficients

Regression coefficients		
b_0	Constant	5.66329
b_1	Brand cluster (high)	0.24642
b_2	Brand cluster (low)	− 0.1428
b_3	Maximum spin speed	0.0005339
b_4	Waterproofing (high)	0.05264
b_5	Capacity	0.10508
b_6	Top loader	0.18836

- The variables that were deemed relevant to quality adjust for have been collected as discussed under *Topic 1*. These were included into the regression equation. Potentially, some of the considered variables might not be significantly related to the price.

Those "insignificant" variables could be identified by their t-values. At the design stage when the regression equation is tested, variables with t-values tending to be within the interval of − 2 to + 2 could be considered for skipping from the regression equation to be used operatively. One may have to be a little careful here, and some skilled judgement is called for. It should be noted that the t-test is approximate, as strictly seen it depends on assumptions that are usually not under perfect control.

- Particularly in the testing of the regression equation at the design stage, it should be checked whether the algebraic signs of the coefficients are as expected in view of the meaning of these. If a "wrong" sign occurs, the possible cause should be searched: Whether it is just expected random variation, or a misspecification of the variable, or contaminated data, or something else. Possibly a variable may then be identified as problematic and ultimately have to be skipped from the regression equation. But DON'T skip a variable automatically as soon as a "wrong" sign turns up, as doing so may just sweep problems under the carpet and produce invalid results.

- The particular regression coefficients can be interpreted as follows: The coefficient for a continuous variable like capacity ($b_5 = 0.10508$) indicates that a capacity of one additional kilogram results in an expected price increase of approximately 10.508 %. The coefficient for a dummy variable like "Brand cluster (high)" ($b_1 = 0.24642$) means that the price difference of "Brand cluster (medium)" (as reference brand cluster) and "Brand cluster (high)" is approximately 24.642 %. That means, a replacement of a washing machine of a low brand by a washing machine of a high brand inherits a price increase of approximately 24.642 %.

- In order to assess the adequacy of the regression estimation, consider the adjusted R^2 value. For washing machines this value should probably be expected to be around 0.5-0.6 or higher, as in principle a persistent relation of technological characteristics and the price should be expected. An R^2 very close to 1 should not normally occur and may indicate severely contaminated data. On the other hand, an adjusted R^2 considerably below 0.5 indicates a relatively low explanatory ability of the regression equation. A possible cause may be that the sample is taken from a fairly narrow and homogeneous stratum, where large characteristics differences do not occur. If so, the results may possibly be useful anyhow, in spite of the low R^2; here some skilled judgement may be called for. Another possible cause for a low R^2 may be that some essential characteristics variable has been left out and would have to be included in the regression equation.

Topic 4: Index calculation

- In the following the index sample is considered.

- At first those situations where a replacement takes place have to be detected. In these cases the sampled models change from one month to the next which implies different characteristic values and thus different quality levels of the two products. Those quality differences have to be adjusted as described in the following.

- In each replacement situation the values of the hedonic function h for the replaced and the replacement model has to be calculated. Therefore, insert the variable values of the respective model in the hedonic equation. The coefficients of the hedonic

equation have been calculated in *Topic 3* and the variable values of the respective models are collected within the scope of price collection.

- In the next step, the quality adjustment factor has to be computed. The quality adjustment factor ("g") is the relation of the values of the hedonic function *h* of replaced and replacement model. In other words, it is the mathematical ratio of quality for the new and the old model and refers to only this particular replacement situation:

$$g = \frac{h(X_t^B)}{h(X_{t-1}^A)} = \frac{Market\ value\ of\ the\ replacement}{Market\ value\ of\ the\ replaced\ model}$$

- This quality adjustment factor is used to adjust the quality of the replaced model by multiplying its price with the quality adjustment factor:

$$P_{t-1}^A \cdot g = quality\ adjusted\ price\ of\ the\ replaced\ model$$

- To calculate the quality adjusted price development, divide the price of the replacement product by the quality adjusted price of the replaced product:

$$\frac{P_t^B}{P_{t-1}^A \cdot g} = \frac{observed\ price\ of\ the\ replacement}{observed\ price\ of\ the\ replaced\ model \cdot g}$$

- For the index calculation, insert the quality adjusted price development in cases of replacements instead of the normal term. Here model A has been replaced by model B:

$$I = \left(\frac{P_{t=1}^B}{P_{t=0}^A \cdot g} \cdot \frac{P_{t=1}^C}{P_{t=0}^C} \cdot \frac{P_{t=1}^D}{P_{t=0}^D} \cdot \frac{P_{t=1}^E}{P_{t=0}^E} \cdot \frac{P_{t=1}^F}{P_{t=0}^F} \right)^{1/5} \text{, with } \frac{P_{t=1}^B}{P_{t=0}^A} \text{ being replaced by } \frac{P_{t=1}^B}{P_{t=0}^A \cdot g}$$

Topic 5: Refreshing the hedonic function

- Monitor the market in order to consider technological progress and market changes.
- As the product-specific market develops the validity of the calculated linear regression can change. Especially the significance of the variables as well as the regression coefficients themselves can change since the product undergoes technological progress. In order to reflect those technological changes, the regression equation has to be updated regularly. In the empirical studies conducted within the scope of the CENEX two indices were compared, one with a monthly re-estimation and one with an infrequent re-estimation. The indices showed a small difference. However, the difference was so small that for washing machines it is probably sufficient to re-estimate the hedonic function twice a year (e.g. in January and July) or yearly. Therefore, a new regression sample may have to be collected twice a year or yearly, following the procedure described for the target sample.

5.5　Cost estimation

One-time effort for the introduction

- Two members of staff are needed to introduce the method. Of these, one should have sufficient hedonic expertise and the other a knowledge of washing machine variables.

One should be responsible for implementing hedonic calculations, the other staff member should have responsibility for identifying variables and models for the sample.

- Up to six months seem to be necessary for the introduction. This can include an initial design study on data requirements, market research, testing new price collector forms, testing and assessment of the regression equation, methodology reporting, approval and documentation as well as system designs for smooth regular production.
- If an initial pilot study with extended data collection is needed, this of course requires additional resources.

Current effort of price collection

- There are two aspects to price collection. The prices can be collected by regular price collectors which also conduct the model selection. The variables can be obtained from the internet by one central office expert on washing machines.
- Estimated amount of work:
  - price collection: 50 hours,
  - variable collection and model selection: 15 hours,
  - total: 65 hours per collection.

Current effort of index calculation

- In order to set up the index calculation the price statistician would have to be competent in hedonic modelling. Once created the required expertise to maintain the system is minimal.
- Estimated amount of work: This should be automatic following data entry.

5.6   Examples

Example for the construction of a target sample:

- As described for the compilation of the target sample a market evaluation yielded that capacity and washing machine type are important to be considered. Let us assume that in our example the following three strata are relevant:
  - front loaders (capacity up to 5 kg),
  - front loaders (capacity 5 – 7 kg),
  - top loaders (capacity up to 5 kg).
- In our example, we only cover front loaders with a capacity of 5 to 7 kg. Consider in month 1, the price collector observes a number of representative washing machine models for the stratum front loader (capacity 5 – 7 kg):

Chart 168
Example of the price collection table

Model	Brand	Type	Capacity (kg)	Price in month 1 (€)	⋮
A	Bosch	WAS 28440	7	649.–	. . .
B	Miele	W1624	6	819.–	. . .
C	AEG-Electrolux	Lavamat 64840	6	599.–	. . .
. . .	. . .	. . .	. . .	. . .	. . .

- Besides the price and the capacity, a set of further relevant characteristics is also collected corresponding to the applied price collection form, e.g.:

Chart 169
Price collection form

Washing machine, front loader, capacity of 5 – 7 kg, higher brand	
Price (€):	649.–
Brand and model description:	Bosch WAS 28440
Capacity (kg):	7
Electricity consumption (kWh):	1.19
Water consumption (litres):	49
Maximum spin speed (rpm):	1400
Waterproofing:	Aqua-Stop
Built-in possibility:	☒ Yes ☐ No
Switch-on delay:	☒ Yes ☐ No
Shop: _____	
Date: _____	

Example for the replacement strategy:

- Suppose that in month 3 the washing machine version AEG-Electrolux Lavamat 64840 is no longer available or no longer well sold and it is replaced by the washing machine version Siemens WM 14 E 421.

- Those replacement situations can be marked with a "Q" in the price collection table.

Chart 170
Example of the price collection table

Model	Brand	Version	Capacity (kg)	Price in month 1 (€)	Q	Price in month 2 (€)	Q	Price in month 3 (€)
A	Bosch	WAS 28440	7	649.–		629.–		629.–
B	Miele	W1624	6	819.–		799.–		799.–
C	AEG-Electrolux	Lavamat 64840	6	699.–		699.–	**Q**	
D	Siemens	WM 14 E 421	7					749.–

- The different models could exhibit different characteristics with inherent different qualities. To match the products quality adjustment has to be applied.

Example for quality adjustment by applying hedonic re-pricing:

Topic 1: Data needed

- The compilation of the regression sample is described in the section on the target sample.

- The regression sample could look like this:

Chart 171
Example of a data base of a regression sample for washing machines

t	Model	Price (in €)	Brand	Maximum spin speed	Waterproofing	Capacity (kg)	Type	Water consumption (l)	Electricity consumption (kWh)	Built-in possibility	Switch-on delay
1	A	649.–	Bosch	1400	High	7	Top	49	1.19	Yes	Yes
1	B	819.–	Miele	1400	High	6	Top	49	1.02	Yes	Yes
1	C	699.–	AEG-Electrolux	1400	High	6	Top	49	1.02	Yes	Yes
...	...	...	...	...	...	...	...	...	...	...	...

Topic 2: Data editing

- After the regression sample is established, the data should be put in shape. That means, the variables should be defined as numerical or dummy variables.

- Reformat category (alphanumerical) variables to dummy variables. These can only take values of 0 or 1 depending on whether the model is equipped with a specific feature or not. In this example the characteristics "waterproofing", "type", and "brand cluster" have to be reformatted to a dummy variable. The waterproofing system – which was collected via the price collection form (here: aqua stop) – has to be assigned to a waterproofing level cluster. In this example we defined "high waterproofing" and "low waterproofing". In this example, "aqua stop" is assigned to "high waterproofing". For each dummy variable, one characteristic value has to be defined as default (reference) value.
    - The reference value for the brand dummy variables is the medium brand cluster. That means, in the case of a medium brand washing machine, the alternative brand dummies have a value of 0.
    - The reference value for the washing machine type variable is "front loader". That means, in the case of a front loader washing machine, the top loader dummy has a value of 0.
    - The reference value for the waterproofing variable is "waterproofing (low)". That means, in the case of washing machines equipped with a higher level waterproofing system the "waterproofing (high)" dummy has a value of 1. In this example we assume that there are only two waterproofing levels. In other cases it might be useful to define more waterproofing levels.

Chart 172
Example of a modified data base of a regression sample for washing machines

t	Model	Price (ln)	Brand cluster (high)	Brand cluster (low)	Maximum spin speed	Waterproofing (high)	Capacity (kg)	Top loader	Water consumption (l)	Electricity consumption (kWh)	Built-in possibility	Switch-on delay
1	A	6.475	1	0	1400	1	7	0	49	1.19	1	1
1	B	6.708	1	0	1400	1	6	0	49	1.02	1	1
1	C	6.550	1	0	1400	1	6	0	49	1.02	1	1
...	...	...	...	...	...	...	...	...	...	...	...	...

Topic 3: Creating the hedonic function

- The procedure of data collection for the regression sample and the subsequent creation of the hedonic function are exemplarily described in the section on quality adjustment. The significant coefficients of the hedonic equation which are needed for the example can be seen in the following chart:

Chart 173
Example of the regression coefficients

Regression coefficients		
b_0	Constant	5.66329
b_1	Brand cluster (high)	0.24642
b_2	Brand cluster (low)	− 0.1428
b_3	Maximum spin speed	0.0005339
b_4	Waterproofing (high)	0.05264
b_5	Capacity	0.10508
b_6	Top loader	0.18836

Topic 4: Index calculation

- In the following tables you find three price series for three periods containing the data that are required for the index calculation. At first, all replacement situations (marked with a "Q") have to be detected since only in those cases quality adjustment has to be applied. In this example from month 2 to month 3 there is one replacement situation.

Chart 174
Example of the price collection table

Model	Brand	Version	Capacity (kg)	Price in month 1 (€)	Q	Price in month 2 (€)	Q	Price in month 3 (€)
A	Bosch	WAS 28440	7	649.–		629.–		629.–
B	Miele	W1624	6	819.–		799.–		799.–
C	AEG-Electrolux	Lavamat 64840	6	699.–		699.–	Q	
D	Siemens	WM 14 E 421	7					749.–

- The index calculation from month 1 to month 2 follows the formula below:

$$I_2 = \left(\frac{P_{t=2}^A}{P_{t=1}^A} \cdot \frac{P_{t=2}^B}{P_{t=1}^B} \cdot \frac{P_{t=2}^C}{P_{t=1}^C} \right)^{1/3} = \left(\frac{629\ €}{649\ €} \cdot \frac{799\ €}{819\ €} \cdot \frac{699\ €}{699\ €} \right)^{1/3} = 0.9815$$

- The index from month 2 to month 3 contains replacement cases (marked with "Q"). The AEG-Electrolux model is replaced by a Siemens model. For both price observations, the replaced and the replacement model, the values of the hedonic function h

have to be calculated. In this example the hedonic regression equation is a semi-logarithmic function. Hence, the exponential function is needed to obtain the values of the hedonic function which are needed for the quality adjusted price. This is done by taking the anti-log of the sum of the constant and the respective products of characteristics and coefficients:

$$h_t = e^{(b_0 + b_1 \cdot v_1 + \dots + b_{10} \cdot v_{10})}$$

- To calculate the values of the hedonic function for both models, it is necessary to know the particular characteristics, which can be seen in the table below:

Chart 175
Example of the characteristics of replaced and replacement model

t	Model	Brand cluster (high)	Brand cluster (low)	Maximum spin speed	Waterproofing (high)	Capacity (kg)	Top loader	Water consumption (l)	Electricity consumption (kWh)
2	C	1	0	1400	1	6	0	49	1.02
3	D	1	0	1400	1	7	0	49	1.19

- Inserting the variables into the hedonic equation yields the values of the hedonic function for the particular models:

$$h_{t=2}^{C} = e^{(5.66329 + 0.24642 \cdot 1 + 0.0005339 \cdot 1400 + 0.05264 \cdot 1 + 0.10508 \cdot 6 + (-0.0144) \cdot 49 + (-0.0473) \cdot 1.02)}$$
$$= 725.20 \text{ €}$$

$$h_{t=3}^{D} = e^{(5.66329 + 0.24642 \cdot 1 + 0.0005339 \cdot 1400 + 0.05264 \cdot 1 + 0.10508 \cdot 7 + (-0.0144) \cdot 49 + (-0.0473) \cdot 1.19)}$$
$$= 799.10 \text{ €}$$

- The mathematical ratio of the values of the hedonic function from the replacement and the replaced model yields the quality adjustment factor "g" which can be calculated as follows (the subscript $r = 1$ indicates that the regression was run in month 1):

$$g_{r=1}^{C,D} = \frac{h_{t=3}^{D}}{h_{t=2}^{C}} = \frac{799.10 \text{ €}}{725.20 \text{ €}} = 1.1019$$

- To calculate the index from month 2 to month 3 the following formula is applied:

$$I_3 = \left(\frac{P_{t=3}^{A}}{P_{t=2}^{A}} \cdot \frac{P_{t=3}^{B}}{P_{t=2}^{B}} \cdot \frac{P_{t=3}^{D}}{P_{t=2}^{C}} \right)^{1/3}$$

- The index contains one replacement from model C in month 2 to model D in month 3. As hedonic re-pricing is used for quality adjustment

$\dfrac{P_{t=3}^D}{P_{t=2}^C}$ is replaced by $\dfrac{P_{t=3}^D}{P_{t=2}^C \cdot g_{r=1}^{C,D}}$

- The index for month 3 is calculated in the following (including the application of hedonic re-pricing):

$$I_3^{QA} = \left(\frac{P_{t=3}^A}{P_{t=2}^A} \cdot \frac{P_{t=3}^B}{P_{t=2}^B} \cdot \frac{P_{t=3}^D}{P_{t=2}^C \cdot g_{r=0}^{C,D}} \right)^{1/3} = \left(\frac{629\ \euro}{649\ \euro} \cdot \frac{799\ \euro}{799\ \euro} \cdot \frac{749\ \euro}{699\ \euro \cdot 1.1019} \right)^{1/3} = 0.9804$$

Chart 176
Monthly indexes

Model	Brand	Version	Capacity (kg)	Price in month 1 (€)	Q	Price in month 2 (€)	Q	Price in month 3 (€)
A	Bosch	WAS 28440	7	649.–		629.–		629.–
B	Miele	W1624	6	819.–		799.–		799.–
C	AEG-Electrolux	Lavamat 64840	6	699.–		699.–	**Q**	
D	Siemens	WM 14 E 421	7					749.–
Quality adjusted Price								
C	AEG-Electrolux	Lavamat 64840	6			770.22		
Monthly indexes				*100*		*98.2*		*98.0*

6 Books

- As a first step the COICOP four-digit-level 09.5.1 Books is divided into two head-lines: "rapidly changing market" and "long-selling market".
  - Rapidly changing market ("changing-product principle"): Applicable to products which have relatively short commercial life-spans and high rates of introduction of new products (books for children, books for leisure and culture including recently published books).
  - Long-selling market ("constant product principle"): Applicable to products that have relatively long commercial life-spans and low rates of introduction of new products (schoolbooks, dictionaries, encyclopaedia, evergreens and the like).
- The hedonic method is deemed most reliable in the HICP standards for the rapidly-changing market (A-method). Furthermore, the empirical studies of the CENEX showed that the index with hedonic adjustment exhibits the smallest volatility for the rapidly-changing market.
- Neither the empirical studies nor the HICP Standards propose the application of the hedonic method for the long-selling market. For this reason, the following section deals with the application of hedonic re-pricing for books in the *rapidly changing market only*.

Note:

- The quality adjustment method depends on the homogeneity of the available best-seller list:
  - A homogeneous bestseller list is, for example, a list only containing pocket fiction books. The books on the list are similar in the type of binding and size and in many cases the number of pages varies between certain ranges. In such circumstances where homogeneous bestseller lists are available there is no further need for quality adjustment as all books can be seen as essentially equivalent. The prices of these books may then be directly compared.
  - Another case is a national bestseller list which does e.g. not account for the binding but instead any book that is well sold can appear on the list. In this case there is a need for quality adjustment and then the method which is regarded as superior in the HICP Standards is the hedonic method.
- Bestseller lists may be either nation-wide or collected locally in stores, e.g. only books that are prominently placed on tables are observed. Please note that national bestseller lists are not generally preferred to local bestseller lists. Both approaches can be used depending on the index to be published. If only a nationwide index is to be published then a national bestseller list of all book sales may be the more appropriate choice. If additionally regional indexes are to be published regional bestseller lists may the better choice. Books on bestseller lists can differ in their characteristics from month to month.

6.1 Proposal for the identification of consumption segments

- The suggested consumption segments are identified as described in the non-hedonic section for books.

6.2 Proposal for the construction of a target sample

- For the application of hedonic re-pricing, usually two samples have to be collected. The first sample is called "regression sample" which serves the calculation of the hedonic regression equation. The second sample is called "index sample" and is used to calculate the price index for books. The index sample may also be a sub-sample of the regression sample or it can be independent from the regression sample.

- It is suggested to collect one regression sample for each consumption segment.

- The procedure suggested for the construction of a sample is valid for both the regression and the index sample which is already described in the non-hedonic section for books.

The regression sample

- To apply the hedonic method, a regression sample has to be collected. This sample is needed for the calculation of a systematic relationship between the prices of the books and their particular characteristics. Resulting from this relationship the hedonic equation can be established.

- To find out which characteristics are relevant to quality adjust books for:
  - Use experience from other national statistical offices, which may be further ahead in implementation of hedonics for books, or from other research.
  - A more ambitious approach could be to conduct a pilot study with a rather broad-minded collection of characteristics. But do not do that if you do not already have a rather clear mind about what you are looking for, as else you would likely just waste your and respondents' resources.

- The same set of characteristics needs to be collected for each book, regardless of whether it belongs to the regression sample or to the index sample.

- The following characteristics may serve as orientation for books:
  - number of pages,
  - format (length in cm),
  - binding (hardback, binds in board, special binding),
  - weight,
  - . . .

- Record two or three characteristics. In general the number of pages, the format (length) and the kind of binding are available.

- It should be stressed that there is no reason to overdo things here and collect lots of variables, as doing so would not be worth the effort. Actually, for books the application of hedonics has a more limited role than for most other products. For books the use of bestseller lists is the main device to control for quality, and hedonics is there merely a supplementary device to reduce disturbing variation which may occur in bestseller lists.

- Distinguish between different versions of a title since different versions of a title (for example different bindings) could be on the market at the same time. If so, include more than one version of a book title in the sample.

- An appropriate form which could be distributed to the price collectors should precisely ask for the considered characteristics and might look like this:

Chart 177
Example of a price collection form

Author: Paulo Coelho	
Title: The Witch of Portobello	
ISBN: 978-0007251865	Price: 20.99 €
Number of pages: 320	Length: 21.6 cm
Binding: ☐ binds in board ☒ hardback ☐ special binding	
Shop: _____	
Date: _____	

- The ISBN is needed for a clear identification of different book titles and its respective editions.

- For the estimation of the regression equation it is desirable that price observations used reflect a state of equilibrium (balance between supply and demand). That means that if it is practically possible, it would normally be preferable that temporarily reduced prices due to promotion offers or stock clearances can be identified in the price collection and not used for estimating the regression equation. (However, note that in the index calculation, on the other hand, reduced prices shall not be excluded.)

**Minimum size of the target sample**

- The regression sample should contain 50 to 100 observations depending on the number of characteristics that are used in the regression equation (see section on quality adjustment). As a rule of thumb, 15 to 20 observations per characteristic which is finally included in the regression equation should be collected. In case that the suggested characteristics variables are length, number of pages and binding the regression sample should contain at least 45 to 60 observations.

- The determination of the number of observations in the index sample depends on the level of precision that is to be attained on the one side and cost calculations on the other side. A rapidly changing market approach will however be rather demanding with regard to sampling issues. The reason is that book-samples that are based on the most representative items of the moment can be quite heterogeneous and therefore probably will have an instable structure over time. A sufficient sample size will be a necessary (but not sufficient) condition to ease this problem.

6.3   Proposal for the replacement strategy

- Please consider that the replacement strategy refers only to the index sample. The regression sample is a cross-sectional sample where no "replacements" can occur.

- The general remarks for the replacement strategy are the same as described in the non-hedonic section for books.

Chart 178
Monthly replacement of bestseller lists

Change to updated bestseller list
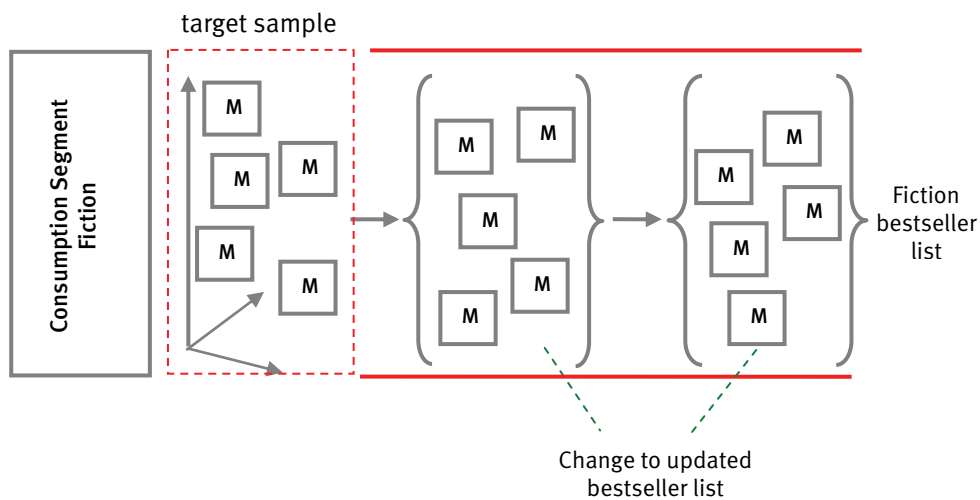
Reorganisation of price observations

- In case of using the hedonic method in connection with a bestseller list it is advisable to use the following approach to organise your price observations. The chart below gives an overview of the recommended approach which was originally presented in the final report of TF QAS I (p. 10, with modifications):

Chart 179
Identification of each book on the bestseller list

Price series	Top five bestsellers of a specific bestseller list and their ranks									
	period 1		period 2		period 3		period 4		period 5	
	rank	model	rank	model	rank	model	rank	model	rank	model
1	(1)	A	(1)	A	(3)	F	(2)	F	(2)	K
2	(2)	B	(2)	B	(2)	B	(5)	H	(4)	H
3	(3)	C	(3)	C	(1)	G	(3)	I	(3)	L
4	(4)	D	(4)	D	(4)	D	(4)	D	(5)	D
5	(5)	E	(5)	E	(5)	E	(1)	J	(1)	M

- In the chart above, each alphabetic character stands for one specific book. No matter on which rank a certain book title on the bestseller list is as long as it remains among the "top 5" it stays on the same price series to minimize the need for quality adjustment procedures.

- Example:
    - In the example above, in price series 1 book A is observed in periods 1 and 2.
    - In period 3, book A is no longer among the five bestsellers and therefore drops out of the sample. Instead, book F enters the "top 5" of the bestseller list on rank (3) and is placed in price series 1.
    - Book F remains in the same price series in period 4 even after its rank on the bestseller list changes from (3) to (2).
    - In period 5, book F is no longer among the five bestsellers and therefore drops out of the sample. It is replaced by book K which for the first time enters the bestseller list on rank (2).

- Furthermore, the chart indicates the duration of each book in the sample (e.g. in period 5 only the initial book *D* remains in the sample).

6.4 Proposal for the quality adjustment

- As stated in the section on the construction of the target sample, for the application of hedonic re-pricing it may be necessary to collect two data sets. In order to calculate the hedonic equation a comprehensive database is necessary which is called "regression sample". The hedonic equation is used to apply quality adjustment in the case of replacement situations which can only occur in the index sample. In the following sections the individual steps are described in great detail.

Topic 1: Data needed

- The compilation of the regression sample and of the index sample is described in the section on the target sample.

- The regression sample could look like this:

Chart 180
Example of a data base of a regression sample for books

Author	Title	ISBN	Number of pages	Length	Binding
Steel	Rogue	978-0593056752	320	23.6	hardback
Coelho	The Witch of Portobello	978-0007251865	320	21.6	hardback
. . .	. . .	. . .	. . .	. . .	. . .

- The variables "Author", "Title" and "ISBN" are not needed for the calculation but enable the identification of individual books.

- In order to gain information on characteristics of a certain book the ISBN is a unique identifier. It can be used to centrally collect the characteristics of a certain book title in databases rather than locally in the stores. They can, for example, be found on the internet (e.g. at *www.amazon.xx*) or in the respective national library.

Topic 2: Data editing

- After the regression sample is established, the data should be put in shape. That means, the variables should be defined as numerical or dummy variables.

- Reformat category variables to dummy variables. These can only take values of 0 or 1 depending on whether the model is equipped with a specific feature or not. In the case of books the characteristic "binding" has to be transformed to a dummy variable. For each dummy variable, one characteristic value has to be defined as default (reference) value.

- The price, the number of pages and the length are continuous variables. They can be transformed to their natural logarithm if a semi-log or double-log formulation is desired. In the present example a linear formulation is chosen. This results from the final report of the Task Force on Quality Adjustment and Sampling where the linear, the semi-log, and the double-log functions showed similar results. To simplify matters, the linear function is taken as example here.

Chart 181
Example for the modified database of the regression sample for books

Author	Title	ISBN	Length	Number of pages	Binds in board *
Steel	Rogue	978-0593056752	23.6	320	0
Coelho	The Witch of Portobello	978-0007251865	21.6	320	0
. . .	. . .	. . .	. . .	. . .	. . .

* Default value: hardback binding.

Topic 3: Creating the hedonic function

- After the data has been arranged, the hedonic regression equation can be set up. In this regard, the price (as dependent variable) should be explained as a function of the model's characteristics (independent variables).

- A number of 50 to 100 representative observations should be sufficient for establishing a regression equation.

- Statistical programs like SPSS, Stata or SAS are helpful to calculate the regression. The computer program is set up to perform a linear regression analysis on the data of the regression sample. The price is to be considered as the "dependent" variable and the characteristics (binding dummies, number of pages, size, etc.) are considered as "independent" variables.

- With regard to the general function form of the hedonic regression equation a linear function form is suggested.

  $P = b_0 + b_1 \cdot length + b_2 \cdot number\ of\ pages + b_3 \cdot binds\ in\ board + ... + \varepsilon$

- The hedonic regression equation contains continuous variables (length, number of pages) and one dummy variable (binds in board). For each dummy variable, one characteristic value has to be defined as default (reference) value. In the example above, for the binding the hardback binding serves as a default value. That means that for all hardback books the characteristic variable binds in board has a value of zero.

- Alternatively, as mentioned above under the Topic 2 data editing, a double-logarithmic form of the hedonic regression equation can be used. Especially, the number of pages variable can be transformed to the natural logarithm since the double logarithmic form may be more suitable when continuous variables may vary over wide ranges, with high ratios between upper and lower bound.

- The statistical program computes the coefficients (corresponding to the particular characteristics) and further statistical values which contain information on the significance of the variables.

- The result of the regression analysis could look like this:

Chart 182
Example for the results of the hedonic regression

Regression coefficients			t
Year 2007 (R = 0.869; n = 245)			
b_0	Constant	− 11.625	− 4.853
b_1	Length (cm)	1.416	12.837
b_2	Number of pages	0.004	4.022
b_3	Binds in board *	− 6.743	− 15.906

* Default value: hardback binding.

- The variables that were deemed relevant to quality adjust for have been collected as discussed under Topic 1. These were included into the regression equation. Potentially, some of the considered variables might not be significantly related to the price. Those "insignificant" variables could be identified by their t-values. At the design stage when the regression equation is tested, variables with t-values tending to be within the interval of − 2 to + 2 could be considered for skipping from the regression equation to be used operatively. One may have to be a little careful here, and some skilled judgement is called for. It should be noted that the t-test is approximate, as strictly seen it depends on assumptions that are usually not under perfect control.

- Particularly in the testing of the regression equation at the design stage, it should be checked whether the algebraic signs of the coefficients are as expected in view of the meaning of these. If a "wrong" sign occurs, the possible cause should be searched: Whether it is just expected random variation, or a misspecification of the variable, or contaminated data, or something else. Possibly a variable may then be identified as problematic and ultimately have to be skipped from the regression equation. But DON'T skip a variable automatically as soon as a "wrong" sign turns up, as doing so may just sweep problems under the carpet and produce invalid results.

- The particular regression coefficients can be interpreted as follows: The coefficient for a continuous variable like number of pages (b2 = 0.004) indicates that one more page within a books results in an expected price increase of approximately 0.004 EUR. The coefficient for a dummy variable like binds in board (b3 = − 6.743) means that a book with binds in board results in an expected price decrease of approximately 6.74 EUR.

- In order to assess the adequacy of the regression estimation, consider the adjusted R^2 value. For books this value should probably be expected to be around 0.5 − 0.6 or higher, as in principle a persistent relation of technological characteristics and the price should be expected. An R^2 very close to 1 should not normally occur and may indicate severely contaminated data. On the other hand, an adjusted R^2 considerably below 0.5 indicates a relatively low explanatory ability of the regression equation. A possible cause may be that the sample is taken from a fairly narrow and homogeneous stratum, where large characteristics differences do not occur. If so, the results may possibly be useful anyhow, in spite of the low R^2; here some skilled judgement may be called for. Another possible cause for a low R^2 may be that some essential characteristics variable has been left out and would have to be included in the regression equation.

Topic 4: Index calculation

- This step describes the procedure for the index calculation. This procedure needs to be repeated for each consumption segment.

- Select the price observations for the HICP sample (e.g. include the five bestsellers of each bestseller list). Restructure the list so that a certain book is on a single price series as long as it is within the "top 5" in order to minimise quality adjustment cases and collect the corresponding characteristics.

- At first those situations where a new book has appeared in the "top 5" have to be detected. In these cases the sampled books change from one month to the next which implies different characteristic values and thus different quality levels of the two books. Those quality differences have to be adjusted as described in the following.

- In each replacement situation the values of the hedonic function *h* for the replaced and the replacement model has to be calculated. Therefore, insert the variable values of the respective model in the hedonic equation.

- The coefficients of the hedonic equation have been calculated in Topic 3 and the variable values of the respective models are collected within the scope of price collection. In the example, the regression coefficients are:

Chart 183
Example of the regression coefficients

Regression coefficients		
b_0	Constant	– 11.625
b_1	Length (in cm)	1.416
b_2	Number of pages	0.004
b_3	Binds in board	– 6.743

- In the next step, the quality adjustment factor has to be computed. The quality adjustment factor ("g") is the relation of the values of the hedonic function h of the replaced model A and the replacement model B. In other words, it is the mathematical ratio of quality for the new and the old model and refers to only this particular replacement situation:

$$g = \frac{h(X_t^B)}{h(X_{t-1}^A)} = \frac{Market\ value\ of\ the\ replacement}{Market\ value\ of\ the\ replaced\ model}$$

In the following this functional form is used. Alternatively, as in the case of books there is no one-to-one matching (books are more or less individual objects and cannot be matched between periods) the non-matching form of the hedonic re-pricing method can be considered:

$$g = \frac{h\,(standard\ set\ of\ characteristics)}{h\,(characteristics\ of\ actual\ model)}$$

The numerator here is the value of the hedonic function for some hypothetical "standard" model with given characteristics. The idea is that all prices of both the price reference period and the current period, are modified so as to correspond to the same standard quality.

- This quality adjustment factor is used to adjust the quality of the replaced model by multiplying its price with the quality adjustment factor:

$$P_{t-1}^A \cdot g = quality\ adjusted\ price\ of\ the\ replaced\ model$$

- To calculate the quality adjusted price development, divide the price of the replacement product by the quality adjusted price of the replaced product:

$$\frac{P_t^B}{P_{t-1}^A \cdot g} = \frac{observed\ price\ of\ the\ replacement}{observed\ price\ of\ the\ replaced\ model \cdot g}$$

- For the index calculation, insert the quality adjusted price development in cases of replacements instead of the normal term. Here model A has been replaced by model B:

$$I = \left(\frac{P_{t=1}^{B}}{P_{t=0}^{A} \cdot g} \cdot \frac{P_{t=1}^{C}}{P_{t=0}^{C}} \cdot \frac{P_{t=1}^{D}}{P_{t=0}^{D}} \cdot \frac{P_{t=1}^{E}}{P_{t=0}^{E}} \cdot \frac{P_{t=1}^{F}}{P_{t=0}^{F}} \right)^{1/5} \text{, with } \frac{P_{t=1}^{B}}{P_{t=0}^{A}} \text{ being replaced by } \frac{P_{t=1}^{B}}{P_{t=0}^{A} \cdot g}$$

Topic 5: Refreshing the hedonic function

- Given the slow evolution on the book market a yearly up-date of the regression equations is sufficient.

6.5   Cost estimation

One time effort for introduction

- The implementation, including for example the collection of data for the estimation of the regression, may require up to four months.

Current effort of price collection and index calculation

- For the price collection and the index calculation all in all up to five days may be required.

6.6   Examples

Example for the identification of consumption segments:

- It is assumed that three consumption segments are relevant in our example:
    - fiction books,
    - non-fiction books,
    - children's books.
- In the following, the focus lies on fiction books. In order to deal with the two remaining consumption segments you would need to proceed analogously.

Example for the construction of a target sample:

- In a first step, check whether a national bestseller list is available for fiction books for your country. If a bestseller list is unavailable, please proceed as described above in the section on sampling.
- For this example, a bestseller list for fiction books is available. It is, furthermore, assumed that prices are fixed throughout the country.
- The top five fiction titles from the bestseller list are exemplarily considered for price collection.

Chart 184
Fictitious example of the sample of bestseller fiction books in the base period

Position	Author/Title	Price (€)
1	Danielle Steel/Rogue	17.95
2	Paulo Coelho/The Witch of Portobello	20.99
3	Robert Menasse/Don Juan de la Mancha	20.99
4	Catherine Coulter/Tailspin	16.45
5	Henning Mankell/Italian Shoes	19.99

• As the price development is similar throughout regions due to fixed prices, the prices can be collected centrally, for example from a big bookstore. The characteristics of the books are also collected.

Chart 185
Example of a price collection form

Author: Paulo Coelho	
Title: The Witch of Portobello	
ISBN: 978-0007251865	Price: 20.99 €
Number of pages: 320	Length: 21.6 cm
Binding: ☐ binds in board ☒ hardback ☐ special binding	
Shop: _____	
Date: _____	

Example for the replacement strategy

• The following replacement situation refers to the index sample only.

• In the case of bestseller lists one can not speak of one-to-one replacements. Instead, for our example, in each month the first five books are chosen from the bestseller list originating from the same source that was already considered in the previous month. This way, the sample remains representative over time.

Chart 186
Fictitious example of the sample of bestseller fiction books in three sequent months

Posi-tion	Month 1		Month 2		Month 3	
	Author/Title	Price (€)	Author/Title	Price (€)	Author/Title	Price (€)
1	Danielle Steel/ Rogue	17.95	Joanne K. Rowling/ Harry Potter and the deathly hallows	18.95	Joanne K. Rowling/ Harry Potter and the deathly hallows	18.95
2	Paulo Coelho/ The Witch of Portobello	20.99	Paulo Coelho/ The Witch of Portobello	20.99	Paulo Coelho/ The Witch of Portobello	20.99
3	Robert Menasse/ Don Juan de la Mancha	20.99	Danielle Steel/ Rogue	17.95	Danielle Steel/ Rogue	17.95
4	Catherine Coulter/ Tailspin	16.45	Cornelia Funke/ Inkdeath	17.99	Stephenie Meyer/ The Host	18.95
5	Henning Mankell/ Italian Shoes	19.99	Stephenie Meyer/ The Host	18.95	Henning Mankell/ Italian Shoes	19.99

- The chart above demonstrates the dynamics of bestseller lists:
    - Two books remain in the sample in all three months: *Rogue* by Danielle Steel and *The Witch of Portobello* by Paulo Coelho.
    - The book *Italian Shoes* by Henning Mankell is in the sample in the first month, loses representativity in the second month so that it needs to be excluded and re-gains representativity in the third month when it is again among the five top selling books and therefore re-included in the sample.
    - The remaining books stayed in the sample either only for one month or for two sequent months.
- As long as a book title is among the top five of the bestseller list it is not replaced. This book stays in the same price series. In order to keep the number of quality ad-justment situations as low as possible you need to re-organise your observations as illustrated by the following chart.

Chart 187
Re-arrangement of the bestseller list to obtain price series

Price series	Month 1		Month 2		Month 3	
	Author/Title	Price (€)	Author/Title	Price (€)	Author/Title	Price (€)
1	(1) Danielle Steel/ Rogue	17.95	(3) Danielle Steel/ Rogue	17.95	(3) Danielle Steel/ Rogue	17.95
2	(2) Paulo Coelho/ The Witch of Portobello	20.99	(2) Paulo Coelho/ The Witch of Portobello	20.99	(2) Paulo Coelho/ The Witch of Portobello	20.99
3	(3) Robert Menasse/ Don Juan de la Mancha	20.99	(1) Joanne K. Rowling/ Harry Potter and the deathly hallows	18.95	(1) Joanne K. Rowling/ Harry Potter and the deathly hallows	18.95
4	(4) Catherine Coulter/ Tailspin	16.45	(4) Cornelia Funke/ Inkdeath	17.99	(5) Henning Mankell/ Italian Shoes	19.99
5	(5) Henning Mankell/ Italian Shoes	19.99	(5) Stephenie Meyer/ The Host	18.95	(4) Stephenie Meyer/ The Host	18.95

- In our example in month 2 the book by Robert Menasse is no longer available or no longer well sold and it is replaced for example by the book by Joanne K. Rowling.
- The two books exhibit different characteristics with inherent different qualities. To match the products quality adjustment has to be applied.

Example for quality adjustment by applying hedonic re-pricing:

Topic 1: Data needed

- The compilation of the regression sample is described in the section on the target sample.
- The regression sample could look like this:

Chart 188
Example of a data base of a regression sample for books

Author	Title	ISBN	Number of pages	Length (cm)	Binding
Steel	Rogue	978-0593056752	320	23.6	hardback
Coelho	The Witch of Portobello	978-0007251865	320	21.6	hardback
. . .	. . .	. . .	. . .	. . .	. . .

Topic 2: Data editing

- After the regression sample is established, the data should be put in shape. That means, the variables should be defined as numerical or dummy variables.

- Reformat category variables to dummy variables. These can only take values of 0 or 1 depending on whether the model is equipped with a specific feature or not. In the case of books the characteristic "binding" has to be transformed to a dummy variable. For each dummy variable, one characteristic value has to be defined as default (reference) value.

- The price, the number of pages and the length are continuous variables. In the present example a linear formulation is chosen.

Chart 188
Example for the modified database of the regression sample for books

Author	Title	ISBN	Number of pages	Length (cm)	Binds in board *
Steel	Rogue	978-0593056752	320	23.6	0
Coelho	The Witch of Portobello	978-0007251865	320	21.6	0
. . .	. . .	. . .	. . .	. . .	. . .

* Default value: hardback binding.

Topic 3: Creating the hedonic function

- The procedure of data collection for the regression sample and the subsequent creation of the hedonic function are exemplarily described in section on quality adjustment. The coefficients of the hedonic equation can be seen in the table below again:

Chart 189
Example of the regression coefficients

	Regression coefficients	
b_0	Constant	− 11.625
b_1	Length (in cm)	1.416
b_2	Number of pages	0.004
b_3	Binds in board	− 6.743

- The reference binding is hardback.

Topic 4: Index calculation

- In the following chart you can find five price series for three periods containing the data that is required for the index calculation. At first, all replacement situations (marked with a "Q") have to be detected since only in those cases quality adjustment has to be applied. In this example from month 1 to month 2 there are three replacement situations, from month 2 to month 3 there is one replacement situation.

Chart 190
Example of the price collection table

Model	Author	Title	Price in month 1 (€)	Q	Price in month 2 (€)	Q	Price in month 3 (€)
A	Danielle Steel	Rouge	17.95		17.95		17.95
B	Paulo Coelho	The Witch of Portobello	20.99		20.99		20.99
C	Robert Menasse	Don Juan de la Mancha	20.99	Q			
D	Catherine Coulter	Tailspin	16.45	Q			
E	Henning Mankell	Italian Shoes	19.99	Q			19.99
F	Joanne K. Rowling	Harry Potter and the deathly hallows			18.95		18.95
G	Cornelia Funke	Inkdeath			17.99	Q	
H	Stephenie Meyer	The Host			18.95		18.95

- The index from month 1 to month 2 contains replacement cases (marked with "Q"). Model C is replaced by Model F, Model D by Model G, and Model E by Model H. As long as a book stays in the top five no quality adjustment is necessary regardless of the exact rank on the list. For the price observations of the replaced and the replacement model the values of the hedonic function h have to be calculated. For this example a linear function is:

$$h_t = b_0 + b_1 \cdot v_1 + b_2 \cdot v_2 + b_3 \cdot v_3$$

- To calculate the values of the hedonic function h for both the replaced and the replacement model, it is necessary to know the particular characteristics, which can be seen in the following chart :

Chart 191
Example of the characteristics of replaced and replacement models

Model	Author	Title	Number of pages	Length (in cm)	Binds in board
C	Robert Menasse	Don Juan de la Mancha	274	20.2	0
D	Catherine Coulter	Tailspin	416	23.0	0
E	Henning Mankell	Italian Shoes	448	20.8	0
F	Joanne K. Rowling	Harry Potter and the deathly hallows	608	20.4	0
G	Cornelia Funke	Inkdeath	656	21.6	0
H	Stephenie Meyer	The Host	617	22.0	0

- Inserting the variables into the hedonic equation yields the values of the hedonic function h for the particular models:

$$h(\text{Menasse})_{t=1} = -11.625 + 0.004 \cdot 448 + 1.416 \cdot 20.2 = 18.77 \text{ €}$$

$$h(\text{Rowling})_{t=2} = -11.625 + 0.004 \cdot 608 + 1.416 \cdot 20.4 = 19.69 \text{ €}$$

- The mathematical ratio of the values of the hedonic function from the replacement F (Rowling) and the replaced model C (Menasse) yields the quality adjustment factor "g" which can be calculated as follows (the subscript $r = 0$ indicates that the regression was run in month 0):

$$g_{r=0}^{C,F} = \frac{h(\text{new})_{t=2}}{h(\text{old})_{t=1}} = \frac{h(\text{Rowling})_{t=2}}{h(\text{Menasse})_{t=1}} = \frac{18.77 \text{ €}}{19.69 \text{ €}} = 0.95327$$

- Concerning the other replacement cases proceed in the same way. For the replacement of *Coulter* by *Funke*, calculate

$$h(\text{Coulter})_{t=1} = -11.625 + 0.004 \cdot 416 + 1.416 \cdot 23 = 22.61 \text{ €}$$

$$h(\text{Funke})_{t=2} = -11.625 + 0.004 \cdot 656 + 1.416 \cdot 21.6 = 21.58 \text{ €}$$

$$g_{r=0}^{D,G} = \frac{h(\text{new})_{t=2}}{h(\text{old})_{t=1}} = \frac{h(\text{Funke})_{t=2}}{h(\text{Coulter})_{t=1}} = \frac{21.58 \text{ €}}{22.61 \text{ €}} = 0.95444$$

and for the replacement of *Mankell* by *Meyer*, calculate

$$h(\text{Mankell})_{t=1} = -11.625 + 0.004 \cdot 448 + 1.416 \cdot 20.8 = 19.62 \text{ €}$$

$$h(\text{Meyer})_{t=2} = -11.625 + 0.004 \cdot 617 + 1.416 \cdot 22 = 22.00 \text{ €}$$

$$g_{r=0}^{E,H} = \frac{h(\text{new})_{t=2}}{h(\text{old})_{t=1}} = \frac{h(\text{Meyer})_{t=2}}{h(\text{Mankell})_{t=1}} = \frac{22.00 \text{ €}}{19.62 \text{ €}} = 1.12130$$

- To calculate the index from month 1 to month 2 the following formula is applied:

$$I_2 = \left(\frac{P_{t=2}^A}{P_{t=1}^A} \cdot \frac{P_{t=2}^B}{P_{t=1}^B} \cdot \frac{P_{t=2}^F}{P_{t=1}^C} \cdot \frac{P_{t=2}^G}{P_{t=1}^D} \cdot \frac{P_{t=2}^H}{P_{t=1}^E} \right)^{1/5}$$

- The index contains three replacements: model C is replaced by model F, model D by model G, and model E by model H. As hedonic re-pricing is used for quality adjustment

$$\frac{P_{t=2}^F}{P_{t=1}^C} \text{ is replaced by } \frac{P_{t=2}^F}{P_{t=1}^C \cdot g_{r=0}^{C,F}}$$

$$\frac{P_{t=2}^G}{P_{t=1}^D} \text{ is replaced by } \frac{P_{t=2}^G}{P_{t=1}^D \cdot g_{r=0}^{D,G}}$$

$\dfrac{P_{t=2}^{H}}{P_{t=1}^{E}}$ is replaced by $\dfrac{P_{t=2}^{H}}{P_{t=1}^{E} \cdot g_{r=0}^{E,H}}$

- The index for month 2 is calculated in the following (including the application of hedonic re-pricing):

$$I_2^{QA} = \left(\frac{P_{t=2}^{A}}{P_{t=1}^{A}} \cdot \frac{P_{t=2}^{B}}{P_{t=1}^{B}} \cdot \frac{P_{t=2}^{F}}{P_{t=1}^{C} \cdot g_{r=0}^{C,F}} \cdot \frac{P_{t=2}^{G}}{P_{t=1}^{D} \cdot g_{r=0}^{G,D}} \cdot \frac{P_{t=2}^{H}}{P_{t=1}^{E} \cdot g_{r=0}^{E,H}} \right)^{1/5}$$

$$= \left(\frac{17.95\,€}{17.95\,€} \cdot \frac{20.99\,€}{20.99\,€} \cdot \frac{18.95\,€}{20.99\,€ \cdot 0.95327} \cdot \frac{17.99\,€}{16.45\,€ \cdot 0.95444} \cdot \frac{18.95\,€}{19.99\,€ \cdot 1.12130} \right)^{1/5}$$

$$= 0.9829$$

- In month 3 only one replacement occurs: model G is replaced by model E which was in the "top 5" in month 1 lost representativity in the second month so that it needed to be excluded and re-gained representativity in the third month when it is again among the five top selling books and therefore re-included in the sample. The values of the hedonic function h for both models are calculated:

$$h\,(Funke)_{t=2} = -11.625 + 0.004 \cdot 656 + 1.416 \cdot 21.6 = 21.58\,€$$

$$h\,(Mankell)_{t=3} = -11.625 + 0.004 \cdot 448 + 1.416 \cdot 20.8 = 19.62\,€$$

$$g_{r=0}^{G,E} = \frac{h\,(new)_{t=2}}{h\,(old)_{t=1}} = \frac{h\,(Mankell)_{t=3}}{h\,(Funke)_{t=2}} = \frac{19.62\,€}{21.58\,€} = 0.90918$$

- As in month 2 the index for month 3 is calculated in the following way:

$$I_3^{QA} = \left(\frac{P_{t=3}^{A}}{P_{t=2}^{A}} \cdot \frac{P_{t=3}^{B}}{P_{t=2}^{B}} \cdot \frac{P_{t=3}^{F}}{P_{t=2}^{F}} \cdot \frac{P_{t=3}^{H}}{P_{t=2}^{H}} \cdot \frac{P_{t=3}^{E}}{P_{t=2}^{G} \cdot g_{r=0}^{G,E}} \right)^{1/5}$$

$$= \left(\frac{17.95\,€}{17.95\,€} \cdot \frac{20.99\,€}{20.99\,€} \cdot \frac{18.95\,€}{18.95\,€} \cdot \frac{18.95\,€}{18.95\,€} \cdot \frac{19.99\,€}{17.99\,€ \cdot 0.90918} \right)^{1/5}$$

$$= 1.0409$$

Chart 192
Monthly indexes

Model	Author	Title	Price in month 1 (€)	Q	Price in month 2 (€)	Q	Price in month 3 (€)
A	Danielle Steel	Rouge	17.95		17.95		17.95
B	Paulo Coelho	The Witch of Portobello	20.99		20.99		20.99
C	Robert Menasse	Don Juan de la Mancha	20.99	**Q**			
D	Catherine Coulter	Tailspin	16.45	**Q**			
E	Henning Mankell	Italian Shoes	19.99	**Q**			19.99
F	Joanne K. Rowling	Harry Potter and the deathly hallows			18.95		18.95
G	Cornelia Funke	Inkdeath			17.99	**Q**	
H	Stephenie Meyer	The Host			18.95		18.95
Quality adjusted prices							
C	Robert Menasse	Don Juan de la Mancha	20.01				
D	Catherine Coulter	Tailspin	15.70				
E	Henning Mankell	Italian Shoes	22.41				
G	Cornelia Funke	Inkdeath			16.36		
Monthly indexes			*100*		*98.3*		*104.1*

7   Annexes and references

7.1   Annexes

Annex 1: Details on different types of hedonic methods

Four main types of hedonic methods can be identified, namely the following (Triplett 2006; cf. National Research Council 2002):

- The hedonic time dummy variable method.
- The hedonic characteristics price index method.
- The hedonic price imputation method.
- The hedonic re-pricing method.

These four types of hedonic methods will now be described and discussed. For each of the types there are different variants.

The hedonic time dummy variable method

Alias: The direct method.

The hedonic time dummy variable method *computes the price index as a transformed regression coefficient from analysis on pooled data from more than one time-period.*

Index computation with this method. Consider an example with three characteristics variables, z_1, z_2, z_3. In the case of two considered periods, the reference period $t = 0$ and the comparison period $t = 1$, the hedonic regression equation may have this form,

(15) $\ln P = b_0 + b_1 \cdot z_1 + b_2 \cdot z_2 + b_3 \cdot z_3 + \gamma \cdot D_{t=1} + \varepsilon$

where $D_{t=1}$ is a time dummy variable taking the value 1 for the period $t = 1$ and 0 otherwise.

The price index, for period 1 with reference period 0, now appears as the exponentiated value of a regression coefficient in the regression equation,

$I_{t=1} = e^{\gamma}$.

The computation procedure is that a regression analysis is run on data from both periods $t = 0$ and $t = 1$ simultaneously, and then the index $I_{t=1}$ is obtained from one of the estimated regression coefficients.

Variants: The same method could be applied directly in a setting with more than two periods, by taking several time dummy variables, one for each period after the reference period. However, another alternative is to fit the regression equation (15) for each pair of adjacent periods, and then chain.

Remark: The index number is here obtained by another way than a familiar "index formula" such as Jevons index or Dutot index. Nevertheless, if there are no quality changes, the index number $I_{t=1}$ obtained by fitting Eq. (15) to the observed prices turns out to be equal to the usual Jevons index.

The hedonic characteristics price index method

Alias: The direct characteristics method.

The hedonic characteristics price index method *computes a price index for a fixed basket of characteristics, priced by currently updated hedonic functions.*

Index computation with this method. Consider an example with five sampled product-offers, labelled A, C, D, E, F, in the reference period $t = 0$. In the comparison period $t = 1$ the product-offer A has been replaced by another product-offer labelled B. The Jevons index unadjusted for quality change is then computed as

$$(16) \qquad I = \left(\frac{P_{t=1}^B}{P_{t=0}^A} \cdot \frac{P_{t=1}^C}{P_{t=0}^C} \cdot \frac{P_{t=1}^D}{P_{t=0}^D} \cdot \frac{P_{t=1}^E}{P_{t=0}^E} \cdot \frac{P_{t=1}^F}{P_{t=0}^F} \right)^{1/5} .$$

The hedonic characteristics price index method then means that the index is computed as in eq. (16) but with this modification:

$$(17) \qquad \text{Use Eq. (16) but in place of } \frac{P_{t=1}^B}{P_{t=0}^A} \text{ take } \frac{P_{t=1}^B}{P_{t=0}^A \cdot h(z^B)/h(z^A)} .$$

Here $h_{t=0}(.)$ and $h_{t=1}(.)$ stand for hedonic functions estimated on data for each of the two periods separately. Furthermore z^A is the set of characteristics values of product-offer A.

Variants: Using the characteristics z^A of the earlier product-offer A in Eq. (17) is in the vein of a Laspeyres index, by implying a characteristics basket from the earlier period. Similarly there is a Paasche-style alternative, taking in the place of z^A in (17) instead the characteristics z^B of the later product-offer B, and a Fisher-style alternative with an index equal to the geometric mean of the latter two indices.

The hedonic price imputation method

Alias: An indirect method.

The hedonic price imputation method *computes a price index with some prices given by a hedonic function.*

Index computation with this method. In the example described in connection to eq. (16), the hedonic price imputation method in a simple form could mean that the index is computed as in eq. (16) but with this modification:

$$(18) \qquad \text{Use Eq. (16) but in place of } \frac{P_{t=1}^B}{P_{t=0}^A} \text{ take } \frac{P_{t=1}^B}{h_{t=0}(z^A)} .$$

Like in Eq. (17) for the Hedonic characteristics price index method just described, $h_{t=0}(.)$ here stands for a hedonic function, ideally pertaining to the period $t = 0$.

Variants: By Eq. (18) a price given by a hedonic function is imputed for the newly observed product-offer B in the earlier period, when it did not exist or its price was not collected. On the other hand the vanishing product-offer A, not available in the comparison period, is

dropped from the index computation. An alternative way is to do it the other way around, to impute for the vanishing product-offer A in the comparison period and drop the newly observed product-offer A from the index computation.

Imputing for both vanishing and newly observed product-offers is a further alternative. Then both the vanishing product-offer A and the newly observed product-offer B can be included, and the index computation becomes

$$(19) \qquad I = \left(\frac{h_{t=1}(z^A)}{P_{t=0}^A} \cdot \frac{P_{t=1}^B}{h_{t=0}(z^B)} \cdot \frac{P_{t=1}^C}{P_{t=0}^C} \cdot \frac{P_{t=1}^D}{P_{t=0}^D} \cdot \frac{P_{t=1}^E}{P_{t=0}^E} \cdot \frac{P_{t=1}^F}{P_{t=0}^F} \right)^{1/6}$$

Actually the number of observed prices here does not necessarily have to be the same in the two periods, as one just imputes a price whenever a product-offer is absent in either of the two periods.

Double imputation is yet another alternative, meaning that imputation is made also to avoid comparison between observed and hedonically estimated prices, by an index computation like

$$(19') \qquad I = \left(\frac{h_{t=1}(z^A)}{h_{t=0}(z^A)} \cdot \frac{h_{t=1}(z^B)}{h_{t=0}(z^B)} \cdot \frac{P_{t=1}^C}{P_{t=0}^C} \cdot \frac{P_{t=1}^D}{P_{t=0}^D} \cdot \frac{P_{t=1}^E}{P_{t=0}^E} \cdot \frac{P_{t=1}^F}{P_{t=0}^F} \right)^{1/6} .$$

The hedonic re-pricing method

Alias: "The hedonic quality adjustment method"; the hedonic method of pricing of characteristics; an indirect method.

The hedonic re-pricing method *computes a price index from observed prices that may be modified in proportion to a hedonic function.*

Note on terminology: "Hedonic re-pricing" is here suggested as name for the method that Triplett (2006) and Eurostat (2005) refer to as "The hedonic quality adjustment method". The reason for this suggestion is that the name "The hedonic quality adjustment method" may be very likely to be mistaken for "quality adjustment by hedonic methods" in general. The latter would include also the time dummy method etc. It seems advisable to avoid that evidently misunderstanding-prone wording.

Index computation with this method. In the example described in connection to eq. (16), the hedonic re-pricing method means that the index is computed as in eq. (16) but with this modification:

$$(20) \qquad \text{Use Eq. (16) but in place of} \quad \frac{P_{t=1}^B}{P_{t=0}^A} \quad \text{take} \quad \frac{P_{t=1}^B}{P_{t=0}^A \, h(z^B)/h(z^A)} \quad .$$

Again $h(.)$ stands for a hedonic function, which should ideally be estimated fairly recently, but the timing of its estimation is far less critical in this method than in those just described.

Variants: By Eq. (20) the reference price is adjusted for the quality change, and this should often be a convenient practice. However it would in principle be possible to invert the adjustment factor and put it in the numerator and not in the denominator, meaning that instead the comparison price is adjusted to the same effect.

More interestingly, the method can be generalised to settings where there is no matching of product-offers between the reference period and the comparison period. Then each price in both periods is increased or decreased by a factor corresponding to how the value of the product-offer on account of its set of characteristics relates to that of a standard-level set z^S of characteristics. The computation goes like this:

(21)
$$I = \frac{\left(P_{t=1}^B h(z^S)/h(z^B) \cdot P_{t=1}^G h(z^S)/h(z^G) \cdot P_{t=1}^H h(z^S)/h(z^H) \cdot \right.}{\left(P_{t=0}^A h(z^S)/h(z^A) \cdot P_{t=0}^C h(z^S)/h(z^C) \cdot P_{t=0}^D h(z^S)/h(z^D) \cdot \right.}$$
$$\frac{\left. \cdot P_{t=1}^J h(z^S)/h(z^J) \cdot P_{t=1}^K h(z^S)/h(z^K) \right)^{1/5}}{\left. \cdot P_{t=0}^E h(z^S)/h(z^E) \cdot P_{t=0}^F h(z^S)/h(z^F) \right)^{1/5}}$$

Here all the product-offers observed in the comparison period, labelled B, G, H, J, K, are newly observed, not observed in the reference period. Actually the number of observed prices here does not necessarily have to be the same in the two periods.

The non-matching form by Eq. (21) of the hedonic re-pricing method is useful in combination with the bestseller list approach for products like books and recorded media (cf. Eurostat 2002).

Remark: It may be noted that if double imputation, like in Eq. (19), is applied in the same setting as Eq. (21), the formula becomes very similar to Eq. (21). Effectively it differs from Eq. (21) only in its more specified timing of the hedonic functions, and in the exponent becoming 1/10 instead of 1/5. The difference in exponents may at first seem paradoxical but is as it should. This is indicated by the fact that the mentioned exponents make both indices satisfy the proportionality axiom (cf. ILO et al. 2004, Sect. 16.37). That is, the indices are such that if all prices change in the same proportion (and quality is unchanged), then the index changes in the same proportion.

It may be illuminating to notice that the index by double imputation becomes identical to the geometric mean of the hedonic characteristic price index method (as by Eq. (17)) and the index by hedonic re-pricing of Eq. (21), if the hedonic function in Eq. (21) is taken as the geometric mean of the two period-specific hedonic functions.

Choice of which type of hedonic method – normally use the hedonic re-pricing method

The question of which of the described types of hedonic method to choose will now be dealt with.

The hedonic time dummy variable method appears to have been fairly much used in academic studies but not so much in official statistics, as Triplett (2006) notes. That method has some difficulty in transparency. Quality adjustment and index calculation here take

place in the same "black box", in a way hiding what is going on. As Melser (2004) notes, the method also leads to non-compliance with some usually expected axiomatic index properties.

The hedonic re-pricing method seems to be the one most often used in hedonic applications to official statistics, and there are apparently good reasons for this, as Triplett (2006) notes. The updating of the hedonic function is not so critical with this method. The hedonic regression may thus where suitable be performed on a larger data material than the monthly index computations. This may often be an important practical advantage, as the number of monthly price observations may in many cases be rather small for a monthly regression analysis on fresh data.

The hedonic re-pricing method also affects only such prices that are associated with quality change, which is in line with usual practice on quality adjustment generally and supports transparency. This feature is not least an advantage to effective data editing, as it makes it feasible to search for errors in data which may lie behind suspicious results.

Furthermore the generalised form of the Hedonic re-pricing method, as described in connection to Eq. (10), makes this method suitably applicable also to situations where there is no effective matching over time, such as for book titles or newly built houses.

It may also be noted that the HICP "Implementation Regulation", as well as a later amendment to it (Commission of the European Communities 1996, 2007), contains the following definition:

> "Quality adjustment" means the procedure of making an allowance for an observed quality change by increasing or decreasing the observed current or reference price by a factor or an amount equivalent to the value of that quality change.

Apparently the hedonic re-pricing method is the hedonic method that is most clearly compatible with this formulation, although the formulation should probably not be seen as ruling out other hedonic methods.

The hedonic re-pricing method should be regarded as a default choice among hedonic methods, to be used except possibly where there are very particular reasons to choose some of the other hedonic methods.

Annex 2: Brief theoretical digression on number of price observations

In the treatment of "Topic 1" in *Applying hedonic regression – concepts and guidance for use*, the following rule of thumb was stated on the number of price observations needed:

For regression analysis use a sample so large that there are at least some 15 to 20 price observations per characteristics variable in the regression equation.

The rule of thumb has some basis in statistical theory. A heuristic argument may be stated briefly. Following Atkinson & Riani (2000, Sect. 2.1.2) and using the notation there, one may express essentially the variances of the values of the hedonic function for observations number $i = 1,\dots, n$ as

$$(22) \quad \begin{aligned} &\mathrm{var}\,\hat{y}_i \;=\; \sigma^2 h_i \\ &\text{where}\;\; h_i \;=\; x_i^T (X^T X)^{-1} x_i \end{aligned}$$

Here σ^2 is the variance of the residual, and X is the $n{\times}p$-matrix and x_i are column p-vectors, made up of the observed values of the characteristics variables. (Sorry, just here h is used in quite another sense than hedonic function.)

Strictly the cited variance relation assumes certain ideal conditions, of independent identically distributed residuals etc. If those conditions are not quite met the equation may not hold strictly, as neglected covariance terms may then interfere. Furthermore variances are here to be understood in the sense of theory of model-based statistical analysis, which means that variability is due to the residual term only and conditional on the characteristics variables.

For the number of observations n and the number of characteristics variables p, the following fact holds:

$$(23) \quad \frac{1}{n}\sum_{i=1}^{n} h_i \;=\; p\,/\,n$$

As the numbers h_i express proportions of variances, corresponding proportions of standard deviations are given by square roots. It may then be concluded that a condition for the hedonic function not to be heavily disturbed by noise is that the square root of the number p/n is well below one, perhaps at most around 1/4 or so. This entails the above rule of thumb.

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