Revision of the Hedonic Quality Adjustment Method
in the Corporate Goods Price Index and the Services Producer Price Index

Research and Statistics Department

Bank of Japan

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Abstract

The Research and Statistics Department (RSD) of the Bank of Japan applies the hedonic quality adjustment method in the compilation of the Corporate Goods Price Index (CGPI) and the Services Producer Price Index (SPPI). The hedonic quality adjustment method is not only a highly objective quality adjustment method, but as the relationship between price and characteristic are estimated statistically, is also applicable to a broad range of changes in product characteristics. Consequently, the hedonic quality adjustment method has been applied to nine products including, for example, IT-related products and passenger cars.

The RSD has reviewed the hedonic quality adjustment method, and in order to deal with multicollinearity and the omitted variable problem—both of which are well known to exist—has decided to employ a new estimation method using sparse estimation for the hedonic regression models. The new estimation method allows the RSD to quantify a larger number of price and characteristic relationships through the increased number of explanatory variables used in the regression models. It will also improve the fit of regression models to actual prices as a whole.

In response to the revision of the estimation method and recent changes in market structure—such as a leveling off or a reduction of the market size and an extension in product life cycle—the RSD has also decided to terminate the application of the hedonic quality adjustment to several products, to integrate part of the hedonic regression models and to decrease the frequency of re-estimation of the models for some other products.

With these revisions, the RSD intends to enhance the price index and improve its accuracy while facilitating more efficient compilation of statistics. The RSD would like to start to apply these revisions to the CGPI and the SPPI from December 2020.

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1. Introduction

The Research and Statistics Department (RSD) of the Bank of Japan applies the hedonic quality adjustment method in the Corporate Goods Price Index (CGPI) and the Services Producer Price Index (SPPI). To compile the price index, the prices of the same goods and services must be surveyed on a continuous basis. Therefore, in the case of product turnover accompanied by a quality change, the difference in the observed prices between new and old products should be decomposed into a quality change and a pure price change, and then only the latter should be counted in the price index. This treatment is called the quality adjustment in the practice of compilation of the price index.

The hedonic quality adjustment method, which is one of the major quality adjustment methods, is not only a highly objective quality adjustment method, but as the relationship between price and characteristic are estimated statistically, is also applicable to a broad range of changes in product characteristics. In addition, this method is likely to reduce reporting costs for firms as it generally does not require firms to provide information regarding quality change. Taking these advantages into account, the RSD has applied the hedonic quality adjustment method to nine products: "smartphones," "LCD televisions," "digital cameras (compact digital cameras, mirrorless interchangeable-lens cameras, and digital single-lens reflex cameras)," "computers (desktop computers, notebook computers, and tablet computers)," and "passenger cars."[1] In the application of the hedonic quality adjustment method, the RSD has employed the estimation method with the regression model using Box-Cox transformed terms, and has re-estimated the regression models 14 times in total over a year to appropriately reflect technological innovations and demand changes in markets (Chart 1).

Although the hedonic quality adjustment method is highly useful, there are also a number of issues relating to improving the accuracy of its estimation. In particular, the importance of treatments for multicollinearity and the omitted variable problem have been well known for a long time. In addition, there is a significant workload involved in mainly the construction of a large dataset and in the estimation itself. Therefore, the RSD has selected the estimation method and target products in the hedonic quality adjustment for the CGPI and the SPPI, while taking both improvement in the precision of the price index and its cost (including operational costs) into consideration.

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[1] Specifically, the hedonic regression models are applied to the quality adjustments for the sample replacements for these nine products in the CGPI, and for the sample replacements for the corresponding products (computers and LCD televisions) used as rental assets for the group "Rental" in the SPPI.

Keeping these points in mind, the RSD conducted a review of the hedonic quality adjustment method in the CGPI and the SPPI. Based on the results of that review, the RSD has decided to employ the new estimation method with sparse estimation for the hedonic regression models to deal with the aforementioned issues in the estimation[2]. With the application of the new estimation method, "mirrorless interchangeable-lens cameras" and "digital single-lens reflex cameras" are integrated into "digital interchangeable-lens cameras." Reflecting recent changes in market structure, the RSD has terminated the application of the hedonic quality adjustment to "compact digital cameras" and "tablet computers." In addition, the RSD has also decided to decrease the frequency of re-estimation of the hedonic regression models for "desktop computers" and "notebook computers" from twice yearly to once yearly reflecting the extending life cycle of the product.

As a result of these revisions, the scope for applying the hedonic quality adjustment and the frequency of re-estimation of the regression models have been amended as shown in Chart 1. It should be noted that the re-estimation results will be published on the Bank's website with the summary of revisions if the data and the method used in the estimation are revised.

In the following sections, this paper explains the details of these revisions and the estimation results of the hedonic regression models using the new estimation method.

2. Revision of the Estimation Method

As for the hedonic quality adjustment method, a number of estimation issues have been well known for a long time. For example, the estimation results are not stable due to multicollinearity, and the parameters can be biased by omitted variables, when the explanatory variables (characteristics in the hedonic regression model) are highly correlated. In practice, it is likely, for instance, that the first issue could result in insignificant coefficients for some characteristics in the model due to the high correlation among those characteristics given that high-end products generally have a wider range of features than low-end products. Regarding the second issue, omitted characteristics could generate bias—such as through over-stating the effects of included characteristics on price—if the significant characteristics are the only ones selected in the estimation of a regression model.

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[2] For the summary of the new estimation method, see Box.

In order to deal with these problems, the RSD has decided to employ the new estimation method with sparse estimation for the hedonic regression models. Estimation results using the new estimation method show that compared with the current estimation method, the number of explanatory variables in the regression models increase and this is accompanied by a reduction in dependence on just a few specific variables (Chart 2 and 3). For instance, regarding the driving performance of passenger cars, in addition to the maximum output, which has been already included in the current model, the new estimation method enables the incorporation of characteristics related to the acceleration performance into the model, such as number of gears and maximum torque. Similarly, it also allows the assessment of CPU characteristics—which determine the basic performance of a computer—using not only maximum clock speed (as in the current method), but also the number of cores and the thread count.

In addition, the fit of regression models to actual price generally improves in the new estimation method for both in-sample and out-of-sample (Chart 4). It is implied, however, that these improvements are relatively marginal for products such as LCD televisions and computers which are likely to have a relatively simple relationship between characteristics and prices.

The impact of this revision on the price index is likely to be limited. Looking at the price index of "standard passenger cars (gasoline cars)" in the PPI, it can be seen that the estimated index, which is retrospectively calculated by applying the new hedonic estimation method to all quality adjustments, shows similar developments to the current published price index (Chart 5)[3].

In addition, it has become possible to incorporate heterogeneity between different product types (i.e. the effects of the particular characteristic on the price differ depending on product types) thanks to more interaction effects in regression models under the new estimation method. Therefore, the RSD has decided to integrate "mirrorless interchangeable-lens cameras" and "digital single-lens reflex cameras," which are currently regressed separately, into "digital interchangeable-lens cameras" (Chart 2 - 4).

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[3] In practice in the compilation of the CGPI, even if the hedonic quality adjustment method is available for a product, the RSD would choose the most appropriate method, based mainly on a plausibility check of an estimated quality improvement with a firm and a comparison using estimates of other quality adjustment methods such as the production cost method. As mentioned in the text, similar developments between the current published index and the estimated index based on the new estimation method would imply not only the plausibility of the hedonic quality adjustment based on the new estimation method, but also the possible increase in the number of cases where the hedonic quality adjustment is applied.

It should be noted that the characteristics of the new method, such as automatic variable selection in the regression model, would also promote more efficient compilation of statistics through the reduction of practical workloads mainly in the estimation.

3. Revisions Reflecting Changes in Market Structure, etc.

On the other hand, regarding "compact digital cameras" and "tablet computers," domestic production of these products has been on a decreasing trend while the market size has been leveling off or shrinking in Japan (Chart 6). Given a decreasing trend of the number of these products surveyed in the CGPI under the current market situation, the RSD has decided to terminate the application of the hedonic quality adjustment to these products in light of the balance of costs and benefits of the method.

In addition, the RSD has also decided to decrease the frequency of re-estimation of the hedonic regression models of "desktop computers" and "notebook computers" from twice yearly to once yearly, reflecting the extending product life cycle (Chart 7). It should be noted that the effect of a decrease in the frequency of re-estimation on the precision of the price index would be marginal.

4. Estimation Results by New Estimation Method

Estimation results of "passenger cars," "digital interchangeable-lens cameras," "smartphones," "desktop computers," "notebook computers," and "LCD televisions" using the new estimation method are shown in Charts 8 - 13. It should be noted that the re-estimation results will be published on the Bank's website with the summary of revisions as long as the data and the method used in the estimation are revised.

5. Final Remarks

This paper has explained the revisions of the hedonic quality adjustment method in the CGPI and the SPPI. These revisions will contribute not only by enhancing the price index and improving its accuracy, but also facilitate the more efficient compilation of these statistics. The RSD would like to start to apply these revisions to the CGPI and the SPPI in December 2020.

The RSD would like to thank the many academics for their valuable comments in the process of these revisions. The RSD will continue its efforts to improve its price index and the efficiency of the compilation of its statistics through the replacement of sample

prices and the continual review of pricing methods in addition to the review of quality adjustment methods.

Box: Summary of the new estimation method using sparse estimation

As mentioned above, the RSD has decided to employ a new estimation method using sparse estimation for the hedonic regression model. This box provides an overview of the new estimation method and compares it to the current method[4].

Taking into account the nonlinear relationship between the price and characteristic of a product, the current method has estimated the following hedonic regression model with the Box-Cox transformed term[5], by using the ordinary least squares (OLS) method.

Current estimation method: Hedonic regression model with the Box-Cox transformed term

$$y_i^{(\lambda_0)} = \beta_0 + \sum_{j=1}^{p_c} \beta_{cj} x_{cj,i}^{(\lambda_j)} + \sum_{k=1}^{p_d} \beta_{dk} x_{dk,i} \tag{1}$$

y_i: theoretical price, $x_{cj,i}$: continuous variable, $x_{dk,i}$: dummy variable,

β_0: constant term, β_{cj}: coefficient on a continuous variable,

β_{dk}: coefficient on a dummy variable,

λ_0: Box-Cox parameter for theoretical price,

λ_j: Box-Cox parameter for a continuous variable,

p_c: number of continuous variables, p_d: number of dummy variables

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However, there are some issues with the current method in that the parameters are not stable due to multicollinearity and omitted variables, which can cause bias in the parameters when the explanatory variables (characteristics in the hedonic regression model) are highly correlated.

In particular, it is known that the omitted variable bias becomes more severe on complex functional forms, and it poses a risk of generating downward bias in the price index through an overestimation of the rate of quality improvement.

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[4] For a detailed description of the new method (including empirical analysis), see the following paper.
Furuta, Hatayama, Kawakami, and Oh, "New Hedonic Quality Adjustment Method using Sparse Estimation," Bank of Japan Working Paper Series, *Forthcoming*.

[5] The Box-Cox transformation of a variable x with the Box-Cox parameter (λ) is as follows.

$$x^{(\lambda)} = \begin{cases} \dfrac{x^\lambda - 1}{\lambda} & (\lambda \neq 0) \\ \log x & (\lambda = 0) \end{cases}$$

To deal with the aforementioned issues, the RSD has decided to employ the new estimation method with "adaptive elastic net: AEN", a type of sparse estimation[6]. Sparse estimation performs variable selection and coefficient estimation at the same time under the property called "sparsity"[7]. This method has an advantage over the current one with the OLS method in that it can automatically derive a more stable and fitted model. In addition, the AEN incorporates the L_1 norm (sum of absolute values) and the L_2 norm (sum of squares) of coefficients as regularization terms in the two-stage estimation of coefficients (see equations (3)-(5) below). Then it enjoys two desirable properties: the "Grouped Effect" that gives robustness for multicollinearity and the "Oracle Property" that ensures the adequacy of variable selection and coefficients.

Given these properties, the new estimation method selects variables and a functional form simultaneously by extracting variables from the quadratic multivariate regression model with interaction terms, shown as equation (2), in the AEN estimation. Note that this regression model is to incorporate interaction effects among characteristics of a product while maintaining the nonlinear relationship between price and characteristic in the regression model.

New estimation method: Hedonic regression model with the AEN estimation

$$Y_i \equiv \log y_i$$

$$Y_i = \hat{\beta}_{00} + \sum_{j=1}^{p} \hat{\beta}_{0j} x_{j,i} + \sum_{j=1}^{p} \hat{\beta}_{jj} x_{j,i}{}^2 + \sum_{k>j\geq1} \hat{\beta}_{jk} x_{j,i} x_{k,i} \qquad (2)$$

where

$$\hat{\boldsymbol{\beta}} = \left(1 + \frac{\lambda_2}{n}\right) \left\{ \underset{\boldsymbol{\beta}}{\text{argmin}} \left(|\boldsymbol{Y} - \boldsymbol{X}\boldsymbol{\beta}|^2 + \lambda_2 \sum_{k\geq j\geq 0} \beta_{jk}{}^2 + \lambda_1{}^* \sum_{k\geq j\geq 0} \widehat{w}_{jk} |\beta_{jk}| \right) \right\} \qquad (3)$$

$$\widehat{w}_{jk} = \left(\left| \hat{\beta}_{jk}{}^{1st} \right| \right)^{-\gamma} \qquad (4)$$

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[6] For details of the AEN, see the following article.

    Zou, H. and Zhang, H. H., "On the Adaptive Elastic-Net with a Diverging Number of Parameters," *The Annals of Statistics*, Vol. 37(4), pp. 1733-1751, 2009.

[7] "Sparsity" refers to a property that selects only the meaningful variables from many explanatory variables and gives exactly zero coefficients to the rest of the variables.

$$\widehat{\boldsymbol{\beta}}^{1st} = \left(1 + \frac{\lambda_2}{n}\right)\left\{\underset{\boldsymbol{\beta}}{\mathrm{argmin}}\left(|\boldsymbol{Y} - \boldsymbol{X}\boldsymbol{\beta}|^2 + \lambda_2\sum_{k \geq j \geq 0}\beta_{jk}^{~2} + \lambda_1\sum_{k \geq j \geq 0}|\beta_{jk}|\right)\right\} \quad (5)$$

y_i: theoretical price, $x_{j,i}$: explanatory variable, $\hat{\beta}_{jk}$: coefficient on $x_{j,i}x_{k,i}$,

p: number of candidate explanatory variables, n: number of samples in dataset,

$\lambda_1 > 0$: L_1 norm regularization parameter (1st stage),

$\lambda_1^{~*} > 0$: L_1 norm regularization parameter (2nd stage),

$\lambda_2 > 0$: L_2 norm regularization parameter,

$\gamma > 0$: adaptive parameter, $\widehat{w}_{jk} > 0$: adaptive weight

The introduction of the new estimation method is expected to make the price index more accurate by improving the precision of the hedonic quality adjustment and the possible increase in the number of cases where the hedonic quality adjustment is applied. Regarding the efficiency of compilation of statistics, the new estimation method is a highly useful method as it can automatically build a good performance model by extracting all necessary information even with the large dataset.
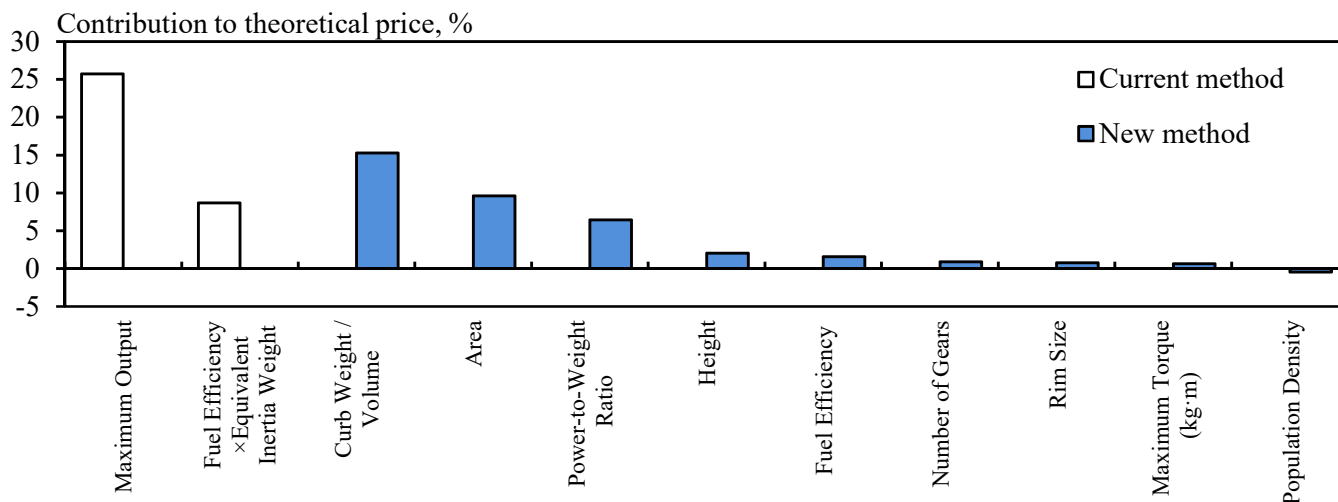
Chart 1

Scope for Applying Hedonic Quality Adjustments
in the CGPI and the SPPI

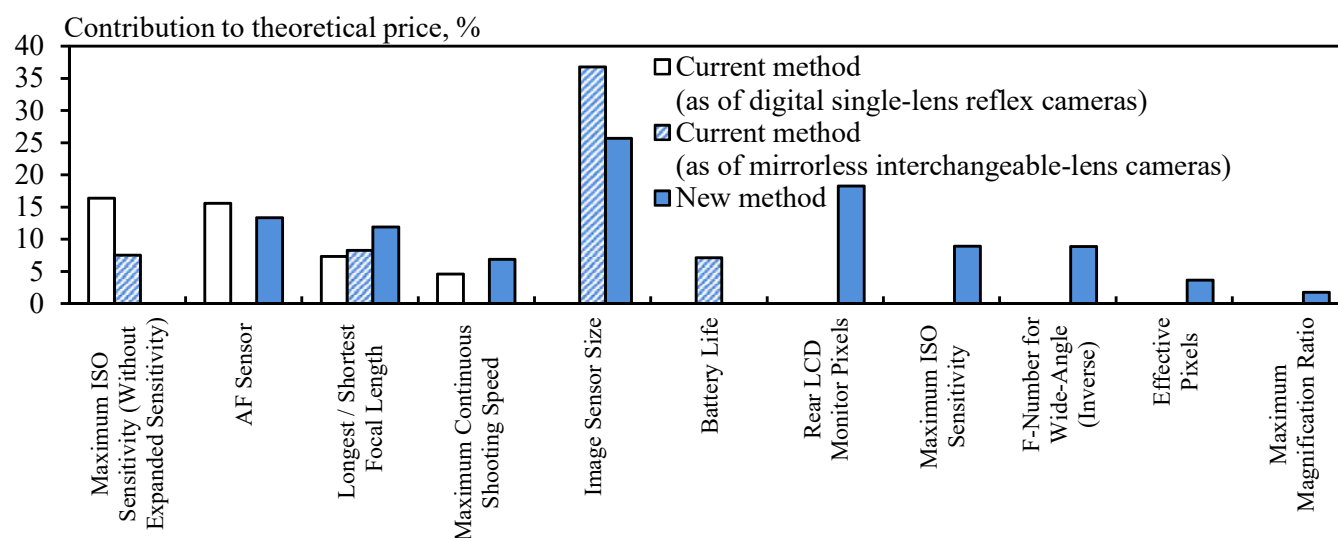| Target products	Frequency of re-estimation	
	Current	Revised
Passenger cars	1 time per year	1 time per year
Mirrorless interchangeable-lens cameras	1 time per year	1 time per year (Integrated)
Digital single-lens reflex cameras	1 time per year	
Smartphones	2 times per year	2 times per year
Desktop computers	2 times per year	1 time per year
Notebook computers	2 times per year	1 time per year
LCD televisions	1 time per year	1 time per year
Compact digital cameras	2 times per year	Terminated
Tablet computers	2 times per year	Terminated

Note: The hedonic regression models are applied to the quality adjustments for the sample replacements for these nine products in the CGPI, and for the sample replacements for the corresponding products (computers and LCD televisions) used as rental assets for the group "Rental" in the SPPI.

Chart 2-1

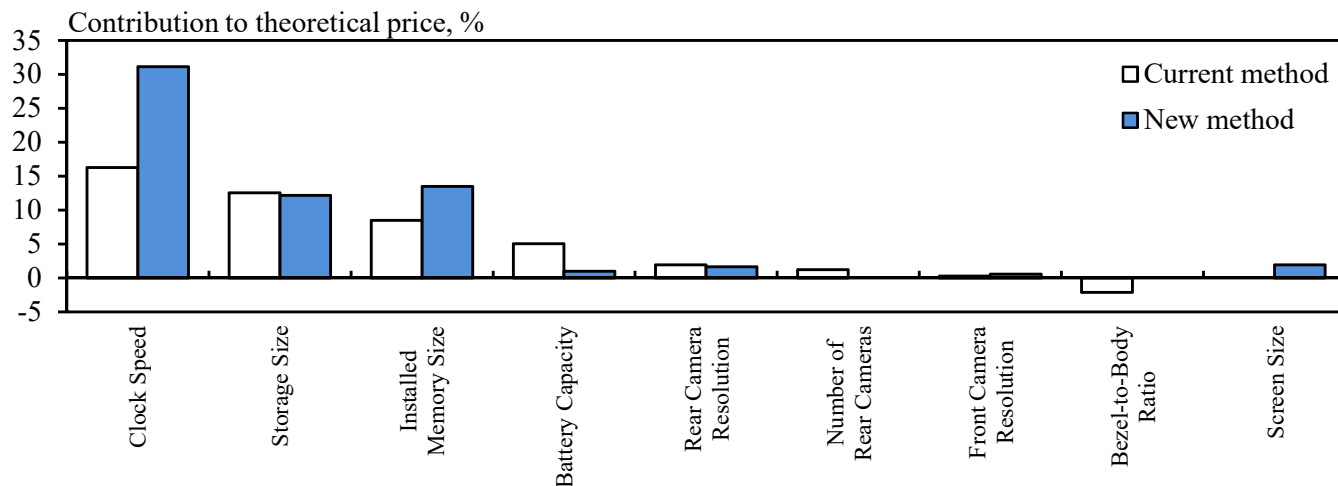# Continuous Variables in Hedonic Regression Models

(1) Passenger Cars

(2) Digital Interchangeable-lens Cameras
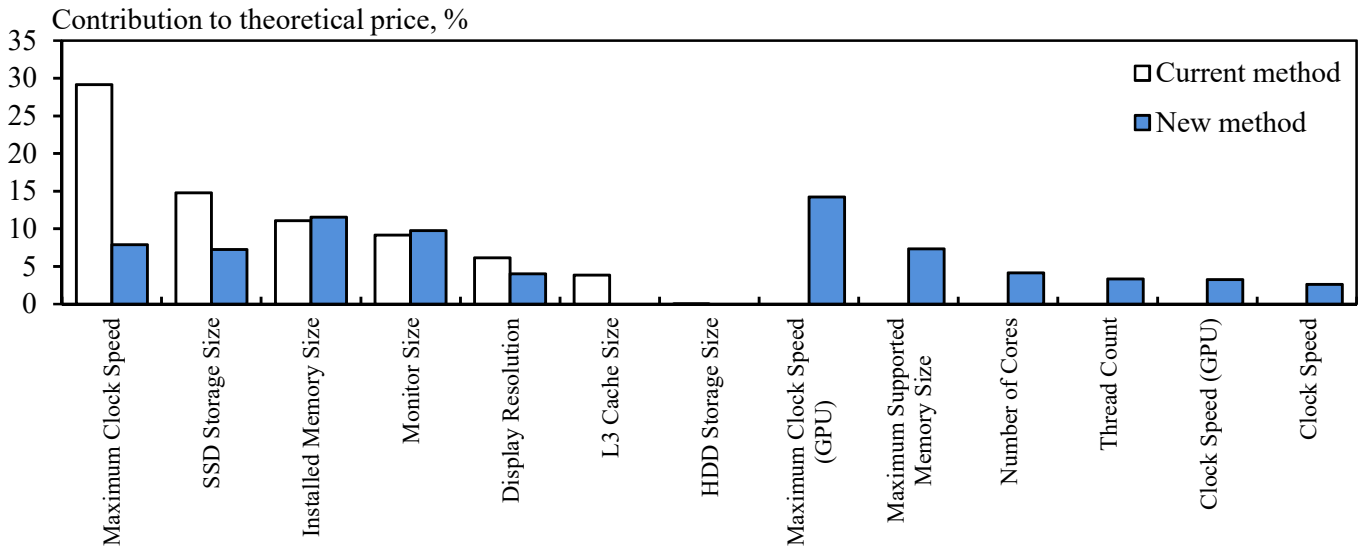

(3) Smartphones

Notes: 1. Bar charts indicate the rates of change in theoretical price due to one standard deviation increase in variables where all variables of a product are set at sample means.
2. Figures for passenger cars are those for sedan and wagon.

Chart 2-2

Continuous Variables in Hedonic Regression Models

(4) Desktop Computers

Contribution to theoretical price, %

(5) Notebook Computers

Contribution to theoretical price, %

(6) LCD Televisions

Contribution to theoretical price, %

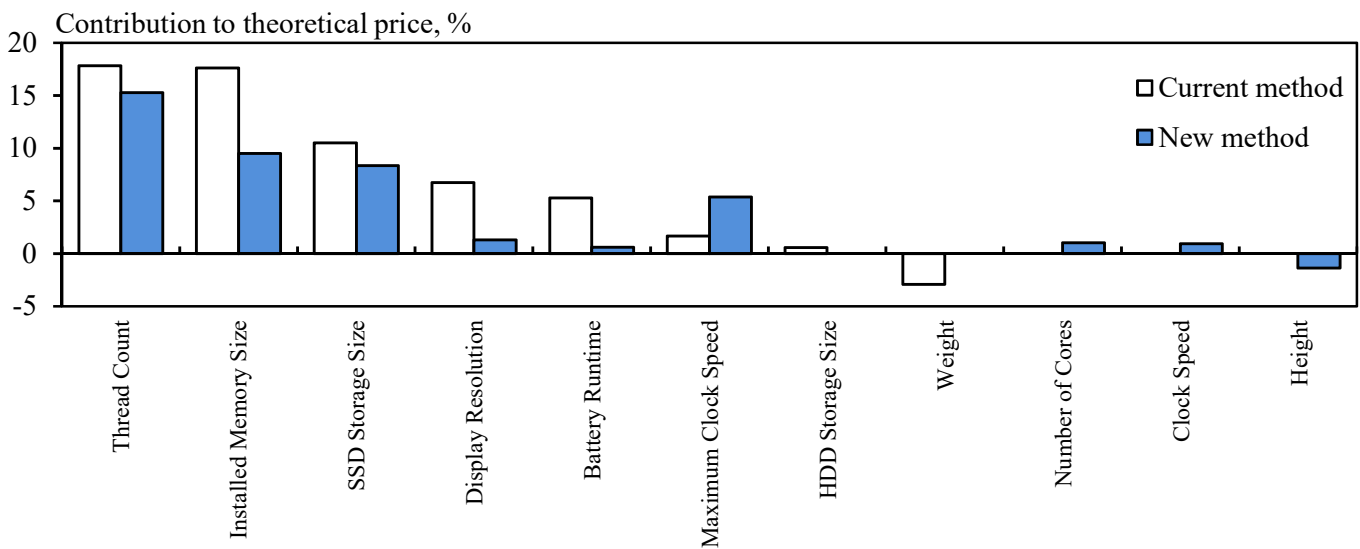Note: Bar charts indicate the rates of change in theoretical price due to one standard deviation increase in variables where all variables of a product are set at sample means.

Chart 3-1

Dummy Variables in Hedonic Regression Models

(1) Passenger Cars

Contribution to theoretical price, %

☐ Current method
■ New method

(2) Digital Interchangeable-lens Cameras

Contribution to theoretical price, %

☐ Current method
(as of digital single-lens reflex cameras)
▨ Current method
(as of mirrorless interchangeable-lens cameras)
■ New method

(3) Smartphones

Contribution to theoretical price, %

☐ Current method
■ New method

Notes: 1. Bar charts indicate the rates of change in theoretical price due to one unit increase in variables
where all variables of a product are set at sample means.
2. Figures of dummy variables regarding manufacturers and time, etc. are not shown.
Figures for passenger cars are those for sedan and wagon.
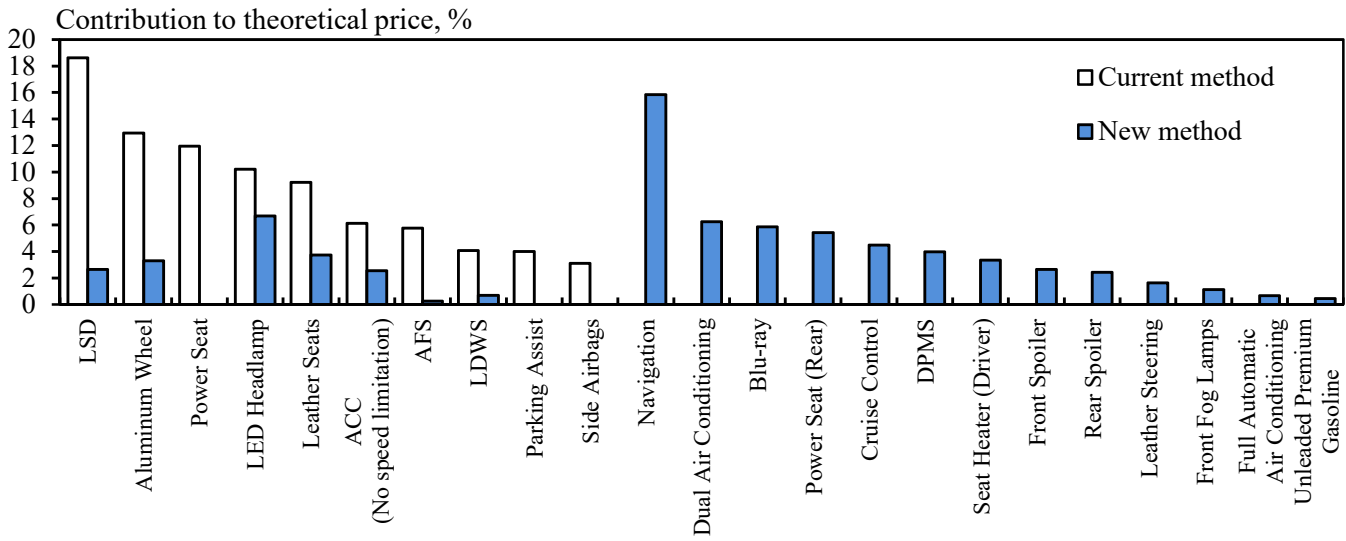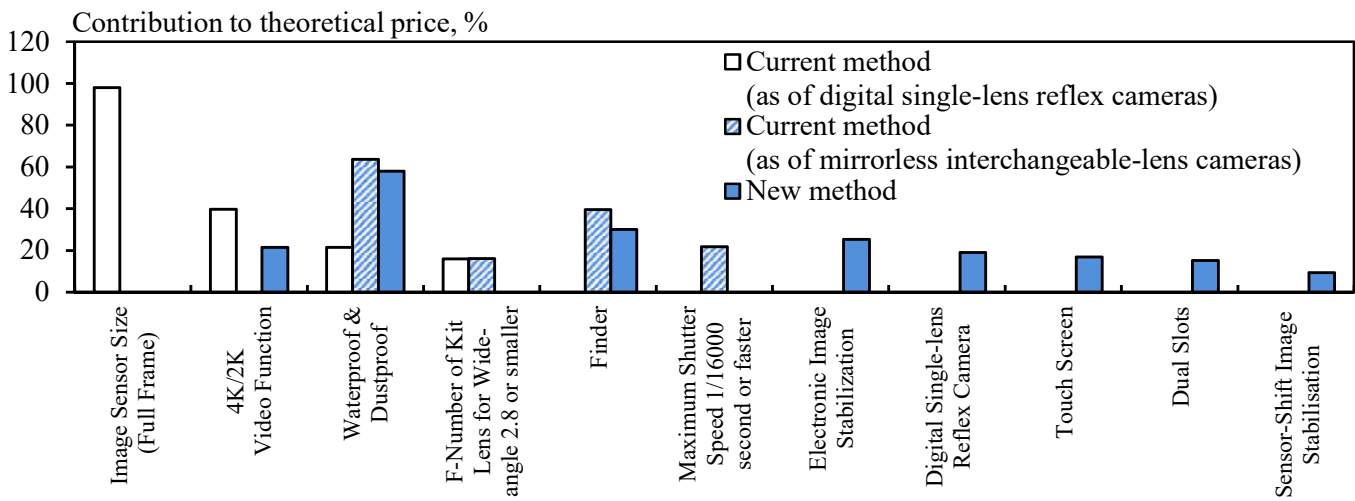
Chart 3-2

Dummy Variables in Hedonic Regression Models

(4) Desktop Computers

Contribution to theoretical price, %

□ Current method
■ New method

Blu-ray Disc Drive / Microsoft Office / TV Tuner / All-in-One Computer / Windows 10 Pro 64bit / Turbo Boost Technology / Hybrid HDD and SSD / HDMI Terminal / Chrome OS / eMMC / No L3 Cache

(5) Notebook Computers

Contribution to theoretical price, %

□ Current method
■ New method

L3 Cache / Microsoft Office / LTE / Touch Screen Display / Blu-ray Disc Drive / NVIDIA GPU / No L3 Cache / eMMC

(6) LCD Televisions

Contribution to theoretical price, %

□ Current method
■ New method

Portable / HDD / Video On Demand / Refresh Rate (120Hz) / BS/110°CS 4K Broadcasting Tuner / 3 or more Speakers / HDMI-CEC / HDR / Cable LAN / Wireless LAN
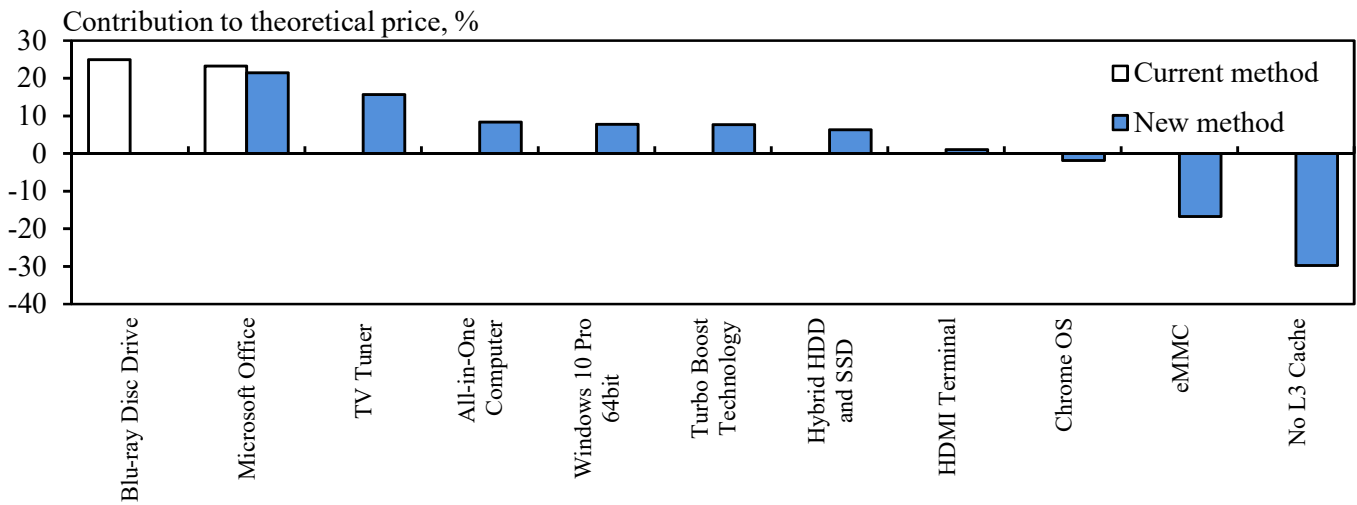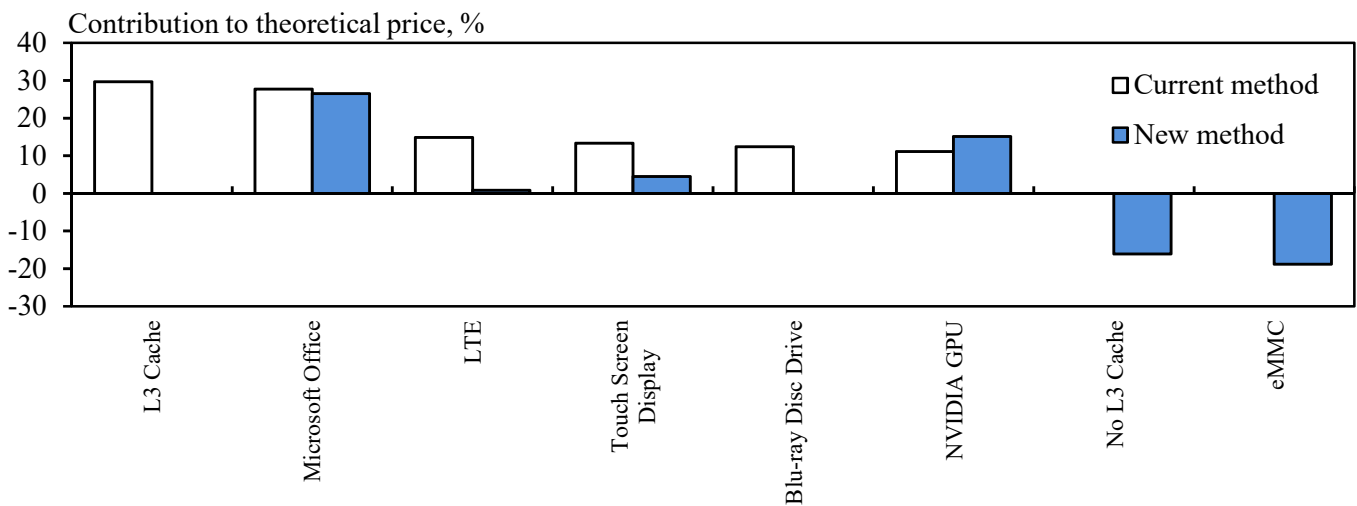
Notes: 1. Bar charts indicate the rates of change in theoretical price due to one unit increase in variables
where all variables of a product are set at sample means.
2. Figures of dummy variables regarding manufacturers and time, etc. are not shown.

Chart 4

Fit of Hedonic Regression Models

(1) Passenger Cars

(2) Digital Interchangeable-lens Cameras

(3) Smartphones

(4) Desktop Computers

(5) Notebook Computers
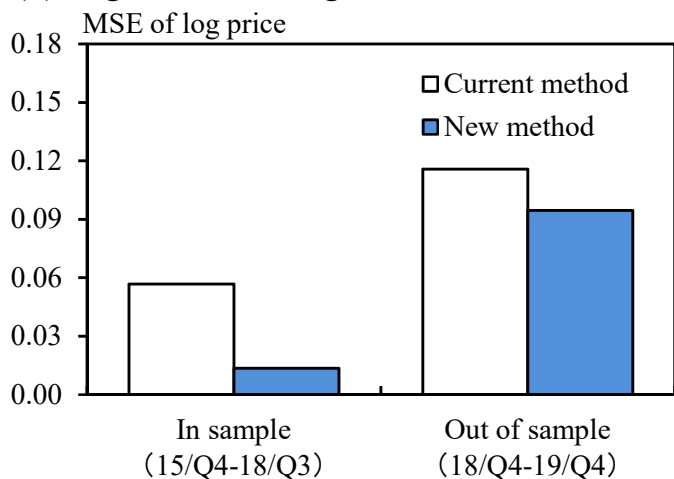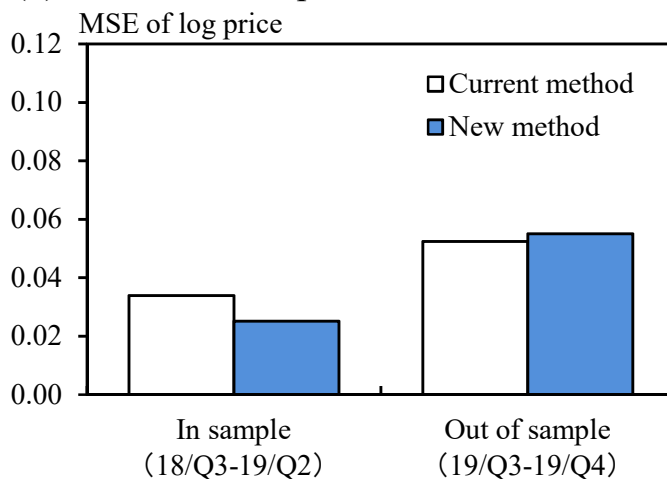
(6) LCD Televisions

Chart 5
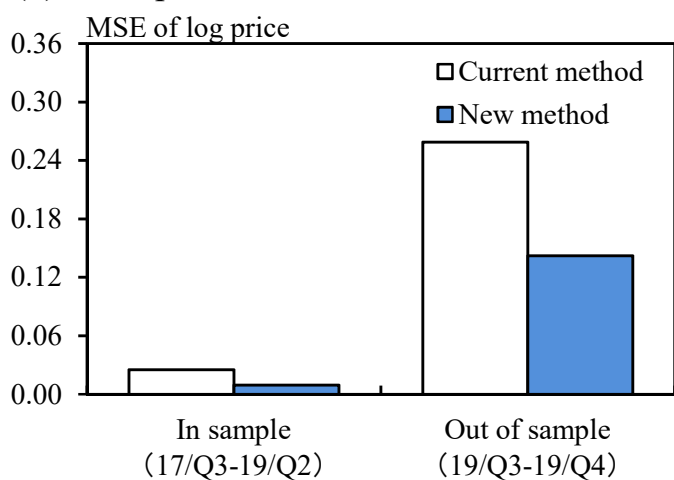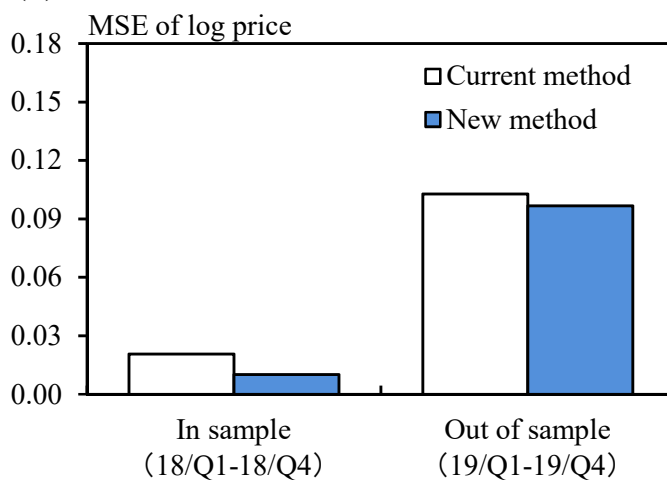
Estimated Price Index Adjusted by the New Method

PPI: Standard Passenger Cars (Gasoline Cars)
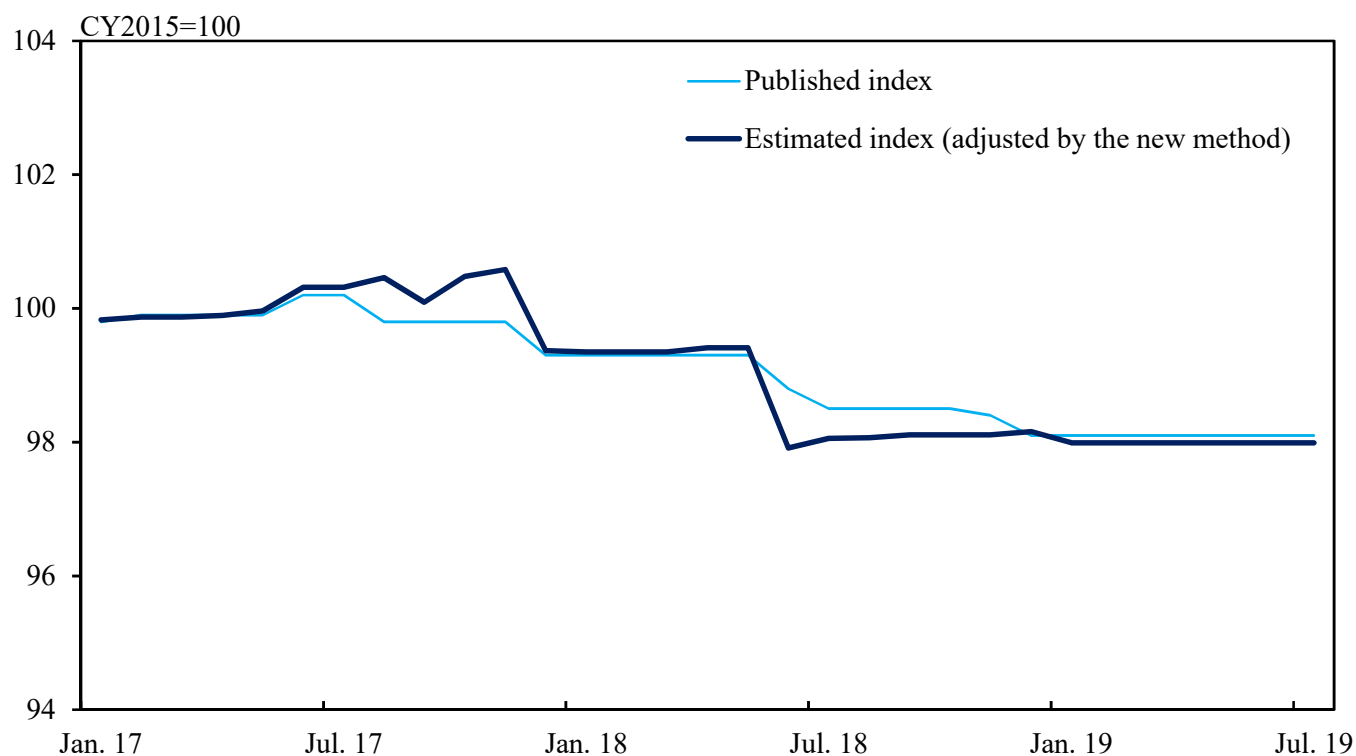
Note: Estimated index is calculated by applying the new hedonic quality adjustment method to all past sample replacements.

Source: Furuta, Hatayama, Kawakami, and Oh, "New Hedonic Quality Adjustment Method using Sparse Estimation," Bank of Japan Working Paper Series, *Forthcoming*.

Chart 6

Market Size

(1) Tablet Computers (Domestic Shipments)

10 thous. units
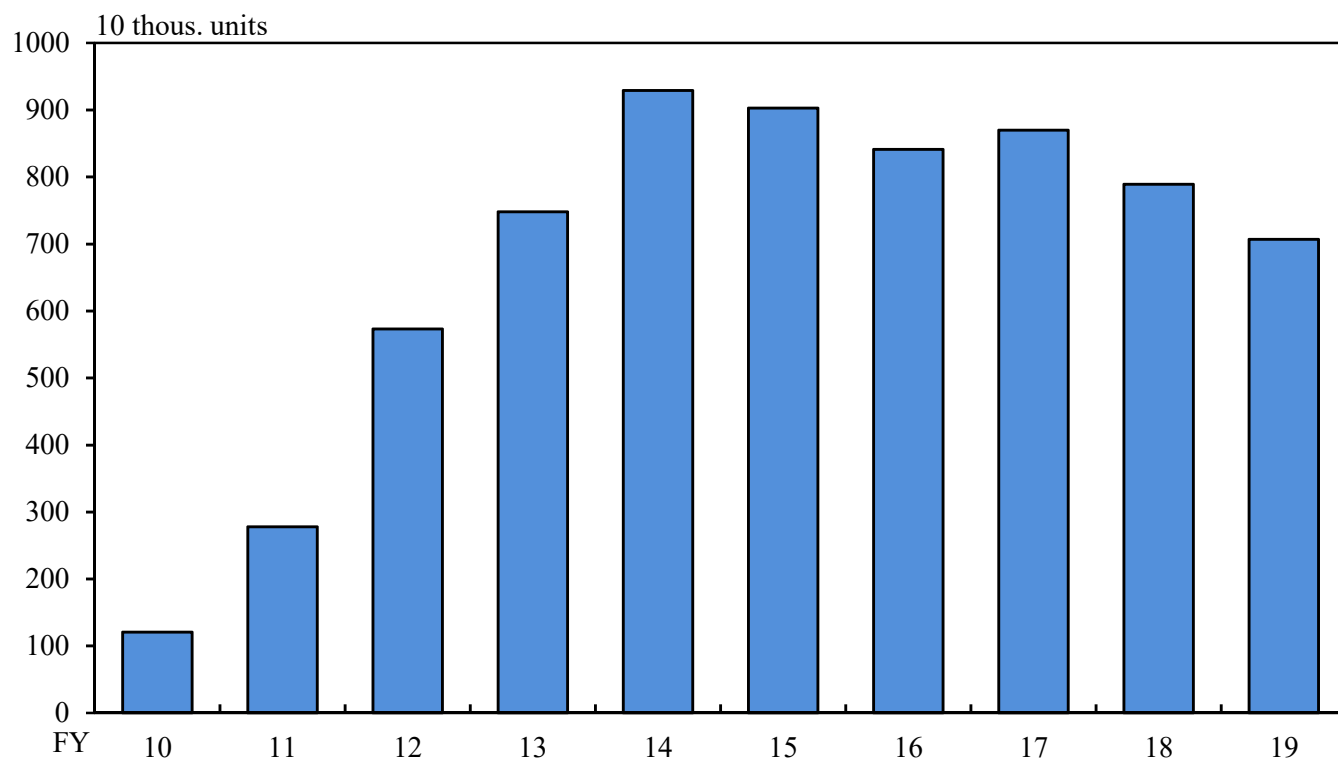
(2) Digital Cameras (Shipments to Japan)

100 mil. yen

- □ Digital interchangeable-lens cameras
- ■ Compact digital cameras
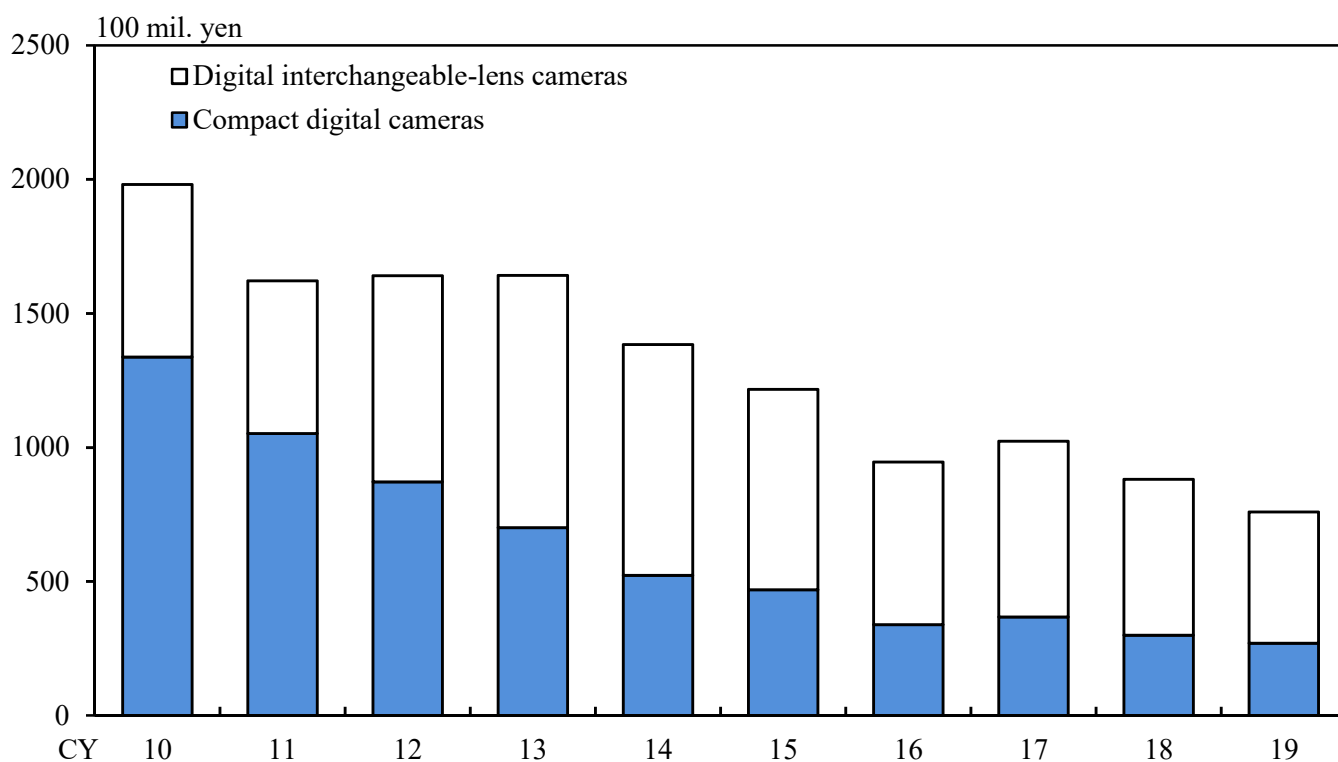
Notes: 1. Figures in (1) and (2) are based on surveys by the MM Research Institute and the CIPA, respectively.
    2. Figures in (1) include imports.
Sources: MM Research Institute, CIPA.

Chart 7

Replacement Cycle

(1) Average Number of Days Listed in the BCN Ranking of Computers

days

Notebook computers
Desktop computers
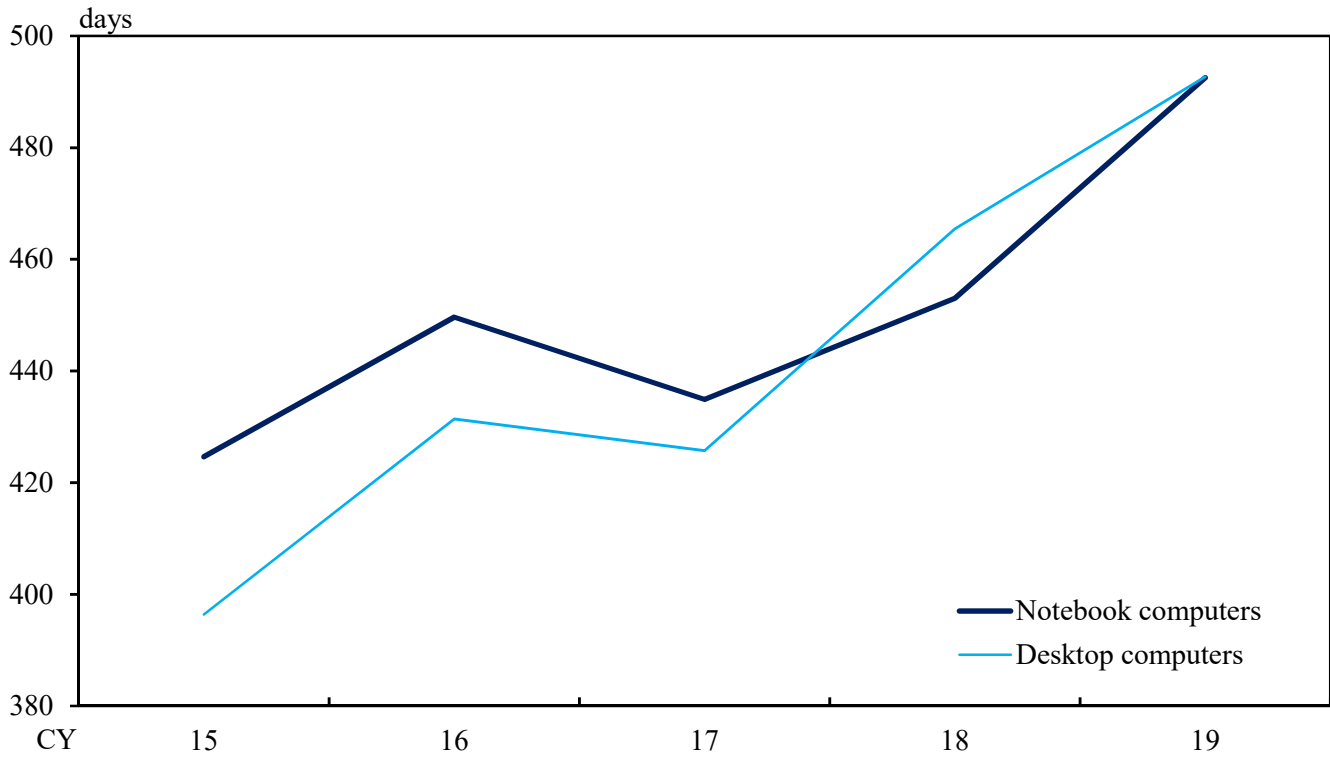
(2) Average Years of Use of Computers

years
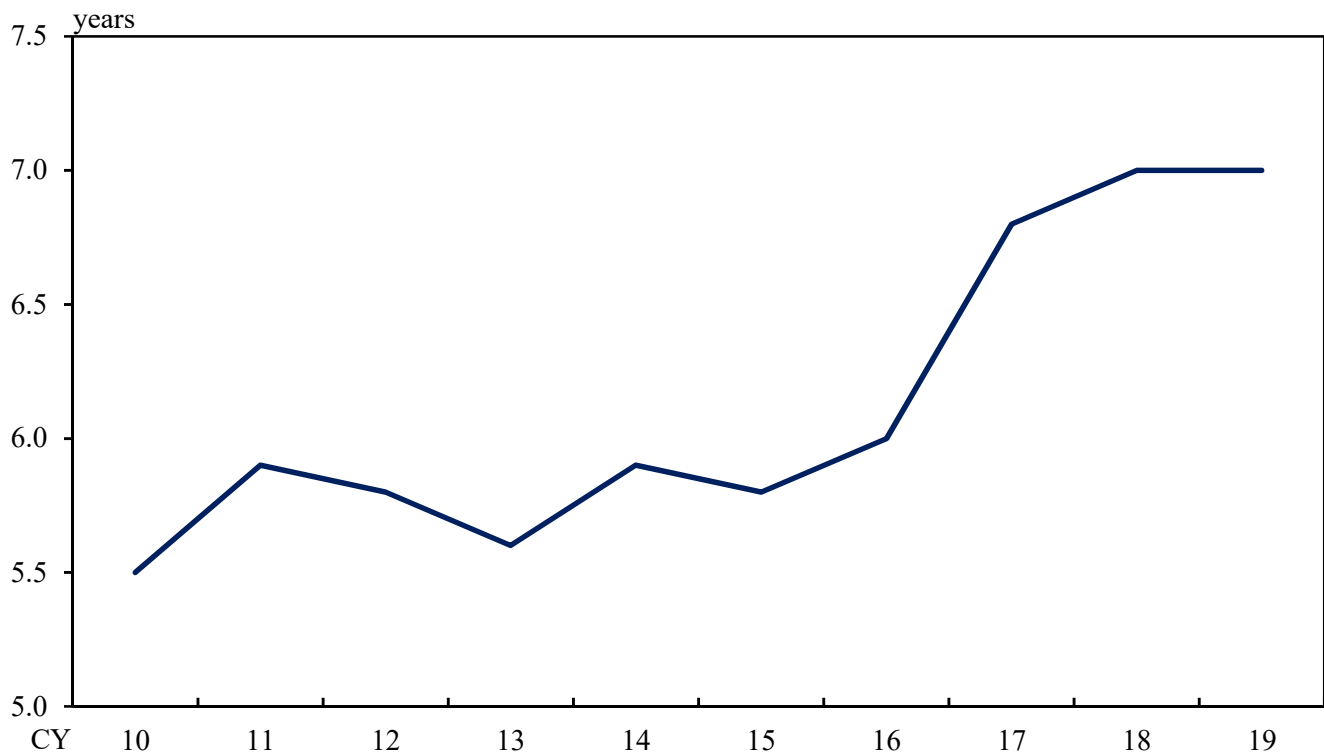
Note: Figures in (2) are of households which replace their computers.
Sources: BCN, Cabinet Office.

Chart 8

Estimation Result of Hedonic Regression Model
-- Passenger Cars --

(1) Overview of the Estimation

Scope of application	Gasoline cars, hybrid vehicles, plug-in hybrid electric vehicles, and diesel cars (sedans, station wagons, minivans, SUVs, and hatchbacks), classified in "Passenger cars" in the Producer Price Index, the Export Price Index, and the Import Price Index.
Dataset	Source: The retail price data are taken from the *Goo-net* by the PROTO CORPORATION and the average discounts are taken from the *Monthly Car Magazine JIKAYOSHA* by the Naigai Publishing Corp. The price data on passenger cars are compiled by the retail prices and average discounts. The specification data are taken from the *Goo-net* as well. Other important specifications unlisted in the database are taken from the specification sheet of each passenger car. Number of observations (release periods): 1304 (from 3rd quarter 2017 to 2nd quarter 2019)
Frequency of estimation	Every October

(2) Estimation Result (Marginal Effect on Price, MEP)

| Variable Name	MEP	Variable Name	MEP	Variable Name	MEP
Area	12.721	Front Fog Lamps	1.553	MT	3.152
Curb Weight / Volume	21.892	Front Spoiler	2.285	Turbo	0.450
Number of Gears	0.904	Unleaded Premium Gasoline	1.563	Twin Turbo	15.840
Height	7.972	Leather Seats	2.858	Brand A	2.564
Fuel Efficiency × Curb Weight	0.811	LED Headlamp	4.695	Brand B	3.342
Maximum Torque (kg·m)	0.773	LSD *	3.002	Brand C	6.614
Power-to-Weight Ratio	6.145	Navigation	15.011	Brand D	-3.281
Population Density	-0.084	Power Seat (Passenger)	1.708	Brand E	7.661
Rim Size	1.703	Rear Spoiler	1.188	Brand F	0.981
Automatic High Beam	1.964	Rear Vehicle Ditection System	0.331	Brand G	-9.241
Full Automatic Air Conditioning	6.332	DPMS **	4.889	Brand H	-7.701
Dual Air Conditioning	1.671	Tire-Air Pressure Alarm	4.847	Brand I	13.266
Aluminum Wheel	3.940	Coupes	3.739	3rd quarter 2017	-0.969
Acoustic Vehicle Alerting System	2.715	Hatchbacks	-1.934	4th quarter 2017	-2.793
Back Camera	2.173	Minivans	1.785	1st quarter 2018	6.299
Cornering Lamp	2.077	Convertibles	3.174	2nd quarter 2018	0.609
Passenger Injury Lessening Seat	2.391	Hybrid Vehicles	7.336	3rd quarter 2018	1.936
Cruise Control	0.795	FR	8.399	4th quarter 2018	0.864
Seat Heater (Driver)	2.731	V-type Engine	1.974	1st quarter 2019	2.245
ETC	1.274	CVT	0.366		

* : Limited Slip Differential
**: Driver's Seat Position Memory System

Hyperparameters

λ_1	0.011	λ_2	1.000E-05
λ_1^*	1.920E-05	γ	0.500

Notes: 1. The same model is applied to domestic goods, exported goods, and imported goods.
2. Mini passenger cars, etc. are excluded from observations.
3. The model is estimated by mixing up price data of both domestic goods and imported goods.
4. Marginal effect on price indicates the rate of change in theoretical price due to one standard deviation increase in a continuous variable/one unit increase in a dummy variable where all variables of a product are set at sample means.

Chart 9

Estimation Result of Hedonic Regression Model
-- Digital Interchangeable-Lens Cameras --

(1) Overview of the Estimation

Scope of application	Digital interchangeable-lens cameras classified in "Visual equipment" in the Producer Price Index and the Export Price Index, and "Digital cameras & video cameras" in the Import Price Index.
Dataset	Source: The retail price (quarterly average price) and specification data are taken from the *BCN Ranking* by the BCN Inc. Other important specifications unlisted in the database are taken from the specification sheet of each digital interchangeable-lens camera. Number of observations (release periods): 176 (from 4th quarter 2016 to 3rd quarter 2019)
Frequency of estimation	Every November

(2) Estimation Result (Marginal Effect on Price, MEP)

Variable Name	MEP	Variable Name	MEP
AF Sensor	27.171	Without Kit Lens	-9.582
Battery Life (CIPA Standard)	1.686	Additional Lens	-8.936
Image Sensor Size	37.164	Manufacturer A	6.364
Maximum Continuous Shooting Speed	12.044	Manufacturer B	214.461
F-Number for Wide-Angle *	4.693	Manufacturer C	-1.213
Effective Pixels	3.499	4th quarter 2016	-4.303
Maximum ISO Sensitivity **	5.976	1st quarter 2017	3.718
Maximum Magnification Ratio	0.158	2nd quarter 2017	2.657
Rear LCD Monitor Pixels	7.344	3rd quarter 2017	-5.202
Maximum Shutter Speed	3.073	4th quarter 2017	-7.626
Longest / Shortest Focal Length	7.572	1st quarter 2018	-3.132
4K/2K Video Function	3.907	2nd quarter 2018	-9.601
Waterproof and Dustproof	30.772	1st quarter 2019	-17.271
Dual Slots	46.496		
Electronic Viewfinder	35.153		
GPS	6.774		
Digital Single-lens Reflex Camera	50.329		
Electronic Image Stabilization	15.394		
Sensor-Shift Image Stabilisation	18.650		
Touch Screen	15.747		

* : Inverse
**: Including expanded sensitivity

Hyperparameters

λ_1	0.006	λ_2	0.001
λ_1^*	1.104E-05	γ	2.000

Notes: 1. The same model is applied to domestic goods, exported goods, and imported goods.
2. The model is estimated by mixing up price data of both domestic goods and imported goods.
3. Marginal effect on price indicates the rate of change in theoretical price due to one standard deviation increase in a continuous variable/one unit increase in a dummy variable where all variables of a product are set at sample means.

Chart 10

Estimation Result of Hedonic Regression Model
-- Smartphones --

(1) Overview of the Estimation

Scope of application	Smartphones classified in "Cellular phones" in the Producer Price Index and the Import Price Index, and "Fixed & mobile radio communications equipment" in the Export Price Index.
Dataset	Source: The price data are taken from the *K-tai Watch* by the Impress Corporation and the specification data are taken from the *BCN Ranking* by the BCN Inc. Other important specifications unlisted in the database are taken from the specification sheet of each smartphone. Number of observations (release periods): 227 (from 3rd quarter 2017 to 2nd quarter 2019)
Frequency of estimation	Every March and September

(2) Estimation Result (Marginal Effect on Price, MEP)

Variable Name	MEP	Variable Name	MEP
Battery Capacity	1.011	Manufacturer D	-9.489
Rear Camera Resolution	1.670	Manufacturer E	-5.760
Screen Size	1.942	Manufacturer F	10.284
Front Camera Resolution	0.557	Manufacturer G	-18.489
Clock Speed	31.129	Manufacturer H	-23.722
Storage Size	12.178	Manufacturer I	27.961
Installed Memory Size	13.488	Manufacturer J	-0.266
Face or Fingerprint Recognition	2.121	Manufacturer K	4.182
Iris Scanner	31.859	Manufacturer L	8.426
OLED Display	10.476	Manufacturer M	9.261
Waterproof (IPX7or8)	15.280	3rd quarter 2017	31.266
Waterproof (IPX7to8)	14.256	4th quarter 2017	29.734
Carrier A	6.518	1st quarter 2018	19.543
Carrier B	-11.329	2nd quarter 2018	24.760
Carrier C	-4.947	3rd quarter 2018	4.349
Carrier D	-0.448	4th quarter 2018	5.701
Carrier E	19.908		
Manufacturer A	83.668		
Manufacturer B	-7.651		
Manufacturer C	-13.935		

Hyperparameters

λ_1	0.004	λ_2	0.010
λ_1^*	8.003E-06	γ	1.500

Notes: 1. The same model is applied to domestic goods, exported goods, and imported goods.
    2. The model is estimated by mixing up price data of both domestic goods and imported goods.
    3. Cash sales prices for new subscription without calling plan are used for SIM free phones.
    4. Marginal effect on price indicates the rate of change in theoretical price due to one standard deviation increase in a continuous variable/one unit increase in a dummy variable where all variables of a product are set at sample means.

Chart 11

Estimation Result of Hedonic Regression Model
-- Desktop Computers --

(1) Overview of the Estimation

Scope of application	"Desktop computers" in the Producer Price Index and the Import Price Index. Rental desktop computers classified in "Computer rental" in the Services Producer Price Index.
Dataset	Source: The retail price (quarterly average price) and specification data are taken from the *BCN Ranking* by the BCN Inc. Other important specifications unlisted in the database are taken from the specification sheet of each computer. Number of observations (release periods): 180 (from 3rd quarter 2018 to 2nd quarter 2019)
Frequency of estimation	Every August

(2) Estimation Result (Marginal Effect on Price, MEP)

Variable Name	MEP	Variable Name	MEP
Clock Speed	2.606	Windows 10 Pro 64bit	7.721
Maximum Clock Speed	7.883	Intel Celeron	-3.415
Number of Cores	4.158	Manufacturer A	-10.863
Clock Speed (GPU)	3.229	Manufacturer B	27.559
Maximum Clock Speed (GPU)	14.221	Manufacturer C	-14.173
Monitor Size	9.750	Manufacturer D	4.083
Installed Memory Size	11.535	Manufacturer E	-4.658
Maximum Supported Memory Size	7.349	Manufacturer F	-15.381
Display Resolution	3.993	Manufacturer G	2.068
SSD Storage Size	7.229	3rd quarter 2018	3.663
Thread Count	3.349	4th quarter 2018	4.130
Chrome OS	-1.871	1st quarter 2019	3.967
eMMC	-16.790		
HDMI Terminal	1.066		
Hybrid HDD and SSD	6.271		
All-in-One Computer	8.316		
No L3 Cache	-29.799		
Microsoft Office	21.431		
Turbo Boost Technology	7.669		
TV Tuner	15.647		

Hyperparameters

λ_1	0.008	λ_2	0.010
λ_1^*	1.010E-06	γ	2.000

Notes: 1. The same model is applied to domestic goods and imported goods.
 2. The model is estimated by mixing up price data of both domestic goods and imported goods.
 3. Marginal effect on price indicates the rate of change in theoretical price due to one standard deviation increase in a continuous variable/one unit increase in a dummy variable where all variables of a product are set at sample means.

Chart 12

Estimation Result of Hedonic Regression Model
-- Notebook Computers --

(1) Overview of the Estimation

Scope of application	"Notebook computers" in the Producer Price Index, the Export Price Index, and the Import Price Index.
	Rental notebook computers classified in "Computer rental" in the Services Producer Price Index.
Dataset	Source:
	The retail price (quarterly average price) and specification data are taken from the *BCN Ranking* by the BCN Inc. Other important specifications unlisted in the database are taken from the specification sheet of each computer.
	Number of observations (release periods):
	450 (from 3rd quarter 2018 to 2nd quarter 2019)
Frequency of estimation	Every August

(2) Estimation Result (Marginal Effect on Price, MEP)

Variable Name	MEP	Variable Name	MEP
Battery Runtime	0.593	Convertible notebook PC	7.086
Clock Speed	0.919	Manufacturer A	-19.149
Maximum Clock Speed	5.367	Manufacturer B	32.326
Number of Cores	1.026	Manufacturer C	-15.374
Installed Memory Size	9.500	Manufacturer D	-9.749
Height	-1.390	Manufacturer E	-12.846
SSD Storage Size	8.347	Manufacturer F	-19.724
Thread Count	15.269	Manufacturer G	-27.674
Display Resolution	1.292	Manufacturer H	10.356
eMMC	-18.798	Manufacturer I	-33.993
LTE	0.812	Manufacturer J	-22.889
No L3 Cache	-16.133	Manufacturer K	48.239
NVIDIA GPU	15.088	Manufacturer L	16.595
Microsoft Office	26.524	Manufacturer M	21.621
Touch Screen Display	4.523	3rd quarter 2018	-2.283
AMD	-14.743	4th quarter 2018	-0.585
Celeron	-22.261	1st quarter 2019	4.450
Corei9	14.539		
Pentium	-26.913		
Windows 10 Pro	0.246		

Hyperparameters

λ_1	0.040	λ_2	0.001
λ_1^*	1.81E-04	γ	0.500

Notes: 1. The same model is applied to domestic goods, exported goods, and imported goods.
2. The model is estimated by mixing up price data of both domestic goods and imported goods.
3. Marginal effect on price indicates the rate of change in theoretical price due to one standard deviation increase in a continuous variable/one unit increase in a dummy variable where all variables of a product are set at sample means.

Chart 13

Estimation Result of Hedonic Regression Model
-- LCD Televisions --

(1) Overview of the Estimation

Scope of application	LCD televisions classified in "Television receivers" in the Producer Price Index and the Import Price Index.
	Rental LCD televisions classified in "Communications & office equipment rental and machinery & equipment rental for service industries" in the Services Producer Price Index.
Dataset	Source:
	The retail price (quarterly average price) and specification data are taken from the *BCN Ranking* by the BCN Inc. Other important specifications unlisted in the database are taken from the specification sheet of each LCD television.
	Number of observations (release periods):
	174 (from 1st quarter 2018 to 4th quarter 2018)
Frequency of estimation	Every May

(2) Estimation Result (Marginal Effect on Price, MEP)

Variable Name	MEP	Variable Name	MEP
# of HDMI Terminals	5.770	Manufacturer F	53.099
Display Resolution	10.025	Manufacturer G	66.573
Screen Size	69.652	Manufacturer H	39.841
Maximum Effective Output Power	5.972	Manufacturer I	412.163
# of BS/110°CS Tuners	3.576	1st quarter 2018	12.419
# of BS/110°CS 4K Tuners	2.221	2nd quarter 2018	0.458
# of Tuners for DTB *	1.145	3rd quarter 2018	0.946

Variable Name	MEP
HDD	49.560
HDR	13.263
HDMI-CEC	18.846
Wireless LAN	3.794
Portable	201.689
Refresh Rate (120Hz)	17.076
Video On Demand	22.562
Cable LAN	12.857
Manufacturer A	1.858
Manufacturer B	-21.296
Manufacturer C	23.729
Manufacturer D	79.049
Manufacturer E	35.082

*: Digital Terrestrial Broadcasting

Hyperparameters

λ_1	0.003	λ_2	0.010
λ_1^*	3.710E-05	γ	0.500

Notes: 1. The same model is applied to domestic goods and imported goods.
2. The model is estimated by mixing up price data of both domestic goods and imported goods.
3. Marginal effect on price indicates the rate of change in theoretical price due to one standard deviation increase in a continuous variable/one unit increase in a dummy variable where all variables of a product are set at sample means.