Abstract

The growth in the Information and Communication Technology (ICT) sector has created a need for more sector-specific economic indicators. Prices Division at Statistics Canada (STC) currently produces price indexes for several ICT goods that include computers and computer equipment or peripherals (e.g. printers and monitors). These indexes measure the price movement of ICT goods at the final or end-purchaser level (i.e. government, businesses and households) for consumption.

The ICT price index series are used by economists, industry analysts and the general public to track and comprehend events and trends as they occur in this important area of the ICT sector. Within STC, the series pertaining to consumers are used in the calculation of the Consumer Price Index. In addition, several series are used by the Canadian System of National Accounts in deflating the value of gross investment by government and businesses.

This document outlines what ICT goods price indexes are produced and their underlying data sources and methodology.

1. Introduction

The growth in the Information and Communication Technology (ICT) sector has created a need for more sector-specific economic indicators.[1] Prices Division at Statistics Canada (STC) currently produces price indexes for several ICT goods that include computers and computer equipment or peripherals (e.g. printers and monitors). These indexes measure the price movement of ICT goods at the final or end-purchaser level (i.e. government, businesses and households) for consumption.

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This reference document outlines what ICT goods price indexes are produced and their underlying data sources and methodology.

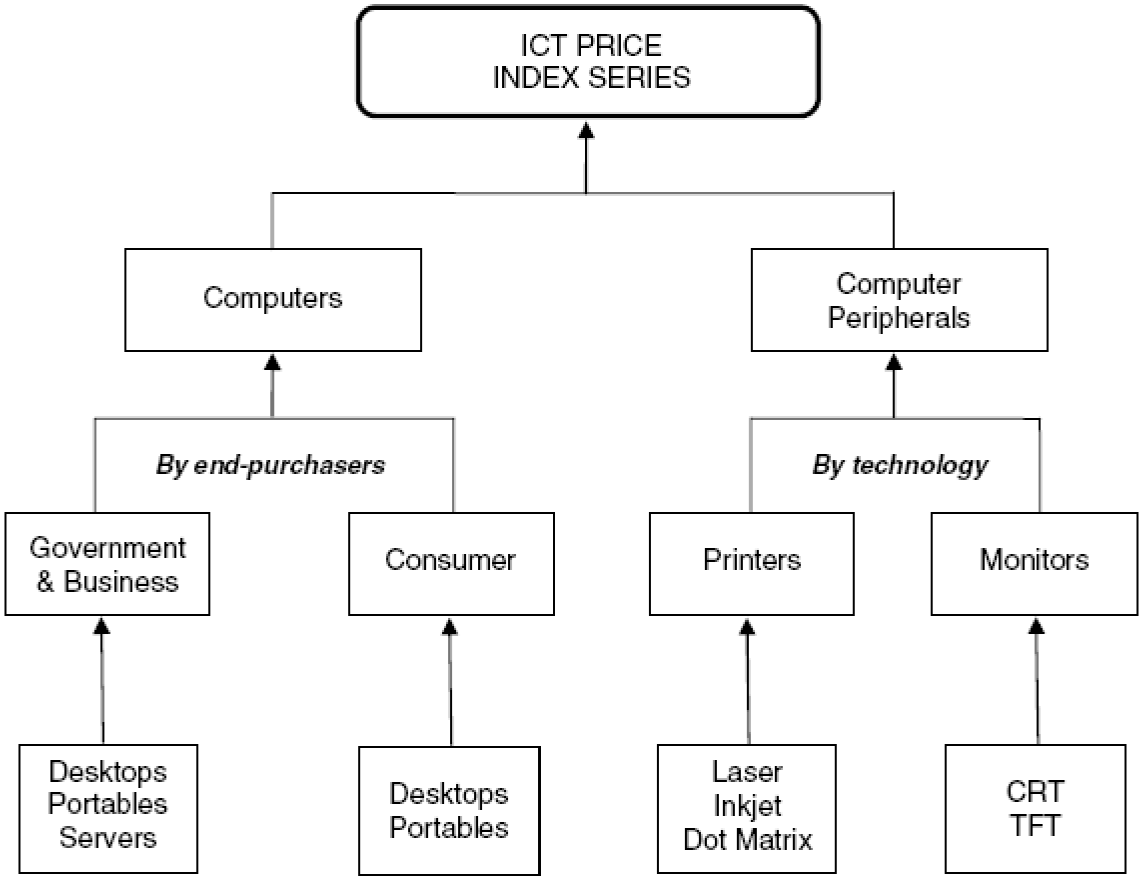
2. Target population and commodity coverage

The ICT price index series cover two major product groups: computers and computer peripherals (see Figure 1.1). Under the category of computers, indexes are produced for two end-purchaser groups: government and business, and consumer. The government and business category has three product sub-components (desktop computers, portable computers and servers), while the consumer category has two (desktops and portables).

Due to data availability, computer peripherals are classified by type of technology rather than the intended end-user or purchaser group. As a result, the series for printers is composed of three types of printer technology (laser, inkjet and dot matrix). Similarly, the price index for monitors is sub-divided by technology into cathode ray tube (CRT) monitors and thin film transistor (TFT) monitors.

[1] . Statistics Canada has defined the ICT sector as a special aggregation of industries under the North American Industry Classification System (NAICS). “This sector comprises industries primarily engaged in producing goods or services, or supplying technologies, used to process, transmit or receive information.” See Statistics Canada (2003).

Figure 1.1 – Schematic of ICT price index series



3. Data sources

The price and shipment data used in the production of the ICT price index series are obtained from International Data Corporation (IDC) of Canada. Additional information on CPU performance scores is obtained from the Internet for the purpose of adjusting computer prices for changes in quality.

3.1 Prices

Monthly price information is provided by IDC for commercial and consumer computers, printers and monitors. For commercial computers, the data include desktops, portables, and entry-level server models that are shipped in Canada. Commercial systems typically represent computers targeted toward medium and large businesses and public sector purchases. Consumer computers include desktops and portables primarily bought by households and small businesses.

The reason for the two separate computer price index series stems from the difference in the markets. The computer systems sold to the government and business sectors are typically more powerful, better serviced (in terms of warranties) and, therefore, more costly than the computers typically sold to the consumer.

In the consumer market, the smaller, third-party or "white-box" manufacturers and suppliers play a much larger role relative to the commercial market. The machines are generally lower priced, reflecting among other things, a more simple and standardized internal configuration. For these reasons, a separate series specifically for consumer-branded PCs was developed, beginning in January 2001.

In the case of printers and monitors, price information is provided based on the various technologies rather than whom the intended purchasers are, and this is due to data availability. Pricing for printers spans the categories of laser, inkjet and dot matrix technologies, while monitor pricing is composed of cathode ray tube (CRT) and thin film transistors (TFT).

For all computers and computer peripherals, "street" prices are provided, where the street price is an approximation of an actual transaction price. IDC calculates the street price using an average re-seller cost per computer system observed at various points throughout the distribution channel. Starting with the vendor's suggested list price (often referred to as a "do not exceed" price for re-sellers and retailers to obey), IDC surveys the various points in the distribution channel to determine what the products are actually selling for (e.g. 10% below the suggested list price for product *x*) and applies this estimate to arrive at the street price. Until the recent advent of Internet or web-pricing, the difference between a vendor's suggested list price and the actual transaction price could be large or small, depending on the final seller and the number of distribution points in the channel (i.e. wholesaler then retailer versus a direct seller such as Dell or Gateway). At this stage, virtually all vendors in the IDC sample provide web-pricing, with the resulting phenomenon that the suggested list price and street price have converged to the point where the two are virtually the same, especially in the case of computers.

3.2 Product characteristics

In addition to pricing data, descriptive information about the products is available. For all products, identifiers such as the vendor, model name and manufacturing number are used to match the sample from one period to the next. Other information for computers pertains to characteristics such as the CPU processor type, amount of RAM (random access memory), hard drive type and size, and warranty information. Additional product descriptions for printers include the type of technology and speed, while for monitors, the type of technology and screen size are captured.

3.3 Weights

The computer price index series for government and business is an aggregate obtained by combining the desktop, portable and server micro indexes using the weights for each category. For the computer price index series for consumers, the composite index is obtained by combining the desktop and portable indexes in the same way.

The annual weights for all the computer series are based on the annual data on the number of units shipped, which comes from IDC. These data are broken down by level of vendor, major product lines and CPU. At this stage, the shipment data are combined with corresponding estimated average prices for the year in order to calculate shipment values for the purposes of weighting. The resulting weights by vendor are distributed equally among the number of models per vendor within the sample. It is then possible to aggregate the vendor weights in each computer series to arrive at a relative weight for desktops, portables and, in the case of government and business, servers.

In the case of monitors and printers, no detailed shipment data are currently available. General shipment information at the technology level is used to arrive at an approximate share of the market for monitors and printers. This breakdown is used to produce the aggregate index for monitors and printers.

4. Overview of the methodology

This section outlines the methodology used to produce the ICT price indexes. It describes the approach to sampling, estimation and the treatment of quality change for replacement items.

4.1 Sampling and replacement

All components of the ICT price index series are produced using the matched model approach. This is the traditional method for measuring "pure" price change used by many statistical agencies in the world. Under this procedure, a representative sample of products or models is chosen and matched from period to period. The ratio of the prices from these matched models between successive periods of time is calculated to produce price relatives, which can then be aggregated to produce the price index series. Unmatched models are either discarded from the sample or more likely replaced in order to maintain an acceptable sample size.

The major premise of this method is that by matching the models through time, one is comparing the same item in terms of quantity and quality. Since the item remains constant, comparison bias (i.e. comparing different items) is avoided and only "pure" price changes drive the index.[2]

The difficulty arises, however, when models disappear due to obsolescence or some other factor. If a replacement model exists with the exact same quality, then linking in the new model is straightforward, as the only difference between the model that has disappeared (old) and the replacement model (new) would be the price.

In the case of ICT goods, the reality is that the new item almost always differs significantly from the old. Moreover, the nature of the ICT industry is such that quality improvement in ICT products has been continuous and, at times, quite large. As a result, when new models are introduced, serious consideration must be given to adjusting for the difference in quality, otherwise the comparison bias might be substantial. There are different ways to handle the quality change for new and improved replacement items. The ICT series covered in this document employ the use of hedonics to address this concern.[3]

4.2 Overview of the hedonic method

[2] Comparison bias is a general term used to encompass a variety of bias sources associated with comparing two *different* items when the intention is to compare two *identical* ones. In this context, the main source of bias arises from differences in quality. However, there are other product dimensions that, when not controlled, can contribute to the overall level of bias (differences in quantity or unit value pricing, differences in terms of sale, etc.).

[3] Other choices include the overlapping matched sample method, estimating quality change subjectively or linking to show no change.

Essentially, the hedonic approach attempts to relate the price of a good to the different characteristics embodied within. The relationship can generally be expressed as:

$$P_i = f(X_i^k, D_i^l) \qquad (1)$$

where P_i is the price of the good, X_i^k represents the set of k continuous descriptive variables or characteristics of the good, and D_i^l denotes a set of l binary variables associated with the good.[4] In the case of computers, a simple interpretation of (1) would be that the price of a computer system i is a function of each of the components or characteristic X's (e.g. CPU speed, amount of RAM and size of the hard drive). Additional information that helps to determine the price, such as the vendor company, the duration and type of warranty, the type of hard drive included, would be explained by the D's.

Estimating this relationship by means of regression analysis results in the implicit price of each characteristic, as represented by their corresponding coefficient estimate. The results derived from estimating (1) can be used in several ways to produce a quality adjusted price index.[5] One method in particular (and used by STC) is based on the matched model procedure using the hedonic adjustment for replacements. Models are matched from one period to the next and the price relatives contribute to producing the index. However, when a change in product quality occurs or a model is no longer available, a replacement model is selected. The results from the hedonic regressions are then used to assess the quality change between the old model and the new replacement model when linking in the replacement model.

In this procedure, the coefficient estimates for the explanatory variables in (1) are used for the purpose of imputing a "shadow" price for the replaced model. The shadow price for the old model represents what the price of the old model would have been if it had the same level of quality (same CPU, same amount of RAM and so on) as the replacement model.

The actual adjustment is carried out in the following manner. Differencing (1) provides

$$\Delta P_i = f(\Delta X_i^k, \Delta D_i^l) \qquad (2)$$

which merely states that the difference in the prices of the old and new models will result from the differences in their respective quality characteristics. To arrive at an approximation for P_i , one simply "plugs in" the differences in the relevant explanatory variables in the estimated regression. Then, P_i is applied to the original price of the old model to produce the shadow (or quality adjusted) price. Since the shadow price accounts for the change in quality, the new model can now be linked into the sample directly

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[4] In econometric textbooks and literature, D_i^l is commonly referred to as a set of qualitative or "dummy" variables.

[5] There is a variety of hedonics-based methods available to the statistician. For examples and a more in-depth description and discussion of hedonics in the context of computers, see Barzyk and MacDonald (2000).

(see example below). This method is analogous to that used by the U.S. Bureau of Labor Statistics.[6]

4.3 Example of hedonic quality adjustment calculation

Assuming a semi-log functional form best represents the hedonic regression, the shadow price will be computed as:

$$SP_i = P_i * \left[\exp\left(\sum_{k=1}^{n} \hat{\beta}_k (X_{new}^k - X_i^k) \right) \right] \qquad (3)$$

where SP is the shadow price for the model i being replaced, P_i the current price, X_{new}^k the value of the k^{th} characteristic of the replacement item, X_i^k the value of the k^{th} characteristic of the replaced item, and β_k is the estimated hedonic coefficient associated with the characteristic k.[7]

For simplicity, suppose the price of the old model and the price of the replacement model were the *same* ($2,000), and the *only* quality difference between the two came in the form of a larger amount of RAM for the new model (128 MB, up from 64 MB of RAM in the old model). The regression results from estimating (3) would be

$$lnP = 6.58992 + 0.00138\ (RAM) \qquad (4)$$

Combining the results of (4) with the formula in (3), the following calculations are obtained:

$$lnP = 0.00138\ (RAM)\ 0.08832 = 0.00138\ (128 - 64)$$

where the shadow price or *SP* is

$$\$2,000 * \exp(0.08832) = \$\ 2,184.60$$

That is, the price of the old model would have been $2,184.60 if it had been equipped with 128 MB of RAM instead of 64 MB. With this shadow price, it is now possible to compare the price of the replacement model directly with the quality-adjusted price for the old model, resulting in a price change of

$$(\$2,000/\$2,184.68) * 100 - 100 = -8.5\%$$

It is evident from the example what impact this form of adjustment has. If the difference in quality had simply been ignored, then there would be no price change in the models, since they both cost the same. However, taking into account the quality change leads to a decline in price of 8.5%—two very different results. As one can see, the matched sample with hedonic adjustment procedure allows for the incorporation of quality change into the index.

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6 See Holdway (2000).

7 The aspect of selecting a functional form and relevant explanatory variables is discussed in the latter part of this section. Generally speaking, the goal is to maximize the fit of the regression while still providing sensible results.

4.4 Updating of hedonic regression results

In order for the hedonic quality adjustment procedure to produce timely and robust results, it is necessary to update the hedonic equations on a regular basis.[8] The periodicity for revising an equation is determined primarily through the use of stability tests (i.e. Chow Test), conducted on the data.[9]

At each revision, several functional forms for the hedonic equation are tested, as well as the list of explanatory variables. The approach taken is to treat each revision as a new exercise, starting completely anew, rather than simply updating the old equations with new data. In this way, more work is required, but it is felt that the results are more robust.

4.5 Other Quality Adjustment Methods Used – Option Pricing

In the event that no hedonic adjustment can be made for a particular quality difference, option pricing is used. Option pricing refers to the attempt to measure the market value of the new option and assess its impact on the quality difference between the new replacement model and the old model. The need for option pricing can occur for two reasons: the option is new and is not yet captured in the existing hedonic equation, or the option already exists but is not incorporated in the hedonic equation for practical reasons.[10]

When new options are introduced on a computer or peripheral which are not yet measured in the hedonic equation, the market value of this new option is estimated and used to quality adjust the price. As the hedonic equations are updated, these new options should appear in the new estimates if they are important in the industry.

Employing both hedonic adjustment *and* option pricing limits the risk of missing a quality change or miscalculating the size of the quality change due to the reliance on statistical procedures associated with hedonic methods. Option pricing is considered a valid quality adjustment alternative to hedonics when the situation demands.

4.6 Sampling and choosing replacement items

The goal of sampling for the ICT price index series is to establish and maintain a high level of representation within the component indexes. For each of the ICT indexes, the universe from which the sample is drawn can be stratified into three groups, based on technology, performance and sales. At the extremes, there are "low-end" or soon-to-be discontinued models with inferior technology, and "high-end" or newly-introduced models with leading technology. In both cases, the market share is small when compared to the "mainstream" group, which consists of current popular technology and represents the bulk of market activity. The sample allocation strategy used for the ICT price index series is to choose those models coming from the mainstream group, since this group represents the largest portion of the market and the price behaviour is therefore more representative than in the two extremes of low-end and high-end

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[8] For a more detailed illustration of what is involved in updating the hedonic equations for computers, see Barzyk (1999).

[9] For a description of the Chow Test, see Chow (1960).

[10] These reasons include data availability and statistical inference. Hedonic equations are estimated on sample data using econometric procedures, and the results are evaluated in terms of their reasonability and statistical strength. Accurate and reliable estimation for a particular option is difficult when data is lacking. Similarly, as options are standardized across models (e.g. every model in the sample contains 256MB of RAM as a standard feature) , nonsensical results can occur and these variables are removed from the equation.

models.

5. Notes to users

5.1 Revision policy

The ICT price index series are subject to revision for six months after their initial release. For instance, January's price indexes, which are released in February, would be finalized in August. Monthly, quarterly and annual averages are available on CANSIM, along with the month-to-month and 12-month percentage changes. When the series are re-based periodically, revisions to indexes may be made more than six months after they have been published.

5.2 Dissemination

The ICT price index series are produced and published monthly and are released officially with an announcement in *The Daily* (Catalogue No. 11-001), which is available on Statistics Canada's Internet site www.statcan.ca. All publicly available indexes are posted on CANSIM at the same time as the release in *The Daily*. Users may also choose, usually for a fee, to receive information by email, phone, fax or letter at any time after the indexes have been released. On request, STC can also supply any publicly available information in electronic format. For additional information, please contact Client Services of Prices Division by telephone at (613) 951–9606 or toll-free at 1–866–230–2248, by fax at (613) 951–1539, or by email at infounit@statcan.ca.

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