Quality Adjustment
in the BLS Price Programs

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Quality Adjustment Overview

Aric Schneider
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Introduction

1. Overview – Why and What is Quality Adjustment
2. When does BLS Quality adjust
3. How we Adjust
4. Questions

Why and what is quality adjustment

When to quality adjust

- Old and new products are comparable
- Explicit quality adjustment
  - Cost-based
  - Hedonic quality adjustment
- Change in size/quantity
- Old and new products are not comparable
  - New product previous price
  - Price imputation

When to quality adjust (cont.)

	CPI	PPI	MXPI
Old/new products comparable	Direct Comparison	Direct comparison	Direct Comparison
Explicit quality adjustment	Cost-Based Hedonics	Cost-Based Hedonics	Cost-Based Hedonics for computers
Change size/quantity	Quantity Adjustment	Ratio method	Link Adjustment
New product previous price	*new products previous price not used	Overlap method	Discontinue and Replace
Price imputation	Class mean imputation and cell relative imputation	Link to cell relative	Discontinue and Replace

Quality Adjustment for Consumer Prices

Ryann Watkins
Consumer Price Program

Consumer Price Index (CPI) quality adjustment

- The quality adjustment (QA) method is 1 of 3 methods used when handling replacement items
- 3 methods used:
  - Directly use price change
  - Impute price change
  - Adjust for quality changes
    - Occurs at the item level, not index level

Consumer Price Index (CPI) quality adjustment: Why?

- Why do we use quality adjustments in the CPI?
  - Items in the market basket sometime leave the marketplace and need to be replaced
  - Often, replacement items have quality differences and cannot be compared directly to the unavailable item
  - This is where QAs come in!
    - QAs make it possible to compare different items across time periods

Consumer Price Index (CPI) quality adjustment: When

- When do quality changes happen in the CPI?
  - Quality changes in replacement items are most likely to occur during:

Seasonal Changes
(Mostly apparel items)

Innovation and
Technological Changes

Upgrades to Existing
Items (model year
changes for new vehicles)

*Note: technological changes and upgrades are not mutually exclusive

CPI quality adjustment: by the numbers

Number of CPI replacement items in 2020

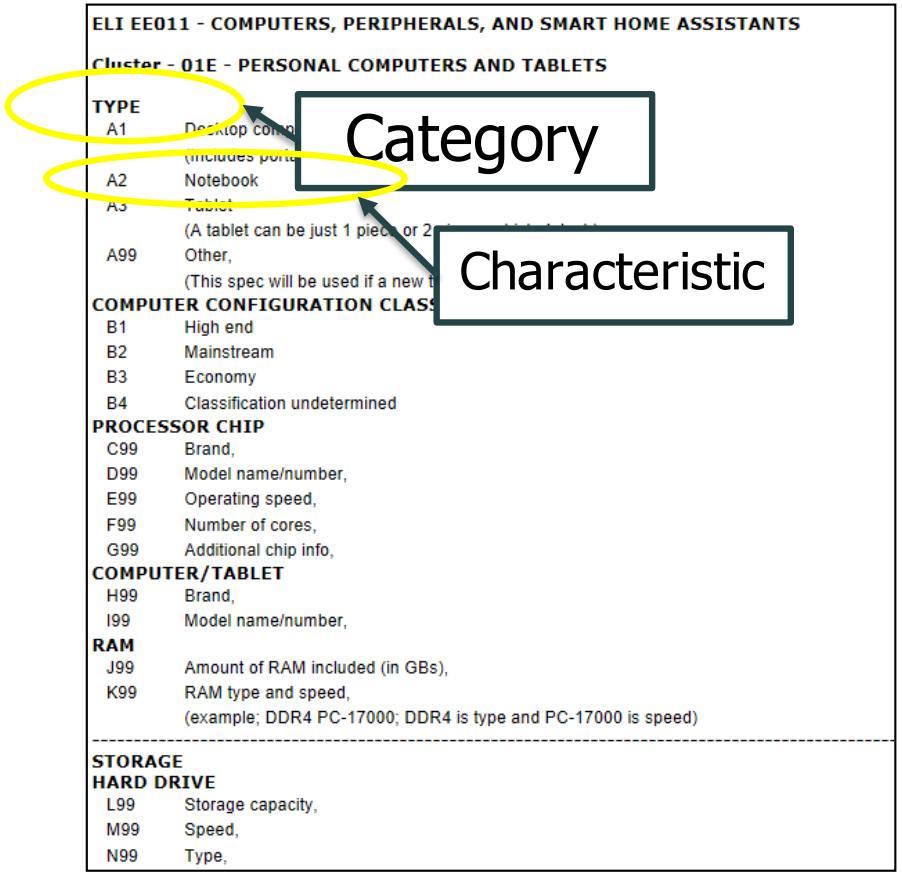
Item Group	Total Items	Items with a Price	# Replacement Items	% Replacement Items	% Direct Comparison	% Quality Adjusted	% Non-comparable
APPAREL	181028	93797	8408	9%	39.0%	23.5%	37.5%
FOOD	393277	264313	4608	1.7%	19.6%	15.8%	64.3%
HOUSEHOLD	56170	36385	1202	3.3%	31.0%	13.1%	55.8%
SERVICES	249083	155790	6794	4.4%	23.9%	36.5%	39.4%
TRANSPORTATION	214144	166159	10011	6%	51.7%	11%	37.2%
Total	1093702	716444	31023				
Average				4.3%	33.0%	20.0%	47.0%

CPI item checklists

- How do we know when the replacement item has a quality difference?

  "Item checklist"
- Each item has a checklist that capture all its important characteristics
- Data collectors use checklists to choose replacement items
- Analysts review the characteristic changes to determine if there's been quality changes

CPI item checklist example: computers



ELI EE011 - COMPUTERS, PERIPHERALS, AND SMART HOME ASSISTANTS

Cluster - 01E - PERSONAL COMPUTERS AND TABLETS

TYPE

A1 Desktop comp
(Includes port

A2 Notebook

A3 Tablet

(A tablet can be just 1 piece or 2

A99 Other,

(This spec will be used if a new t

COMPUTER CONFIGURATION CLASS

B1 High end

B2 Mainstream

B3 Economy

B4 Classification undetermined

PROCESSOR CHIP

C99 Brand,

D99 Model name/number,

E99 Operating speed,

F99 Number of cores,

G99 Additional chip info,

COMPUTER/TABLET

H99 Brand,

I99 Model name/number,

RAM

J99 Amount of RAM included (in GBs),

K99 RAM type and speed,

(example; DDR4 PC-17000; DDR4 is type and PC-17000 is speed)

STORAGE

HARD DRIVE

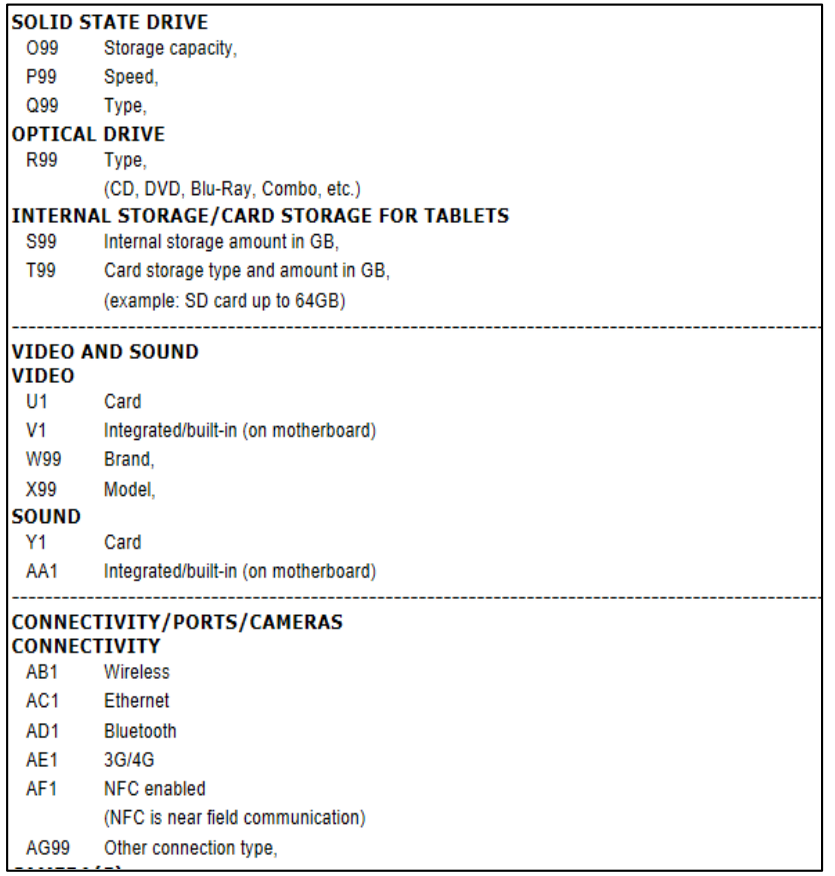
L99 Storage capacity,

M99 Speed,

N99 Type,

Category

Characteristic



SOLID STATE DRIVE

O99 Storage capacity,

P99 Speed,

Q99 Type,

OPTICAL DRIVE

R99 Type,

(CD, DVD, Blu-Ray, Combo, etc.)

INTERNAL STORAGE/CARD STORAGE FOR TABLETS

S99 Internal storage amount in GB,

T99 Card storage type and amount in GB,

(example: SD card up to 64GB)

VIDEO AND SOUND

VIDEO

U1 Card

V1 Integrated/built-in (on motherboard)

W99 Brand,

X99 Model,

SOUND

Y1 Card

AA1 Integrated/built-in (on motherboard)

CONNECTIVITY/PORTS/CAMERAS

CONNECTIVITY

AB1 Wireless

AC1 Ethernet

AD1 Bluetooth

AE1 3G/4G

AF1 NFC enabled

(NFC is near field communication)

AG99 Other connection type,

QA methods used in CPI

- Hedonic based QA method
  - Uses statistical regression models to estimate the values of specific characteristics
  - Data used to build models come from CPI sample or alternative data sources
  - Examples: apparel items, televisions, cell phones

- Cost based QA method
  - Exact monetary values are assigned to specific characteristics
  - Values are obtained from manufacturers, alternative data sources, website information, etc.
  - Example of items: new vehicles, computers

Hedonic based QA

Purpose: Hedonic QAs remove the difference in quality between replacement items and unavailable items allowing us to show a better estimate of price change

Data: Item's CPI sample or alternative data source

Requirements: Sample ≥ 100 observations and has sufficient variation

Regression Equation (semi-log function):

$$Log(Price) = a + \beta_1 x_1 + \beta_2 x_{2+} + \ldots. \beta_n x_n + \varepsilon$$

Hedonic model example: women's dresses

Variable Category	Independent Variable (X_n)	Parameter Estimate (β_n)
Fiber	Spandex	-0.00894
	Silk	0.00480
	Wool	0.00356
	Nylon	0.00169
	Poly, Rayon, Cotton	base
Type	Bridal	1.23375
	Formal	0.20270
	Casual	base
Brand Cat.	Exclusive	1.13463
	Boutique	0.89729
	High end national	0.63105
	National	base
	Special line private	-0.15400
	Private label	-0.28324
	Misc	-0.26275

Variable Category	Independent Variable (X_n)	Parameter Estimate (β_n)
Size	Misses, Petites, Plus	base
	Juniors	-0.37011
Lining	No lining	-0.10506
	Full/partial lining	base
Length	Below knee	0.05881
	Knee and above	base
Sleeve length	Long sleeve	0.12287
	Short sleeve, sleeveless	base
Closure	Zipper	base
	Button	-0.07697
	None	-0.17508
Features	Sequin, bead, rhinestone	0.11495
	Jacket	0.09642
	None	base

Hedonic based QA example: women's dresses

Type of Quality Change	Old Item	Replacement Item
Fiber	100% Polyester	60% Nylon 40% Polyester
Type of Dress	Casual dress	Formal dress
Lining	No lining	Lining
Closure	No closure	Zipper closure
Price	$125	$250

Hedonic based QA example: calculation for women's dresses

1. Calculate the adjusted price of the old item, which will be used to calculate the price change used in the index

$$\text{Price}_{\textit{old item}} * e^{(\Sigma\, replacement\ estimates - \Sigma\, old\ estimates)} = \text{Price}_{\textit{adjusted old item}}$$

$$\$125_{\textit{old item}} * e^{((0.101+0.203)-(-0.105-0.175))} = \mathbf{\$224.15}_{\textbf{\textit{adjusted old item}}}$$

Hedonic based QA example: calculation for women's dresses (cont.)

2. Calculate the price change of the adjusted old price and the replacement item's price:

$$[(\text{Price}_{\textit{replacement}} - \text{Price}_{\textit{adjusted old item}}) / \text{Price}_{\textit{adjusted old item}}] * 100 = \text{Adjusted Price Change}$$

$$[(\$250 - \$224.15) / \$224.15] * 100 = \mathbf{12\%} \leftarrow \text{Adjusted price change used in index}$$

NOTE: QA, in this case, is more accurate than directly comparing prices:

[($250 – $125)/ $125] ∗100 = 100% ←Price change without QA (not used in index)

Cost based QA

Purpose: Cost based adjustments also remove the difference in quality between replacement and unavailable items

Difference from hedonic QA: Cost based adjustments use actual dollar values, not estimated dollar values from a regression model

Data: Price & characteristic data provided by manufacturers, alternative data sources, and/or online info

Requirements: Prices associated with specific characteristics are available

Cost based QA example: new vehicles

Type of Quality Change	2020 Model (MSRP $33,550)	2021 Model (MSRP $34,750)	Reported Value of Characteristic
Interior	Not standard	Smartphone integration	$50
Transmission	6 speed transmission	9 speed transmission	$399
Remote/ keyless entry	No	Yes (Auto Start/Stop)	$459

Cost based QA example: calculation for new vehicles

1. Calculate the adjusted price of the old item, which will be used to calculate the price change used in the index

Price $_{old\ item}$ + New Characteristics – Old Characteristics = Price $_{adjusted\ old\ item}$

$33,550 + ($50+$399+$459) – 0 = **$34,458**$_{adjusted\ old\ item}$

Cost based QA example: calculation for new vehicles (cont.)

2. Calculate the price change of the adjusted old price and the replacement item's price

$$[(\text{Price}_{\textit{replacement}} - \text{Price}_{\textit{adjusted old item}}) / \text{Price}_{\textit{adjusted old item}}] * 100 = \text{Adjusted Price Change}$$

$$[(\$34{,}750 - \$34{,}458) / \$34{,}458] * 100 = \mathbf{0.85\%}$$ ← Adjusted price change used in index

NOTE: QA, in this case, is more accurate than directly comparing prices:

[($34,750 –$33550)/ $33550] ∗100 = ***3.6%*** ← *Price change without QA (not used in index)*

Quality Adjustment for Producer Prices

Steven Sawyer
Producer Price Program

Why the PPI quality adjusts

- Continual innovation and improvements across the U.S. economy means products change on a regular basis
- All of this change makes quality adjustment crucial to the PPI, a matched-model price index

Common changes to goods

- Upgraded parts
- Different materials
- Different physical properties
- Software

Common changes to services

- Time
- Location
- Speed
- Activity
- Software

Base prices and price relatives

- Price change is measured as the change in the ratio of the net price (NP) to the base price (BP), known as the long-term relative (LTR)

$$\Delta\text{Price} = \Delta\frac{NP}{BP} = \Delta\text{LTR}$$

- Quality adjustment involves changing the BP
- Product's price can change because of a change in NP, BP or both

Explicit quality adjustment

- Used when a PPI Industry Analyst (IA) can obtain the change in production cost (typically from the respondent) associated with the change in the product
- Change in production cost also is called the value of quality adjustment (VQA)

Explicit quality adjustment formula

- $BP_{New} = BP_{Old} \cdot \frac{NP_{New}}{NP_{New} - VQA}$

- Denominator of the fraction, $NP_{New} - VQA$, represents the estimated net price of the old product in the month the substitution is made effective

Explicit Quality Adjustment Example

- Price of a new model car is $14,000 and the price of the previous year's version is $13,500
  - $200 of that increase is due to the extra product cost and normal margin associated with the addition of government-mandated safety equipment
  - Pure price change is only $300

Explicit Quality Adjustment Example (cont.)

- Assume $BP_{Old} = 13{,}200$
- $BP_{New} = 13{,}200 \cdot \frac{14{,}000}{14{,}000-200} = 13{,}391.3043$
- Estimated price old model car in current period is 13,800
- $LTR_{Old} = \frac{13{,}500}{13{,}200} = 1.0227$
- $LTR_{New} = \frac{14{,}000}{13{,}391.3043} = 1.0455$
- $\Delta Price = \frac{1.0455-1.0227}{1.0227} = 0.0223$

PPI hedonic models

- Microprocessors
  - Desktop
  - Notebook
  - Server
- Computers (jointly developed with IPP)
  - Desktop
  - Notebook
  - Server
- Broadband high speed Internet service

Computer hedonic QA example

$$Computer\ price = a + b_1 CPU\ speed + b_2 CPU\ cores + b_3 Memory + b_4 Storage + b_5 O/S$$

Variable	Quantity	Coefficient (*a* or *b*)	Marked up cost
Intercept	-	100	100
CPU speed	3.2	50	160
CPU cores	4	22	88
Memory	4	20	80
Storage	750	0.14	105
Operating system	1	100	100
Computer price	-	-	**633**

Broadband hedonic QA example

$$\log(\textit{Broadband price}) = a + 0.45\log(\textit{Download speed}) + 0.1(\textit{Business}) + 0.61(\textit{Company A})$$

	Old	New
Price	40	45
Download speed	50	75

$$VQA = y_0[(\frac{x_1}{x_0})^{b_1} - 1]$$

$$= 40[(\frac{75}{50})^{0.45} - 1]$$

$$= 8.0066$$

Time dummy hedonic models

$$log(Price) = \alpha_0 + \Delta D_{t+1} + \beta_2 log(X_2) + \cdots + \beta_k log(X_k)$$

- Typically in log-log form
- Same form as hedonic quality adjustment model, but with a time dummy ($D(t+1)$)
- Dataset is typically a two time period unbalanced panel (pooled cross-section)

Time dummy hedonic models (cont.)

- Time dummy coefficient (Δ) gives an estimate of quality adjusted price change between time periods
  - Price is directly adjusted
  - Base price does not change
- Currently used in PPI Integrated microcircuits index

Time dummy hedonic model example

$$\log(\mathit{CPU\,price}) = a + -0.02D_{t+1} + 0.09\log(\mathit{CPU\,speed}) + 0.52\log(\mathit{CPU\,cores}) + 0.76\log(\mathit{Cache}) + 0.21\log(\mathit{Threads})$$

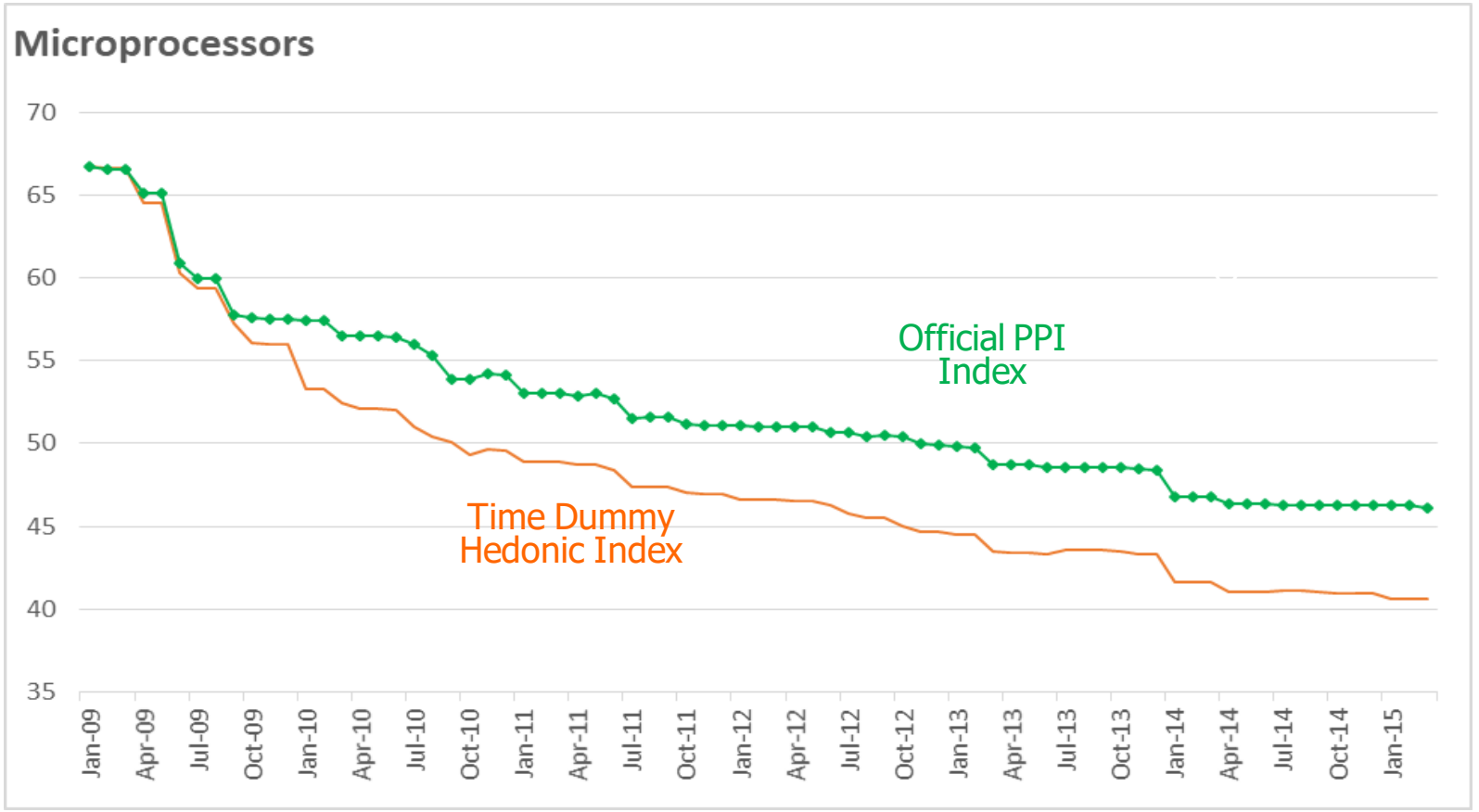
Price change = $e^{\Delta} - 1$

$= e^{-0.02} - 1$

$= -0.0198$

$= -1.98\%$

Microprocessors matched-model vs. time dummy hedonic index



Ratio method

- Useful when the ratio of the old and new price are expected to be equal to the ratio of two values such as a quantity or size
  - One associated with old product
  - Another associated with new product

$$BP_{New} = BP_{Old} \cdot \frac{V_{New}}{V_{Old}}$$

where

V_{New} = value corresponding to the new product

V_{Old} = value corresponding to the old product

Ratio method example

- A ready-mix concrete company used to report prices by cubic yard and now reports by truckload
  - Mixer contains 8.5 cubic yards
  - Price increased from $100/cubic yard to $850/truckload
- If the old base price is $95, then

$$BP_{New} = \$95 \cdot \frac{8.5}{1} = \$807.5000$$

Overlap method

- VQA not available
- Net prices for both the old product and the new product are available for previous time period
- Ratio of the two net prices can be used to calculate a new base price:

$$BP_{New} = BP_{Old} \cdot \frac{NP_{New\ product*}}{NP_{Old\ product*}}$$

*in previous time period

Overlap method (cont.)

- Method captures price changes between previous and current period
  - Input price changes
  - Demand changes
  - Other market changes

Overlap method example

- Tire company discontinues a passenger car tire
  - No direct replacement available
- Respondent provides a tire from another product line that has been in production for a few months
  - Previous month's price for the old tire is $105
  - Previous month's price for the new tire is $103
  - Current month's price for new tire is $107
- If the old base price is $101, then

$$BP_{New} = \$101 \cdot \frac{\$103}{\$105} = \$99.0762$$

Overlap example price change

- $LTR_{Old} = \frac{105}{101} = 1.0396$
- $LTR_{New} = \frac{107}{99.0762} = 1.0800$
- $\Delta Price = \frac{1.0800 - 1.0396}{1.0396} = 0.0389$

Link to cell relative

- Used with a non-comparable substitute
  - No VQA available
  - No overlap price available
- Method imputes a price change for the product
  - Price change (the “cell relative”) equals the average price change for all products in the product’s lowest level index (“cell”) which actually have good (non-imputed) prices

Link to cell relative formula

$$BP_{New} = BP_{Old} \cdot \frac{NP_{New}}{est\ NP}$$

where est NP represents the estimated net price (aka, cell relative) for the old product in the month that the substitution is made effective

Link to cell relative example

- Steel foundry provides a substitute casting
- Respondent cannot provide a VQA for the new casting and there is no overlap pricing
- New casting price is $29.30, old casting price is $28.90, old base price is $26.70 and cell relative price is $33.50

$$BP_{New} = \$26.70 \cdot \frac{\$29.30}{\$33.50} = \$23.5636$$

Link to cell relative example price change

- $LTR_{Old} = \frac{28.9}{26.7} = 1.0824$
- $LTR_{New} = \frac{29.3}{23.5636} = 1.2434$
- $\Delta Price = \frac{1.2434 - 1.0824}{1.0824} = 0.1487$

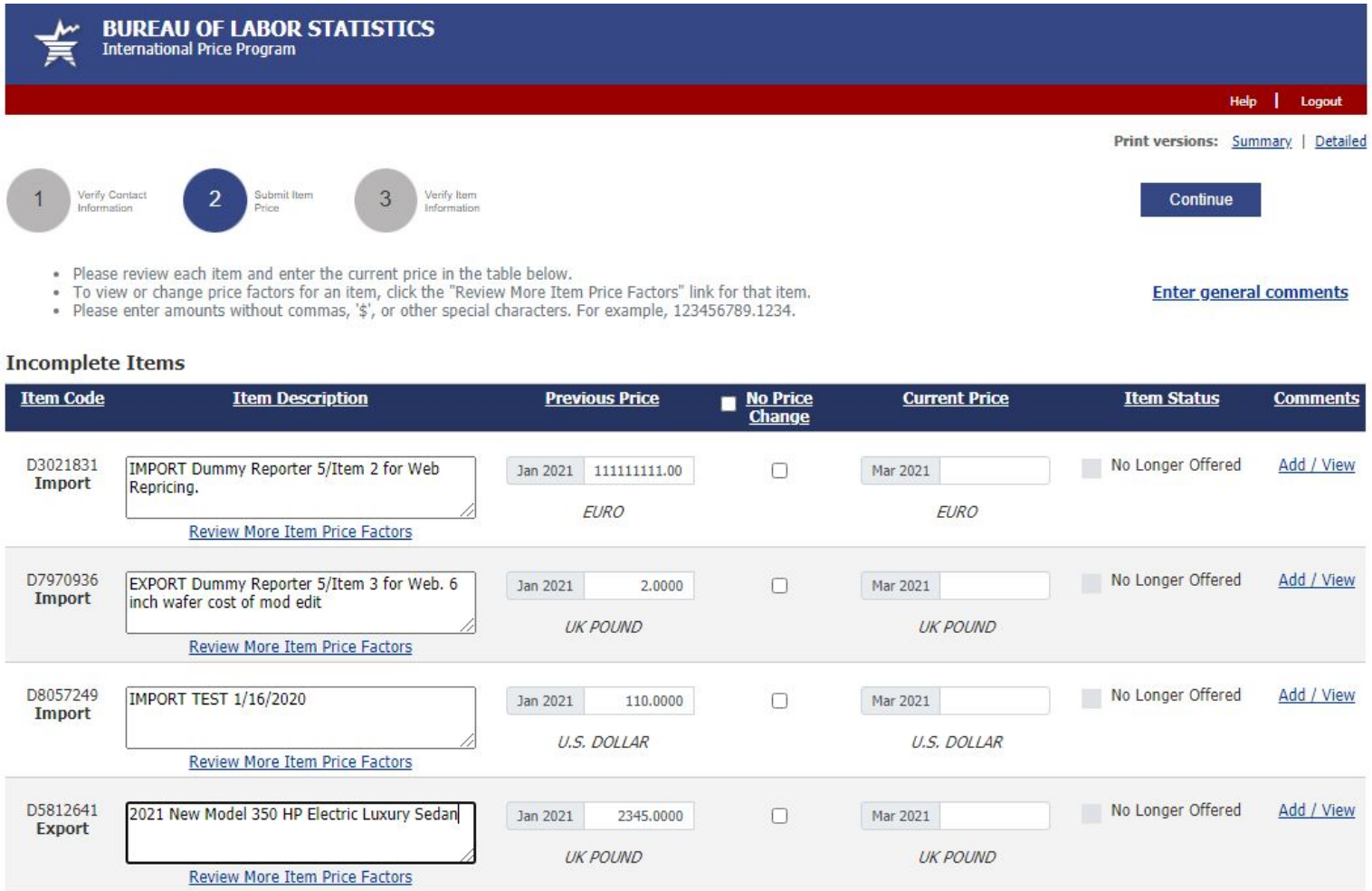
Quality Adjustment for Import and Export Prices

Aric Schneider
International Price Program

Import and Export Price Index (MXPI) quality adjustment

- MXPI – Primarily explicit cost-based QA, quantity/size adjustments and new item replacements
- Hedonic modeling for computers and soon microprocessors
- MXPI uses a “link price” method to QA

How we capture this information



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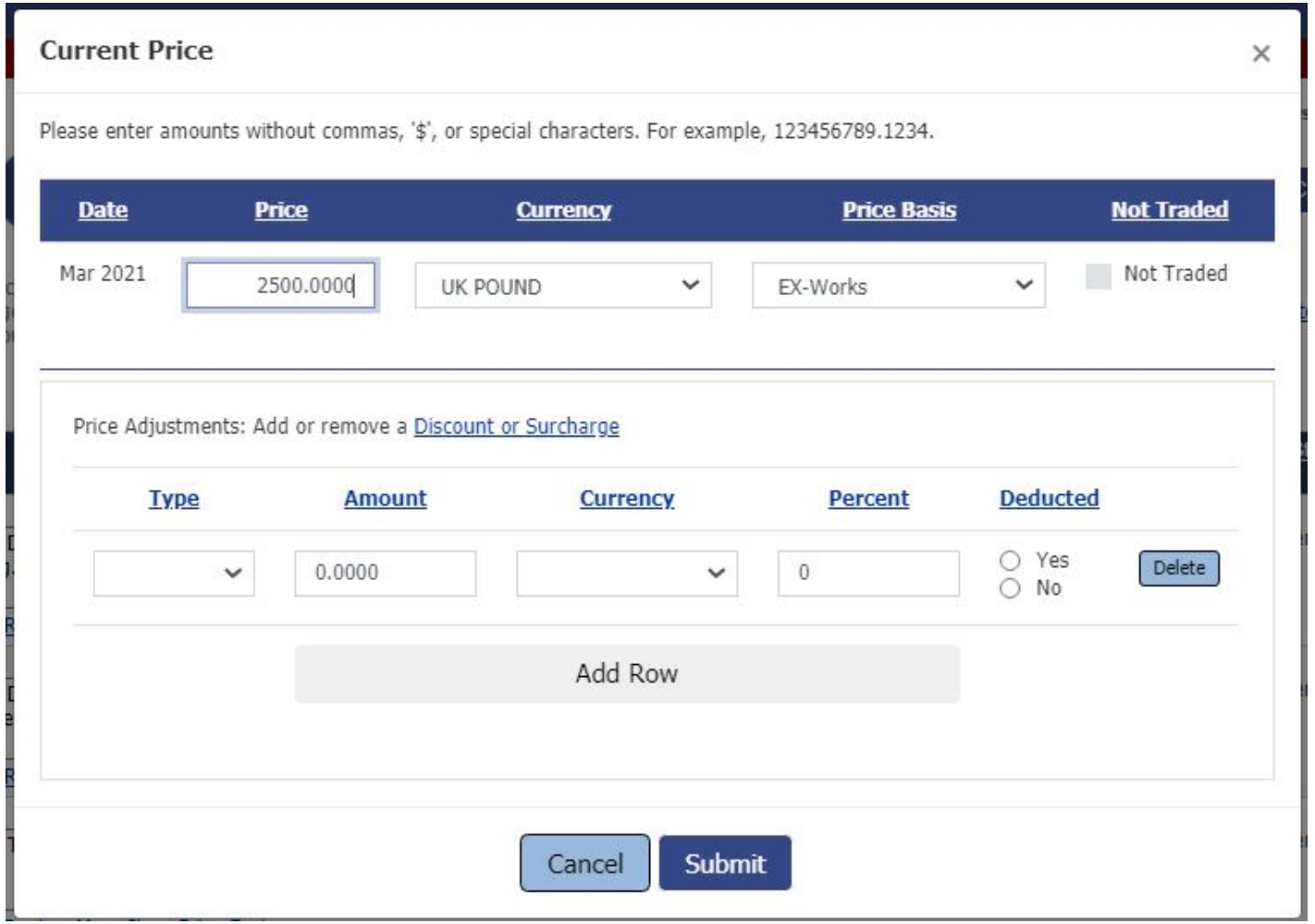
Enter general comments

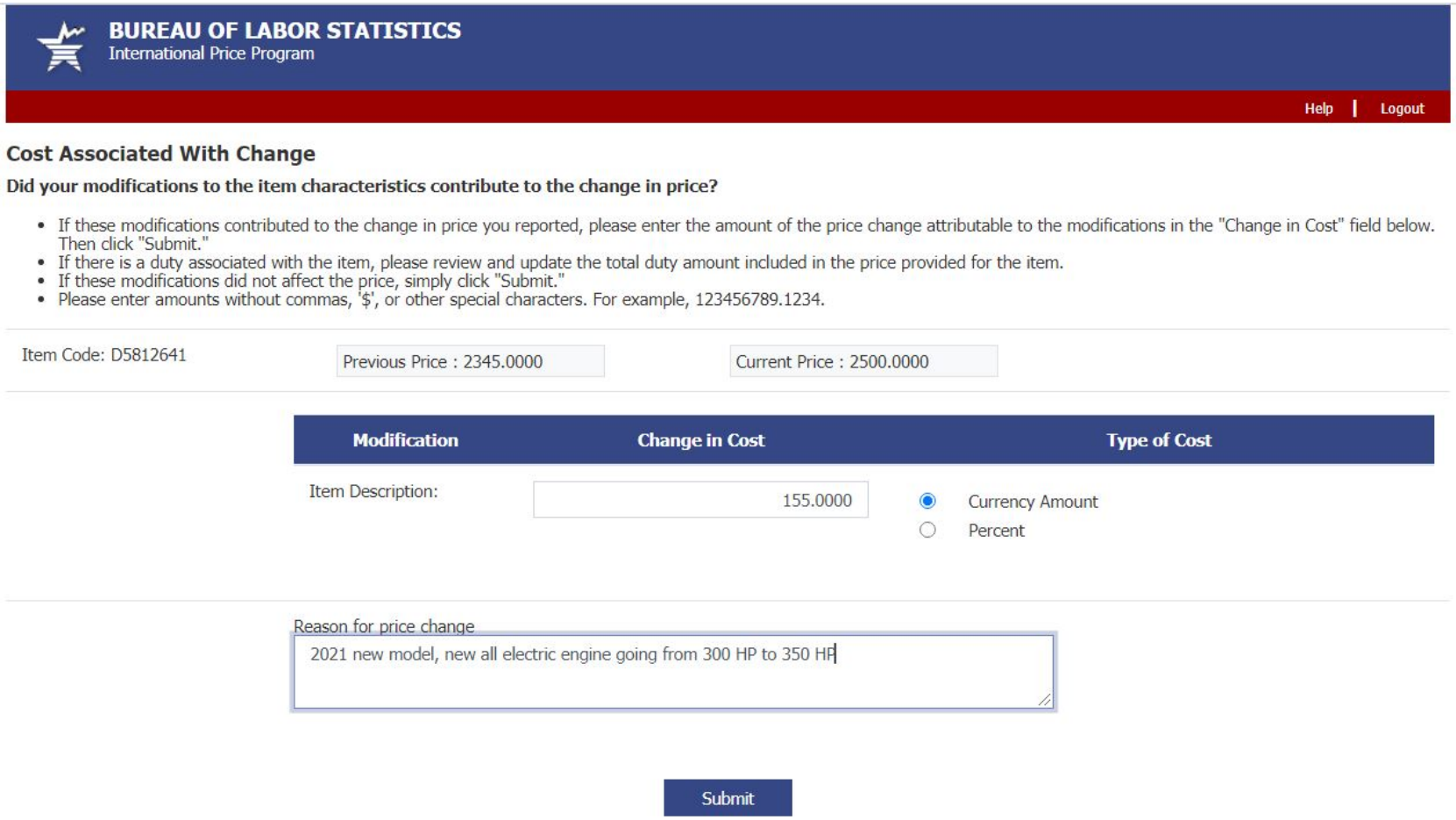
Incomplete Items

Item Code	Item Description	Previous Price	No Price Change	Current Price	Item Status	Comments
D3021831 **Import**	IMPORT Dummy Reporter 5/Item 2 for Web Repricing. Review More Item Price Factors	Jan 2021 111111111.00 *EURO*	☐	Mar 2021 *EURO*	No Longer Offered	Add / View
D7970936 **Import**	EXPORT Dummy Reporter 5/Item 3 for Web. 6 inch wafer cost of mod edit Review More Item Price Factors	Jan 2021 2.0000 *UK POUND*	☐	Mar 2021 *UK POUND*	No Longer Offered	Add / View
D8057249 **Import**	IMPORT TEST 1/16/2020 Review More Item Price Factors	Jan 2021 110.0000 *U.S. DOLLAR*	☐	Mar 2021 *U.S. DOLLAR*	No Longer Offered	Add / View
D5812641 **Export**	2021 New Model 350 HP Electric Luxury Sedan Review More Item Price Factors	Jan 2021 2345.0000 *UK POUND*	☐	Mar 2021 *UK POUND*	No Longer Offered	Add / View

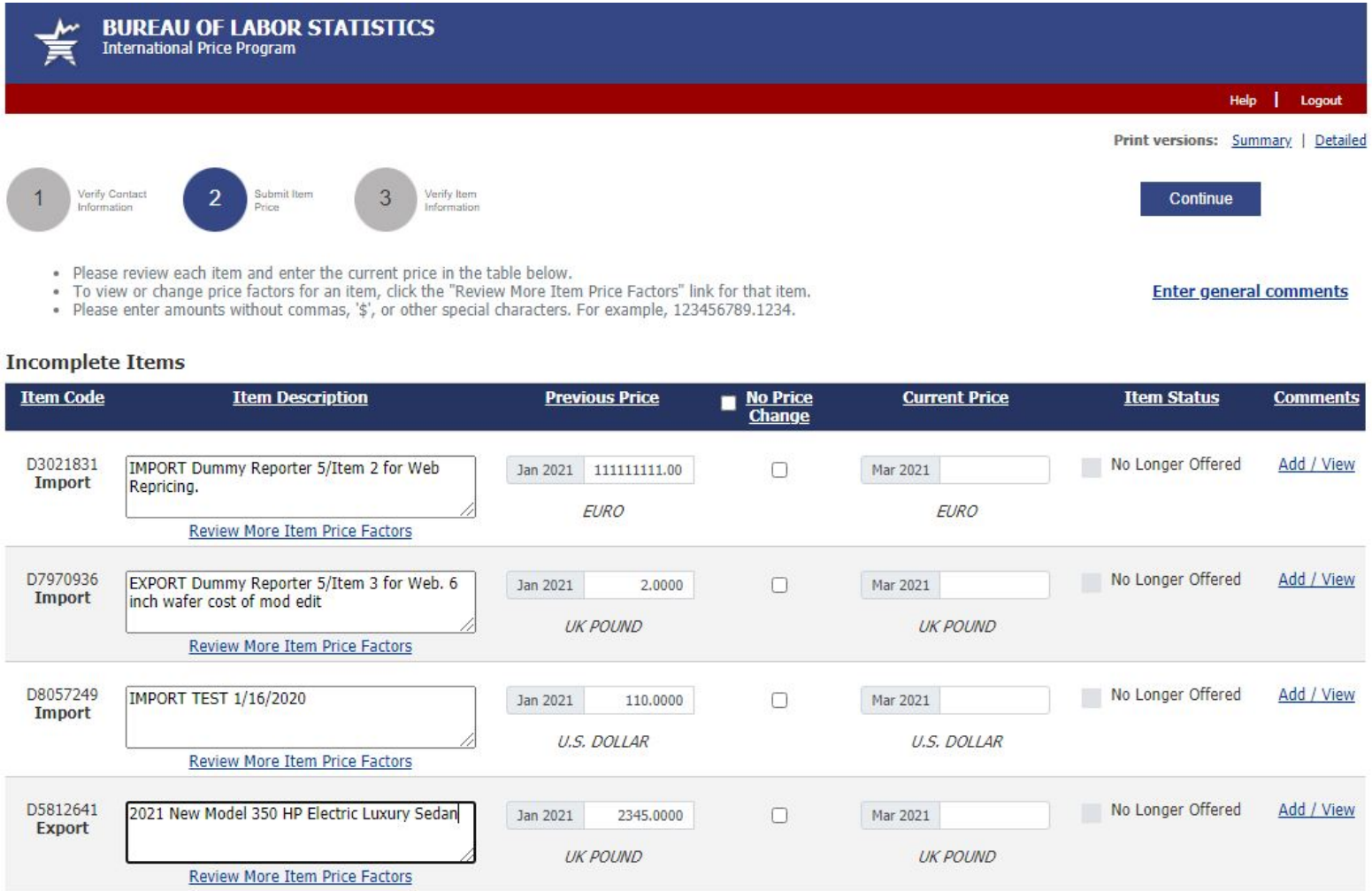
Quality adjustment - MXPI



How we capture this information: cost associated with change



How we capture this information: incomplete items



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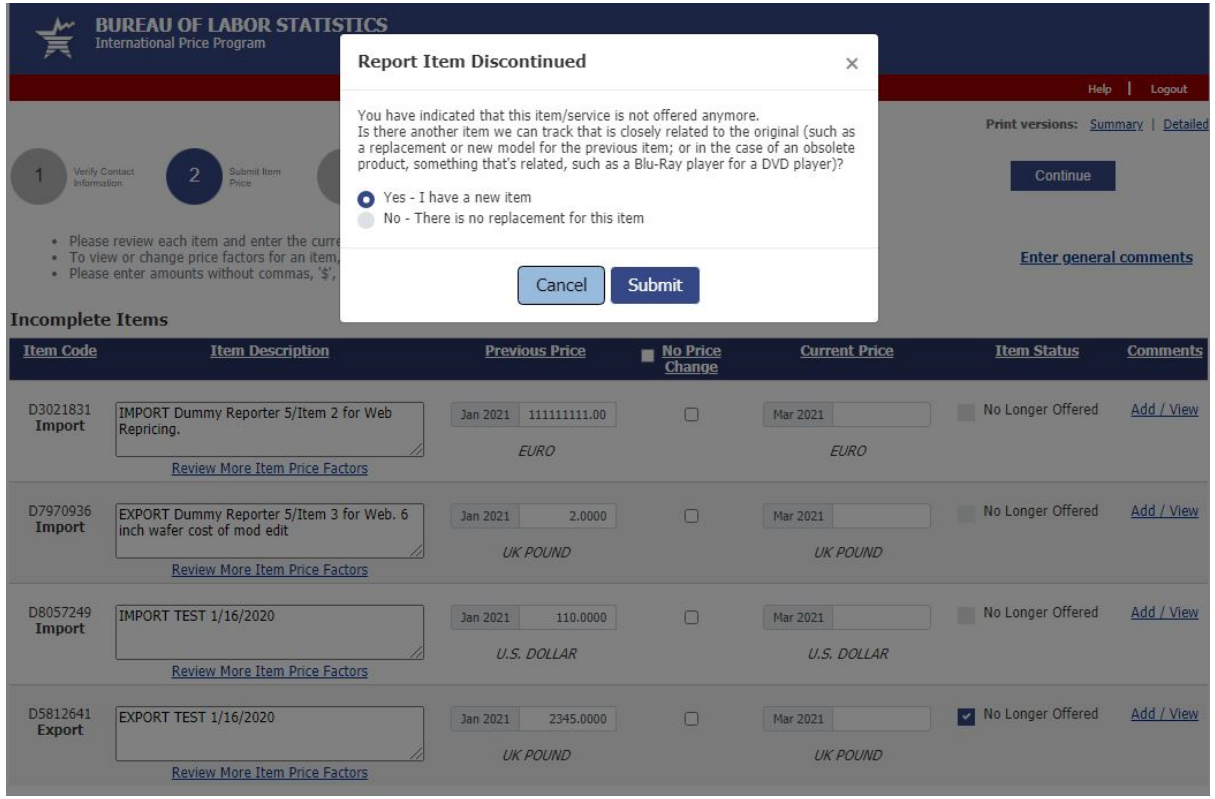
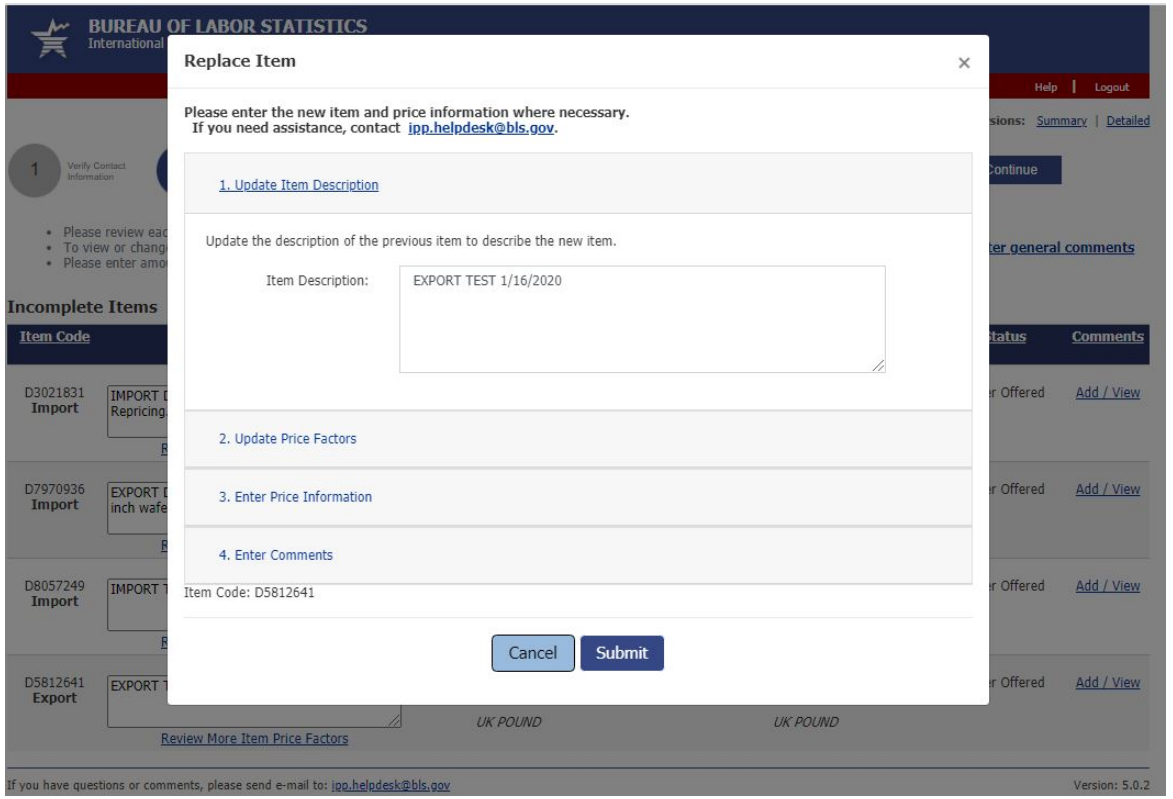
D5812641 **Export**	2021 New Model 350 HP Electric Luxury Sedan Review More Item Price Factors	Jan 2021 2345.0000 *UK POUND*	☐	Mar 2021 *UK POUND*	No Longer Offered	Add / View

How we capture this information: replace items





MXPI explicit quality adjustment

$$\text{Price Ratio} = \frac{LP_t}{P_{t-1}} = \text{LPSTR}$$

- Link Price (LP) used in place of New Price
- $QA\ Index\ Value\ _t = LTR_{t-1} \cdot LPSTR$

Explicit cost-based quality adjustment MXPI

- Using the same scenario for an explicit QA that Steve demonstrated:

		202101	202102	202103
Pre-link	Price	$13,500.00	$13,500.00	$14,000.00
	Percent Change		0.0%	3.7%
Link	Price			$13,800.00
	Percent Change			2.22%

Quantity/size quality adjustment

- Again using the same example that Steve showed us using the PPI Ratio Method:

		202101	202102	202103
Pre-link	Price	$100.00	$100.00	$850.00
	Percent Change		0.0%	0.0%
Link	Price			$100.00
	Percent Change			0.0%

New item replacement MXPI

- New Item Replacements are introduced as a New Series vs. a continuation
- MXPI uses similar “link to cell relative” concept as the PPI
- MXPI again uses a similar “overlap” concept as PPI

Contact information

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