The use of the regression approach to quality change for durables in Canada

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Abstract: While there is now a substantial body of work on hedonic methods, there are still relatively few examples of their use in practice. This paper reviews some of the theoretical concerns about applying this method, and describes the experience and results where it has been tested or used in production of price indexes. It finds that the method works better in those areas where there is variety within a limited range of important characteristics, but less satisfactorily when the characteristics or their values change rapidly. There remain a number of questions to be tested empirically on the data requirements and robustness of index estimates based on hedonic models, and when large amounts of data are collected for hedonic estimates, it appears that other statistical methods may be equally promising.
Keywords: price indexes, quality change, regression methods, hedonics.

1. Introduction.

There have been, in Canada and elsewhere over the last several years, a large number of "hedonic" studies to measure price change. Despite this, there are still relatively few cases of their use in regular production of price indexes. This raises some questions on why this method is not widely used, and what are the problems and issues related to it. This report is to review the pros and cons of this method in the light of experience in Canada and in the context of the requirements of consumer price indexes.

In Canada, a hedonic approach was first used in the New Housing Price Index for Vancouver from 1974 to 1976. More recently there have been other areas in which it has been investigated: in clothing, personal computers and television sets. In the first two

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areas, hedonic methods were used to develop a system of explicit price adjustment to changes in the sample. For televisions they were used as one aspect of the analysis of scanner data. Notes on these studies are given in Appendix A.

In the rest of this paper we shall distinguish between two types of application of this approach. Most attention is given to the narrow application, its use in adjusting small samples. The theoretical problems in its use are discussed, then the results from using it are evaluated. The Canadian experience from wider applications is also described.

2. Concepts and purposes of hedonic methods.

Before this method is assessed, it should be described, and its purpose defined. An early description by Nicholson (1967) has stood the test of time:

“Most commodities...have numerous aspects which satisfy different needs and tastes. Durability, appearance, size, comfort, efficiency, convenience, conditions of sale, various technical characteristics – these and other features can affect the prices of different grades and qualities. If we can distinguish the various characteristics and if we know the prices of the different qualities available at a particular date, it should be possible by fitting an appropriate form of regression equation to find out how much of the price is associated with each characteristic.”

Unfortunately, the first features on that list have been almost universally ignored, and multiple regression has been run only on size, conditions of sale and technical characteristics. Assessing the durability of a new commodity, rating its appearance, or estimating the comfort it provides, requires a degree of judgement that is impractical, but without valuing these characteristics we have no claim to measure the services a product provides. In fact, the word hedonic is a misnomer, because in reality we are left with a multiple regression model based on the objective descriptions that the manufacturer or retailer can provide.

Historically, this kind of regression technique has been applied in both a narrow and a wider way. In its narrow use, the regression approach is proposed as a means to ensure that the sample of representative products in the computation of an index for a particular basic class[2] reflects no change in quality. As in many countries, the most detailed calculations for the Canadian CPI are based on maintaining samples for the representative products. Although the selection of representative products are changed from time to time[3], there is no evaluation of quality differences when that occurs; quality change evaluation is restricted to examining the replacements that occur within the sample for a particular representative product. Diewert (1998, Section 7.4.4), in his categorisation of sources of bias, discusses hedonic regression studies only as a solution to “the bias that can occur when the statistical agency replaces an older model or variety of a commodity by a newer one.” To do this, the element of quality change in any replacement of one variety by another must be excluded from the comparison of nominal prices in the estimate of pure price, or index change. In Canada, the use of regression methods to adjust for quality change in clothing and computers falls into this category.

Since it is only possible to apply quality change adjustments to the replacement of one example of a representative product by another, that satisfies the same specifications, how widely the specification is drawn affects the changes that can be accounted for. If the product specifications are general, the gradual replacement of products by newer, more popular ones can help keep the sample representative of the market generally. But usually the representative products are quite tightly defined, and their weights are rarely changed, so the problems of accommodating new goods, of reflecting the changed preferences

[2] This nomenclature describes the situation in the Canadian CPI. The CPI is divided into 182 basic classes. The indexes for most of these are designed by identifying one or more representative products within each class and observing prices of varieties of these products. An example of a basic class is Video Equipment for which the following five representative products are surveyed: 20” colour televisions, 27” colour televisions, 2-head VCRs, 4-head VCRs, and video cameras. There are typically further restrictions on what varieties of representative products should be observed, including not allowing a change of outlet.
[3] 32” to 36” televisions are about to be added to the video equipment commodity.

among them and the effect of changing outlets[4] cannot be dealt with. The regression method in its narrow use does not address these problems.

Many studies have adopted a broader use of the regression method that potentially allows all these bias problems to be addressed. This can be done by treating the commodity[5] as one product rather than an aggregation of products, and not matching pairs of observations. The replacement of one outlet by another, the appearance of products with new bundles of characteristics, and the replacement of some products in the marketplace by others with similar but not identical characteristics, all occurrences that cut across the definitions of representative products, no longer need to be treated to have no impact on the index. The whole set of data for one commodity can be regarded as a sample of its varieties, where the range of varieties has been transformed from a number of physical objects to a number of groups of characteristics, so a price index can be calculated from the price behaviour of these characteristics.

A good index so calculated requires the sample data to be representative of the universe, but this requirement is no different from what is presently demanded of a sample. The difference is that there are no inhibitions built into modifying the sample to reflect changed conditions, as there are when using the design based on monitoring representative products. The work on housing and televisions was based on this wider approach to the use of the regression method.

3. Use of the regression method for evaluating changes in the sample in principle.

First, let us consider the narrow use of the regression method, whose objective is to ensure that replacements in the sample are made correctly. One may wonder why there is a need to evaluate quality directly in the first place. Since consumer price indexes are based on the assumption that consumers make informed choices in the market in reaction to the pattern of relative prices, we might expect that on the whole, items are placed in the

[4] Observations from one outlet are never compared to another.

market according to their relative value. This is the basis for most replacements in the sample, overwhelmingly so for many commodities. However, for durable goods, we often cannot make that assumption.

In fact, at the time of replacement of many durable goods items it is likely that the ratio of prices of the replaced and replacing item does not represent the ratio of their value. There are several reasons for this. First, due to inertia in our sampling method, an item will probably only be replaced when it can no longer be found on the market. In such cases its price will often have been discounted immediately before disappearing, to clear the stock and leave the field clear for its replacement. Second, a new item may be introduced at an unusually high price to capture that part of the market that puts a premium on the latest version. In areas where a cycle of replacement has been institutionalised these two effects are combined. Third, a new item may be introduced at an unusually low price as an inducement to new customers. Fourth, the manufacturer or retailer may have misjudged the value of the replacing item in the marketplace and introduced it at a level which has to be corrected later. Fifth, the purchaser may not be able to assess the relative qualities correctly, particularly when there are no common items to be compared, and when the new item has features apparently not available before. The first four effects are indicators that the market for the item is abnormal; the last indicates the difficulty of making quality judgements at all.

We are not short of methods to evaluate quality change. For a long time, for clothing, price collectors in the field have been asked to make explicit comparisons between a replacement item and the previously priced one, by comparing physical characteristics, and valuing the differences. The weakness of this method lies in that it relies on the skill and experience of the individual collector, on the fact that it is inconsistently applied, and that the collector's evaluation appears to be coloured by the price difference between the old and new items. For many commodities we can also obtain estimates from manufacturers of their perceived difference in value of any change in the products that

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[5] In the rest of the paper "commodity' will be used for basic class.

they make. These estimates are used to help evaluate quality change for several durable commodities, most notably and routinely, automobiles. However, they are not so useful when there are major changes between models.

The regression method is a proposed better alternative to these methods. In fact it is described in Boskin as an alternative to cost estimates[6]. A number of alternative formulations are possible, but they all depend on regressing a function of price on a number of characteristics for a cross-sectional sample of observations at some chosen time. The application used in clothing is shown in Appendix B.

Statistical questions aside, there are two difficulties with the use of the regression method. The first relates to the reliability of the relative prices used to drive the model. We use this method because we cannot assume that relative prices at any time reflect relative values in the market. But to establish relative qualities the method uses relative prices observed in the market. It is difficult to claim that consumers cannot make accurate judgements about relative quality, while at the same time using unadjusted relative prices to estimate the values of significant characteristics.

A way out of this paradox can be found by distinguishing between the sample and the universe. We can accept that in the marketplace consumers can make good estimates of quality, but we must recognise when the comparison forced on us when replacing an item in the sample is not founded on market comparisons. Usually, the replaced item is not available on the market, or if it was available, it was priced under abnormal conditions. In those conditions, when a replacement in the sample occurs, it reflects both the substitution of one item by another and a return to a normal market price for the replaced item. If we accept that consumers can value items correctly, then we can splice the effect of the substitution, but we are left with the job of estimating the normal market price of

[6] The hedonic approach can be viewed as an alternative method to manufacturers' cost estimates in making quality change adjustments. …(Thus) the hedonic approach is less a new method than an alternative to cost estimates to be used when practical factors make it more suitable than the conventional method. (Boskin (1996), chapter V.)

the disappeared item.[7] Thus the exercise is transformed from comparing the price of the new item with its expected price, to comparing the price of the disappeared one with its expected normal price. Since we are estimating some notion of normal prices, the data sets from which the regression model is estimated need to be purged of all abnormal market prices. If we use the regression model to estimate the price of the disappeared item, using, for example, the method given in Appendix B, which adjusts according to the difference in characteristics, the resulting estimates of quality and pure price change are the same as they would be if we used it to estimate the price of the new item. However, note that if the old item was around to be included in the data set from which the regression model was estimated, its expected value at the time of replacement would have been the same as its actual value at the time the model was calculated. In other words, in applying the regression estimates, it is assumed there is no price change between the period from which the regression model was calculated and the time the replacement occurs.

This brings us to the second difficulty. The evaluation, in most periods when a replacement is made, is based on the estimated values from a regime of relative prices in an earlier period. We calculate an estimated value by applying the prices from that period to the quantities of characteristics in the current period, and compare that estimate to the current actual price. If there is the usual substitution between prices and quantities - in this context, between the prices and quantities of characteristics - this results in an overvaluation of the current item and a downward bias to the index estimate. The extent depends on the size of the changes and the elasticities of substitution in the characteristics.

In a true hedonic index the elasticities of substitution may be small but for these models, which depend mainly on physical attributes, it is a different matter. For clothing, for example, the effect of such substitution may be small, mainly because we do not think

[7] We could be faced with estimating a normal market price for the new item, but at that time there is no reason to think that the new item is in an abnormal market. Consumers have a recollection of the price of the disappeared item but not of the new one yet.

that there is much change in either the significant characteristics affecting the price, or in their values. For example, for shirts, the percentage of cotton can vary from about 35% to 100%, but the variation in the sample appears to be random rather than systematic. Also, we are not usually dealing with large changes in the prices of characteristics.

For other durable goods, however, particularly those undergoing rapid technological change, it is different. In many cases the newest features, appearing on the models at the high end of the quality spectrum, command a significant premium. By the time these features filter down to the mainstream models that are replacing older models in the sample, they command much less of a premium, but the features are valued according to the earlier higher values. Even when the same significant variables remain in the regression model from one time to another, the change in their relative values has the same effect. Also, in some durable goods, prices are changing rapidly, so that irrespective of any shifts in relative prices the estimates of price change based on some prior period may well be out of date.

4. Using the regression method to evaluate sample changes in practice.

In this section we review the application of the regression method to clothing and personal computers. Regression models are being developed for a number of clothing items. The one which is most advanced is for men's shirts, for which we have some evidence comparing quality adjustments actually made with what would have been obtained using the regression estimates.

It has been observed for clothing that apart from discounts at the end of an item's life, very little price change occurs after its introduction[8]. The indexes are driven by what happens at the time replacements are made. This seems to be a common experience (Lakin, 1998). If all changes are spliced, extremely low indexes result. Therefore there is a need for explicit quality adjustment, if only because of the discounting of replaced items

[8] At least, not in periods of low inflation. In periods of high inflation, behaviour may be different.

before their replacement. There is not any evidence to suggest that consumers are unable to assess quality differences among the items available; in fact, conventional belief is quite the opposite.

Shirts are one of the commodities little affected by seasons or fashion, and replacements are fairly evenly distributed through the year. However, it is clear that the index for shirts is subject to the effect of price cuts at the end of a product line. From January 1997 to May 1999 the index rose 7.4%, but had it been computed just from matched samples the rise would have been only 0.8%. Nearly all the index movement occurred at the time replacements were made. An examination of the behaviour of prices of items just before their replacement makes it clear that most of the index movement was a return of prices to a normal level after they had been discounted. (On a seasonal item, women's dresses, the difference is much greater; if all replacements in that index had been spliced the index would have been 25% lower since the beginning of 1997.)

In estimating the regression model for shirts the normal sample was doubled for one month, from about 100 observations to 200. In addition, price collectors were given some direction as to what extra observations to collect; they deliberately included items different from what was in the sample already to get more diversity on the characteristics that were expected to be important. As replacements are made for shirts throughout the year there were probably some, but not many, observations for items that were at the end of their market life. About thirty characteristics were collected and recorded, and twelve were included in the larger regression model. They included some direct measures of quality, such as the percentage of cotton in the shirt, some judgements on quality by classifying outlets, brands and countries of origin into high, medium or low prestige groups, and some indirect indicators, such as the number of buttons on the front, and the type of sleeve. A detailed account of the analysis is available in Markle, (1998). Comparing the quality adjustments produced by applying the regression model to those actually used shows that the overall impact of the two approaches is similar. If the adjustments from the regression model had been used the index would have risen by 7.8%

instead of 7.4% over the period. An analysis of the individual assessments shows a small correlation (30%), between the two approaches. Most regression adjustments estimate a quality change of more than ten percent between the replaced and replacing items, unless there is no quality change at all. This is not surprising as the smallest adjustment implied by any change in a characteristic is 10%.

In the present climate of price change we do not expect large pure price changes. The residuals between the nominal price change and the estimated quality change should be quite small. The regression method therefore provides a rather crude tool for making these adjustments. We should also view the r-squared measures in these models with some caution. In the model for shirts, a significant amount of price variation is accounted for by a coding of the type of outlet according to its prestige. However, as we do not replace one item for another in a different outlet, the amount of variation to be accounted for is reduced. A more extreme example is the case of televisions. Typically r-squareds of .90 or more are found. However, well over .80 is accounted for by variation in the size of the screen. Within each of our representative products the screen size is constant. If the variation in screen size is excluded, these regression models for televisions do not do such a good job of accounting for the source of the remaining price variation.

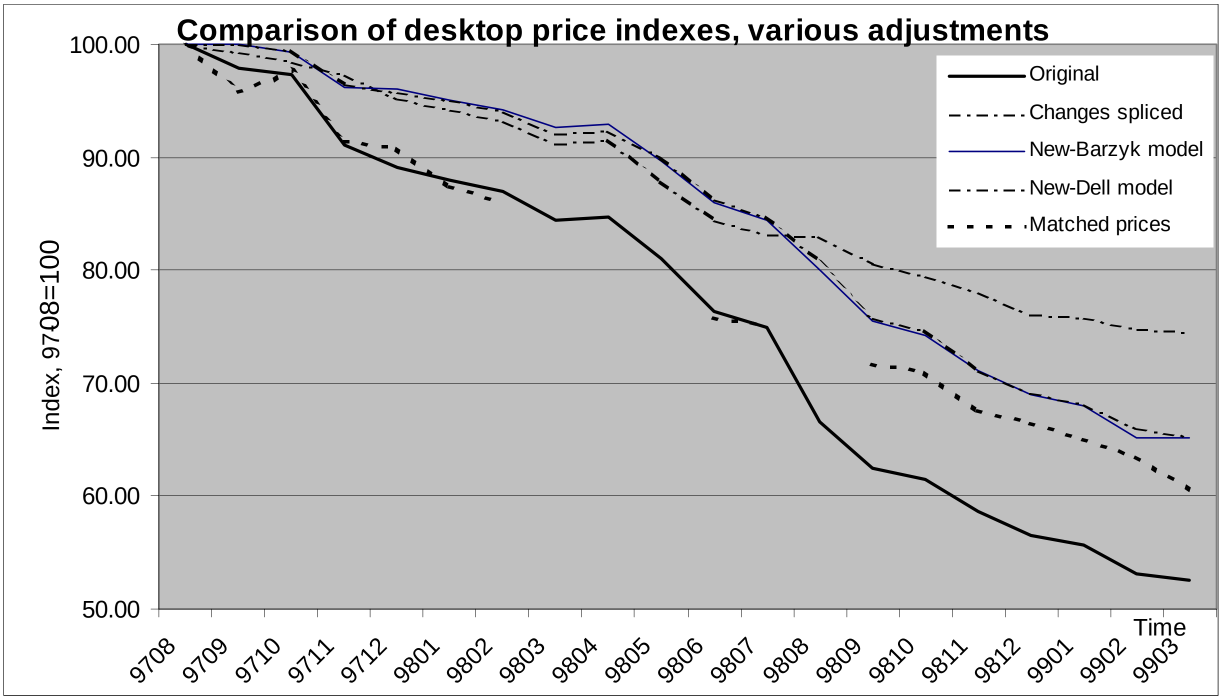
We have been using a regression model for adjusting replacements in the personal computers' sample for several years. This index has been falling steadily in the nineties by about 30% a year. If we had spliced all replacements it would have fallen at a rate of about 20%.

Clearly, prices have fallen consistently fast. Our sample also is subject to the same inertia as samples for other commodities, continuing to include items after other newer versions are available. If the same market behaviour existed for computers as for clothing and other items, we might expect that splicing would cause the index to be abnormally low. We should expect that old items, just before their disappearance from the market, would be drastically reduced in price. This does not seem to be the case for computers. The more extensive data we have been collecting recently suggests that after a while the prices of older computers tend to stop falling. If we are slow replacing them in the sample this would introduce an upward drag on the index decline.

Regression models for computers have been estimated three times, in 1989/90, in 1995/96, and just recently, in 1999. In the first study the data were drawn from market estimates, in the second, from standing offer prices for purchases by the Federal Government. They were assumed to vary approximately like normal market prices. In the first model, price was estimated directly from speed, RAM, the size of the hard disk, and a small number of other indicators; in the second model, used since 1997, the logarithm of the price was estimated from the same variables and a shorter list of indicators. In both cases the overvaluation of new models eventually became so obvious that their estimated prices had to be rejected, and replaced by estimates based on deflating the value of the changes by the movement of the index since the model reference period. That has only happened recently, however. The most recent model is similar to the second except that log of the RAM is used, and the speed variable has been transformed by a scoring of the behaviour of different chips. This measure shows decreasing returns to scale.

A number of alternative measures for a recent eighteen months (August 1997 to March 1999) are shown in the accompanying graph. One aspect of the definition of this commodity is that there is only one representative product for it – a stand-alone desktop personal computer – so that any variation in speed and size can be accommodated. Thus the main characteristics in the regression models are relevant for quality adjustment. This contrasts with clothing and televisions, for example.

The bottom line shows, effectively, the official index, rebased to August 1997=100. The top line shows what the index would have been if all replacements had been introduced to show no index change. Because all changes have been valued in the prices from the 1995/96 model, improvements have been systematically overestimated. We took the latest (Barzyk) model and reworked all the replacements from its prices. That is the solid line in the middle. We would estimate that this and the original index bracket the best estimate, as using 1999 prices to value the earlier changes undervalues them. It indicates, at the least, the need to rework the models frequently – maybe even each month.



Notes: Barzyk model: *LnPrice=5.641+.140RANK+.342LnRAM+.0192GB+other variables*
Dell model: *LnPrice = 6.433+.244Speed+.00126RAM+.0103GB*
RANK: rating of chips from "The CPU Scorecard". (island.net/~msloan/computer/all_cpus.htm)
RAM is random access memory in megabytes, GB is size of hard disk in gigabytes.
As only changes in speed, RAM or hard disk are evaluated, other variables are irrelevant.

This is possible. We also calculated a quick crude model from Dell Canada's website. This is a direct-order company and you can order on their site. You can also buy a custom configuration by substituting from among the range of options, whose prices are given. We created a random array of different mixes of speed, random access memory, and hard drive and estimated a model from them, for July 1999. Then the replacements were revalued using that model. The result is shown on the line "Dell model".

The comparison of the two 1999 model-based results raises some interesting questions. The two models are different in representing the chip, and RAM. The adjustments for individual replacements differ considerably; changes in speed have much less impact in the Barzyk model, and changes in RAM much more, but the resultant indexes are virtually identical. We need to research how robust index calculations are to alternative regression models.

The other index estimate given is based on comparing prices for the models that have prices in both periods compared. Usually this is a monthly comparison, but in some cases the matching had to be done across more than one month, which explains the gaps in the line. This is based on the full data estimates we have been receiving recently. Thus this match price index differs from the top line, because that was based on a much smaller sample. This one, which weights each quoted model equally, shows a tremendous shift in composition over the eighteen months, but the shifts occur gradually. At the beginning of the period most quotations were for 233MHZ and slower models; by the end the main sellers were 350MHZ or more. But the newest models entered the sample gradually – in the first month there were perhaps two or three, but it quickly rose to ten then twenty or more alternative models. It is interesting that this index estimate falls right in the middle of the regression estimates, and it raises the possibility that we may be able to avoid regression adjustments if we can capture replacements through a large database.[9] All in all, we can say at present that the price index for personal computers is not biased upwards due to unsatisfactory treatment of quality change.

<u>Use of the regression method to address all elemental index problems</u>

Two studies have been done in Canada on a full range of items within a commodity, where the resulting implicit prices for characteristics have been used to estimate a price index directly by weighting them according to the incidence of the various characteristics. Like most studies of this kind the estimates have been done retrospectively, using the same set of characteristics over the whole period. While this method avoids the problem of having to choose, at the time, what characteristics are significant in the current market,

[9] See also Silver, in this volume.

it means that it would have to be modified to be used in regular production of price indexes.

One advantage of this method is that it can deal with the effects of substitution of products or outlets if the database includes a current representation of the market.

Usually, the design of the sample causes it to trail the market in many respects, and the sampling fraction is so small that we cannot claim that the sample represents the universe. However, in some circumstances it may be possible to get information from a representative sub-section of the universe. The studies on housing and televisions were based on such information.

From 1973 to 1975 the house component of the New Housing Index for Vancouver was derived from a regression model. Unlike in most Canadian cities at that time the housing construction industry was fragmented due to a lack of developmental tract land, so there were no large companies to survey. However, most mortgages had to be insured and the necessary details of the price and characteristics of the house, as well as some on the land on which it stood, were recorded. All new purchases of single family houses whose mortgages were insured with a particular company were recorded over a two-year period. This was a significant fraction of all sales in that time period. The price used was the sales price less the appraised value of the land.

The model depended mainly on the size of the house and various aspects of its design, the number of bathrooms, type of garaging provided, whether it had a fireplace (at that time regarded as an indicator of quality.) The results obtained were consistent with the kind of price movement going on in other cities at that time (a rapid increase in the rate of inflation), and the shifts in the pattern of housing were reflected in the self-selection of the data. Although the study covered only one past period, (the measure was developed before the first publication of this index), it could have been continued if we had been willing to keep that list of significant characteristics. For housing that would have been reasonable. The method was not continued with as the data collection was costly, and data only became available with a lag of several months.

The other study, more recently, is on televisions, using scanner data from retail stores. In this case, we have complete sales data from the stores involved, within a month of the sales. The data could be used in regular production if the method were adopted. However, the characteristics have to be collected independently from manufacturers and matched to the model numbers, which were recorded on the sales data.

The most noticeable result from the scanner data is that they showed much greater price declines than the regular indexes. Indexes were calculated using matching samples as well as a number of regression approaches. Because the study was done retrospectively the significant characteristics were identified over the whole period. Work still has to be done to allow the list of significant characteristics to vary with current conditions. As the most recent data were available, current as well as base-weighted indexes could be calculated. As a general rule, the matched sample indexes were lower than the regression based ones. There was some downward bias in the matched samples when older models were heavily discounted as their successors were introduced, but corrections for that only raised the indexes to measures comparable with the regression models. The impact of this overlapping was comparatively small when weighted with sales data.

In our index calculations for televisions we keep separate the measures of price change for different sizes. In recent years there has been a shift towards larger size televisions in Canada. Analysing the pooled data for all sizes showed that part of the decline in prices was due to this shift among sizes. It may be that part of the results of other regression studies that show declines in price compared with the previously calculated indexes are also due to shifts in representative commodities.

<u>Summary:</u>

The regression approach has been applied with varying success, depending on the circumstances. It works well when there is a wide variety of bundles of characteristics sold, those characteristics changing little in importance or in value. It is particularly useful when items in a small sample, on which many of our indexes are based, have to be replaced by items that are a substantially different mix of these characteristics. Clothing and housing are examples of this. Nevertheless, even for clothing the main value in using the method may be in supporting price collectors' evaluations, rather than replacing them. There is no evidence at present that the results are systematically different, and price evaluators on the spot may be able to make more subtle assessments than with the comparatively crude regression model.

For commodities where the list of significant characteristics, or their values, are changing rapidly, the method appears to be less suitable. Retrospectively, when the model can be estimated on an average of values over the whole period, it may be possible to estimate price movement reliably. However, using models from a previous period to adjust current replacements in the sample is likely to produce low estimates. It is not always the case that regression studies produce lower results. They have tended not to where there has been little overall change in quality, and it should be recognised that in some cases where regression studies have produced lower results it has been partly due to substitution effects, rather than quality change within well-defined products.

Many of the problems at the detailed level arise from having too small a sample, so that too much dependence is placed on the evaluation of replacements. It may not be practicable to obtain a large fraction of all clothing sales, but for many consumer durables the range of choices at any one time is limited. Electronic data recording allows us (potentially) to collect a much larger volume of data, and that could help alleviate the problems of substitution and of including new varieties. The returns from investing in such data, even in using matched samples without capturing characteristics data, are more likely to produce useful results than trying to estimate quality changes for these commodities on a supposedly representative small sample.

References:

Boskin, M.J. et al. (1996); Towards a more accurate measure of the cost of living, 1996, U.S. Senate.

Diewert, E. (1998); Measuring New Zealand's Productivity, 1998, Diewert Enterprises Ltd.

Lakin, C. et al. (1998); Report for the July 1998 working party, Eurostat study group on clothing, Eurostat.

Markle, T. (1998); An application of the hedonic approach to clothing items in the CPI (Paper 9), and A pilot study using checklists (Paper 11), 1998, Statistics Canada, Catalogue 62F0014MPB.

Nicholson, J.L. (1967); The measurement of quality changes, The Economic Journal, 77, 512-530.

Silver, M. (1999); The measurement of quality-adjusted prices, Proceedings of the Fifth Meeting of the International Working Group on Price Indices, Reykjavik, Aug 25-27, 1999.

Appendix A: Notes on regression studies on durable goods.

Type of study	Source of data	Results	Future development
Identification of significant characteristics for new single-family **housing** in Vancouver, 1974-1976, and direct estimate of price change from the movement of implicit prices and incidence of characteristics.	Information filed with mortgage insurance company. Selling price of property, appraised value of land, physical description of house and land, and neighbourhood amentities were provided.	Model determined high degree of price variation. Estimated price indexes, which rose sharply, considered credible in the context. Most coefficients could be directly related to costs of providing characteristic. All observations had equal weight in determining model, and selection was self-weighted for determining incidence.	Not used in regular production because capture of information (copying from xeroxed copies of forms) was expensive, and data was not filed until several months after the sale.
Identification of and estimation of prices for significant characteristics for about fifty **clothing** products, to provide a method to estimate quality difference by valuing changes in these characteristics when sample items change.	Field collection of occasional, augmented sample for individual products, the extra pricing being determined by the need to observe certain characteristics.	In early results, amount of variation accounted for varies from 50 to 80%, depending on product. Some characteristics are clearly proxies for other indicators of quality. First estimates suggest overall quality evaluation similar to current method.	Still under development. Probably will be implemented in production provided no major operational problems are discovered.
Estimation of prices for significant characteristics for **personal computers** for adjusting quality changes when sample items change. Follows U.S. identification.	In 1989/90, from street estimates of market monitoring company; 1995/96 from standing offer list to Canadian Federal Government; 1999, from market analyst, who is also providing prices	Model depends largely on speed, hard drive and RAM. Most changes in options, CD player, monitors, etc. are valued by option prices at time of replacement. With falling prices for characteristics, value estimates of differences from old model have been high. Recently value of changes has been deflated by price movement since reference period (1995/96).	Has been used in production indexes since 1991 and in CPI since 1995. Emphasis being put on more frequent model estimates, and accumulation of much larger database of prices.
Identification of significant characteristics for conventional colour **televisions**, up to 36", 1997-1998 and direct estimate of price change from the movement of implicit prices and incidence of characteristics.	Retail sales of models of televisions by month.	Very high degree of variation accounted for, largely due to variation in size. Much lower percentage of remaining variation accounted for if controlled for size. Most other significant characteristics are proxies for other indicators of quality. Similar indexes as are produced from estimates of matched samples – both much lower than index produced from survey data. Models were equally weighted for estimating regression model, sales data were used to determine incidence of characteristics.	Need to collect from broader sample of sellers. Undecided yet whether defects of matched sample or of regression method are greater. Have still to see effect of using currently varying list of characteristics instead of retrospectively determined best list.

Appendix B: Deriving the Quality Adjusted Back Price for a Replacement Item

Given the original model specification,

$$\log(P) = \beta_o + \sum_{i=1}^{k} \beta_i x_i + e \qquad (1)$$

The OLS regression technique yields the following equation,

$$\log(P) = b_o + \sum_{i=1}^{k} b_i x_i \qquad (2)$$

where b_i is the parameter estimate for β_i, and x_i is a variable representing the value of the i^{th} characteristic.

Now, assuming the same model applies in the current period (replacement) and the reference period (original), then the log change in prices from the reference period to the current period attributable to changes in any of the k quality characteristics can be derived from (2) as follows,

$$\log(P^{replacement}) - \log(P^{original}) = \sum_{i=1}^{k} b_i (x_i^{replacement} - x_i^{original}) \qquad (3)$$

Taking the natural exponent of both sides of equation 3 yields,

$$\frac{P^{replacement}}{P^{original}} = \prod_{i=1}^{k} e^{b_i (x_i^{replacement} - x_i^{original})} \qquad (4)$$

Since the price of the replacement item could not be observed in the reference period, its "back price" ($\tilde{P}^{replacement}$) must be estimated. This may be done by multiplying the original item's price by the hedonic model's adjustment factor as follows,

$$\tilde{P}^{replacement} = P^{original} \prod_{i=1}^{k} e^{b_i (x_i^{replacement} - x_i^{original})} \qquad (5)$$