

**Quality Adjustment of Second-hand Motor Vehicle –  
Application of Hedonic Approach in Hong Kong’s Consumer Price Index**

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**Abstract**

Adjustment for quality change is important in compiling pure price indices. In compiling a price relative of second-hand motor vehicle, comparing the price for the same brand and model between two reference time points may not be able to remove the portion of price change due to time depreciation perfectly. While a matched model approach is currently adopted in compiling the Consumer Price Index (CPI) for second-hand motor vehicle, hedonic regression models using characteristics price and time dummy variable methods have recently been examined. This paper presents the findings and shares some practical considerations.

## **Introduction**

In compiling a pure price index, it is crucial to compare the price of a product of constant quality over time. However, the quality of some products changes over time. The value of a second-hand motor car, for example, depreciates naturally in the course of time. In compiling a price relative for such products, comparing the price for the same brand and model between two reference time points may not be able to remove the portion of price changes due to such time depreciation perfectly. As an alternative to the matched model approach currently adopted in compiling Hong Kong's CPI for second-hand motor vehicle, the hedonic regression technique for quality adjustment, which is an explicit method practiced in some economies, has recently been examined. Hedonic regression models using characteristics price and time dummy variable methods have been considered for simulation study. This paper presents the preliminary results as compared with that compiled by the current approach; and shares some practical considerations in applying hedonic approach for quality adjustment of second-hand motor vehicle.

## **Hedonic regression**

2. A hedonic price function describes the relationship between characteristics of a product and its price. The economic theory underlying hedonic price functions rests on the hedonic hypothesis: goods are aggregation of characteristics. They are used to predict the price of new goods to adjust for quality change (Triplett, 2004). A hedonic price function uses regression analysis to predict the influence of product features on the sales price. Therefore price changes due to quality change in certain features can be distinguished and purged from the pure price change which the price index is actually called upon to measure.

3. The characteristic price index method and the time dummy variable method are common methodologies of applying hedonic regression. For the latter, price data in different reference periods are pooled together to form one single regression model, using additional time dummy variables to distinguish the reference time points of a particular record. As for the former, price data in different reference periods are treated by different models.

### Characteristic Price Index Method

4. For second-hand motor vehicles, characteristics being transacted included (i) displacement of the car engine; (ii) age of the motor vehicle at the time of transaction; and (iii) brand of the motor vehicle. These characteristics can be expressed as independent variables of a regression model on the price of motor vehicle in the form of

$$\ln(P_i) = \alpha + \beta_1 \ln(cc_i) + \beta_2 age_i + \sum_j \delta_j D_{ij} + \varepsilon_i \quad \dots (1)$$

where

$P_i$ : price of motor vehicle for the  $i$ -th observation

$cc_i$ : displacement of the car engine (in c.c.) for the  $i$ -th observation

$age_i$ : age (in year) of motor vehicle for the  $i$ -th observation

$D_{ij}$ : indicator variable for whether the  $i$ -th observation is of a specific brand  $j$

5. To compile the price relative for quarter  $t$ , a regression model based on the  $n$  observations for quarter  $t$  and another model based on  $m$  observations for quarter  $t-1$  are constructed. The motor vehicles data collected in quarter  $t-1$  were then put in the model of quarter  $t$  in order to estimate the transacted price if the motor vehicle had been transacted in quarter  $t$ . Average price relative is then compiled by taking geometric means of all cases.

### Time Dummy Variable Method

6. The time dummy variable method, which is another widely-used hedonic function approach, was also considered. A dummy variable  $t$  is added to indicator the reference quarter of the observations. In terms of the formulation of the index, there are two popular methods: fixed-based formulation and chained formulation.

7. The fixed-based formulation approach uses data of two consecutive quarters where a dummy variable  $T$  indicating the current quarter is added. The model can be expressed in the form of

$$\ln(P_i) = \alpha + \beta_1 \ln(cc_i) + \beta_2 age_i + \beta_3 T_i + \sum_j \delta_j D_{ij} + \varepsilon_i \quad \dots (2)$$

where

$T_i = 1$  for observation  $i$  collected in quarter  $t$

$= 0$  for observation  $i$  collected in quarter  $t-1$

8. The chained formulation approach deploys data of several successive quarters. Suppose data collected from four successive quarters are to be used, the regression model will contain three time dummy variables and look like

$$\ln(P_i) = \alpha + \beta_1 \ln(cc_i) + \beta_2 age_i + \gamma_0 T_{0,i} + \gamma_1 T_{1,i} + \gamma_2 T_{2,i} + \sum_j \delta_j D_{ij} + \varepsilon_i \dots (3)$$

where

$T_{0,i}$  = 1 for observation  $i$  collected in quarter  $t$   
= 0 otherwise

$T_{1,i}$  = 1 for observation  $i$  collected in quarter  $t-1$   
= 0 otherwise

$T_{2,i}$  = 1 for observation  $i$  collected in quarter  $t-2$   
= 0 otherwise

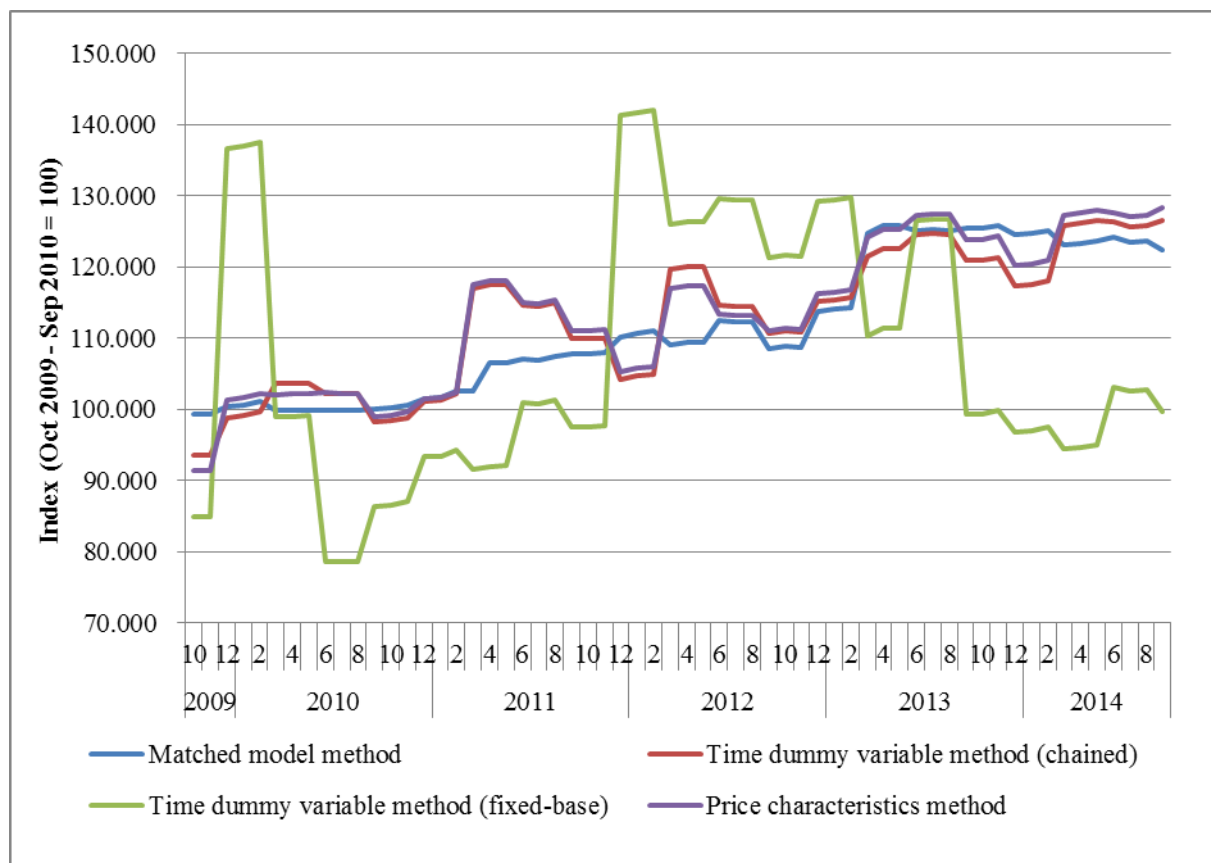
9. By pooling data of four successive quarters, the average price relatives can be derived through matching different combinations of the price data (e.g. comparing the actual transaction prices of each vehicle transacted in quarter  $t-3$  with the estimated prices at quarter  $t$ ; and then taking arithmetic mean, which can be denoted as  $PR_{t,t-3}$ ). As such, the average price change for quarter  $t$  as compared to quarter  $t-1$  can be derived in three ways, namely  $PR_{t,t-1}$ ;  $[PR_{t,t-2} / PR_{t-1,t-2}]$  and  $[PR_{t,t-3} / (PR_{t-2,t-3} PR_{t-1,t-2})]$ . An overall average price relative from  $t-1$  to  $t$  can then be derived by taking geometric mean of these three price relatives.

### **Simulation results**

10. Price relatives for second-hand motor vehicle for the period October 2009 – September 2014 are recompiled by using formulae (1), (2) and (3). All three hedonic approaches yield similar goodness of fit as indicated by the R-square of around 0.8.

11. The published CPI sub-index for “Purchases of and repairs to motor vehicles”, of which the purchase of second-hand motor vehicles is the major component, using the matched-model approach is compared to the simulated index using the above three hedonic methods (see Chart 1). The general trend for those compiled using the characteristic price and time dummy variable (chained formulation) approaches are rather similar, whereas relatively large fluctuations are observed for that simulated using the time dummy variable (fixed-based formulation). The direction of movement and the level of the indices compiled by the former two approaches are broadly in line as compared to the published index.

**Chart 1: Index for “Purchases of and repairs to motor vehicles” in the Composite CPI compiled by the current and hedonic approaches**



### Advantages of applying hedonic approach

12. Being an explicit method of quality adjustment, hedonic regression is appropriate where data on price and characteristics are available for a range of models and where the characteristics are found to predict and explain price variability well in terms of priori reasoning and econometric terms. This fits in well with the data availability of second-hand cars and the general perception on the relationship between price and characteristics of a second-hand motor vehicle.

13. Moreover, price quotations collected can be more thoroughly utilized when applying hedonic approach because all observations under those selected brands are considered as inputs to the regression model. This contrast to the matched-model approach where only those observations which can be matched with those transacted in the previous period would be included in the index compilation.

## **Practical considerations**

14. Large amount of data is required to ensure good predictive power of the regression model. Gathering adequate data is costly in terms of human resources and time. In particular, the chained formulation of time dummy variable approach requires more observations for the regression model since more independent variables are involved. Additional price quotation would thus need to be collected. While data collection is now performed in various second-hand car dealers each month, it is worthwhile exploring ways of collecting more price quotations through alternative channels such as the Internet.

15. The selection of independent variables has to be reviewed from time to time (say once per few years) so as to catch up with the market development as some brands may become more popular or alternative factors (e.g. odometer reading) which would affect the prices of second-hand motor vehicles may emerge.

16. Periodic review on the selection of model and transformation of variables is also necessary. In particular, for the characteristic price index approach, each hedonic function can be different in each reference period. There can be numerous choices on the model and transformation of variables. Different transformation may result in different interpretation over the parameter estimates. For some functional forms, those estimates may even be impossible to interpret in an economic way (Triplett, 2004).

## **Concluding remarks**

17. This paper presents the simulation results of deploying hedonic methods for quality adjustments of second-hand motor vehicles for the CPI compilation. Hedonic method is preferred to the matched-model method since it could utilize the data collected more thoroughly and take into account the quality characteristics. The sample size of second-hand motor vehicle and the effectiveness of the hedonic models will be kept under review and optimized as appropriate. With the accumulation of sufficient data collected under the hedonic approach, timely assessments will be made to compare the results of the parallel compilation concurrent with that under the current matched model with a view to switching to the hedonic approach in relevant CPI compilation.

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