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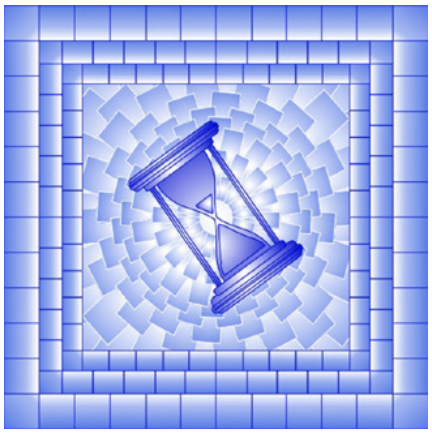

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Measuring the price of digital computing equipment and devices in the Consumer Price Index

by **Roobina Keshishbanoosy, Kevin Roche and Lance Taylor**

The Consumer Price Index (CPI) measures the change in prices of consumer goods and services over time. To accurately reflect trends in the market and consumer behavior, Statistics Canada periodically updates the methods applied to various components of the CPI.

The digital computing equipment and devices index (DCEDI) represents 0.56% of the 2021 basket, and 6.03% of the recreation, education, and reading index, a major component of the CPI. It is comprised of two sub-indices:

1. The computer equipment, software, and supplies index (CESSI), which makes up 0.37% of the 2021 CPI basket. This index tracks prices of computer equipment products such as laptops, desktops, monitors, and printers.
2. The multipurpose digital devices index (MDDI), which makes up 0.19% of the 2021 CPI basket. This index tracks prices of products such as tablets, smartwatches, and smartphones.

Enhancements to the Index

The DCEDI in the CPI measures the monthly changes over time in the price of laptops, desktops, monitors, printers, smartphones, smartwatches, and tablets. As part of modernization initiatives, Statistics Canada plans to implement enhancements to the estimation of the DCEDI, including:

- A new and more comprehensive web scraped data source for the MDDI covering more product brands;
- An improved approach to constructing weights in order to ensure representativeness in monthly aggregation;[1]
- The introduction of a statistical model for quality adjustment in the MDDI, as well as updates to the CESSI[2] statistical model to have a unified approach in estimating the DCEDI;
- Refinement to the data cleaning process to ensure an improved sample quality in the index.

These enhancements will bolster the quality of the DCEDI by increasing the index's sample size and coverage through timelier receipt of data. Prices will be collected[3] from retailer websites. Weights used in aggregating monthly prices will be updated periodically from other surveys and/or sources such as Statistics Canada's retail sales data, market data on brand and product expenditures, and supplementary data collected online.

The New Methodology

The nature of the consumer electronics industry and its rate of technological advancement cause the frequent replacement of outgoing items with new and improved products. To estimate pure price movements and control for these quality changes,[4] statistical models are used for quality adjustment by imputing monthly prices of incoming and outgoing items. Apart from printers,[5] all products in the DCEDI are subject to this model-based quality adjustment process.

In the case of laptops, desktops, monitors, smartphones, smartwatches, and tablets, the log of monthly prices in a window corresponding to a set of monthly periods[6] are modelled as a function of a set of explanatory variables

1. The aim being to ensure representativeness of each product, brand, retailer, and share of true entries and exits into the sample.
2. For detailed information on the previous update to the CESSI, please consult the technical paper A new approach for estimating the Computer Equipment, Software and Supplies Index in the Consumer Price Index (published in February 2021).
3. Prices will be collected by third parties on behalf of Statistics Canada.
4. Infographic: Measuring Pure Price Change in a Constantly Changing World (Archived).
5. A pure matched model is used for printers in the multi-purpose digital devices sub-index. For further discussion on matched models, see The Canadian Consumer Price Index Reference Paper: Chapter 6.
6. Analysis showed that the sample prediction for the current period price was improved via the pooling of observations in a given window. This also aided in accommodating observations which would drop in and out of the sample. Window size was determined on a product-by-product basis.

using an XGBoost[7] algorithm, which was found to outperform other algorithms without increasing operational burden.

Each product (e.g., laptops) has a separate model that uses explanatory variables specific to that product in order to estimate a price. For example, the following characteristics are currently used to model laptops: brand, retailer, display size, ram size, drive space, number of cores, processor speed, vertical resolution, weight, operating system, and whether the laptop has a touch screen. The decision of which variables to use were based on a combination of subject matter expertise, their explanatory power in modeling prices, and operational requirements.[8]

Initially, price changes for each observation, ($\Delta\tilde{p}_{t,i}$), are calculated as the current period log price less the previous period log price, where, in the case of entries and exits, the missing period price is imputed via a statistical model:

$$\Delta\tilde{p}_{t,i} = \begin{cases} p_{t,i} - p_{t-1,i}, \text{if } i \text{ is in both periods, or} \\ \hat{p}_{t,i} - p_{t-1,i}, \text{if } i \text{ is not in current period, or} \\ p_{t,i} - \hat{p}_{t-1,i}, \text{if } i \text{ is not in previous period.} \end{cases}$$

where,

$p_{t,i}$ is the log observed price of the i observation in period t,

and $\hat{p}_{t,i}$ is the log price of the i observation imputed using the model estimated in period t.

In the next steps, indices[9] for each brand within each product are calculated (for example, laptops from brand X). These are then aggregated to product level price relatives, which are then finally aggregated to elementary product level price relatives. The brand relatives are calculated as the exponential of the arithmetic mean of differences in log price between periods:[10]

$$I_{t,brand,product} = \exp\left(\sum_{i \in s_{t,brand,product}} \Delta\tilde{p}_{t,i} * w_{t,i}\right)$$

where,

$S_{t,brand,product}$ is the set of observations with observed or imputed prices in period t of a given brand within the product,

and $w_{t,i}$ is the observation's weight, constructed to ensure an observation's representativeness within each product-brand.

For the estimation of each product level index, the arithmetic mean of each product's brand price relatives is then taken, with their corresponding expenditure weights, to obtain a product level index $I_{t,product}$, i.e.:

$$I_{t,product} = \sum_{brand \in product} I_{t,brand,product} * w_{t,brand,product}$$

where $w_{t,brand,product}$ is a constant quality price-updated expenditure weight.[11]

The elementary product class index follows a similar approach to that of product level index calculations described above, i.e. a weighted arithmetic mean of the corresponding product relatives. The elementary product class[12] index movement at time t, $I_{t,element}$ can be expressed as:

$$I_{t,element} = \sum_{product \in element} I_{t,product} * w_{t,product}$$

7. XGBoost, short for extreme gradient boosting, is an optimized implementation of gradient boosting trees.
8. These variables are subject to change on the recommendation of subject matter experts as technological advancements alter the relevance of a given variable.
9. A measure of the price change from one period to the next, given by the current period constant quality price over the previous period constant quality price.
10. This is equivalent to a weighted geometric mean.
11. For further discussion on price-updated expenditure weights, see The Canadian Consumer Price Index Reference Paper: Chapter 6.
12. The computer equipment, software and supplies elementary product class is comprised of laptops, desktops, monitors, and printers. The tablet personal computers elementary product class is comprised of tablets and smartwatches. The smartphones elementary product class is comprised solely of smartphones.

In summary

Through the incorporation of web-scraped data and methodological updates, the new approach to estimating the components of the digital computing equipment and devices index constitutes an important enhancement towards the measurement of price change for goods which are critical to the digital economy. This enhanced methodology will be used in place of the previous methods for the corresponding elementary product classes of the DCEDI. Due to the changes in methodology and data, users are advised not to make year over year index comparisons until a full year has passed since implementation.

Statistics Canada continues to work with price experts, national statistical organizations, and other partners to ensure data and methods used in the calculation of the CPI are aligned with international standards and best practices. The agency is continuing to monitor prices for digital computing equipment and devices to ensure the ongoing accuracy and relevance of the CPI.

For additional information, users may contact the Consumer Prices Division at statcan.cpddisseminationunit-dpcunitedediffusion.statcan@ statcan.ca.