# Institut National de la Statistique et des Études Économiques (INSEE)

# *French National Institute of Statistics and Economic Studies*

# Dish-washers and PCs in the French CPI: hedonic modeling, from design to practice

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## Abstract

*French statisticians have developed an original method for handling consumer-durables replacements in the CPI. A centralized team of specialists manages the nationwide replacements, which are carried out on the basis of recommendations by price collectors. This arrangement brings gains in efficiency and–above all–in quality. In particular, it allows the use of hedonic methods. These are being applied to dish-washers and, on a trial basis, to personal computers. Another hedonic model of PC prices is already being used for the compilation of the producer price index (PPI).*

*The theoretical and practical performance of these models is uneven. They are very effective for dish-washers, but more problematic for PCs. There are three main reasons for this inconsistency: (1) the different levels of complexity of the products, (2) differences in the pace and scope of changes in product lines, and (3) the availability of relevant information. The latter appears to be a critical factor. How can one explain otherwise the fact that a comparable model yields wholly satisfactory results in the PPI?*

## Introduction

Contrary to what their name suggests, consumer durables are anything but... durable. More precisely, their post-purchase lifetime may be long but their shelf life in stores is very brief, ranging between one and twelve months. The term "consumer durables" actually covers a wide diversity of products. To put it briefly, consumer durables have become complex goods, often with a substantial high-tech content. By definition, high technology evolves–and at a quickening pace: witness, for example, the exponential improvement in microprocessor performance. The replacement rate is thus very high, since new products almost routinely incorporate the latest innovations. Product lines follow one another in frantic succession, driven by the competition strategies of leading brands and of merchandisers.

This situation weakens the constant-basket assumption underlying the CPI. The frequency of replacements–and of the changes in product characteristics with each replacement–is an argument in favor of using advanced methods to deal with the numerous quality adjustments involved. The approach that currently raises the fewest objections is the hedonic method. INSEE's Consumer Price Index Division is developing hedonic models. In the first section, we describe the range of methods used to deal with replacements for consumer durables and their frequency. In the second section, we show that the management of replacements offers a good opportunity for using hedonic methods despite the difficulty of putting these methods into practice.[1] In the third section, we use dish-washers as an example to illustrate the stages and effects of hedonic modeling. Last, the discussion on PCs reveals that gathering of reliable information is the hardest challenge to meet.

[1]See also Kinnunen (1998).

# I - Standard treatments of consumer-durables replacements

## 1.1. An important phenomenon

Consumer durables account for 2.4% of the French CPI weighting and 5.7% of varieties, or 6,405 price quotations a month out of a total 111,124 quotations for standard items in 1998.[2] For our purposes, "consumer durables" include electrical appliances, hi-fi and video, photographic equipment, and vehicles other than automobiles. Automobiles require specific processing methods and are dealt with differently (*Pour comprendre l'Indice des Prix* 1998).

*1.1.1. Replacement methods used for consumer durables[3]*

INSEE currently uses four methods to treat replacements of consumer durables:

*Method 1: "Direct Comparison" (Équivalent: EQ)*

The removed variety is replaced by a very similar product with identical technical characteristics. The change is calculated on an equivalent basis using:

EQ: New base price ( $P_B^N$ )= old base price ( $P_B^A$ )

*Method 2: "Dissimilar" (Dissemblable: DI)*

The removed variety is replaced by a slightly different product (for example, same type of oven but with a digital clock instead of an ordinary timer). The change in the variety's price index is regarded as null since the products, being of different quality, are deemed non-comparable. In consequence, the entire price change is attributed to the quality change.

DI: $P_B^N = \dfrac{P_m^N}{I_s(m-1)}$ where $I_s(m-1)$ is the index of the variety replaced in month m-1[4] and $P_B^N$ the observed price of the replacement variety in month m.

NB: This method relies on two assumptions: (1) there is no inflation[5] when the product is replaced, and (2) there is no price change between months m and m-1. The method effectively eliminates the problem of measuring the price movement at the time of replacement. It creates a downward bias when the indexes are positive. To comply with the regulations adopted for the European Harmonized Index of Consumer Prices (HICP) in 1998, INSEE has virtually phased out this method (table 2).

*Method 3: "Adjusted Dissimilar" (Dissemblable Corrigé: DC) and "National Dissimilar" (Dissemblable National: DN)*

The approach is identical to that of method 2 except that we collect at least four "real" quotations in m and m-1 for the same item in the same region (three[6] quotations in

[2]Fresh products and tariffs ( mainly centralized determined prices) are not included in standard items.
[3]For more details, see Bascher and Lacroix (1998).
[4]m is always considered the replacement month, m-1 being the last month in which a price was collected in "normal" conditions.
[5]Inflation is defined here in the broad sense, i.e., an upward or downward movement in prices.

small regions). The price movement of the replacement variety is deemed identical to that of the (item x region) aggregate between months m-1 and m[7].

DC: $P_B^N = \frac{P_m^N}{I_s(m-1)} * \frac{I_{va}(m-1)}{I_{va}(m)}$ where $I_{va}(m)$ is the index for the (item x region) in month m and $I_s(m-1)$ is the index of the replaced variety in month m-1.

However, there are not always enough varieties available for the estimation. In 1998, INSEE therefore set up a complementary procedure called the "national dissimilar." To estimate the "national dissimilar" price change between months m-1 and m, we take the change in the national item, under constraints that–by definition–are more easily complied with at an aggregate level. This procedure is used only in those residual cases for which a DC estimation was impossible.[8]

DN: $P_B^N = \frac{P_m^N}{I_s(m-1)} * \frac{I_v(m-1)}{I_v(m)}$ where $I_v(m)$ is the index of the national item in month m.

*Method 4: Econometric or hedonic method (EC)*

In cases where a hedonic estimation is possible and offers satisfactory results, we use it to recalculate a product's base price as follows:[9]

EC: $P_B^N = P_B^A + (f^0(x^N) - f^0(x^A))$ where $f^0(x^A)$ is the price that the regression estimated in period 0 gives for the formerly tracked product with the characteristics $x^A$[10].

*1.1.2. Quantifying consumer-durables replacements*

Table 1 lists the replacements of consumer durables for each month of 1998. The replacement rate is consistently above the average recorded for standard items. The annual average replacement rate for consumer durables is 9.4%, or twice the aggregate rate of 4.8% for all products.

*Table 1 - Monthly replacements of consumer durables (CDs), 1998*

| Month | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec | Ave. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of CD replacements | 829 | 701 | 556 | 537 | 610 | 544 | 590 | 462 | 644 | 701 | 556 | 498 | 602 |
| % of CD replacements | 12.9 | 10.9 | 8.7 | 8.4 | 9.5 | 8.5 | 9.2 | 7.2 | 10.1 | 10.9 | 8.7 | 7.8 | 9.4 |

[7] *these couples of quoted prices may be non replaced products between m-1 and m or replaced products using EQ* method.

[8] On average, a consumer-durable item comprises 120 quotations, and between 80 and 90 actual observations are available for a monthly DN estimate, whereas there are only four or five observations per region that can be used for the DC. Also, the sample size varies considerably from one item to another. Quotations are more abundant when the price-change dispersion is greater (Ardilly and Guglielmetti 1993). In particular, for "small items", there are often too few varieties to allow the use of the DC—hence the usefulness of the DN (§1.1.2).

[9] For a defense of this method, see Bascher and Lacroix (1998).

[10] Log-linear modeling is often preferred to direct linear modeling for a number of reasons, including price positivity, price independence from monetary or quantity unit, etc.

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % of replacements of all standard items | 4.2 | 5.7 | 6.5 | 5.0 | 4.5 | 3.9 | 3.1 | 4.5 | 7.4 | 5.2 | 4.1 | 3.7 | 4.8 |

The replacement rates are computed for all 6,405 varieties of consumer durables and 111,124 varieties of standard items.

The sample of a consumer-durable item is often entirely replaced during the year, and some products are even replaced several times.

*Table 2 - Breakdown of consumer-durables replacements by method used, 1998*

%

| Month | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec | Ave. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EQ | 3.7 | 3.5 | 4.5 | 2.0 | 3.3 | 2.4 | 3.4 | 2.8 | 3.1 | 1.0 | 3.8 | 3.8 | 3.1 |
| DI | 1.7 | 1.1 | 0.2 | 1.2 | 0.2 | 1.0 | 0.5 | 0.7 | 0.4 | 0.3 | 0.7 | 0.6 | 0.7 |
| DC | 67.8 | 84.3 | 83.1 | 80.2 | 87.5 | 82.3 | 89.0 | 83.5 | 79.3 | 89.3 | 85.2 | 85.5 | 83.1 |
| DN | 25.5 | 9.1 | 11.3 | 15.2 | 8.0 | 11.0 | 4.7 | 10.8 | 15.7 | 8.3 | 9.7 | 8.5 | 11.5 |
| EC | 1.3 | 2.0 | 0.9 | 1.4 | 1.0 | 3.3 | 2.4 | 2.2 | 1.5 | 1.1 | 0.6 | 1.6 | 1.6 |
| Total | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

The conversion to monthly price collections–completed in 1998–and the introduction of the DN procedure have enabled INSEE to virtually eliminate the most controversial method, DI. Today, it is used for less than one percent of replacements (table 2). The "adjusted dissimilar" method (DC) and its variant DN are by far the most common: they are used in 94.6% of total replacements. Interestingly, the DN share undergoes rather wide swings from one month to another. This is mainly due to the combination of the product replacement rates and the number of quotations for each of these products. In the two main post-vacation periods (the September and January *rentrées*), the high number of replacements explains the lack of estimation varieties for the DC process. The DN provides an effective and convenient alternative in both periods. Although superior to DI, the "adjusted dissimilar" method (DC) and its variant DN are still at a rudimentary stage of development.

## 1.2. Centralized management of consumer-durables replacements

INSEE uses a single operating procedure for replacements in all sectors other than consumer durables. The price collector is free to find a replacement product–at the same sales outlet–whose specifications most closely resemble those of the replaced product (or service). Collectors act alone and with full discretionary authority, using their best judgment.[11] For consumer durables, however, the central team in charge of consumer durables at the Institute's Head Office provides assistance and recommendations to collectors.

### *1.2.1. Why is a different method used?*

The choice of this method is dictated not by arbitrary theoretical assumptions but by the intrinsic nature of consumer durables. One of the main features of the consumer-durables market is its nationwide consistency. The products on the shelves are practically identical throughout France, as are the types of sales outlets.

[11]Replacements by collectors are, however, checked by the Price Department managers at the INSEE Regional Office for the area where the prices are collected.

For almost all other products, either the specific local features are too pronounced to allow anything other than a local treatment, or the products are easily described and require no other judgment that the collector's to ensure adequate statistical treatment.

With consumer durables, by contrast, national homogeneity offers opportunities for alternative treatments in the CPI.

### *1.2.2. A welcome expertise*

The twofold problem discussed in the subsection above is on its way to being solved.

The sales outlets for consumer durables in France consist of (1) specialized nationwide chain stores, (2) hypermarkets, which have an equally nationwide presence, and (3) independent stores, which constitute a tiny proportion of the total. Many of these merchandisers put out sales catalogs with detailed product descriptions. Some retailers even publish quality tests on each product they carry.

We also note that the consumer-durables market, despite its intense competition, is composed of a rather small number of brands. This is due to its high access cost for manufacturers. For example, the number of brands included in the price index for television sets is 30, for dish-washers 25, and for electric shavers barely ten or so. This does not mean that only 30 types of television sets are tracked, since each brand produces several different models, some of which can be tracked in different places. In fact, we collect almost 600 prices for TV sets, about 230 for dish-washers, and about 50 for shavers.

Because the consumer-durables market is national, its information sources can be usefully centralized. Most manufacturers and many retailers publish catalogs for intra-industry or promotional purposes. These documents provide wide-ranging information on products; the advertising material also gives prices. The second good reason for centralization is that consumer durables are often complex products, which individual price collectors cannot easily monitor in a comprehensive manner. That is why INSEE has decided to handle consumer-durables replacements through a cooperative effort involving price collectors and a specialized team at the Institute's Head Office. The team can supply collectors with concise and relevant technical documentation to guide them in their field-work. The arrangements for continuous information-gathering are an advantage and enhance the quality of the final result. The details of this centralized system are described below.

In the field, when a monitored product is discontinued, the collector is asked to select two potential replacements. The technical characteristics of both products (listed on the collection form) must resemble those of the replaced product as closely as possible. After the collector'sending of collection forms, the Regional Price Department managers fax the descriptions of both alternatives to the Head Office team, which examines the products along with the additional information at its disposal before deciding which product should henceforth be tracked in the price index.

What are the selection criteria? In fact, there is no hard and fast rule. Depending on the place and date, the Head Office may respond differently to identical proposals. This is because centralized management allows "strategic" sampling choices. The prime criterion is maximum resemblance to the replaced product. Another important criterion is the expected lifespan of the new product. In the age of color TV, what's the point of substituting one black-and-white set for another! Sample representativeness should not be sacrificed in the name of the "closest resemblance" mantra. With these aims in mind, the Head Office team determines its theoretical sample (distribution by type of sales outlet, by brand, etc.) subject to the constraints of price-collectors' proposals "from the field." In the other sectors of the CPI, *full theoretical control of the sample is not* feasible under present organizational arrangements, although "optional" annual updates do leave room for some adjustments.

The additional benefit that has emerged from centralized management is a fuller update of the data base of tracked products, complete with their technical characteristics, price, place of purchase, and so on.[12] This data base–which allows sample checking–is of special value to us because its file format is suitable for hedonic modeling.

# II - Hedonic modeling of consumer durables

## 2.1. Construction of the hedonic model

Our main prerequisite was to collect the largest possible set of reliable data in order to perform regressions with the maximum number of variables. Any data whose significance proved unacceptably low could always be discarded later on: that is standard practice in all econometric work. Initially, we would make no arbitrary assumption about the influence of any variable. This condition was dictated by the fact that some variables apparently without a marked influence on prices could be strongly correlated with other, unmeasurable variables, which they proxy.

To avoid adding to the modeling cost and to prevent selection bias, we decided to perform the regressions from the sample tracked by the CPI. The main challenge in modeling is to find the data that verify the initial hypotheses. The reliability and fullness of the information are especially critical. As new products appear in the tracked sample, our consumer-durables team builds a data base in conformity with those two criteria.

The first criterion is reliability. The information is not entered into the data base until it has been checked, and until the data gathered in the field have been matched against the data in the manufacturers' catalogs. The second criterion is fullness. The data are enhanced with the aid of the technical specifications in the catalogs: this is information that the price collector cannot find in the store, or at least not without asking for advice from a specialized sales person there–who will, in fact, look it up in the manufacturer's catalog.[13]

Sometimes, however, the lack of information may prevent the price quotation from being used for the estimation. The model's improvement may also be hindered by the fact that the information on an apparently decisive variable is supplied by some but not all manufacturers. Our choice–which is open to discussion–is to resort as seldom as possible to imputation in the case of non-response. We prefer deleting a datum to imputing it.

[12]This information is compiled, as far as possible, in the field; it is enhanced with information from catalogs (§2.1).

[13]In practice, the salesperson is often unable to supply the missing data on products in the store. The salesperson may be unavailable at the time of the survey, may be uncooperative, or, more simply, may not have the information available (or be incapable of locating it, which amounts to the same).

### 2.2. Implementation

For each product replacement, the centralized team uses the hedonic model to estimate the quality difference between the old and new products. It calculates the variety's new base price and forwards it to the Price Department of the Regional Office, along with its choice of replacement product from the two proposals. The Price Department incorporates this information into the regional data base from which the monthly basic aggregates are calculated and sent at month's end to INSEE's Head Office.

The effectiveness of the process specifically depends on our being able to use the hedonic model. We therefore need to know all the product's technical characteristics required for the use of the econometric equation. If the product is already included in the data base, the task is easy.[14] Otherwise, the central team searches the catalogs and calls the manufacturer's customer-service department to obtain the missing information. After gathering the information, the team enters the name and characteristics of the new model into the national data base.[15]

## III - Application of the model to dish-washers

The dish-washer is the first item for which INSEE has developed an econometric model to perform quality adjustment. In the consumer-durables sector, the hedonic method has been used for current CPI production since September 1997.

### 3.1. Model description

The model is estimated on a fairly large sample of 333 observations (appendix 1). Three broad categories of variables emerge: (1) technical characteristics of the appliance (temperatures, number of programs, noise level); (2) product brand; (3) sales outlets. Variable 1 is linked to those of the dish-washer's qualities that are directly measurable because they can be observed. Paying more for a more sophisticated product is not only logical but also theoretically justified in microeconomic terms. Variable 2 implies two different price determinants: (1) a "marketing" effect that is not always closely correlated with the machine's intrinsic quality but is linked to the company's margin; (2) a "reputation" effect that represents a quality recognized by the consumer but not measured in statistical terms, such as durability, mean time between failures, defectiveness, etc. Variable 3 separates the actual cost of the appliance—the "factory-gate" price—from merchandisers' margins and the service that merchandisers are supposed to offer. We now need to establish how these factors interact to form the price.

[14]The consumer-durables data base is ranked first by item, second by brand, and third by model (table listing technical characteristics).

[15]If the model is not recorded in the national data base, the regional Price Department cannot capture the new base price arising from the product change. This procedure is used for all consumer-durables replacements, whatever the replacement method chosen.

The price is decomposed into quantitative variables and dummies: P=$\sum_i a_i X_i$ where $X_i$ is a dummy qualitative variable or a quantitative variable and $a_i$ the coefficients estimated with SAS® (least squares method). We tested a classic log-linear estimation. In the appendix, we describe only the model in actual use for CPI production.

The results obtained are logical and of good quality ($R^2$=0.87 and very significant explanatory variables). Sales outlets are distributed according to a familiar price scale: hypermarkets offer the best buys, small conventional stores are the most expensive. Similarly, the Miele brand (highly reputed), which is known to be much more expensive, stands out in our estimation after inspection of the residuals. Two other brands are also distinguished. They may not be singled out in a later estimation, or they may change class. Likewise, the model will not necessarily remain linear: the variables may differ, and the noise ranges may vary (§3.3.4).

### 3.2. Daily use

The central team is also in charge of the model's day-to-day management. There are several reasons for this. First, the unit that designed the model is in the best position to use it effectively. The team can make alterations at any time if there is evidence that the regression's validity is disproved (§3.3.4). Second, as the central team has the entire data set at its disposal, a near-automatic procedure supplies the estimated quality effect at the same time as the replacement product is entered into the data base. Third, specialization allows gains in efficiency and reliability.

However, the operational cost of a quality-effect estimation is high. The initial phase of coefficient estimation is very expensive, and the practical use of the model to treat replacements is inevitably more complex than the use of standard methods. On this latter point, the crucial problem is the missing information. Gathering information from outside sources–particularly manufacturers' and distributors' customer- and product-support departments–is time-consuming.

### 3.3. Effects of the econometric method

#### *3.3.1. Replacements and their treatment*

*Table 3 - Monthly replacements of dish-washers by method, 1998*

| Method | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec | Ave. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EC | 14 | 24 | 6 | 8 | 8 | 21 | 16 | 13 | 10 | 8 | 4 | 10 | 11.8 |
| DC, DN[16] | 14 | 8 | 3 | 7 | 9 | 14 | 7 | 5 | 4 | 6 | 12 | 2 | 7.6 |
| Total | 28 | 32 | 9 | 15 | 17 | 35 | 23 | 18 | 14 | 14 | 16 | 12 | 19.4 |

The pace of product changes is fairly erratic from one month to another (table 3). Most of the occasional monthly peaks are due to the launch of new product lines by leading brands or the main retailers. The total number of replacements in 1998 was 223, which

[16]There were, in fact, only six DNs in the entire year.

gives an effective replacement rate of 100% for the sample–slightly below the 112.8% average replacement for all consumer durables. In fact, 59.2% of the sample was replaced, but the price collections linked to the replacements were changed an average 1.7 times.

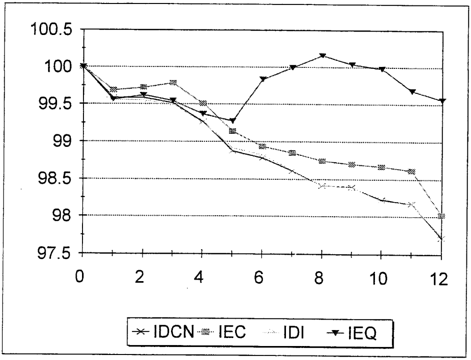
At first glance, one may be surprised by the persistently large share of the DC-DN method: it is used for almost 40% of product replacements, which means that the econometric method is used in just over 60% of them. This breakdown reflects the difficulty of obtaining all the required information in real time. Often the replacement is an entirely new product, and the central team does not have enough time to collect the full information needed for the explicit estimation of the quality change. In other words, the choice of method is influenced by the speed of information access and by the workload.

*3.3.2. Effects on the indexes*

What is the impact of these replacements and their quality changes on the choice of index-computation method? For a detailed answer, we simulated the calculation of the dish-washer index if other replacement methods had been used in 1998 (§1.1.1).

IEC = index as calculated in the CPI, with the econometric (i.e., hedonic) method (EC) and "adjusted dissimilar" method (DC and DN).
IEQ = index if all replacements had been performed with the "direct comparison" method (EQ)
IDI = index if all replacements had been performed with the "pure dissimilar" method (DI)
IDCN = index if all replacements had been performed with the "adjusted dissimilar" method (DC and DN).

*Figure 1 - Dish-washer indexes in 1998 using alternative replacement methods*[17]



The first observation is that the choice of method is not neutral! The difference between the "direct comparison" (IEQ) and "dissimilar" (IDI, IDCN) methods is almost 2%. The face value of the products is practically stable in average terms, even if prices move up or down (cf. IEQ). The prices of "long-life" products trend down (cf. IDCN), but new products seem more expensive than those they replace (cf. IEQ versus IDCN). However, the price rises entailed by product changes are due partly to a price increase by the manufacturer and/or retailer and partly to a quality effect. This is shown by the fact that the IEC curve lies between IDI and IEQ from May onward. Why are the IDI and IDCN curves so close to each other? The reason is the weak concomitance of price declines and replacements in a single region: either some models are replaced while other prices remain stable, or prices fall and no replacements occur.

### *3.3.3. Quantifying the quality changes*

Drawing on all the information available *ex post*, we set out to examine which variables were actually used in the product changes. For this, we analyzed the dish-washer replacements handled with the hedonic method in 1998 (table 4). At each replacement, an average 3.4 characteristics of the product change, out of a possible 6;[18] the median is 4, which is a high number: replacements entail many changes in the products' technical characteristics[19].

*Table 4 - Changes in product characteristics entailed by replacement, 1998*

| Number of characteristics changed | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| % of replacements involved | 94.5 | 90.7 | 77.7 | 51.7 | 19.9 | 3.8 |

*Table 5 - Average frequency of quality increases and decreases per variable, for replacements carried out in 1998*

%

| | Number of programs | Delayed start | Noise | Brand | Water consumption | Power consumption |
|---|---|---|---|---|---|---|
| Increase | 37.9 | 18.5 | 34.1 | 11.8 | 43.1 | 36.0 |
| Decrease | 30.3 | 13.2 | 35.1 | 19.9 | 24.6 | 37.9 |
| Total changes | 68.2 | 31.7 | 69.2 | 31.7 | 67.7 | 73.9 |

All the variables exhibit quality changes in both directions (table 5). The net balance between quality increases and quality decreases is small by comparison with the flows in each direction. This result is somewhat surprising given the continuous technological improvements in this type of product. The likely explanation is the marketing strategy of manufacturers and merchandisers, who try to keep their prices within a specified range and to maintain a diversified product offering for consumers. Not all products embody the latest technology, since they would otherwise become too expensive. Some products are more efficient than the ones they replace for certain features but less for others.

Our study of the individual variables shows that the frequency of quality changes differs for each technical characteristic of the products. The figure is one-third for "brand" and "delayed start" versus more than two-thirds for the other characteristics. Looking at the breakdown between quality increases and quality decreases, we find an increase for "water consumption" (environmental concerns and the underlying water bill have made this a strong selling point), for "delayed start" (regarded as a modern convenience),

[18]In principle, the sales outlet cannot be changed for a replacement, unless the store has gone out of business. In that case, however, the new sales outlet is chosen in the same channel as the replaced product: this procedure ensures that the quality estimation in the regression for the sales oulet chosen will not be affected.

[19]This also shows that the hedonic method is used "to the full" for assessing quality changes induced by replacements.

and the number of programs (a gimmick that has consistently boosted sales[20]). By contrast, the apparent quality decrease in "brands" is due to the shift by consumers toward purchases of products that are "simply" cheaper, all other things being equal. For the other two variables–"noise" and "power consumption"–the average quality has not significantly changed, despite their being the most frequently modified factors.

Let us now analyze the changes in the base price, which reflect the "price" impact of quality changes. We find that product changes modified 93.7% of base prices, causing 64.1% of them to rise (hence a decline in the price index), and 29.6% of them to fall. The average quality change between two products translates into an estimated price increase of FRF76.50, or 1.8% of the average price of the dish-washers in our sample. This figure, however, conceals a wide diversity: the average price rise comes to FRF291.90, while the average price fall is FRF373.70.

*3.3.4. Is a new estimation needed?*

As we accumulate practical experience with the regression, we realize the model's gaps and limitations. The use of any model relies on implicit assumptions; when these no longer hold, they can lead to erroneous estimates. When a positive technological shock occurs (or, indeed, a negative one–which in practice never happens), the valuation of the technical characteristics changes. Using the old estimation and–to make matters worse–omitting the new quality will lead to errors. Accordingly, the CPI Division has decided to re-estimate its models once a year. As appendixes 1 and 2 clearly show, the changes can be very significant, such as the introduction of new variables for which data have become available (water and power consumption, delayed start). By contrast, the changes in product characteristics between 1998 and 1999 have been minor, moreover there has been correspondingly little change in values.

Not only do we have to see whether some coefficients change, but we also have to note whether they are the coefficients involved in product changes.

As our experience builds up, the usefulness of an annual estimation of the parameters becomes obvious. Our data base develops with time, because of the growing concern for explicit estimation. This offers greater possibilities for improving the regressions.

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[20]A consumer-group study proves that housewives always use the same two programs.

# IV - A hedonic model with inconsistent results: personal computers in the CPI and PPI

## 4.1. A more delicate modeling exercise

### *4.1.1. Description of CPI model*

We increased the size of the "personal computers" item sample in 1998 for two purposes: (1) to improve the precision of the item index; (2) to obtain enough data for a "proper" regression. We expanded the number of varieties observed monthly from 74 to 124. The PCs used for the estimation are those included in the May 1998 sample. In the same spirit, we substantially enlarged the price-collection form so as to increase the potential supply of data for analysis. For example, the number of requested characteristics was raised from five to eleven. We added the CD-ROM drive speed, the sound-card bit rate and type, the loudspeaker power, the number of installed software programs, and the video memory size. All these features have become important with the development of multimedia capabilities.

After checking, making small additions, and re-coding the variables, we were left with only six types of explanatory variables in the estimation data base. The eliminations were due to the large number of non-responses. The seven remaining variables are: processor type, clock speed, hard-disk capacity, RAM size, screen size, brand, and sales outlet.[21] The continuous variables were tested as such, or discretized. We then tested linear, log-linear, and log-log models. We quickly settled on a log-linear model (see appendix 3 for the model):

$\log P = \sum_i a_i X_i + u$ where $X_i$ is a dummy or quantitative variable, and u the estimation residual.

Some variables had to be discarded. For example, RAM correlated with clock speed lost its significance and actually impeded the "proper" overall estimation. Likewise, the sales-outlet types are not sufficiently differentiated and therefore do not show up in the estimate.

This fairly simple model seems consistent with PC pricing logic: the more powerful and efficient the computer, the more expensive it is. The quality of the model is rather poor, however ($R^2$=0.43), and only four explanatory variables are included–as against the more than ten theoretically available.

### *4.1.2. Critical analysis of the model's weakness*

For many PCs in this base, lack of data has led us to remove the computer from the estimation or introduce noise into the estimation. This information gap is due to several factors:

- The main factor is the product's complexity. PCs have become a cocktail of variable sub-elements whose make-up can be infinitely varied. An identical product reference can conceal machines with different screen sizes, CD-ROM drives of different speeds, etc. If the price collector does not record these details accurately, the use of

[21]It will be noted that we were unable to use any of the six new variables introduced in 1998.

econometrics for the explicit estimation of the quality effect will be impaired. For this reason, we eliminated some twenty observations due to lack of information despite the collation of multiple sources. In the end, we used 105 observations for the estimation instead of the 124 potentially available. However, as with dish-washers, improvements are likely in the coming years as index-producers become more aware of the value of explicit quality-effect estimation.

- The second disturbance factor is that all PCs sold to the general public are bundled with software. The number of software programs included, however, is subject to extreme variation. The price collected thus corresponds to a bundle of variable content. Apart from the price of the "bare" hardware, the price quotation includes the price of software programs that are never identical (excluding Windows®, although the operating system is available in several different versions too).

- The third factor is the frequency and scope of replacements, as well as the product's immense diversity, discussed above. These reasons prevent the publication of catalogs suitable for a centralized reconstruction of the missing information. This represents an obstacle to centralized replacement management. The omission of vital variables makes it hard to improve the model's efficiency.

### 4.2. Effects of the econometric method

The hedonic modeling of the PPI differs from that of the CPI. It is based on the "dummy-variables" method. The model relies on a data base that comprises the products present in the current quarterly period and the products present in the previous quarter (regardless of whether they are present in the current period as well). The regression is estimated on this two-period base.

*4.2.1. Description of PPI model*

The model specification is:

$\log P = \sum_i a_i X_i + k_1 C_1 + k_2 C_2 + u$ where $X_i$ is a dummy for technical characteristics, u the estimation residual, $C_1$ the dummy for the products present in both the current and previous period,[22] $C_2$ another dummy for the products present in only one of the two periods.[23]

$\exp(k_1)$ is the estimated average variation between two periods for the products present in both periods. Similarly, $\exp(k_2)$ is the estimated variation of new-product prices as if the products were already present in the previous period.

The data base used for the estimation is compiled at INSEE's Head Office. One of the key differences with the CPI is that the computers sold are described with precision by highly qualified price collectors. The machines' characteristics are generally found on the manufacturers' Web sites; the manufacturers supply INSEE with a code for accessing the information. Previously, the main information sources were manufacturers' trade catalogs. The number of quotations varies with each quarter, i.e., with actual sales, but is approximately 140.

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[22] $C_1$=1 in T2 if the product is present in T1 and T2, 0 if not.

[23] $C_2$=1 in T2 (T1) if the product is present in T2 (T1) but not in T1 (T2), 0 if not.

After compiling the base, INSEE estimates the regression from the current-quarter and previous-quarter PCs. The sample used for the PPI is not fixed, but varies according to sales. The overall quality change between the two quarters is estimated using the above procedure. In the CPI, the quality effect is estimated for each model, then aggregated.

*4.2.2. Reasons for the differences in CPI and PPI performance*

The PPI model explains 91-99% of computer price changes (Moreau 1996, Bourot 1997).[24] What variables were included in 1997 in the PPI's "office computers" index? The 1996 model specified several additional variables: cache memory, bus type, network board, software suite, etc. For the CPI, we can draw one immediate conclusion: this information is simply not available. The PPI "price-collection engineers" do not have the same qualifications as the generalist consumer-price collectors, who cannot be asked to turn into specialists of all the items they track. Sometimes, the information is missing even at the sales outlet and cannot be reconstructed. Finding information on the Web is an interesting possibility, but it should be regarded merely as a way to check and fill in selected information items. The systematic use of Web searches for building the data base would be too costly. Adding up the explanation share of the PPI's additional variables, we obtain slightly less than half the explanation provided by the CPI hedonic model (Bourot, 1997).

Apart from the impossibility of gathering all the relevant information on product characteristics, the lesser performance of the CPI model is very likely due to the difference in the definition of "PC" in the two indexes. Experience shows that prices collected for the CPI sample are those of the hardware plus the software supplied, rather than prices of "bare" PCs as in the producer price index.

Returning to the estimation issue, software clearly introduces a very high noise level. Software would not pose a problem if it was accurately identified. Unfortunately, the list and characteristics of software bundled with PCs are subject to frequent change. The products are hard to describe, and price collectors are often unaware of the changes in the software programs sold with PCs, especially when there is no change in the hardware. Yet collectors are asked to record the number of software programs sold with the PC. This variable is admittedly reductionist. Despite its apparent simplicity, however, it is poorly documented and thus cannot be used in the model. One can understand why the CPI model is less explanatory than the PPI model. What is unsatisfactory, by contrast, is the fact that the CPI model obtained explains such a relatively small share of the price. Granted, there is always a case to be made that explaining 40% is better than applying an all-or-nothing policy. But once the arguments for and against have been lined up, we are left with another question: are the explanatory variables chosen the ones that change when products are replaced? The answer–for the moment–seems yes.

One final difficulty concerns model maintenance. The turnover in product range, and consequently in "standards," is very high and varies with each computer component. In other words, clock-speed standards change twice or three times a year, but screen-size standards change sporadically, at irregular intervals. That is why a recalculation of the coefficients only once a year would introduce an error. The standard framework implicitly assumes that the prices of characteristics follow the same movements as the product price: this is manifestly untrue. Indeed, the PPI Division addresses this problem by re-estimating its model every quarter (i.e., the same frequency as the index publication). The CPI, which is a monthly index, is subject to tighter management constraints–with probably fewer resources in terms of

[24]In an older study, Dalen found 0.76 in 1989 for Sweden.

information-gathering, staff, etc. Model management is therefore a logical issue, on which further work is needed.

*4.2.3. Effects of the CPI and PPI methods*

Having analyzed the source of the differences between the models, let us see whether the econometric method yields different results from simpler methods here as well.

For the CPI, we have assessed the method's impact over a one-month period. In September 1998, 56 product changes took place, a number equal to almost half the sample of 124 quotations. In all, there were 397 replacements during the year, which gives the apparently very high replacement rate of 320%. In the PC market, September is–with December–the month in which new products traditionally flood the market as schools re-open. We estimated the values we would have obtained for the September index if we had used each of the four methods described in section I to treat all the replacements.

The data in table 6 illustrate the key role of the method for treating product replacements. What a difference between the DI method, which keeps the index practically stable (-0.5%) and the econometric method, which shows a -8.2% fall!

*Table 6 - Breakdown of PC price-index movement in September 1998 by method used to treat quality effects and by product duration*

%

| | EQ | EC | DI | DC-DN | CPI[25] |
|---|---|---|---|---|---|
| Non-replaced products (55%) | -0.9 | -0.9 | -0.9 | -0.9 | -0.9 |
| Replaced products (45%) | -8.0 | -17.1 | 0 | -3.8 | -2.9 |
| Total (100%) | -4.1 | -8.2 | -0.5 | -2.2 | -1.8 |

Interpretation: The 4.1% decline in the September index obtained with the econometric method (EC) is due to a 0.9% fall in prices of products not replaced in September (55% of the sample) and a 17.1% fall in replaced products (45% of the sample). The figures for the shares in the total decline are rough, because they do not take into account the different weights actually assigned to the products monitored in the sample.

All the prices appear to be heading down. The decrease is moderate for products not replaced during the month (-0.9%); among these products, it is steepest for those that served as references to estimate price changes for replaced products in the DC-DN method (-3.8%). The apparent fall in prices is even sharper for replaced products (-8.0%), but this is less than their "actual" fall (-17.1%), estimated with the hedonic model. In other words, the actual fall in prices is greater than the increase (steep as it is) in the products' quality. Effective prices fall when products are replaced, which explains why the EQ method yields the results that most closely resemble those of the EC method.

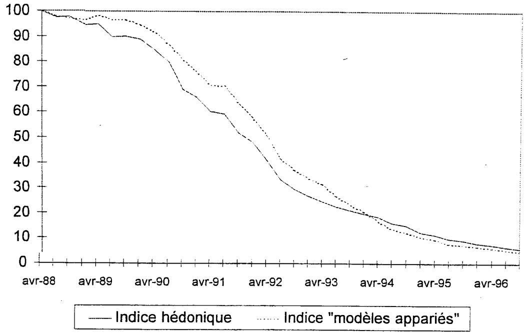
We also note the robustness of the DC-DN method, which takes into account the month-to-month price change, by comparison with the DI method, which neglects the change.

The results also disprove the assumption that "price changes are entirely due to quality changes" and its variant "all changes are pure-price changes." Reality is not even somewhere in between!

The PPI Division performed a similar exercise, comparing the econometric and DC methods (on paired models), but over the medium term (figure 2).

[25]Method used in CPI.

*Figure 2 - PC index: influence of quality effect*




Interpretation: Avr = April
Indice hedonique = hedonic index ; Indice "modèles appariés" = "paired model" index

Apart from their steep downward slope, we note that both indices start and end the period at the same level. Their profiles, however, diverge. The movements are parallel or nearly so, for long spells–which is reassuring. What is more disturbing is the fact that the hedonic and "paired models" indexes do not consistently occupy the same position "above" or "below" each another.

What are we to conclude from these two tests? The CPI test does not support the use of minimal methods–although further comparisons are needed between methods over a longer period before drawing a firmer conclusion. The congruence of medium-term movements in the PPI test shows that DC methods should perhaps not be rejected in certain contexts, but it may also be a pure "coincidence" due to the choice of comparison period. It is thus preferable to use explicit quality-adjustment methods.

## Conclusion

In this paper, we described three hedonic models for consumer durables: dish-washers and personal computers in the CPI, and personal computers in the PPI. The quality obtained was very good in the first and third model, only fair in the second model. However, despite the fact that the personal-computer model in the CPI still seems too simplistic, its use entails greater changes in the index than the dish-washer model. In any event, the hedonic method produces fairly different results from the systematic methods (EQ, DI, or DC). Its resemblance to one of the latter depends not only on the context–that is, the direction and size of the quality and price effects due to product replacements–but also on the model's explanatory power: a simple model such as the CPI personal-computer model may understate the actual quality change. As for the hedonic model's resemblance with the "adjusted dissimilar" (DC) method, it also depends on the link between the movement in prices of unchanged products and the change in the pure prices of products undergoing replacement.

The speed of technological progress and the frequency of product replacements make the hedonic method particularly suited to consumer durables. In the French CPI, only the dish-washer model is currently used at the production stage. The PC index will be improved in 1999 before being applied to the computation of the published index. Two other models are under development, one for television sets, the other for washing machines. The use of a poor hedonic model seems, in any case, preferable to the use of a systematic method. All the same, the proper treatment of product replacements in the CPI calls for effective hedonic modeling.

There are several requirements for the design of good hedonic models and their use in current index production:

- intellectual competencies combined with sufficient time to develop the model, re-estimate it, and carry out current treatment of quality adjustments when products are replaced;
- access to detailed, reliable information on product characteristics;
- a suitable organization of the infrastructure for collecting, checking, and processing information.

Satisfying these conditions calls for heavy investments over a long period.

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# Appendix 1

## Hedonic model for dish-washers, 1998

The dependent variable is the price level. The model adopted is linear. It is based on 333 observations from December 1997. After validation, the model contains eleven variables and the intercept representing the reference situation: three quantitative variables (water consumption, power consumption, and number of programs) and eight dichotomous variables divided into four groups: sales outlet, noise level, delayed start, and brand reputation.

The model's overall indicators are:

- $R^2$=0.87
- adjusted =0.86
- prob>F=0.0001

| VARIABLE TYPE | DESCRIPTION | NUMBER OF OBSERVATIONS (%) | COEFFICIENT | STUDENT'S T |
|---|---|---|---|---|
| . | Number of programs | 100 | 120 | 8.397 |
| Sales outlet | *Hypermarkets and specialized stores* | *72.5* | *reference* | . |
| | Department store | 4.2 | 250 | 3.012 |
| | Conventional stores | 23.3 | 251 | 6.359 |
| . | Water consumption | 100 | -54 | -4.64 |
| . | Power consumption | 100 | -606 | -4.416 |
| Delayed start | *Without* | *81.7* | *reference* | . |
| | With | 18.3 | 248 | 5.296 |
| Noise level | Very noisy | 36.7 | -284 | -5.427. |
| | *Average noise* | *54.5* | *reference* | . |
| | Low noise | 8.9 | 735 | 11.413 |
| Brand reputation | *General class* | *81.1* | *reference* | . |
| | Fair | 6.4 | 350 | 5.051 |
| | Good | 3.6 | 475 | 5.188 |
| . | Very good | 8.9 | 1764 | 21.653 |
| . | Model intercept | . | 5195 | 24.607 |

# Appendix 2

## Hedonic model for dish-washers, 1997

The dependent variable is the price level. The model adopted is linear. It is based on 332 observations from December 1996. After validation, the model contains ten variables and the constant representing the reference situation: two quantitative variables (number of temperatures and number of programs) and eight dichotomous variables divided into three groups: sales outlet, noise level, and brand reputation.

The model's overall indicators are:

- $R^2$=0.87
- adjusted $R^2$=0.86
- prob>F=0.0001

| VARIABLE TYPE | DESCRIPTION | NUMBER OF OBSERVATIONS (%) | COEFFICIENT | STUDENT'S T |
|---|---|---|---|---|
| . | Number of programs | 100 | 93 | 5.325 |
| Sales outlet | *Hypermarket* | *17.4* | *reference* | . |
| | Department store | 4.6 | 302 | 2.909 |
| | Small store | 22.3 | 300 | 4.674 |
| | Specialized large retailer | 53.7 | 175 | 3.298 |
| . | Number of temperatures | 100 | 286 | 7.324 |
| Noise level | *Very noisy* | *3.8* | *reference* | . |
| | Average noise | 58.7 | 567 | 3.957 |
| | Low noise | 38.5 | 1117 | 7.282 |
| Brand reputation | *General class* | *81.7* | *reference* | . |
| | Fair | 9 | 345 | 4.333 |
| | Good | 2.2 | 596 | 4.206 |
| | Very good | 7.1 | 2643 | 33.303 |
| . | Model constant | . | 1986 | 12.743 |

# Appendix 2a

## Hedonic model for dish-washers, 1999

The dependent variable is the price level. The model adopted is linear and resembles the 1998 model. It is estimated from 360 observations.

The model's overall indicators are:

- $R^2$=0.86
- adjusted =0.85
- prob>F=0.0001

| VARIABLE TYPE | DESCRIPTION | NUMBER OF OBSERVATIONS (%) | COEFFICIENT | STUDENT'S T |
|---|---|---|---|---|
| . | Number of programs | 100 | 124 | 8.385 |
| Sales outlet | *Hypermarkets and specialized stores* | *72.6* | *reference* | . |
| | Department store | 4.1 | 244 | 2.847 |
| | Conventional stores | 23.3 | 257 | 6.273 |
| . | Water consumption | 100 | -66 | . |
| . | Power consumption | 100 | -448 | . |
| Delayed start | *Without* | *81.9* | *reference* | . |
| | With | 18.1 | 123 | 2.438 |
| Noise level | Very noisy | 16.1 | -259 | -4.733 |
| | *Average noise* | *71.2* | *reference* | . |
| | Low noise | 12.7 | 598 | 9.963 |
| Brand reputation | *General class* | *81.1* | *reference* | . |
| | Fair | 6.3 | 338 | 4.714 |
| | Good | 3.6 | 523 | 5.515 |
| . | Very good | 8.9 | 1878 | 22.586 |
| . | Model intercept | . | 5153 | . |

# Appendix 3

## Hedonic model for PCs, 1998

The dependent variable is the price log. The model adopted is log-linear. It is based on 105 observations from May 1998. After validation, the model contains five variables and the intercept representing the reference situation: one quantitative variable (clock-speed log) and four dichotomous variables divided into three groups: hard-disk capacity, screen size, and brand reputation.

The model's overall indicators are:

- $R^2$=0.43
- adjusted =0.40
- prob>F=0.0001

| VARIABLE TYPE | DESCRIPTION | NUMBER OF OBSERVATIONS (%) | COEFFICIENT | STUDENT'S T |
|---|---|---|---|---|
| | Clock-speed log | 100 | 0.6565 | 4.510 |
| Hard disk | *> 2.1 Mb* | *28.6* | *reference* | . |
| | ≤ 2.1 Mb | 71.4 | -0.1281 | -3.489 |
| Screen size | 14" | 33.3 | -0.0641 | -1.995 |
| | *other* | *66.7* | *reference* | . |
| Brand reputation | *General class* | *29.5* | *reference* | . |
| | Bell | 41.9 | 0.1499 | 4.058 |
| | Compaq | 28.6 | 0.1380 | 3.493 |
| . | Model intercept | . | 5.6269 | 7.079 |

# Appendix 3a

## Hedonic model for PCs in PPI, 1996

Characteristics specified in Q4 1996 model for office computers in PPI
(source: Bourot 1997)

The regression was estimated on 424 observations. The explained variable is the price log.

The model's overall indicators are:

- $R^2$=0.97
- adjusted =0.96
- prob>F=0.0001

| Characteristics | Coefficient[26] |
|---|---|
| Clock speed | 0.0037 |
| Video memory | 0.043 |
| IDE controller | -0.18 |
| Ultra SCSI controller | 0.20 |
| Hard-disk capacity | 0.000072 |
| Network board | 0.09 |
| Tower case | 0.07 |
| Cache memory | 0.00025 |
| CD-ROM-drive speed log | 0.03 |
| Initial memory log | 0.067 |
| 17-inch screen | 0.12 |
| Software suite | 0.076 |
| EISA bus | 0.11 |
| Video card | 0.026 |
| Modem | 0.018 |

[26]All the coefficients are significant at the 5% limit.