

## **The Quality Adjustment Matrix: a strategic approach to the a priori identification of the most appropriate items in a Consumer Price Index for hedonic quality adjustment.**

David Fenwick (Director, Consumer Prices and General Inflation Division), Adrian Ball (Head of CPI Methodology and Research Branch) and Jay Beaven (Research Analyst) *Office for National Statistics, 1 Drummond Gate, London SW1V 2QQ, United Kingdom.*

### **Abstract:**

*The dynamics of the market place and the accelerating pace of technological development represent a major challenge to the statistical measurement of the trend in prices of goods and services purchased by consumers. To correctly measure the target universe of transactions associated with the expenditure coverage of the price index, is particularly problematic as it raises a tension between keeping the basket fixed and ensuring that it is up-to-date and representative whilst only reflecting pure price changes. A central measurement issue is the effective treatment of ongoing quality developments of existing products and the proper incorporation of entirely new products. Against this background the paper discusses some of the strategic and practical issues that need to be addressed by statistical offices when reviewing the use of explicit quality adjustment techniques and in particular hedonic regression. Drawing on recent work by the UK Office for National Statistics into explicit quality adjustment methods, the paper considers alternative approaches to identifying at an early stage those parts of the consumer prices index where the application of hedonic quality adjustment can be applied to maximum benefit to the statistical integrity of the index. It explores alternative methods of prioritisation and investigates the possibility of generating a single function that can provide a mechanism for an ongoing strategy for the cost-effective application of hedonics. By providing a reliable set of a priori rules it thus attempts to address the criticism in the Schultze Committee report that the use of hedonics in the past has often lacked strategic focus.*

**Key words:** fixed baskets, quality adjustment, hedonics, Schultze Committee, quality adjustment matrix.

### **1.0 Background**

In 2000 the UK Office for National Statistics launched an extensive research programme to investigate the possible application of hedonic methods for the quality adjustment of goods and services in the Retail Prices Index (RPI) and Consumer Prices Index (CPI). The range of goods studied initially was systematically chosen on the basis of two indicators:

- The relative expenditure share of the good or service in the RPI/CPI basket.
- The associated Implicit Quality Index (IQI).<sup>1</sup>

---

<sup>1</sup> IQIs were first developed by Jorgen Dalen and Don Sellwood. They are a measure of the effect of the operational adjustments that have been made to the raw price data in order to obtain the published “quality adjusted” price index. That is the aggregate effect of adjustment, including explicit and implicit methods, to remove non-price effects and arrive at the “true” price change. Relatively large IQIs for specific items may indicate areas where particular attention needs to be given to the quality adjustment techniques particularly where only implicit methods are applied.

The UK approach to the selective introduction of hedonic quality adjustment in consumer price indices may have been more systematic than the targeted intuitive approach<sup>2</sup> employed by the US Bureau of Labor Statistics, but in practice the selection method for hedonic quality adjustment did not prove to be completely effective. Only three of the initial fifteen goods that were deemed to be prime candidates for the application of hedonic quality adjustment were selected for implementation in the live index. The goods concerned were PCs, laptops and digital cameras. In addition, only one good- widescreen televisions- was considered borderline. All the remaining eleven goods did not warrant explicit quality adjustment using hedonics<sup>3</sup>.

Further investigation of the reasons why hedonic quality adjustment did not prove appropriate shows that whilst the corresponding hedonic functions could be computed, when they were compared with implicit quality adjustment the effect of introduction in the index was not large enough to make implementation cost-effective<sup>4</sup>.

Thus whilst it might be true from a statistical viewpoint that “the best candidates for hedonic analysis are categories of goods for which quality change is frequent but incremental and for which the characteristic changes are easy to measure”<sup>5</sup> this isn’t necessarily a good criteria on its own on which to base decisions about practical implementation and impact on the index.

It was against this background that the ONS investigated alternative methods of identifying the best candidates for the implementation in the price index of hedonic quality adjustment. The aim was to try to differentiate between those goods that have sufficiently high levels of quality change to warrant explicit quality adjustment and those that don’t, where implicit quality adjustment is likely to be problematic. This can then be used as an initial filter prior to the consideration of hedonic quality adjustment.

## 2.0 The investigation

Investigations focused initially on two primary quantitative measures relating to quality change:

- The turnover in items as represented by the number of price quotes that disappear from the basket.
- Implicit Quality Indices (IQIs).

However, IQIs can be time consuming to compute and have not proven to be totally reliable indicators in the past of the need for explicit quality adjustment and are, in any case, of limited use as they can only be calculated for items already in the index. In addition, a further study of the retail market suggested that turnover rate as a concept is too simplistic and on its

---

<sup>2</sup> Items are selected that are thought a priori to have undergone quality change.

<sup>3</sup> Fridge-freezers; dishwashers; VCRs; radio-cassette recorders; DVD players; still cameras; vacuum cleaners; audio systems; microwave cookers; mobile phone handsets; Widescreen TVs.

<sup>4</sup> In the cases of VCRs and 14” televisions relative sales declined as a result of being displaced from the market by DVD players and by small televisions, combined with a VCR or DVD.

<sup>5</sup> A direct quote from the Schultze Panel on Conceptual, Measurement and Other Statistical Issues in Developing Cost-of-Living Indexes (“At What Price? Conceptualizing and Measuring Cost-of-Living and Price Indexes”). By way of illustration the Panel offered personal computers which are seen as an obvious candidate whilst cars [where, for example, measuring performance is highly subjective] and clothes [the challenge of fashion] are seen as problematical.

own is a very blunt tool. These considerations led us to consider an alternative two-dimensional matrix approach that is characterised by two statistics:

- Rate of turnover of models – are significant proportions of older models disappearing from the market and being replaced by new ones?
- Rate of technology change in the good- are new features and improvements regularly being introduced?

Clearly if an index item is subject to both a high rate of turnover and of technological change then it is likely to be a prime candidate for explicit quality adjustment. Similarly, the index compiler would not want to give priority to explicit quality adjustment where an item has both low turnover and technological change. Both statistics in the matrix potentially can be calculated from the raw data used to compile the CPI or from scanner data but the CPI data is only available for goods already in the index and its value is constrained by the amount of detailed characteristic information which is collected (usually a lot less than for scanner data). It was for this reason that the study was based in most part on an analysis of scanner data<sup>6</sup>.

	<u>Low</u> rate of technology change	<u>High</u> rate of technology change
<u>Low</u> turnover rate	NO	?
<u>High</u> turnover rate	?	YES

### 3.0 The results

#### *Turnover rates*

Two measures of turnover were investigated:

- *the rate of models leaving the market*. This is defined as the proportion of models that have disappeared from the market in the following month. It is closest in concept to observed turnover rates in the RPI sample itself.
- *the level of churn in the market*. This is constructed by pairing successive months, and determining how many models are only available in one of the months and expressing this as a proportion of the total number of distinct models available in both months

The rate of models leaving the market allows us to directly compare measures derived from RPI and scanner data respectively. It is also of more direct relevance to the reliability of our current implicit method of quality adjustment, since the latter is a function of the number of models that continue to be available in the shops from one month to the next. The churn rate is of limited relevance in this respect, as the arrival of new models has no effect on the reliability of implicit quality adjustment. However, the churn rate gives a better indication of the underlying dynamics of the market place and can therefore be said to better represent overall the position relating to technological change.

---

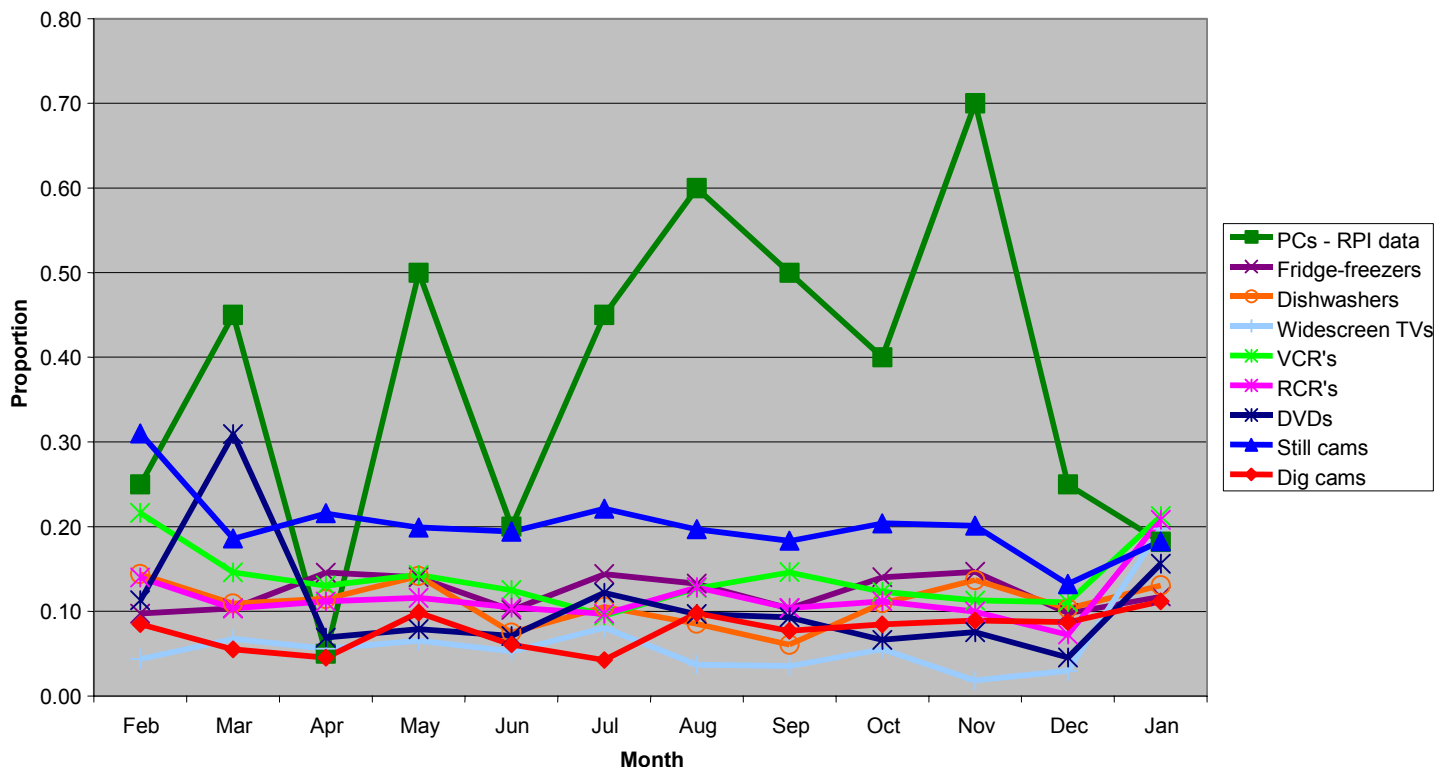
<sup>6</sup> The exception was PCs where models, their characteristics and prices, are collected from the Internet due to the lack of detail in the available scanner data.

Chart 1 shows the monthly turnover rates of models leaving the market for the goods studied. When interpreting this chart it should be noted that, firstly, the reference year varies between goods reflecting the data to hand and secondly, that the volatility of the data plot for PC's results from the use of the relatively small RPI sample which is much reduced compared with scanner data.

Three points emerge:

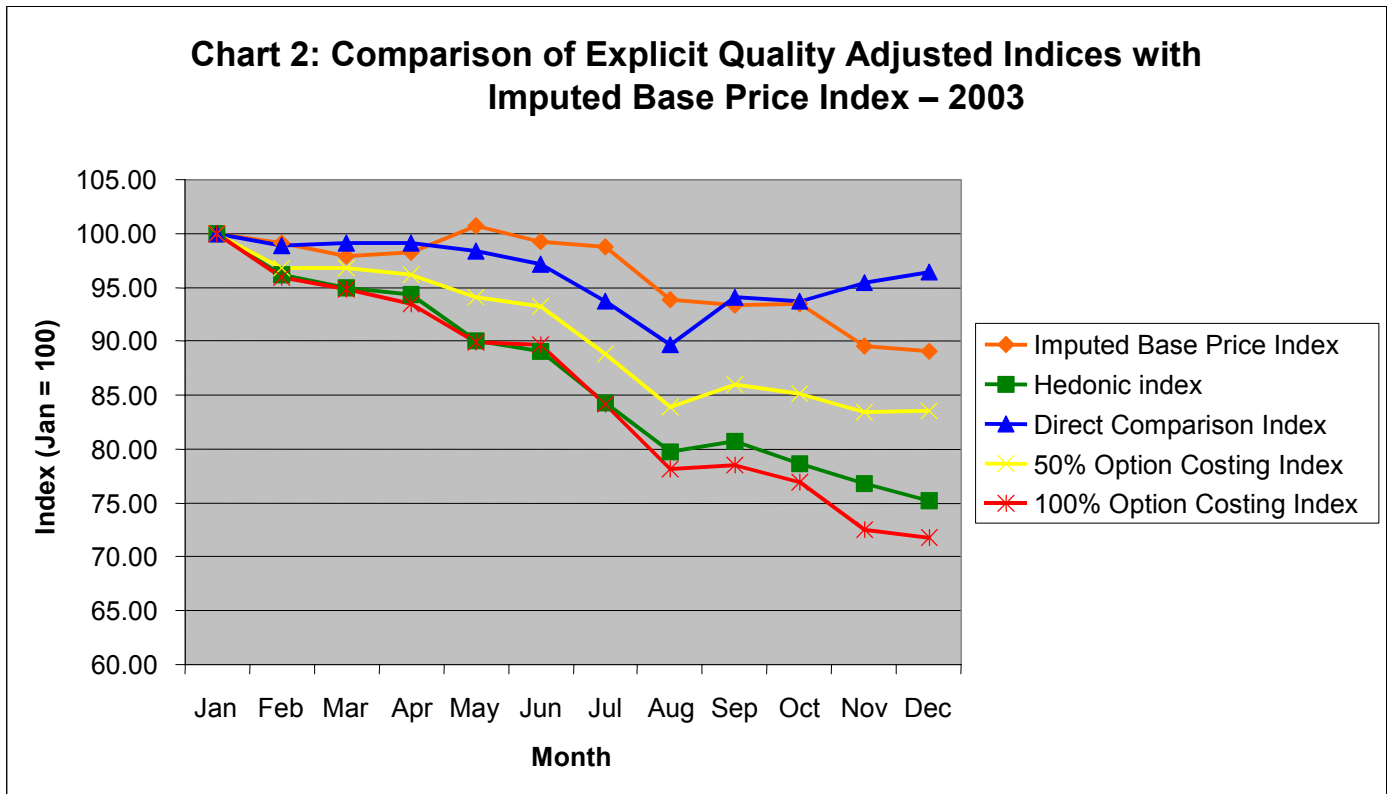
- The special position of PCs. The turnover rate is about twice as high for PCs than for any other good studied.
- Turnover rate appears to be a relatively blunt instrument when used alone in determining the need for explicit quality adjustment. Thus it can be seen that the variation in turnover rate is relatively small between the goods studied although the turnover rates are not small in absolute terms.
- The turnover rate is not on its own a reliable indicator of the need for explicit quality adjustment. For example, although the turnover rate for digital cameras is the second lowest at seven per cent, further investigation lead us to introduce hedonic quality adjustment for this good.

**Chart 1: Proportion of Models Changing - Models Leaving the Marketplace**



Further analysis indicates how a high turnover rate can be strongly associated with poor performance of implicit quality adjustment methods. This is illustrated in Chart 2 which

compares the hedonic quality adjusted PC index with both the corresponding direct comparison index and the corresponding imputed base price index..

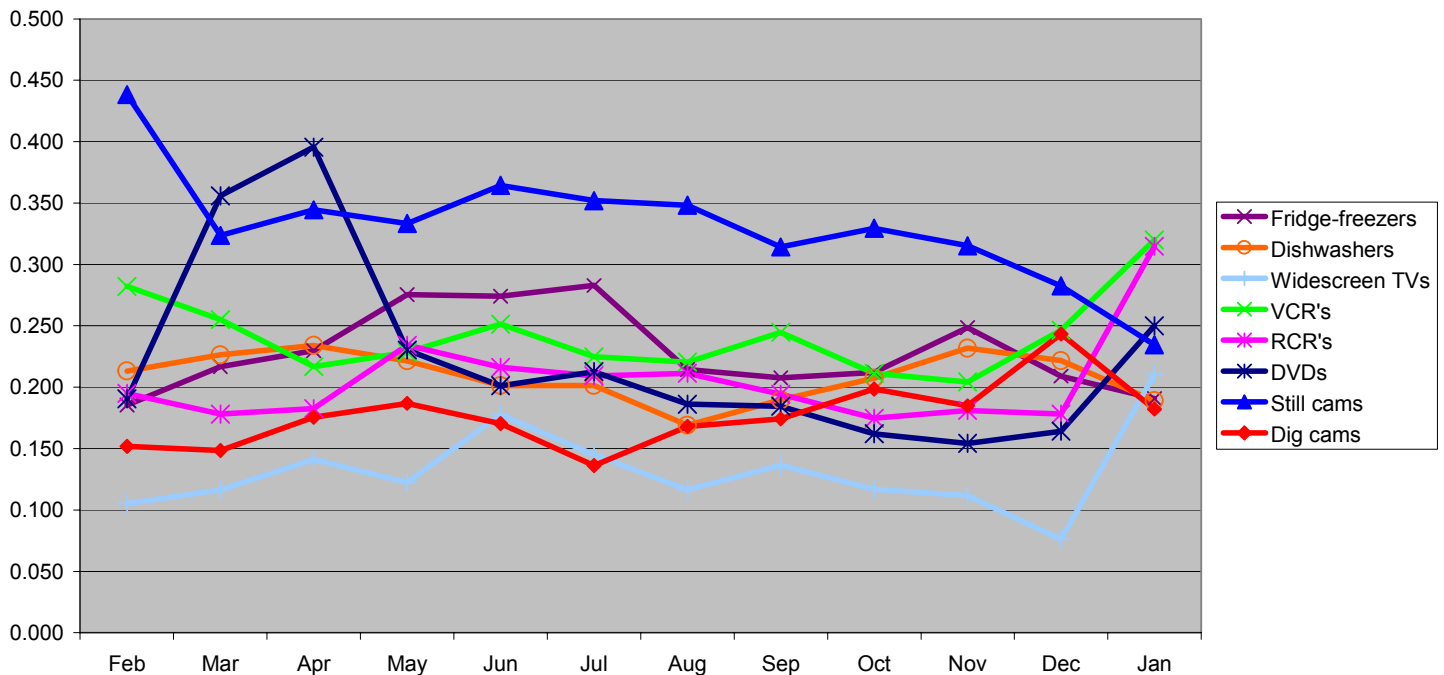


PCs apart, the corresponding levels of churn in the market is shown in Chart 3<sup>7</sup>. As might be expected in a broad state of market equilibrium, the churn rate is about twice as high as the turnover rate.

It is instructive to note that, with the exception of still cameras, the picture to emerge is very similar to that which emerged from an analysis of turnover rates.

<sup>7</sup> PCs have been omitted due to volatility in this measure resulting from the relatively small sample.

**Chart 3: Proportion of models changing - Scanner Data - Models entering and leaving the market**



### *Rate of technology change*

The measurement of the rate of change in technology was more problematic. Early work focussed on examining the rate of emergence of new features for models but this was soon abandoned as being only partially informative. The next thread of work examined the relationship between levels of attributes and the year of introduction of the model. This produced interesting results for digital cameras, indicating that measures of attribute change can yield suitable results. In particular looking at the attribute megapixels over time showed how the technology had changed significantly in the past seven years. However, it could not generally be applied to other items because of a lack of information on year of introduction of a model. Because of this, efforts were re-directed at developing an “index of attribute change” based on a chained measure of the change in the level of attributes between goods leaving the market and those entering the market, with the attributes that significantly influence the price of the item being identified using hedonic regression methods applied to scanner data<sup>8</sup>.

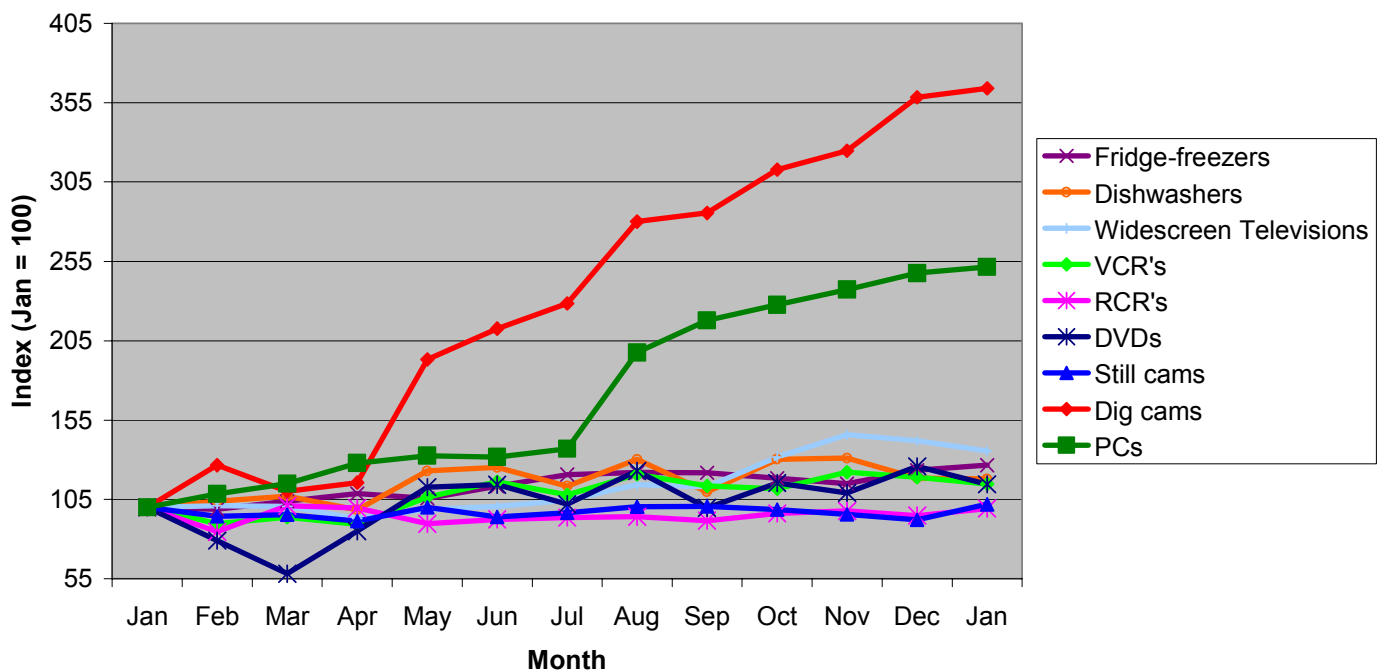
From the same scanner data, the average turnover (entering or leaving the market) of the attributes so identified is then calculated. For numeric variables the latter will be a straight

<sup>8</sup> For instance, hedonic regression shows that for televisions the important price determining characteristics are a mixture of discrete and numeric variables: Screen Size; Flat Screen; NTSC tuning; Dolby sound; DVD player in built; PC in built; Real flat screen; Digital tuner; 100 Hertz picture.

average whilst for discrete features the calculation relates to the proportion of models containing the feature. An overall weighted index is then calculated by taking a weighted average of the log of the turnover in price sensitive features (as calculated above), using as weights the t-values for the attributes from the regressions<sup>9</sup> and expressing this in index form with January =100. The index was computed taking into account whether the attribute represented an increase or decrease in quality - the “net rate of attribute change”- and also in absolute terms where a change in features is treated in the same way regardless of the direction of the quality change - the “gross rate of attribute change”.

It can clearly be seen from Chart 4 that the “net rate of attribute change” is a strong driving factor in determining the potential need for explicit quality adjustment. In particular, there is a strong demarcation between the two goods identified in our earlier research programme as being suitable candidates for hedonic quality adjustment (and where the method was subsequently introduced) and other items which were researched but where hedonic quality adjustment was not found helpful. The two goods concerned had experienced rates of attribute change two to three times higher than for other goods.

**Chart 4: Attribute change Index - all goods**



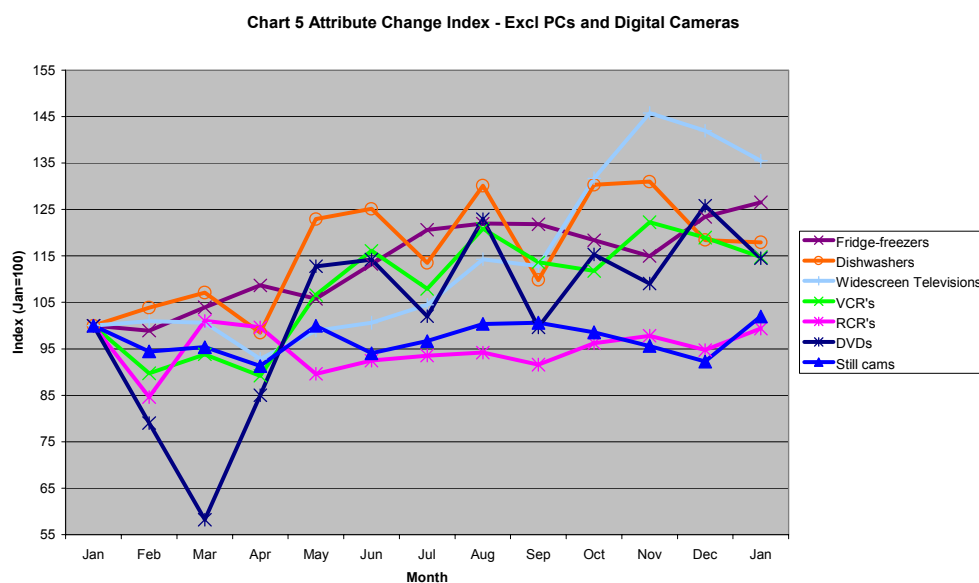
We can conclude that, not surprisingly, it is the level of change in price determining attributes that dictate the need for explicit quality adjustment rather than the turnover in models and that a high turnover of models is not necessarily associated with a high turnover in attributes. This is backed up by our previous work which led us to introduce hedonic quality adjustment for digital cameras despite their relative low rate of “model” replacement. The question then

<sup>9</sup> The t-values indicate both the importance of the variable and whether a change in the attribute increases or decreases the quality of the item. For example the attribute ‘volume’ for digital cameras has a negative t-value, so the heavier a camera the more quality decreases.

is whether a threshold can be set a priori to differentiate between those items where hedonic quality adjustment should be applied and those where there is no strong justification.

A further look at the results- Chart 5 redraws to a larger scale the data in Chart 4 but excludes PCs and digital cameras- leads to the following observations:

- There is very little change in price determining characteristics for radio-cassette recorders and still cameras (film cameras). For radio cassettes, this re-enforces an earlier research conclusion that hedonic quality adjustment added little value to index compilation as there was very little real change in the market place. For still cameras the situation is more complex as earlier research indicated that the market continued to be innovative but that hedonics was unable to capture the quality change. This latest work seems to indicate that the problem may be that the available scanner data excludes important price determining characteristics or that hedonics has not been successful in identifying them.
- All the other items studied, wide screen TVs apart, showed an increase in the rate of change in price-determining attributes, although there was a blip in March for DVDs and there was some volatility associated with dishwashers<sup>10</sup>. Earlier research had indicated that the use of explicit (hedonic) quality adjustment was not justified for these goods even where there was a high turnover rate of models, such as with VCRs. As mentioned, dishwashers and DVDs demonstrate a volatile pattern in attribute change over the year
- There is the same slow increase in attribute changes for widescreen TVs as for most other goods but with major changes occurring in October and November. Earlier research into the application of hedonics to this good suggested that hedonic quality adjustment added very little value to the statistical integrity of the index because of the relatively low turnover rate in models. But clearly such conclusion may need to be re-visited if the turnover rate in models is volatile and becomes significant in particular months. The issue to be resolved is the level at which turnover becomes a significant factor.

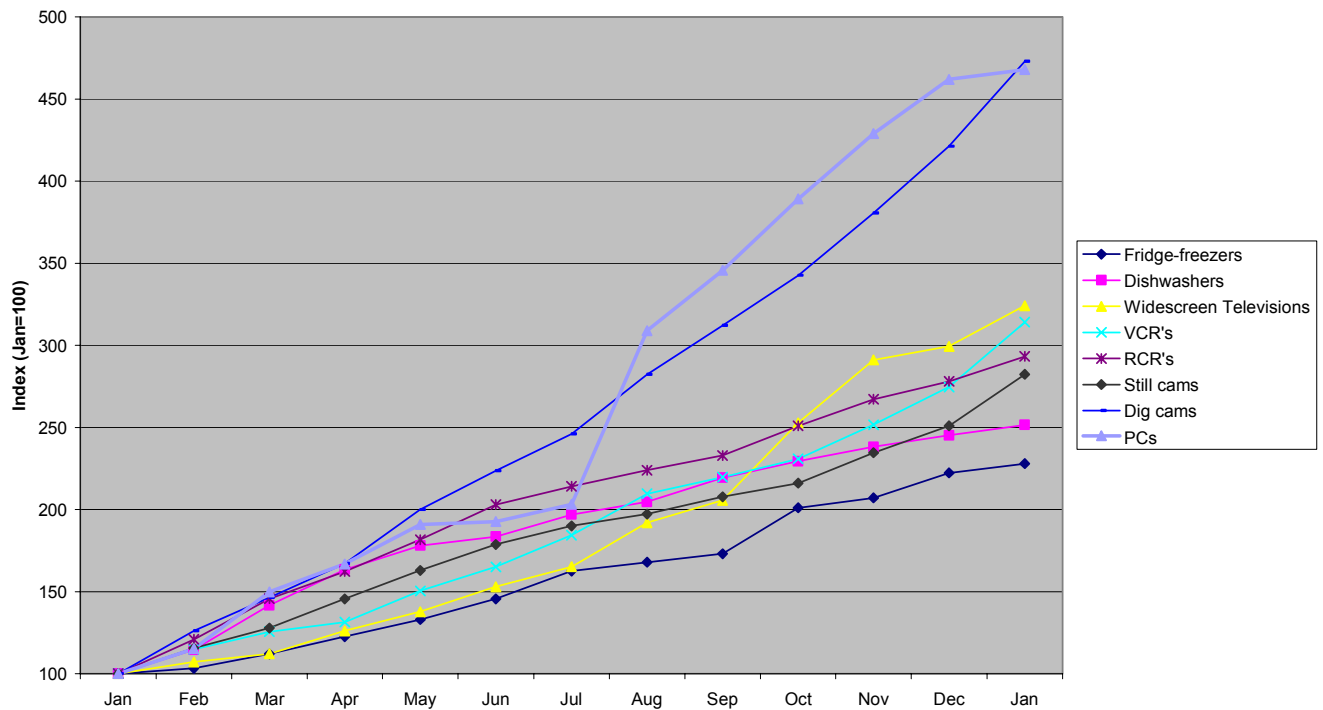


<sup>10</sup> In both cases this is due to limited number of models available.



A corresponding analysis of the “gross rate of attribute change” is shown in Chart 6 and suggests that the gross measure is not particularly helpful in terms of its ability to differentiate between goods that would benefit from explicit (hedonic) quality adjustment and those that wouldn’t. This is because it disguises the fact that a lot of quality change might occur but the increases and decreases in quality might cancel one another out.

**Chart 6: Absolute quality change**



### **Combined measures**

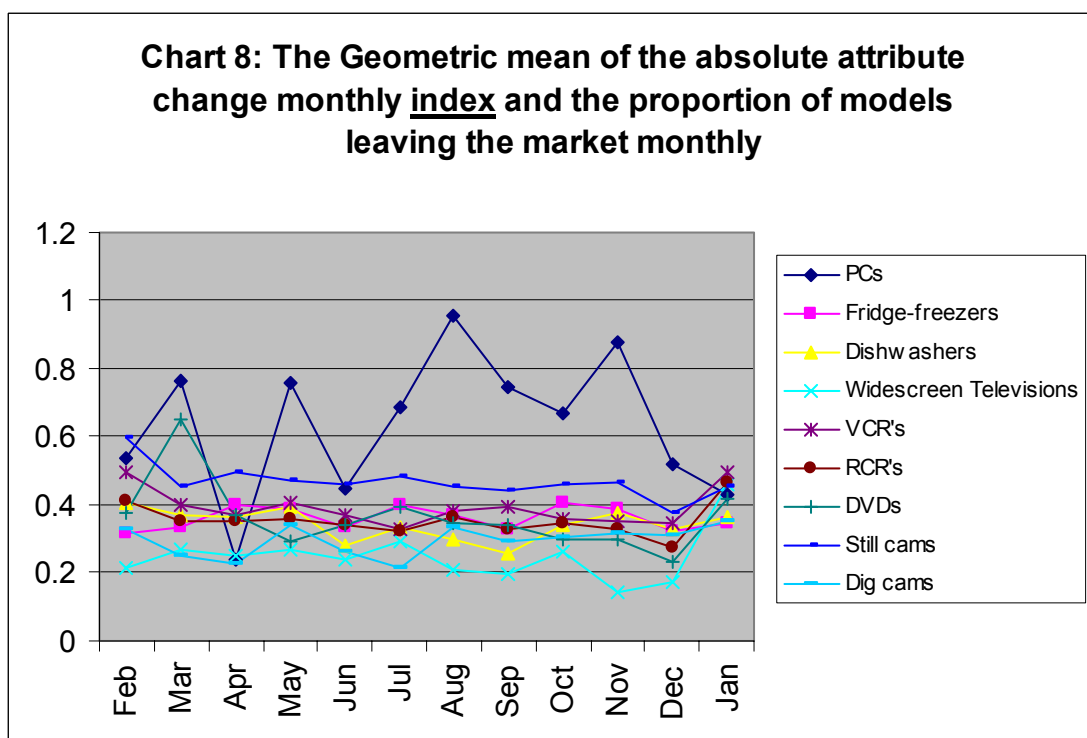
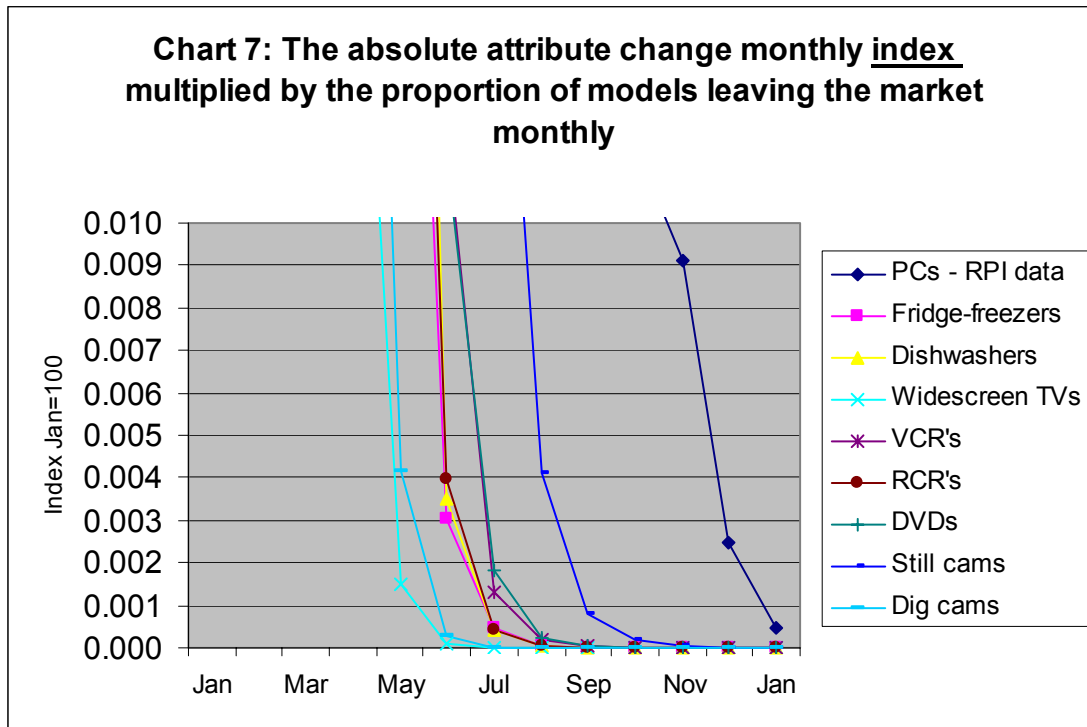
The final step in this research was to explore the potential for compiling a single indicative measure of the a priori need for explicit (hedonic) quality adjustment based on a combination of the measures discussed above. Cluster analysis was also considered but dropped because of the relatively small number of observations involved.

A variety of combined measures were computed.

Chart 7 shows the results of a measure based on multiplying the absolute attribute change monthly index<sup>11</sup> with the proportion of models leaving the market monthly. Because the resulting measure is small in numerical terms the graph focuses on the extreme lower end of the index. The further to the right an item appears on the graph, theoretically the greater the likely need for explicit (hedonic) quality adjustment because the combined measure is higher and falling at a slower rate. Putting to one side the conceptual basis of such a calculation, it

<sup>11</sup> Non-cumulative where the number of attributes in a particular month which differ from the attributes in the base month of January is expressed as a ratio with January=100. Note the index can fall as well as increase.

can be seen at a glance that this combined measure does not increase the ability to pinpoint items that would benefit from explicit quality adjustment- indeed in some respects this combination is less successful. This is illustrated by digital cameras, which are hedonically quality adjusted in the RPI and CPI and which clearly require quality adjustment when looking at a technology change measure, but has one of the lowest combined score on the chart. Unsurprisingly, plotting the geometric mean of this combined measure as shown in Chart 8 to dampen the extreme values doesn't assist the visual presentation.



Finally it should be noted that there was no significant advantage in re-computing this combined measure using the alternative concept of total change in the sample (new models plus old models) instead of the proportion of models leaving the market.

#### **4.0 Concluding remarks**

Research to date suggests that an analysis of the turnover rates in price-determining characteristics has the ability to differentiate between goods that are clear candidates for explicit (hedonic) quality adjustment and those that are not but that there is no easy method of identifying more marginal cases or cases where the rate of model change might be at a level where explicit quality adjustment is desirable even though the rate of change in attributes indicates that the position is marginal. The combined measures that have been tested do not increase the power to discriminate although an alternative option to pursue for future research might be some form of weighting optimised to maximise the predictive power. Finally, it is noted that the compilation of a *net or gross rate of attribute change* involves scanner data and hedonic regression (for the identification of attributes) so operationally does not represent a significant departure from the traditional “test and see” approach of running full pilot studies for individual goods.