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Review of Hedonic Quality Adjustment in UK Consumer Price Statistics and Internationally

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Summary

Hedonic quality adjustment was first introduced in the Consumer Prices Index (CPI) in 2003 for PCs. Since then the use of hedonics has expanded in UK consumer price statistics to include a further five technology products; digital cameras, laptops, pay-as-you-go (PAYG) mobile phone handsets and PAYG smartphone handsets (hereon referred to as mobile phones and smartphones), and tablet PCs. This article reviews the use of hedonic quality adjustment in consumer price indices in the UK and internationally. It also details the reasons for changing the method of quality adjustment for mobile phones and digital cameras, from hedonic adjustment to a standard technique of imputation used elsewhere in consumer price inflation statistics, from March 2014 onwards.

Introduction

Consumer price inflation is the speed at which the prices of goods and services bought by households rise or fall over time. It is measured with reference to a ‘fixed basket’ (think of a very large shopping basket containing all the goods and services bought by households). In practice its measurement is complicated by many factors including the appearance and disappearance of new and old products, as well as changes to existing products. A change to an existing product could include the weight of a chocolate bar reducing from 58g to 51g, a new car which now includes air conditioning or the number of megapixels in a digital camera increasing from 16 million to 18 million. These changes are often referred to as quality changes and their identification and valuation is one of the most challenging issues faced by compliers of price statistics. This needs to be done so that quality changes can be excluded from measures of inflation, leaving the underlying price change only. The process of excluding quality change from a price index is called quality adjustment. This challenge is most pronounced when attempting to quality adjust technology products, particularly computing equipment, as the availability of specific items is subject to frequent change, combined with large and rapid quality improvements.

There are a number of quality adjustment methods and these are described in more detail in Annex A. This paper is mainly concerned with hedonic quality adjustment, which uses regression techniques to relate the price of an item to its measurable characteristics. For computers, the measurable characteristics may include the speed of the processor, the size of the hard disk or the amount of memory. Hedonic regression is often considered the preferred method for quality

adjusting price indices, especially for Information and Technology Communication (ICT) products, although this view is not without its critics. For more information see Triplett, J (2004) *'Handbook on Hedonic Indexes and Quality Adjustments in Price Indexes: Special Application to Information Technology Products'.*

Use of Hedonic Quality Adjustment Internationally

The use of hedonic methods dates back to the first half of the last century, when it was applied in the USA to calculate rental values, taking into account the number of rooms and other amenities. Since then the method has been developed to calculate the cost associated with quality change for use when attempting to measure the underlying price change of goods and services. In the context of estimating a cost of living index, a report by the Boskin Commission (1996) found that traditional matched model indices overstate inflation due to bias being introduced for products that experience rapid technology and quality changes, have short product lifecycles and a quick turnover of stock at retail. The Boskin Commission argued that matched model indices led to an overestimation of inflation for ICT products of 0.6 per cent per annum within the CPI of the US. Comparable results were published by Crawford (1998) for Canada and Cunningham (1996) for the UK. A Eurostat task force also wrote a report in 1999 that highlighted large differences in ICT deflators across European countries and it concluded that this was due to differences in the methods used to make quality adjustments. The findings of these studies along with many other papers on the subject led to a move internationally towards the use of hedonics to quality adjust ICT products.

In order to assess the use of hedonics quality adjustment internationally, the Office for National Statistics (ONS) contacted ten National Statistics Institutes (NSIs) in mid 2013. They were asked a wide range of questions on the use of hedonic quality adjustment in their CPIs including when hedonics was first introduced, what items are covered and whether they have any plans to expand or reduced this list. They were asked for a detailed explanation of the process they follow including the collection of data on price and characteristics, production of a hedonic model and the frequency of updating the model. If hedonics was not used then they were asked whether or not they had considered the method and if so what their findings were. A high level summary of the results is provided in Table 1 below.

ICT products such as PCs, laptops and tablet PCs are the items most commonly quality adjusted using hedonics. The relative importance of these items in terms of consumer expenditure, and hence CPI weight, combined with the issues that ICT products present in terms of product availability and quality change over time, were the main factors presented by NSIs for using hedonics. However, it is important to note that the use of hedonics is still relatively limited, even across ICT products. Of the NSIs contacted, many cited the demand on resources versus low CPI weights as justification for not using hedonics for a wider range of technology products. Of the NSIs that do not use hedonics at all, this was due to either a lack of resources to implement the method, or that feasibility studies had indicated the impact did not justify the cost.

All of the NSIs contacted highlighted the collection and management of data as the main demand on resources. A number of NSIs have attempted to reduce the burden on resource by outsourcing either some or all of the data collection work needed to produce each model. Experiences of using

this approach vary, although data quality was an issue mentioned by several NSIs. The fact that data still needs to be checked also offsets some of the potential savings in outsourcing this element of the work.

Table 1: Use of hedonic quality adjustment internationally

COUNTRY	HEDONICS IN NATIONAL CPI	CPI HEDONIC ITEMS (Date Introduced)	SOURCE OF PRICE QUOTE & ATTRIBUTE DATA
Australia	✓	PCs (2005)	Currently collected internally, although is looking for an external provider due to costs & burden
Canada	✓	PCs, Laptops, Printers, Monitors (all 1996) & Internet Services (2008)	Price quotes collected by external provider / attributes collected Internally
New Zealand	✓	Used Cars (2001)	Quarterly survey managed internally
USA	✓	Clothing, Footwear, Refrigerators, Washing Machines, Clothes Dryers, Ranges & Cooktops, Microwave Ovens, TVs, DVD Players	All collected by external provider
Denmark	✗	-	-
Finland	✗	-	-
Germany	✓	Used Cars (2003), PCs (2003), Laptops (2004), PC Tablets (2013)	Price quotes collected by external provider / attributes collected Internally
Netherlands	✗	-	-
Sweden	✓	20 Clothing & 12 Footwear items (>5 yrs ago)	All collected internally
UK	✓	PCs (2003), Laptops (2005), Tablet PCs (2013), Digital Cameras (2004), Smartphones (2011) & Mobile Phones (2007)	All collected internally
Switzerland	✓	PCs & Laptops (2012)	All collected by external provider

Use of Hedonic Quality Adjustment in the UK

Hedonic regression was used for the first time in 2003 in the UK CPI to quality adjust PCs. At the time a decision was made to be more reserved about introducing the change to the Retail Prices Index (RPI) PCs index so it continued to use 50 per cent option costing for another year. Ball, A (2003) *'The Introduction of Hedonic Regression Techniques for the quality adjustment of computing equipment in the Producer Prices Index (PPI) and Harmonised Index of Consumer Prices (HICP)'* provides more details.

Digital cameras were introduced to the basket in February 2004. Due to the high degree of quality change of this product and the rapid rate of change in the models available, it was decided to introduce digital cameras with hedonic quality adjustment. Since 2004, four additional products have been introduced to the UK consumer price statistics with hedonic quality adjustment; laptops in 2005, mobile phones in 2007, smartphones in 2011 and tablet PCs in 2013. A summary is provided in Table 2 below.

Table 2: Hedonic items in the UK consumer price statistics

Item	Introduction to CPI/RPI	Hedonics Introduction
PCs	1996	CPI – 2003 RPI – 2004
Digital Cameras	2004	2004
Laptops	2005	2005
Mobile Phones	2005	2007
Smartphones	2011	2011
PC tablets	2012	2013

Source: Office for National Statistics

In 2013 the combined weight of all hedonic items in the CPI was 0.73 per cent (or 7.30 parts per 1000), which has fallen from a high of almost 1 per cent in 2007, despite the subsequent introduction of smartphones and tablet PCs. Table 3 below provides items' weights by year. The weight for mobile phones and smartphones represents the purchase of the handset only and therefore does not include phones purchased on contract. This expenditure is captured in the weight for an item called Mobile Phone Charges.

Table 3: Weight in the UK CPI as a part per 1000 by hedonic item

Year	PCs	Laptops	Digital Cameras	Mobile Phones	Smart-phones	PC tablets	TOTAL
2003	5.39						5.39
2004	4.38		1.00				5.38
2005	2.10	2.20	3.28	0.92			8.50
2006	2.15	2.35	2.50	0.96			7.96
2007	3.01	3.36	2.76	0.92			10.05
2008	2.15	2.35	2.88	0.88			8.26
2009	2.00	2.30	2.76	0.88			7.94
2010	2.20	2.64	2.25	1.20			8.29
2011	2.24	2.94	3.50	0.72	0.46		9.86
2012	1.50	2.52	2.56	0.52	0.26	0.24	7.60
2013	1.05	2.31	1.89	0.29	0.29	1.47	7.30

Source: Office for National Statistics

In practice hedonics has proven to be a resource intensive process in the ONS and therefore a costly method. This is due to a number of factors, including the technical nature of the method and the large volume of price and product attribute data that needs to be collected and managed for the production of each hedonic model. Additionally, each hedonic model is updated several times a year to stay relevant to technology changes (for example the introduction of Windows 8 in 2012) which compounds the work involved.

The criteria for introducing hedonics to quality adjust an item has historically been based upon a number of factors including the weight of the item and the rate of technology change. It is therefore appropriate to monitor and review the use of hedonics over time to ensure it is still warranted.

Therefore in 2013 ONS reviewed the use of hedonics in its measures of consumer price inflation and the outcome and findings from the review are discussed in the following section.

Review Findings

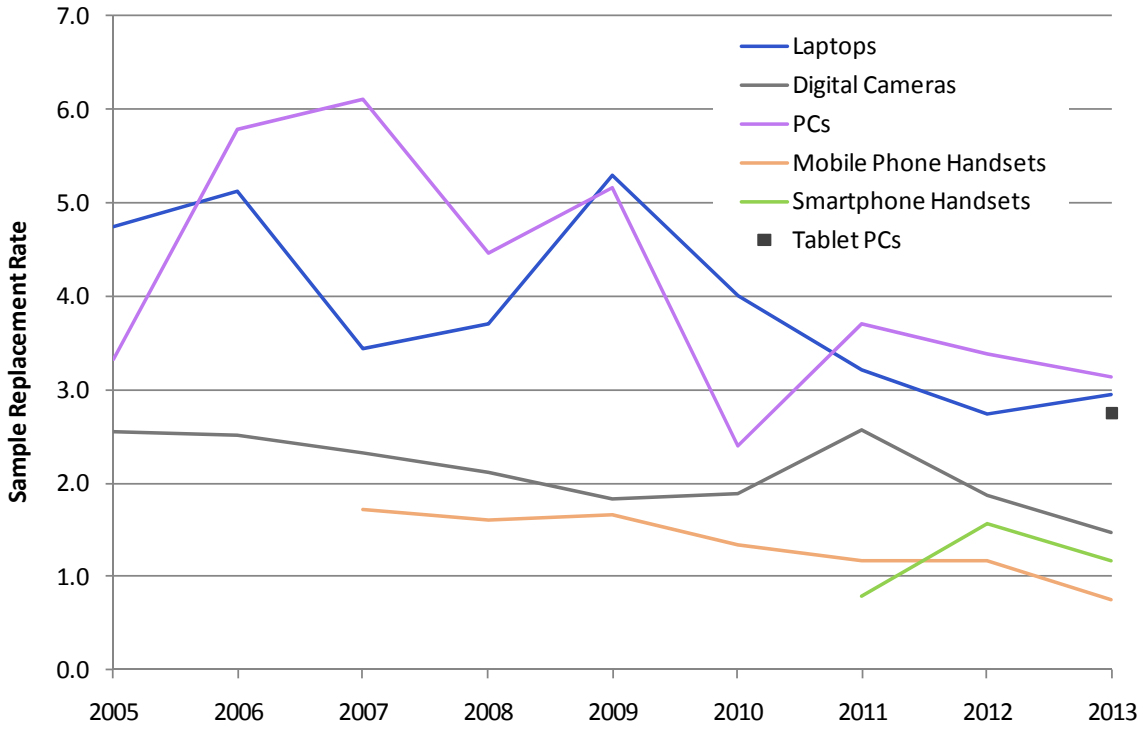
Typically product life cycles extend as the market for a particular good matures. As a result we would expect to see a corresponding decline in replacement rates in the sample of products priced for a particular item as the product matures. Figure 1 below represents the number of replacements made in a 12 month period within each hedonic sample as a proportion of the sample size, e.g. a rate of 3.0 would imply that 60 replacements were made to a sample size of 20 units. Over time the replacement rates of nearly all the hedonic items have declined. It is worth noting that replacement rates can be complicated by other factors including the rotation of stock by retailers and in some cases seasonality.

The replacement rate of an item is important because the need to adjust for quality only arises when a replacement is made. An item with a high replacement rate that also experiences rapid and large quality changes presents the biggest challenge. The replacement rate for PCs and laptops has been consistently higher than other items since they were introduced. The replacement rate for PCs and laptops was 3.1 and 2.9 respectively in 2013. The cause of these replacements relates to the frequently changing combination of specific components used by manufacturers at the point of assembly.

Tablet PCs also had a high replacement rate of 2.8 in 2013, although this was mainly driven by the high number of iterations of each tablet PC model and the fact that specific iterations frequently go out of stock. For example, Apple currently offers 16 different iterations of its new iPad Air, including two colours (black and silver), four different memory capacities (16GB, 32GB, 64GB and 128GB) and two connectivity options (cellular plus Wifi and Wifi only).

The replacement rate for PCs, laptops and tablet PCs is around twice the rate of digital cameras at 1.5 and more so for smartphones at 1.2 and mobile phones at 0.8. To put this into context, there are items within the CPI that do not use hedonic quality adjustment which have a comparable replacement rate. For example, dishwashers had a replacement rate of 1.6 in 2012, fridge freezers 1.5 and washing machines 1.5. The combined weight of these three items was 0.36 parts per 100 in 2012 and all of these products have been subject to quality improvements in recent years.

Figure 1: Hedonic Item Replacement Rates



Source: Office for National Statistics

In terms of the importance of items within the CPI, mobile phones has seen its weight fall from 0.092 per cent in 2005 to 0.029 per cent in 2013 and is expected to decline further in the next few years to the point when the item will most likely be dropped from the index altogether. This is due to consumer expenditure on mobile phones declining as consumers adopt smartphone technology instead.

The weight of digital cameras has fallen from 0.33 per cent in 2005 to 0.19 per cent 2013. Consumer expenditure on digital cameras is also expected to continue falling due to the advent of smartphone technology. The large growth of smartphone ownership in recent years, which stood at 51% of the UK adult population in 2013 (Ofcom 2013), combined with a dramatic increase in the quality of onboard cameras, is the key driver of this trend.

It is worth noting that the weight of smartphones has also been very low for the past three years (0.029 per cent in 2013), which is in combination with a relatively low replacement rate; however as smartphones are still a relatively new product a change of method was not considered. Firstly, it is not clear whether the low replacement rate, driven by lengthy product lifecycles for the most popular models, will persist. Prices for smartphones are also falling, which is likely to translate into growing consumer expenditure on smartphones in the future.

At an international level, the UK uses hedonics to quality adjust three technology items (digital cameras, smartphones and mobile phones) which no other NSI (of those contacted) currently does. For these three items other NSIs currently use a mix of implicit (e.g. overall and targeted mean imputation) and explicit methods (option costing and expert judgement) to adjust for quality.

Review Outcome

Taking a wide range of factors into consideration the review concluded that ONS should change the method of quality adjustment for mobile phones and digital cameras from hedonic adjustment to the standard quality adjustment technique of imputation used elsewhere in consumer price inflation statistics. The method is described in more detail in Annex A under 'imputation'. From March 2014 onwards this change will be implemented in the measures of consumer price inflation published by ONS. Based on historical estimates calculated using the imputation methodology, the change is likely to have a minimal impact at the class level and negligible impact at the all items level of the consumer price inflation statistics. The reasons for making this change are summarised as follows:

- The low replacement rate that mobile phones and digital cameras now exhibit
- The CPI weights for these items are expected to fall to a level within the near future that will mean their impact at the all items level becomes minimal
- There is much anecdotal evidence to suggest that the rate of quality change for these two items has slowed since the time at which they were introduced with hedonics
- Hedonics is costly to implement, particularly in the context of the previous three points, i.e. a cost versus impact argument
- Internationally these items are not commonly adjusted using hedonic methods.

Annex A - Quality Adjustments

Taken from 'CPI Technical Manual 2014', pages 49-52

One of the more difficult issues in producing the consumer price indices is the accurate measurement and treatment of quality change due to changing product specifications. As a measure of price change alone, the measures of consumer price inflation should reflect the cost of buying a fixed basket of goods and services of constant quality. However, products often disappear or are replaced with new versions of a different quality or specification, and brand new products also become available. When such a situation arises, one of the following methods is adopted:

a. direct comparison

b. direct quality adjustment

c. imputation

In all cases, a nominal price in the base month is needed for the new or replacement product; this nominal base price is used until the following January. If the retailer can supply the previous January price of the new product, this can be used as the new base price with no further adjustment.

a. Direct comparison

If there is another product which is directly comparable (that is, it is so similar to the old one that it can be assumed to have the same base price), for example a garment identical except that it is a different colour, then the new one directly replaces the old one and its base price remains the same. This is described as "obtaining a replacement which may be treated as essentially identical", and is equivalent to saying that any difference in price level between the new and the old product is entirely due to price change and not quality differences.

b. Direct quality adjustment

This is the preferred method of dealing with the situation where a replacement product is of a different quality or specification. An attempt is made to place a value on the quality, or specification, difference and the base price is adjusted accordingly. This section discusses quantity adjustment and hedonic regression. Another method of direct quality adjustment, option costing, can be used when a product changes in specification and it is possible to value separately the components that have changed.

Quantity adjustment

The simplest form of direct adjustment is quantity adjustment, which is used when there is a permanent size change in an item. This occurs most frequently with homogenous goods such as food and drink, and has been used recently when the size of some confectionery bars was changed. In this case, in each outlet the nearest equivalent new size of the product priced in that outlet was found, and an adjustment made to the base price pro rata for the change in weight.

Similar adjustments were made in the RPI in October 1995 when many items were changed from imperial to metric quantities. In this case, in each outlet the nearest equivalent new size of the product priced in that outlet was found, and an adjustment was made for the change in weight. More complex calculations are required when a component part of a more complex product changes in specification. In practice adjustments of this sort can only be made where it is possible to value the change separately. The following section describes how this is done using the hedonic regression technique.

Hedonic regression

Hedonic regression is a technique that uses a set of ordinary least squares regressions to relate the price of an item to its measurable characteristics. Currently (for 2013) It is used for quality adjustment of personal computers (PCs), laptop computers, digital cameras, PAYG mobile phone handsets, PAYG smartphone handsets and tablet PCs. For computers, the measurable characteristics may include the speed of the processor, the size of the hard disk drive and the amount of memory. For digital cameras, the characteristics may include the resolution. The results of the regressions are used to value changes in quality when a product that is part of the sample is no longer available and is replaced by another product. An example of how this is done for PCs is given below. A similar approach is used for the other items.

For PCs, hedonic regressions are calculated on the basis of a single month's data, using unweighted regressions based on price data collected from retailers' web sites. The log of price is chosen as the dependent variable in the regression for two reasons. Firstly, a log-linear model produces a multiplicative relationship between price of a PC and its attributes, which is a better reflection of pricing in the retail market. This is because the cost of adding a new feature tends to be related to the underlying quality and price of a machine. For example, the addition of a DVDRW drive to an expensive PC typically costs more than for a cheaper PC, because a higher quality drive will be included in the more expensive PC. Secondly, multiplicative relationships are more robust to general changes in price, and so have a longer life span.

An iterative approach is used to derive the hedonic regressions. This procedure includes an element of statistical judgement and product/market knowledge, and is preferred over the more traditional automatic stepwise regression technique because it is better able to cope with the potential relationships between independent variables in the regressions. For instance, the attributes 'TV tuner' and 'remote control' are often inter-correlated because PCs that have a TV tuner often include a remote control as well. These relationships can cause the automatic methods of regression estimation to produce either sub-optimal regressions, or in some circumstances ones in which the relationships revealed are counter-intuitive.

The regressions are then used to predict prices when an existing PC in the sample is no longer available and has had to be replaced by a PC with a different level of quality. Price adjustments are made based on these predicted prices.

The following is an illustrative example of how hedonic based quality adjustment can be applied in a situation where an individual PC was priced in January, but could not be found in February. The replacement is close in quality, but has a single change in specification – an increase in processor speed.

Step 1: Produce regression function

Step 2: Predict old and new price

		January PC		**February PC**	
Attribute	Coefficient	Level	Effect On Price	Level	Effect On Price
Brand		PC Company		PC Company	
Intercept	5.02277	1	£151.83	1	£151.83
Monitor	0.03886	19	x 2.09	19	x 2.09
Processor Speed	**0.00014**	**1600**	**x 1.25**	**2800**	**x 1.48**
Hard Drive	0.00004	640	x 1.03	640	x 1.03
Memory (MB)	0.00003	3072	x 1.10	3072	x 1.10
Video Card	0.06673	1	x 1.07	1	x 1.07
	Predicted Price	=	£480.87		£569.35
	Actual Price	=	£475.00		£550.00

(only change is processor speed)

The effect on price for each individual attribute is calculated by multiplying the level of the attribute by its coefficient, and then taking the exponential of the resulting value.

For instance: the effect on price or monitor = exponential (19 x 0.03886)
= exponential (0.73834)
= 2.09

These effects on price are then multiplied together to give the overall predicted price:

Predicted price = Intercept x effect of monitor x effect of processor speed x effect of hard drive x effect of memory x effect of video card

For instance:
Predicted price for January PC = 151.83 x 2.09 x 1.25 x 1.03 x 1.10 x 1.07 = £480.87

Step 3: Adjust base price to reflect new attributes

Change in January due to changes in quality = $\frac{\text{Predicted price new PC}}{\text{Predicted price old PC}}$

= £569.35 / £480.87
= 1.184

New base price = Base price old PC x quality change
= £475 x 1.184
= £562.40

Step 4: Compare current price with new base price

PC Index = (£550 / £562.40) x 100 = 97.8

Unadjusted index = (£550 / £475) x 100 = 115.8

The calculation shows that, once the difference in quality between the original PC and its replacement has been taken into account, the price has effectively fallen by 2.2 per cent. This compares with an increase of 15.8 per cent in the unadjusted price.

c. Imputation

If the replacement product is of a different quality or specification, and no information is available to quantify the difference, assumptions must be made. A base price is calculated for the new product by assuming that its price change from the base month up until that month equals the average change in the elementary aggregate for that item. Thus if the price is £14.99 and the elementary aggregate index for that item (calculated excluding the product in question) in that stratum is 108.34, the new base price is:

£14.99 / 108.34 x 100 = £13.836

This procedure ensures that bringing in the new product has no effect on the elementary aggregate for that item in the month that it is introduced.

If an outlet closes, or refuses to allow further price collection, all items priced there are dropped. In that case, a new outlet is selected in the same location and new base prices are imputed for items priced in the outlet as shown above.

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Further Information

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