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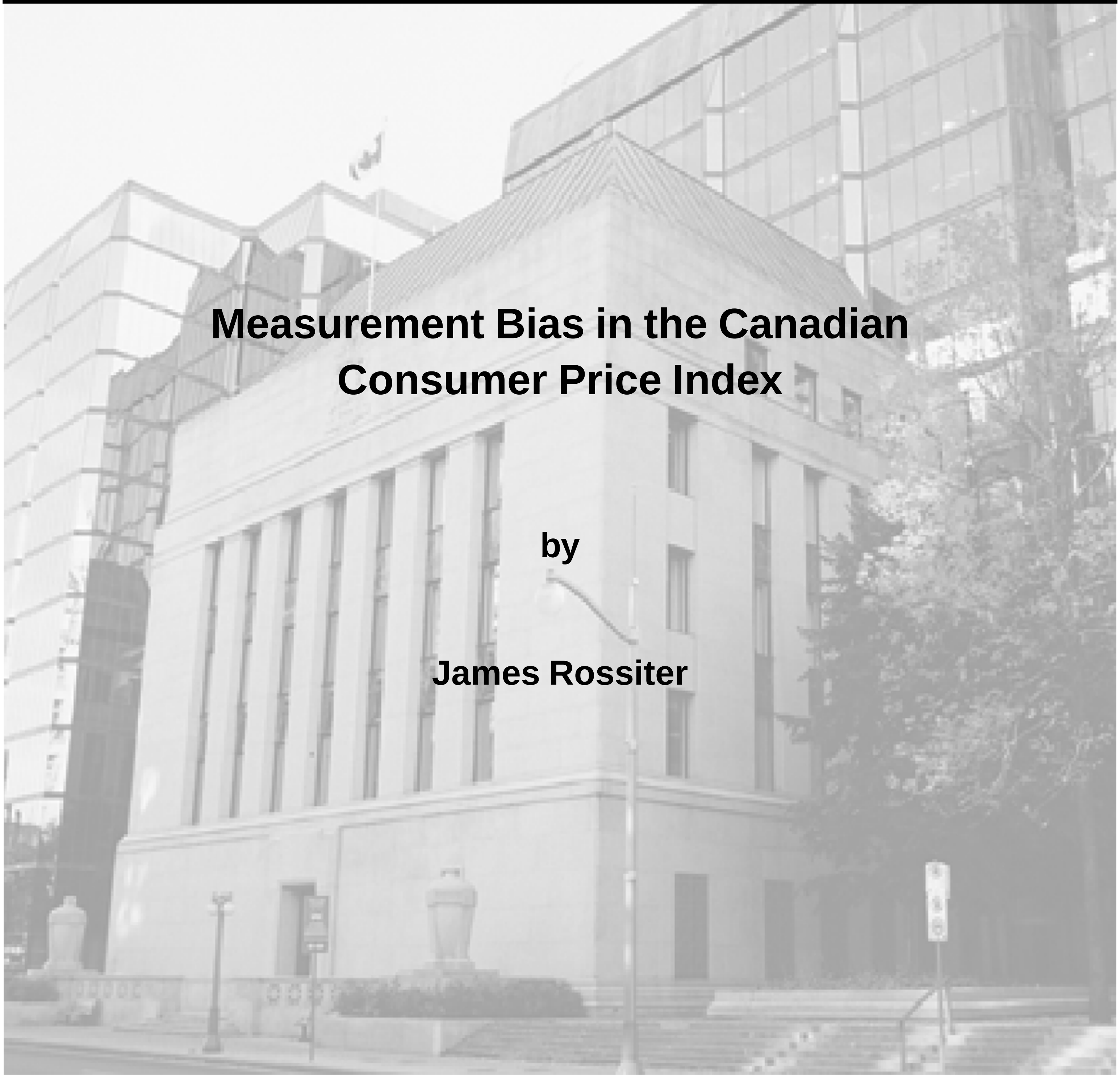

Measurement Bias in the Canadian Consumer Price Index

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James Rossiter

Research Department
Bank of Canada
Ottawa, Ontario, Canada K1A 0G9
JRossiter@bankofcanada.ca

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Abstract

The consumer price index (CPI) is the most commonly used measure of inflation in Canada. As an indicator of changes in the cost of living, however, the CPI is subject to various types of measurement bias. The author updates previous Bank of Canada estimates of the bias in the Canadian CPI by examining four different sources of potential bias. He finds that the total measurement bias has increased only slightly in recent years to 0.6 percentage points per year, and is low when compared with other countries.

JEL classification: E31, E52
Bank classification: Inflation and prices; Inflation targets

Résumé

L'indice des prix à la consommation (IPC) est la mesure de l'inflation la plus couramment utilisée au Canada. Toutefois, à titre d'indicateur des variations du coût de la vie, l'IPC est sujet à divers types de biais de mesure. L'auteur met à jour les estimations de la Banque du Canada quant au biais propre à l'IPC canadien en examinant quatre sources possibles de biais. Il conclut que le biais de mesure total n'a que très peu augmenté ces dernières années (il serait passé à 0,6 point de pourcentage annuel) et qu'il est faible par rapport à d'autres pays.

Classification JEL : E31, E52
Classification de la Banque : Inflation et prix; Cibles en matière d'inflation

1. Introduction

The consumer price index (CPI) is the most commonly used measure of inflation in Canada. Its application ranges from informing annual salary increases and pension payments to determining income tax brackets. It is therefore important that the CPI be as accurate a measure of inflation as possible. Of particular concern is the precise measurement of the CPI for the purposes of conducting monetary policy. The Bank of Canada "aim[s] at keeping the trend of inflation [measured by the CPI] at the 2 per cent target midpoint" of a range of 1 to 3 per cent annually (Bank of Canada 2001). Therefore, the accurate measurement of consumer prices in the economy is critical. As an indicator of changes in the cost of living, the CPI is subject to various types of measurement bias.[1] A significant bias in the CPI would need to be accounted for in an inflation-targeting monetary policy regime.

This paper updates previous Bank of Canada estimates (Crawford 1993a,b, 1998) of bias in the Canadian CPI. It begins with a description of both Statistics Canada's CPI methodology and the methodology pursued in this paper, followed by an overview of recent studies of measurement bias. The paper focuses on four main sources of bias and attempts to quantify each one. The penultimate section details other potential sources of bias, and the conclusion reviews the findings, compares them with other countries' estimates of bias, and discusses the implications for both central banks and statistical agencies.

In summary, it is found that the bias in the Canadian CPI has increased slightly in recent years to 0.6 percentage points per year, but remains low on an international scale. The sources of the increase in bias are higher estimates of commodity substitution and quality change biases.

2. Methodology

This paper seeks to estimate the measurement bias in the Canadian CPI, since it is the price index that is currently targeted by Canadian monetary policy. While other statistics could be used to measure inflation (such as the personal consumption expenditure deflator (PCE), the GDP deflator, unit labour costs, or the industrial product price index), there are a number of compelling reasons to use the CPI as a target. Besides the fact that it shares a common trend with other measures of prices (Crawford, Fillion, and Laflèche 1997), it is also available monthly,

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[1] The four types of measurement biases in the CPI are commodity substitution bias, outlet substitution bias, quality change bias, and new goods bias. They are explained in detail in sections 4 through 7, respectively.

is unrevised, and is published relatively quickly following its reference month, three desirable attributes that are not all simultaneously present in other price indicators.[2] While a PCE deflator could be used for the conduct of monetary policy (for example, the U.S. Federal Reserve Board pays close attention to the U.S. PCE deflator), Clark (1999) concludes that the benefits of the CPI outweigh those of the PCE deflator.[3] The CPI is also the most widely used measure of inflation in Canada, and is thought to be the most relevant measure of changes in the cost of living for most Canadians (Bank of Canada 2001).

2.1 Description of the CPI

The Canadian CPI measures the prices that the typical consumer faces in the economy, using a fixed basket that is periodically updated (see Table A1 in Appendix A for current weights of eight broad expenditure categories). Since the CPI basket is fixed between updates, the Canadian CPI is considered a *chained Laspeyres* (or, more technically speaking, a *Lowe*) price index.[4] It is often referred to as a *cost of goods (and services) index* (COGI), and is considered an approximation to a *conditional* cost of living index (COLI), which measures the minimum cost of attaining a given level of utility.[5]

The CPI basket includes only consumer goods or services with market prices. Thus, goods and services provided by the government at no direct charge to the consumer are not included in the CPI basket. The CPI is constructed by collecting roughly 30,000 price observations monthly, tracking about 600 goods and services in the Canadian economy.[6] Most prices are collected through samples at retail outlets throughout the country and from local and provincial authorities, and include indirect taxes (e.g., GST and PST) paid by the consumer. Price indexes for each basic class of the CPI are aggregated using basket weights to obtain the total CPI.[7] The basket weights are generally updated every four years using data from Statistics

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[2] For further discussions of why the CPI is used to target inflation, see Crawford, Fillion, and Laflèche (1997) and Hogan, Johnson, and Laflèche (2001).

[3] The arguments, though specific to the United States, include doubts over data accuracy of PCE deflators not in the scope of the CPI, and concerns that the PCE deflator would need further methodological improvements to approximate a cost of living index.

[4] Appendix B provides three common price index formulae.

[5] The difference between a *conditional* and *unconditional* COLI is that the unconditional index accounts for changes in environmental variables (such as air quality and social conditions), while the conditional index holds these variables constant. See Gillingham (1974), Pollack (1975), and Hill (2004) for discussions of conditional versus unconditional COLIs.

[6] The methodology used by Statistics Canada to construct the CPI is described in Statistics Canada (1995, 1996).

[7] A basic class is the lowest-level commodity category in the index (e.g., oranges, gasoline).

Canada's Survey of Household Spending (SHS).[8] The most recent basket was updated in January 2003 using expenditure weights from the 2001 SHS expressed at December 2002 prices.[9]

2.2 Estimating the bias

Conceptually, measurement bias is the difference between the published Statistics Canada CPI (a COGI) and a conditional COLI. There are four main causes of bias: the use of an imperfect indexing formula (*commodity substitution* bias); changes in the retail landscape (*outlet substitution* bias); inappropriate quality adjustment techniques (*quality change* bias); and belated treatment of new products and brands (*new goods* bias).

A variety of methods are used to calculate the bias. When available, empirical evidence is used to inform the bias estimate. In some instances, however, it is necessary to impose judgment, since two of the types of bias (namely, the quality change and new goods biases) are both conceptually and quantitatively difficult to measure. Judgment is critical to these estimates, and, as a result, more uncertainty exists around them than around the estimates of commodity and outlet substitution biases, which can be calculated using raw data.[10]

A number of recent studies are drawn upon to help guide the estimates of bias. Notably, Diewert (1998) formulates equations to calculate the contributions of the four sources of bias. These equations are used as a primary tool in this paper to calculate the total bias. Other studies have also estimated bias in Canadian and U.S. CPIs, and these prove helpful in providing further refinement to the estimates of bias. The resulting estimates are compared with those in Crawford (1998) and other recent studies (if available for Canada), before a final estimate is made of both the upper limit and mean of the bias. These estimates are then aggregated and summarized in the conclusion of the paper, after a brief discussion of other potential (and, in some cases, unmeasurable) sources of bias. The methods used differ in places from those used by Crawford (1998), in part through the use of Diewert's equations, which were published after Crawford's calculations were made. Another difference is the use of more detailed and recent Canadian data, which results in less reliance on other authors'

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[8] The SHS replaced the Survey of Family Expenditure (FAMEX) in 1997. Weights are determined using quantities from one year's SHS multiplied by prices from the month preceding the implementation of the new basket (up to one year later).

[9] A minor revision was made to the 2003 basket weights in July 2004. The previous basket update occurred in 1998, using data from the 1996 FAMEX.

[10] Statistics Canada believes that there is too much uncertainty to accurately quantify quality change and new goods biases, but has presented Crawford's estimates of commodity and outlet substitution biases (in Ducharme 1997).

estimates. Judgment also differs somewhat between this paper and Crawford's, but this is acknowledged and explained where appropriate. Despite the variation in methodology between Crawford (1998) and this paper, the two are generally comparable, and any notable differences are discussed herein.

3. Literature Review

Estimates of bias in the Canadian CPI have not been updated in a number of years. Fortin (1990) estimated that new goods and substitution biases contributed approximately 0.5 to 1.0 percentage points (p.p.) to annual measured inflation, and found no evidence of quality bias. The Bank of Canada has twice estimated bias in the CPI. Crawford (1993a) estimated bias to be no more than 0.5 p.p. per year. In an update five years later (Crawford 1998), the previous estimate of bias was increased, putting the upper bound at 0.7 p.p. per year and the mean at close to 0.5 p.p. per year.

Since Crawford (1998) published his estimates of bias in the Canadian CPI, numerous new studies have been undertaken, largely in response to the Boskin Commission's 1996 report on bias in the U.S. CPI (Boskin et al. 1996). The Boskin Commission Report estimates that the U.S. CPI is upwardly biased by 1.1 p.p. per year, and has resulted in many methodological changes at the U.S. Bureau of Labor Statistics (BLS), the agency that collects and compiles the U.S. CPI data. Estimates of the bias made since these methodological changes were implemented have generally been below 1 p.p. per year.[11] The higher measurement bias in the United States (compared with Canada) is primarily attributable to higher commodity substitution, new products, and quality biases.[12] Details of this and other international estimates of bias are discussed in the conclusion and given in Table F1 of Appendix F.

As a result of the Boskin Commission Report, much of the recent literature on bias has focused on the United States. Despite methodological differences, however, experience in the United States and in other countries can help frame an estimate of bias in Canada. A number

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[11] A U.S. government update to the Boskin Commission's report (U.S. General Accounting Office 2000) surveys the original Boskin Commission members to obtain an updated estimate of bias. The four surviving members' range is from 0.73 to 0.90 p.p. per year. See also Gordon (2000) and Lebow and Rudd (2003).

[12] The higher estimate of quality bias is partly attributable to a greater weight for medical services in the U.S. CPI, which is believed to have a significant upward bias. The Boskin Commission estimates that this one component of CPI alone contributes 0.2 p.p. per year to U.S. measurement bias. Since most health care costs are covered by the government in Canada, this component is not as heavily weighted in the Canadian CPI.

of authors have examined the bias in Canada, but they tend to focus on specific types of bias rather than estimating the total; their work will be discussed where relevant in this paper.

Some of the recent literature has examined the costs and benefits of altering the CPI price collection methodology. The wide availability of scanner data (which provides both price *and* quantity information in a timely manner), along with an increasing acceptance of hedonic regression procedures, is leading to the re-evaluation of current techniques. Both the BLS and Statistics Canada have produced a number of papers on these topics.[13]

An altogether different way of estimating the bias is to compare the published CPI with an econometrically determined COLI. Beatty and Larsen (2005) estimate bias in the Canadian CPI using Engle curves to infer the true cost of living.[14] Their results suggest that outlet and commodity substitution bias averaged between 1.33 and 1.86 p.p. per year between 1978 and 2000. Interestingly, they find negative bias twice between 1998 and 2000.[15] However, their results are dependent on strong economic assumptions, such as the functional form of the Engel curves.

4. Commodity Substitution Bias

Perhaps the most readily quantifiable bias is that caused by the choice of aggregation formula. Commodity substitution bias is the result of using a Laspeyres-type price index to calculate the CPI. Since the basket contents of the Canadian CPI are updated only about once every four years, substitution by consumers between goods and services (in response to changes in relative prices) during this time can lead to an overstatement of the cost of living. For example, were the price of beef to increase substantially between basket updates, consumers might substitute away from beef and towards other meats, such as pork or chicken. The weight in the Laspeyres price index for beef, however, would not change until the basket weights were updated, up to four years later. This would lead to an overstatement of the minimum cost of achieving a given level of welfare or utility, and the index would thus be upwardly biased. Other types of indexes more accurately measure changes in the cost of living

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[13] See, for example, Kokoski, Waehrer, and Rozaklis (2001), Liegey (2001a,b, 2003), Lowe (1998, 2001), Scobie (1998), Shepler (2001a), and Thompson (2001).

[14] Engel curves define the relationship between levels of income and the quantity of a good that a consumer will purchase at any given income level.

[15] More precisely, the authors construct CPI series for four strata of the population, and in three of the four they find negative bias twice between 1998 and 2000. The final stratum shows evidence of negative bias in only one of the years.

as consumption patterns change. The Fisher index, which is the geometric mean of the Laspeyres and Paasche price indexes, is one such example (see Appendix B).

Commodity substitution bias (B_C) is estimated by subtracting a chained Fisher price index from the published Laspeyres CPI. Constructing a chained Fisher index requires contemporaneous data on expenditure volumes, and, in real-time production, is not feasible for timely monthly publications. Diewert (1998) derives a formula that provides a real-time approximation of commodity substitution bias (see Appendix C for details):

$$B_C = \frac{1}{2}(1+i)Var(\varepsilon), \tag{1}$$

where ε is the residual variation of each price relative, and i is the measured rate of total inflation. The substitution bias is thus directly proportional to the dispersion of relative prices in the index.

Estimates of commodity substitution bias are calculated from one link period (when a new set of basket weights is introduced) to another, using the basic classes of the CPI. Table 1 shows the commodity substitution bias over the past 10 years.

Table 1: Commodity Substitution Bias (p.p.)

Period	Bias (per year)
1995–1997	0.07
1998–2002	0.25
2003–2004	0.13
Average	0.17

In the years leading up to Crawford’s estimate of bias in 1998, there was just under 0.1 p.p. per year of commodity substitution bias, in line with his estimate. However, the bias increased substantially between 1998 and 2002 to 0.25 p.p. per year. In the most recent period, the bias has abated somewhat to 0.13 p.p. per year. An analysis of the sources of bias shows that one important reason for the increase in the commodity substitution bias since 1997 is the sharp decline in the price index for computer equipment and supplies. Another important factor from 1998 to 2002 was the significant increases in cigarette taxes in mid-2002 (see Table C1 in Appendix C for the important contributors to commodity substitution bias during each period).

The estimate used for commodity substitution bias in this paper incorporates information since the last bias estimate in 1998, with some adjustment, since it is possible to view the increase in cigarette taxes as a one-time price increase. Accounting for this would remove 0.07

p.p. from the estimate of bias between 1998 and 2002, resulting in an alternative estimate of commodity substitution bias of 0.18 p.p. during those years. While the bias can be calculated over the past two years, that is too short a period in which to accurately determine commodity substitution bias, so some weight is given to the previous period's adjusted bias of 0.18 p.p.[16] This yields an estimate for commodity substitution bias of about 0.15 p.p. per year. Other studies have found commodity substitution bias in a similar range. Bérubé (1997) finds a bias of roughly 0.2 p.p. annually between 1962 and 1994 by comparing the published CPI with a chained Fisher index on an aggregate level.[17] Crawford (1998) estimates commodity substitution bias to be 0.10 p.p. per year. He bases this number on Bérubé's results, but takes into consideration the recent more frequent updating of the basket (reducing Bérubé's estimate by 0.10 p.p. annually). A recent exercise performed by Statistics Canada finds that commodity substitution bias amounted to 0.21 p.p. per year between 1996 and 2001, which roughly corresponds to the results in Table 1.[18] Table 2 summarizes the current and previous estimates of commodity substitution bias.

Table 2: Estimates of Commodity Substitution Bias (p.p.)

	Sample	Bias
Bérubé (1997)	1962–1994	0.20
Crawford (1998)	n/a	0.10
STATCAN (unpublished)	1996–2001	0.21
Rossiter (2005)	1998–2004	0.15

There is another form of commodity substitution bias that may arise in some countries' CPIs, resulting from the use of Laspeyres indexes in the micro-aggregation formulae within each basic class. This is often called formula—or elementary substitution—bias. The Canadian CPI uses geometric means to aggregate specific goods within each basic class, since weights

[16] Commodity substitution is also likely to accelerate through the basket weight period, since relative prices move away from those used to calculate basket weights, and consumers are given more time to substitute towards or away from goods and services in reaction to this (see Silver and Ioannidis 1994).

[17] According to Généreux (1983), commodity substitution bias could be reduced by as much as 0.07 p.p. per year if Statistics Canada were to incorporate weights from the SHS during the year in which it is conducted, rather than with a 4- to 6-year delay, as seen over the period that Généreux examines. Statistics Canada has since moved to a much shorter 12-month delay between survey and implementation, so it is likely that this "timing" bias has been reduced somewhat.

[18] Statistics Canada's methodology differs from the one used here, since they use a procedure developed by Bortkiewicz (1924) that was generalized by Bohdan Schultz at Statistics Canada. These results were obtained through discussions with Statistics Canada and work on this project continues. The advantage of Diewert's methodology over Bortkiewicz's is that the former can be updated on a real-time basis, whereas the latter requires end-period weights, and thus can be updated only at the time of new basket weights.

are not available at this level of detail. This methodology minimizes the bias in the Canadian data. Silver (1995), however, shows using scanner data that, if weights below the basic class level were available, then the choice of aggregation formula may in fact lead to a significant upward bias.

5. Outlet Substitution Bias

The Canadian retail industry has undergone substantial change in the past 15 years, due to the emergence of new retailers and growing market shares of some existing stores. In particular, the growth of warehouse and discount retailers (i.e., a shift from high- to low-end retailers) has likely resulted in a positive bias, since their lower prices relative to traditional retailers are almost always completely discounted as quality differences by Statistics Canada.

There are two important factors to consider with outlet substitution bias. One is the quality of the product being sold; the other is the "quality" of the retail outlet.[19] Specifically, when comparing an identical-quality good across two retailers, the difference in services received at each retailer must be taken into account (i.e., the comparable prices should be *quality adjusted*). Some "discount" retailers may offer goods at a cheaper price, but they often offer reduced in-store service, shorter warranties, or are located in inconvenient locations. In these instances, the quality-adjusted price of goods may in fact be the same at both high- and low-price retailers.

The methodology used by Statistics Canada assumes that there is no quality-adjusted difference in prices between retail outlets. During outlet sample rotation, any difference in price between the old and new retailer is generally assumed to be a pure quality difference; that is, the methodology assumes that the quality-adjusted prices are identical. However, this would occur only in a market that was in an equilibrium state, which is often not the case, especially considering that market shares of discount retailers have been growing for many years. Hausman and Leibtag (2004) show how this assumption of market equilibrium has led the BLS (which follows procedures similar to those of Statistics Canada) to act "as if Wal-Mart does not exist" by linking out lower prices at new outlets through quality adjustments. In an effort to counter this bias, Statistics Canada generally does not introduce new outlets into its sample immediately after those outlets enter into the market. Instead, prices at competing outlets are still followed for a period of time, as the market adjusts to the new entrant. It is found that prices at existing sampled outlets sometimes fall, to compete with the new discount outlets, and that,

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[19] Product quality bias is discussed in section 6.

as a result, the lower prices at the new outlets would indirectly be captured by the CPI, somewhat reducing the bias. However, the fact that market shares of discount retailers continue to increase would suggest that the market is not in equilibrium and that outlet substitution bias is present in the CPI.

A formula for outlet substitution bias (B_O), derived by Diewert (1998), is as follows:

$$B_O = (1+i)sd \ , \tag{2}$$

where s represents the annual increase in market share by low-cost retailers not captured in the CPI, d is the percentage discount in the quality-adjusted price offered by the outlet stores relative to the traditional stores, and i is the measured rate of inflation. To calculate outlet substitution bias, the goods category of CPI is broken down into three groups: food, semi-durables, and others, which consists primarily of durable goods (see Appendix D for a list of CPI categories subject to outlet substitution bias). Data are gathered from a number of sources to provide estimates of the required parameters. In the future, however, it would be useful if Statistics Canada could track the data required, in order to obtain a more accurate estimate of outlet substitution bias.

There has been a shift in the Canadian grocery sector in recent years, as retailers move towards offering low-priced food in an environment of high selection that often spreads beyond traditional groceries. Caicco, Piticco, and Wong (2004) examine the growth of “alternative” grocers in Canada in recent years. They show that food sales at alternative grocers (a category that includes Wal-Mart, CostCo, and Zellers) grew at a pace of approximately 13 per cent in 2003, with growth expected to accelerate in the near future. According to Caicco, Piticco, and Wong (2004), the market share of these alternative grocers is expected to grow by between 1.5 and 2.2 p.p. per year between 2004 and 2006. Assuming that Statistics Canada does adjust the sample somewhat to the growth in market share, the mean growth in market share of the low-cost retailers not captured in the CPI (s) is probably 1.5 per cent. Data on the price differential between traditional and low-cost grocers are taken from Hausman and Leibtag (2004), using some judgment to tailor the results for Canada. Hausman and Leibtag find that non-traditional grocery stores have prices that are 27 per cent lower than traditional supermarkets. Caicco, Piticco, and Wong (2004) suggest that the grocery sector in Canada is more competitive than that in the United States across both traditional and discount retailers, so a 15 per cent difference in price between discount and traditional grocers is used for an upper limit of d.[20] Combining these two figures (with a weight of 11.72 per cent for food at home in the CPI) yields an outlet substitution bias of approximately 0.03 p.p. per year from grocery stores.

Recent market data for apparel sales at major retail chains in Canada are used to calculate the amount of outlet substitution bias in the footwear and apparel category of the CPI. The source of the data is an article that appeared in the *Globe and Mail* on 3 March 2005 (Strauss 2005). The data show that discount retailers such as Wal-Mart, Zellers, and Winners have gained an average of 0.4 p.p. of market share in each year from 2001 to 2004, mostly at the expense of the traditional department stores. Assuming that these discount retailers are able to offer discounts on clothing of about 15 per cent over traditional clothiers, this would lead to a combined contribution to outlet substitution bias of 0.003 per cent from apparel (this figure is small, since the clothing and footwear category accounts for less than 5 per cent of the CPI; the bias *within* this category is in fact 0.06 p.p. annually).[21]

The remaining portion of CPI that is subject to outlet substitution bias accounts for roughly 18 per cent of the total basket (see Table D1). The assumptions used in Crawford (1998) are used for this final category. Outlets are assumed to offer discounts of 10 per cent over traditional retailers, and to be increasing their market share by about 2.5 p.p. per year. This last category contributes 0.05 p.p. annually to the bias.

Table 3 summarizes the sources of outlet substitution bias.

Table 3: Contributions to Outlet Substitution Bias (per cent)

CPI component	Weight	Market share growth (*s*)	Outlet discount (*d*)	Outlet substitution bias
Food purchased from stores	11.7	1.5	15	0.03
Clothing and footwear	4.9	0.4	15	0.003
All others (see Table D1)	18.2	2.5	10	0.05
Total				0.08

An upper limit to this estimate would be no higher than 0.10 p.p. per year. Crawford estimates that the effect of outlet substitution bias is 0.07 p.p. per year (with an upper bound of 0.10 p.p.). This is somewhat smaller than a more recent study by White (2000), who measures

[20] This estimate of 27 per cent is also *not* quality adjusted; this is taken into consideration when determining the Canadian figure of 15 per cent.

[21] The figure of a 15 per cent discount is fairly arbitrary. However, the total estimate of outlet substitution bias is not sensitive to this assumption, since it accounts for so little of the total.

the outlet substitution bias in Canada at between 0.10 and 0.15 per cent annually.[22] Table 4 summarizes recent estimates of outlet substitution bias in Canada.

Table 4: Estimates of Outlet Substitution Bias (p.p.)

	Mean	Upper limit
Crawford (1998)	0.07	0.10
White (2000)	0.125	0.15
Rossiter (2005)	0.08	0.10

Another consideration for outlet substitution bias is the recent emergence of Internet retailing. Statistics Canada does not incorporate online purchases into the CPI. But if Internet retailers are able to offer cheaper quality-adjusted goods, then this may contribute to outlet substitution bias. Internet shopping, while still a relatively small portion of total retail sales, is growing rapidly. For example, nominal household online purchases in 2003 grew 25 per cent from 2002. But with e-commerce accounting for only 0.4 per cent of total household spending in 2003, its impact on bias in the Canadian CPI is negligible. However, this is one source of bias that will likely increase in importance over the coming years, as more consumers adopt the Internet as a means of obtaining goods and services.

6. Quality Change Bias

A unique feature of quality change bias is that, unlike other sources of bias described in this paper, quality bias can be negative.[23] Evidence for net negative quality bias on the total CPI, however, appears limited, and many studies have found quality bias (along with new goods bias) to account for a large part of the total *positive* bias in the CPI (Table F1 in Appendix F). Quality change bias is difficult to quantify, since it depends on decisions made by each price-taker at the time of a perceived quality change.[24] Thus, its estimate rests on a certain amount of judgment.

There are three ways to account for observed quality changes in the CPI. The first method is to make explicit quality adjustments, where the price-taker assesses the difference in value between the new and old items based on the perceived quality differences between them.

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[22] White also finds evidence of what he calls "unrepresentative outlet sample bias," which arises when prices increase less rapidly at outlets excluded from, or inappropriately weighted in, the sample. He finds that this contributes an additional 0.12 to 0.24 p.p. to total bias.

[23] Some authors have even argued that, since quality bias can be either positive or negative, its total effect on the CPI may be close to zero (see Hobijn 2003, for example).

[24] According to Statistics Canada (Ducharme 1997), there is not "enough evidence to support any precise numerical assessment of [the effect of quality bias] on the CPI."

For example, a higher price tag on a new-model DVD player that replaces an older model may be 50 per cent attributable to new features and 50 per cent attributable to pure price movements. Cost information from manufacturers may help guide this estimate. Lowe (1998) finds little evidence of bias arising from explicit quality adjustments at the Canada-wide level: "there have been almost as many downward [quality] replacements as upward ones."

The second method, called splicing (or "link-to-show-no-change"), is similar to explicit quality adjustments, but with the important distinction that it assumes that any difference in price is 100 per cent attributable to quality differences. This may cause problems with goods undergoing a high degree of technological change, and likely leads to a positive bias in these cases. Lowe (2001) supports this, with his preliminary results suggesting that splicing for quality changes as prices decline keeps the index higher, particularly for durable goods.[25]

The third method used to account for quality changes is with a hedonic price index, which estimates the way in which different observable features affect the price of the good. In some countries, hedonic price indexes are an increasingly popular alternative to matched-model techniques. The evidence for hedonic price indexes is mixed, although the literature generally favours hedonics over traditional matched-model techniques.[26] Hedonic regressions are typically used for goods with readily identifiable features and quality attributes. For this reason, some statistical agencies are moving towards hedonic regressions for many semi-durable and durable goods (particularly for home electronics and appliances). The move towards hedonics for measuring the prices of some durable goods, however, may be problematic. It has been shown that hedonics are generally more accurate in measuring prices of goods that do not undergo a rapid pace of technological advancement. Somewhat counterintuitively, the BLS employs hedonic price indexes for many electronic goods, as well as a few others.[27] Statistics Canada currently uses hedonic price indexes only for the category of computer equipment and supplies.[28]

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[25] Between 1989 and 1995, over 60 per cent of quality changes in the Canadian CPI were adjusted using splices.

[26] Some authors (see Hobijn 2001, for example) find evidence that hedonic price indexes may in fact be inferior to traditional price indexes. Statistics Canada feels that the evidence supporting hedonic price indexes is mixed, and is therefore proceeding with caution in incorporating hedonic prices into the official CPI.

[27] These include televisions, VCRs, DVD players, audio equipment, video cameras, washing machines, clothes dryers, microwaves, refrigerators, and college textbooks. The BLS *stopped* using hedonics to measure computer prices, switching to the option cost method, in October 2003.

[28] In preliminary work, Markle (1998) examines changes in quality and prices due to sample replacement for men's dress shirts, and finds that the price change attributed to quality (as recorded by the price-taker) does not often correspond (and is in fact sometimes opposite in sign) to what a hedonic price index would suggest. Lowe (1999) reviews Statistics Canada's theoretical concerns and experiences with hedonics.

It is unclear whether replacing traditional price indexes with hedonic indexes would eliminate bias in any particular direction. Evidence in the United States, where a great deal of research on hedonics has been undertaken, suggests that the difference between hedonic and traditional price indexes is not consistently in any one direction. Various research papers by the BLS show that, about half the time, the calculated hedonic price is *lower* than the CPI price, and that for the other half of the time it is *higher* than the CPI index (Shepler 2001b provides numerous examples). While hedonics may help account for readily identifiable (advertised) features of a product, they will not take into account factors that are not as evident at the time of purchase, such as durability improvements. In addition, difficulties may arise if certain new features are not homogeneous across all products. Adopting hedonics in the CPI would therefore not necessarily make the index more accurate.

Quality changes can be mismeasured with any of the three methods of adjustment discussed above, potentially resulting in positive bias if true quality improvements occur faster than they are measured. A fourth source of quality bias arises from the possibility that price-takers may altogether miss some quality changes in non-replaced items.

Much of the research on quality bias focuses on goods bias (which tends to be positive), and overlooks potential bias in service price indexes. Quality adjustments to the services components of the CPI are much more difficult to measure, and are often not performed by the price-takers. According to Statistics Canada (Prud'Homme and Kostenbauer 1997), "some measurement problems appear to be more serious for [the prices of] services than for goods." One could argue that perceived decreases in the quality of services at retail outlets and airlines have occurred in the past decade. Adjustment for these service quality changes have not been explicitly made to the CPI, potentially resulting in *negative* bias.

Crawford's (1998) estimate of quality bias is based on the positive bias that arises from durable goods. His estimate of the mean bias assumes that the quality bias in all goods and services *excluding* durable goods nets to zero; the upper-bound estimate allows for some non-durable net positive bias. This assumption does not seem unrealistic, since positive bias in some non-durable goods categories (such as pharmaceuticals) may well be offset by some negative bias in, among others, the services components highlighted above. Crawford bases his estimate of durable goods bias on a study by Gordon (1990), who finds 1.05 p.p. of positive quality bias in the durable goods category of U.S. CPI between 1973 and 1983. This figure, however, is long out of date and not measured using Canadian goods, though these caveats are fully acknowledged by Crawford.

The formula for quality change bias (B_Q) from Diewert (1998) is:

$$B_Q = \frac{(1+i)se}{1+e}, \qquad (3)$$

where s is the share of goods in the CPI basket that have been replaced by new models, e is the percentage of quality (or efficiency) improvements that are missed through the linking procedures, and i is the measured rate of total inflation. An alternative method is to simply take a weighted average of previous estimates of quality bias in different components of consumer durables. Lebow and Rudd (2003) estimate that many durable goods price indexes (excluding autos and computers) are upwardly biased in the U.S. CPI by 1.5 per cent a year, based on a variety of empirical results, as well as their own judgment.[29] Assuming a similar bias for these goods in the Canadian CPI, this contributes roughly 0.08 p.p. of quality change bias. Lebow and Rudd also estimate that, despite the introduction of a hedonic index in 1998, computer prices were upwardly biased by 4 per cent annually between 1998 and 2003 (when the BLS stopped using hedonic methods to measure computer prices). Since the Canadian CPI component for computers is still estimated with a hedonic regression, this would contribute roughly 0.02 p.p. of quality change bias. For the case of autos, Diewert's formula (equation (3)) is used. The degree of quality change missed, e, is initially assumed to have a fairly low value of 0.03, because quality changes are likely to be fairly accurately measured using detailed cost data from auto manufacturers.[30,31] Data for s are obtained from Statistics Canada. On average, between 1989 and 1994, the probability that any specific durable good in the CPI basket was replaced in a given year is roughly 40 per cent. This would suggest an upward quality bias from autos of 0.10 p.p. per year. Aggregating the estimates for all durable goods (13.75 per cent of the CPI basket), the upper bound for quality change bias in the Canadian CPI is 0.20 p.p. per year.

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[29] Evidence suggests that the bias is even larger for electronic goods than for other durables. Lebow and Rudd disaggregate the U.S. CPI into 33 subcomponents, but not by durability of good. Thus, the estimate of 1.5 per cent is derived by taking the values of those categories that appear to be composed primarily of durable goods, and should be considered only an approximation.

[30] Schultz (1999) states that "the practice of quality adjustments to car prices [by Statistics Canada] leaves many things to desire." Specifically, "incorrect quality adjustments might have been another potential cause of some of the misestimation of price change [of autos] in the CPI." Note that this does not, however, imply a bias in any one direction.

[31] Dalen and Bode (2004) estimate that the Dutch index for passenger car prices overstates a fully quality-adjusted price index by up to 1.4 per cent annually between 1990 and 1999. Reis and Silva (2002) also find that new car prices were overestimated in the Portuguese CPI by 2.2 p.p. per year between 1997 and 2001. Both studies rely on hedonic regressions for their results.

The estimate of quality change bias in cars, however, is probably too high. Crawford (1998), among others, discusses the possibility of negative quality change bias arising from government-mandated safety and anti-pollution technologies. Statistics Canada treats these changes as quality improvements, and adjusts for them accordingly in the CPI using cost data from manufacturers. Triplett (1988), however, argues that increases in prices from government mandates should be treated as pure price changes, suggesting that the current treatment would introduce a negative quality bias.[32] The BLS has treated pollution-control measures in the U.S. CPI for autos as pure price increases since 1999. Using detailed historical quality adjustment data for autos, the BLS (Fixler 1998) shows that the difference in treatment led to a negative bias of 0.03 p.p. per year between 1968 and 1997, when such changes were considered quality changes. An intermediate view is that negative quality change bias could arise if consumers do not value the new features by their full costs. Assuming that government-mandated safety features have a negative bias similar to that of anti-pollution features, the upper limit of quality change bias can be adjusted downward slightly to take this into consideration. This results in a mean estimate for quality change bias of about 0.15 p.p. per year. Table 5 summarizes these findings.

Table 5: Decomposition of Quality Change Bias (per cent)

Component	Weight	Bias	Contribution to total
Durables ex. autos & PCs	5.26	1.5	0.08
Computers	0.49	4.0	0.02
Autos	8.00	1.2	0.10
minus anti-pollution			-0.03
minus mandatory safety			-0.02
Total	13.75		0.15

This updated estimate of quality change bias is higher than Crawford's 1998 estimate primarily due to the adjustment for negative bias caused by the treatment of anti-pollution and safety features on vehicles in Canada. Given the detailed BLS research published since Crawford's estimate, the downward adjustment for this feature is about half that of Crawford's, resulting in a mean quality change bias that is 0.05 p.p. higher than his estimate, despite the comparable estimate of the upper limit (Table 6).

[32] The logic for this is illustrated by the following example: if the government legislates that airbags be installed in all new automobiles, then clearly consumers do not value the feature by its full cost. Thus, the increased price of the vehicle due to the addition of airbags does not represent an increased value placed on the vehicle by the consumer.

Table 6: Estimates of Quality Change Bias (p.p.)

	Mean	Upper limit
Crawford (1998)	0.10	0.20
Rossiter (2005)	0.15	0.20

7. New Goods Bias

A final source of bias in the CPI is new goods bias.[33] This bias can arise if, as new goods and services are introduced into the marketplace, their effects on consumers' standard of living are not accurately captured in the price index. Like quality bias, this form of bias cannot be precisely calculated, but an estimate can be obtained using a certain degree of judgment.[34] It is convenient to divide this bias into new products bias and new brands bias.[35]

7.1 New products bias

New products bias arises from changes in the consumer choice set with the introduction of new products into the marketplace (i.e., inventions). Specifically, new products bias occurs between the introduction of a new good into retail outlets and its introduction into the CPI basket.[36] For some goods, this can be a relatively short period of time, but for others the period can be extensive. Examples of such new products over history include microwaves, cellular telephones, and vehicle leasing. Bias will arise only if the change in the price of the excluded product is not the same as that of the total index. Since prices of new goods and services often decrease following their introduction (especially for consumer electronics), this creates a positive measurement bias.[37]

To accurately estimate new products bias would be a major undertaking. For each point in time, goods and services not concurrently included in the CPI would have to be identified, and their price declines in those periods measured. A number of earlier studies are useful for

[33] Despite its commonly used title, "new goods bias" in fact includes bias arising from both new goods and new services.

[34] As with quality bias, Statistics Canada (Ducharme 1997) states that a value for this bias "cannot be estimated."

[35] The concept of "new brands bias" was first discussed (to the author's knowledge) in Crawford, Fillion, and Laflèche (1997), although the concept seems to originate (under a different name) in Hausman (1994). Previous bias estimates had simply included new brands bias in the overall estimate of new goods bias.

[36] Statistics Canada will occasionally introduce new goods into the CPI basket *between* scheduled basket updates, which shortens the introduction delay, and hence reduces this form of bias.

[37] One could argue that the higher initial prices in fact reflect a "novelty premium" on the products, and that taking this into consideration might limit new products bias. Because it is difficult to estimate a product's novelty at the time of its introduction, this factor is not considered in estimating new products bias.

informing an updated estimate of this bias. Crawford (1993a) cites two examples of new goods that have caused bias: videocassette recorders and microwave ovens. Relative price declines for these two goods are estimated to be 18.9 per cent annually (1980–84) and 7.7 per cent annually (1968–72), respectively.[38] Hausman (1997) reports a decline in cellular phone (service and phone) costs of 5.3 per cent annually between 1985 and 1996.[39] Yu (2003) constructs a price index for Internet service providers in Canada and finds that the index declined an average 14.8 per cent annually between 1993 and 2000, prior to its introduction in the CPI basket in December 2002. These new product price declines are shown in Table E1 in Appendix E.

The combination of rapid technological advances over the past 5 to 10 years and infrequent basket updates has resulted in a number of new products that have not been immediately incorporated into the CPI basket. Goods and services that were fairly widely used prior to their introduction include home Internet services and digital cameras. Examples of new goods being introduced into the CPI basket some years after their initial availability are portable MP3 players and high-definition televisions. The share of consumer spending on these goods is relatively small, but the rapid pace of price decline contributes to upward bias.

It could be argued that the omission of new products in the CPI basket does not lead to a noticeable positive bias, since the new products will put downward pressure on prices of similar existing goods already included in the basket. For example, prior to the introduction of digital cameras into the CPI basket in mid-2003, their prevalence in the marketplace was already putting downward price pressure on the traditional film camera. Thus, while the CPI was not reflecting price declines in digital cameras, it was capturing declines in traditional camera prices that were occurring due to competition with digital cameras. For example, the CPI component “photographic equipment” (which excluded digital cameras at the time) declined, on average, 5 per cent annually from 2000 to 2002. The degrees to which the two goods’ prices declined are potentially very different, however: evidence suggests that price declines for digital cameras were much sharper. A study conducted by Statistics Finland finds that the average price of digital cameras *not adjusted for quality changes* declined an average of 19 per cent from 2000 to 2002 (Manninen 2004). The quality of digital cameras arguably increased substantially during this time, and, as such, quality-adjusted prices likely fell much more than 19 per cent. Thus, while there may be some price deflation for some goods’ prices with the introduction of new goods, it is not likely that it matches the declines in the prices of

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[38] For methodology, see Crawford (1993a) for VCRs and Gordon (1990) for microwave ovens.
[39] Cellular telephones are still not included in the Canadian CPI basket, although cellular airtime services were introduced in 1999.

new goods omitted from the CPI basket. New products bias is therefore almost certainly greater than zero.

Diewert (1998) derives a formula for new goods bias (B_N):

$$B_N = \frac{1}{2}(1+i)sd \text{ ,} \tag{4}$$

where s represents the expenditure share of new goods not yet incorporated into the CPI, d the decline in the relative price of missed new goods prior to their introduction into the CPI basket, and i the measured rate of total inflation. Given the examples in the previous paragraphs, the missed price decline of a new good prior to its introduction into the CPI appears to be roughly 10 per cent annually.[40] The introduction of new products into the CPI in recent years helps provide an estimate of the share that had — until that point — been missed in the basket. In December 2002, for example, Statistics Canada introduced new basic classes into the CPI that accounted for just less than 1 per cent of the basket.[41] Admittedly, it is unlikely that prices were decreasing in the years just prior to their introduction for all products, since a few of these services had already existed for a number of years. Accounting also for new goods and services that are introduced below the level of basic class,[42] it is unlikely that more than 1 per cent of consumer spending in any given year is spent on goods or services not yet included in the CPI basket.[43] This would result in an annual upward bias of 0.05 p.p., with up to 0.10 p.p. of bias in periods of high product introduction (where s equals 2 per cent).

New products bias, however, extends beyond new 'inventions.' For example, Diewert (1998) suggests that anyone with a new Internet connection (and a credit card) has a suddenly expanded selection of products from which to choose, many of which were previously

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[40] That is, the gross deflation is likely slightly higher than 10 per cent (close to the 13 per cent anually in Crawford), adjusted for a small degree of offset from price declines of competing existing goods.

[41] These were Internet access service (0.30 per cent) and financial services (0.51 per cent).

[42] This really only leads to a reassignment of weights within the basic class until the next basket update. New products introduced below the basic class level in 2005 accounted for an implied weight of 0.3 p.p., although this was not reflected in the basket, due to the reallocation of other goods' prices within the basic class (using geometric weights). These new products include MP3 players, recordable DVDs and CDs, and flat panel televisions. Some of these new goods replace obsolete goods (e.g., blank audio tapes), but, on net, the number of products is higher.

[43] The majority of this 1 per cent is due to new electronic goods in categories such as home entertainment equipment and services, computer equipment and supplies, and home appliances, which have a combined weight of about 2.5 per cent in the CPI basket and generally experience sharp price declines following their introduction into the market. Fortin (1990) uses 3 per cent of total consumer expenditure as an example of a period of high introduction of new goods. Diewert (1998) uses a very high estimate of 5 per cent, but this includes both new goods and new brands.

unavailable. Better transportation infrastructure can allow the consumer access to stores selling goods that were previously inaccessible. Significant changes to the attributes of an existing good or service, or the introduction of a new good or service over existing infrastructure (for example, on-demand television services over existing cable lines) may introduce new products to the consumer. Changes in government regulations can also lead to the "introduction" of a new good or service.[44] Accounting for these, it is likely that new products bias is 0.10 p.p. per year, with a maximum of 0.15 p.p., in line with Crawford's estimate (Table 7).

Table 7: Estimates of New Products Bias (p.p.)

	Mean	Upper limit
Crawford (1998)	0.10	0.15
Rossiter (2005)	0.10	0.15

7.2 New brands bias

New brands bias results from gains in consumer welfare owing to greater brand selection. The issue of new brands is more complex than that of new products, because it is difficult to measure the value that consumers place on having a larger selection of available brands.[45]

Hedonic regression analysis on durable goods prices has shown that brands are an important explanatory variable for prices, suggesting that consumers value individual brands differently.[46] If consumers value new brands over existing ones (that is, if the new brands are not perfect substitutes), then positive bias arises if the CPI fails to account for increased consumer welfare, even if the prices of new brands move in the same way as existing brands: with the expansion of the choice set, the consumer can achieve the same level of utility at a lower cost. Since the decline in the welfare-adjusted prices of the new brands at the time of their introduction is not reflected in the CPI, positive bias results. On the other hand, the

[44] However, this would lead to *negative* new products bias, since the price of the product moves from zero to a positive value. For example, prior to 2004, expenses for eye exams were covered by provincial health care in Ontario, and hence not included in the CPI. Since then, however, consumers have had to pay for this service.

[45] The Canadian CPI tracks the price of the most representative brand (subjectively determined, but usually by sales volume) at an outlet, and therefore may fail to account for changes in other brands' prices. New brands are also excluded from the CPI sample, unless they become a volume-selling brand.

[46] See, for example, BLS publications on hedonic price models for clothes dryers (Liegey 2003), microwave ovens (Liegey 2001a), refrigerators (Shepler 2001), videocassette recorders (Thompson 2001), DVD players (Liegey 2001b), and consumer audio products (Kokoski, Waehrer, and Rozaklis 2001). All of these studies include statistically significant brand variables.

elimination of certain brands over time might limit this bias. On net, however, the bias due to new brands is almost certainly greater than zero. Hausman (1994) estimates the effect on consumer surplus of the introduction of a new brand of cereal, and finds that "the impact of new [brands] on consumer welfare appears to be significant." He calculates that the U.S. CPI for cereal may be upwardly biased by as much as 25 per cent (in level terms) because it fails to take new brands into account.

Crawford (1998) estimates new brands bias to be no more than 0.15 p.p. per year, a number based on judgment.[47] However, there is no clear way to quantify this form of bias (Crawford appears to be the only author to do so), and, following his arguments, an upper limit of 0.15 p.p. with a mean of 0.10 p.p. per year seems to be a reasonable estimate of new brands bias (Table 8).

Table 8: Estimates of New Brands Bias (p.p.)

	Mean	Upper limit
Crawford (1998)	0.10	0.15
Rossiter (2005)	0.10	0.15

Aggregating new products and new brands bias, it is likely that the total new goods bias is 0.20 to 0.30 p.p. annually.

8. Other Issues

In general, literature on measurement bias in the CPI focuses on the above four categories of bias. Some authors, however, suggest additional sources of bias. No formal estimates of these biases are made, since they are presumed to be low.

Lebow and Rudd (2003) add a fifth type of bias: *weighting bias*. This arises in the U.S. CPI measure, they contend, because the CPI weights are derived from the BLS's consumer expenditure survey (CEX). As with Statistics Canada, the weights are derived from a survey, and not directly from the national income and expenditure accounts' consumer expenditure data. Thus, any inconsistencies between the two may lead to bias in either direction. Lebow and Rudd find evidence that the U.S. CPI is upwardly biased by 0.1 p.p. per year between 1998 and 2001 because of this.

Consumer-loyalty programs are not captured by Statistics Canada when calculating the CPI. It is thought that the discounts offered by these types of programs would not register on

[47] See footnote 9 in Crawford (1998) for a brief example of the implications of a new brands bias of this magnitude.

the total index, since only certain narrow classes of goods are covered and the discounts are often minimal. Bias would occur only if there was a rapid increase in the incidence of these programs over time. Thus, any positive bias is assumed to be negligible.

Taken together, the above-mentioned biases likely have no impact on the CPI. For this reason, estimates of their magnitude are not made. It is important, however, that these potential sources of bias be monitored for further developments.

9. Conclusion

This section first aggregates the four main sources of bias discussed in the paper to arrive at an estimate of the total bias in the Canadian CPI; it then discusses the implication of bias for inflation-targeting central banks and makes recommendations for statistical agencies to reduce the bias.

9.1 Total bias in the CPI

The total bias in the Canadian CPI can be estimated by aggregating the four main sources of bias described above. The evidence suggests that measurement bias in Canada has a mean of 0.58 p.p. per year, with an upper bound of 0.75 p.p. The lower bound of the bias is almost certainly positive, since quality change bias is the only type of bias that could possibly be negative, and this form of bias contributes less than one-quarter of the total bias.[48] Table 9 summarizes these findings, and compares them with Crawford's (1998) results (the last Canadian study of measurement bias).

Table 9: Total Bias in the Canadian CPI (p.p.)

	Crawford (1998)	Rossiter (2005)	
Type of bias	Mean	Mean	Upper limit
Commodity substitution	0.10	0.15	0.15
Outlet substitution	≅ 0.07	0.08	0.10
Quality change	0.10	0.15	0.20
New goods:	0.20		
New products		0.10	0.15
New brands		0.10	0.15
Total	**≅ 0.50 ***	**0.58**	**0.75**

* Crawford's total. Actual sum is 0.47 p.p.

[48] The lower bound is almost certainly greater than the sum of the commodity and outlet substitution biases (0.23 p.p. per year), because these figures are known with a certain amount of confidence, and quality change bias is almost surely not negative.

Bias in the CPI has increased slightly from 0.50 to 0.58 p.p. per year since Crawford's 1998 estimate. Two factors are primarily responsible for this increase. First, commodity substitution bias has increased from 0.10 p.p. to 0.15 p.p. in recent years, due to larger variations in relative prices, notably in the prices of computer equipment and supplies. Second, quality change bias is estimated to be about 0.05 p.p. higher per year than in 1998. This increase largely results from differences between the two authors' assessments of offsetting negative bias in the auto price index. Other sources of bias have remained essentially unchanged. It is difficult to say whether the increase in measurement bias of 0.1 p.p. per year is due to a true underlying increase in bias, or simply due to differences in judgment. Most likely, about half of the difference (that due to commodity substitution bias) is a true underlying (though possibly temporary) increase in bias, while the other half (from quality change bias) is the result of differing views. Since there is a great amount of uncertainty in some of the estimates, it is probable that these two numbers fall within the same confidence band.

On an international scale, a bias of 0.58 p.p. per year falls below the range of most estimates in other countries, consistent with Statistic Canada's reputation as a global leader in statistics. Most recently, Lebow and Rudd (2003) have estimated that U.S. CPI is upwardly biased by 0.87 p.p. per year. Other recent studies for the United States are in the same range. Gordon (2000) suggests that bias is approximately 0.65 p.p., while the U.S. GAO (2000) update to the Boskin Commission gives a range of 0.73 to 0.90 p.p. per year. Bias in the United Kingdom's retail price index (the Bank of England's inflation target from 1992 to 2003) is estimated by Cunningham (1996) to be in the range of 0.35 to 0.80 p.p. per year, while bias in the New Zealand CPI is estimated to be in the range of 0.65 to 1.0 p.p. per year (Diewert and Lawrence 1999). Bias in the German CPI is estimated at 0.75 p.p. per year (Hoffman 1998), while commodity and outlet substitution biases are estimated to contribute 0.10 to 0.25 p.p. per year to bias in the French CPI (Lequiller 1997). Many of the international estimates are years out of date, and it is possible that the biases may have increased since. For example, the increase in commodity substitution bias since 1998 in Canada due to more rapidly falling computer prices may well have occurred elsewhere. Table F1 in Appendix F provides details of numerous international bias estimates. It also includes a subtotal, providing a sum of the commodity and outlet substitution biases, the two that can be estimated with the greatest certainty.

9.2 Looking forward

Central banks should be aware of both the level and the volatility of measurement bias in the CPI.[49] In an inflation-targeting regime, measurement bias in the CPI can be fairly easily accommodated. The inflation target can be set at any level that equals *or exceeds* the estimated bias, thus providing flexibility in insuring against deflation.[50] This paper has shown that the bias in the Canadian CPI is below the rate of inflation targeted by the Bank of Canada and has not significantly changed since the last estimate was performed in 1998.

The fact that it is almost universally acknowledged that bias continues to be present in all price indexes raises certain questions. Perhaps most important is why statistical agencies have not acted to eliminate this bias. For example, updating the CPI basket weights on an annual basis would surely help eliminate a great part of the commodity substitution bias.[51] Further changes in methodology to minimize outlet substitution bias would also be warranted. Investigating how price differentials between outlets reflect differences in quality would certainly be informative. Finally, a faster adoption of new products into the CPI would minimize new products bias.

Revised current-methods CPIs have recently been developed in other countries, particularly in the United States by the BLS. Largely in response to the recommendations of the Boskin Report, the BLS publishes a CPI Research Series Using Current Methods (the CPI-U-RS), which is released once a year (at a monthly frequency), and is revised to follow current methodologies.[52] If Statistics Canada were to produce such a series, it would help by removing obsolete procedures from the CPI over history, and might enable the calculation of a more accurate ex post measure of the cost of living. This, in turn, might help to more accurately determine bias. A revised current-methods CPI would help economists and the general public alike to gain a deeper understanding of underlying inflation dynamics and economic behaviour.

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[49] Kent (2004) suggests that, although the CPI may be more biased than some other measures of inflation, it has many desirable characteristics that make it preferable as a target of monetary policy.

[50] The measurement bias is not the only factor considered when setting the level of the inflation target.

[51] The BLS currently introduces new basket weights every two years.

[52] The average difference between the published U.S. CPI-U and the CPI-U-RS was 0.45 p.p. per year between 1978 and 1998 (Stewart and Reed 1999). The difference in Canada, however, would probably be considerably smaller, since a large amount of the gap between the two measures in the United States can be accounted for by vast improvements to the U.S.'s micro-aggregation formula and changes in the treatment of owned accommodation.

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Appendix A

The Canadian CPI can be broadly divided into the following eight expenditure categories:

Table A1: CPI Basket Weights (July 2004 to present)

Category	Weight (per cent)
Food:	
From stores	11.72
From restaurants	5.17
Shelter	26.75
Household operations & furnishings	10.58
Clothing & footwear	5.37
Transportation	19.79
Health & personal care	4.52
Recreation, education, & reading	11.96
Alcoholic beverages & tobacco	4.13
Total	100.00

Source: Statistics Canada (2004)
Note: Total may not add up due to rounding.

Appendix B

The Laspeyres price index (P_t^L), which holds quantities constant at base period levels, is:

$$P_t^L = \frac{\sum_{j=1}^{N} Q_{0,j} P_{t,j}}{\sum_{j=1}^{N} Q_{0,j} P_{0,j}}, \tag{B1}$$

where $Q_{t,j}$ is the quantity of good j consumed in period t, and $P_{t,j}$ is the price of good j in period t. Note that there are N goods, and that a subscript of *0* represents the base period.

The Paasche price index, which uses current-period quantities, is:

$$P_t^P = \frac{\sum_{j=1}^{N} Q_{t,j} P_{t,j}}{\sum_{j=1}^{N} Q_{t,j} P_{0,j}}. \tag{B2}$$

Fisher's "ideal" price index is a geometric mean of the Laspeyres and Paasche indexes, and, in effect, accounts for quantity changes in every period:

$$P_t^F = \sqrt{P_t^L P_t^P} . \tag{B3}$$

Appendix C

C.1 Technical Details

This section describes the formula used to calculate commodity substitution bias. See Diewert (1998) for a complete derivation.

The approximation for commodity substitution bias is:

$$B_C = \frac{1}{2}(1+i)Var(e)\,, \qquad \text{(C1)}$$

where $Var(e)$ is the variance of the relative-price ratios $\left(p_n^t / p_n^{t-x}\right)$ for each basic class of the CPI:

$$Var(e) = \sum_{n=1}^{N}\left[w_n\left(\frac{p_n^1/p_n^0}{1+i}-1\right)^2\right], \qquad \text{(C2)}$$

where p_n^t represents the price of component n in period t, w_n is the basket weight of component n measured at basket year quantities *and* prices, and i is the measured rate of inflation. Period 0 is the first month in which a given set of CPI basket weights are used, while period 1 is the final month.

Diewert cleverly shows that the term $(1+i)Var(e)$ in equation (C1) approximates the difference between a Laspeyres and its corresponding Paasche price index. Thus, using a second-order Taylor series approximation, the geometric mean of the two price indexes (i.e., the Fisher price index — see equation (B3)) is approximated by their average. The substitution bias is therefore roughly equal to one half of the difference between the Laspeyres and Paasche indexes, as revealed by equation (C1).

C.2 Sources of Bias

Table C1 decomposes the commodity substitution bias, showing the three largest contributors to the bias in each period.

Table C1: Important Contributors To Commodity Substitution Bias

Period	1995–1997		1998–2002		2003–2004	
Bias	0.07		0.25		0.13	
	Description	Contribution	Description	Contribution	Description	Contribution
1)	Mortgage interest cost	0.012 p.p. (16.8%)	Cigarettes	0.070 p.p. (28.5%)	Computer equipment & supplies	0.023 p.p. (17.8%)
2)	Computer equipment & supplies	0.007 p.p. (9.4%)	Computer equipment & supplies	0.042 p.p. (16.9%)	Electricity	0.020 p.p. (15.3%)
3)	Tuition fees	0.005 p.p. (6.3%)	Natural gas	0.018 p.p. (7.3%)	Fuel oil & other fuel	0.008 p.p. (6.0%)

Appendix D

Table D1 lists the components included in the calculation of outlet substitution bias (as in Crawford 1998, with updated weights).

Table D1: CPI Components Subject to Outlet Substitution Bias

CPI component	CPI weight (per cent)
Food purchased from stores	11.72
Clothing & footwear[1]	4.92
Household operations[2]	5.80
Household furnishings	3.76
Air transportation	0.88
Health care goods	0.93
Personal care, supplies, & equipment	1.31
Recreational equipment & services[3]	1.90
Home entertainment equipment & services	1.25
Tobacco products & smokers' supplies	2.37
Total	34.84
Total excluding food, clothing, & footwear	18.20

[1] Excluding clothing materials, notions & services.
[2] Excluding child care & domestic services; covers items such as communications, household chemical products, paper and plastic household supplies.
[3] Excluding vehicles.
Source: Statistics Canada (2004)
Note: Totals may not add up due to rounding.

Appendix E

Table E1 provides examples of some new products' price declines prior to their introduction into the CPI basket.

Table E1: Price Changes Leading to New Products Bias (per cent)

Product	Period	Annual price decline
Microwaves	1968-1972	7.7
VCRs	1980-1984	18.9
Cellular phones	1985-1996	5.3
Internet	1993-2000	14.8
Digital cameras	2000-2002	19.0

Appendix F

Table F1: International Estimates of Measurement Bias (p.p.)

Source of bias	Canada Rossiter (2005)	Canada Crawford (1998)	France Lequiller (1997)	Germany Hoffman (1998)	New Zealand Diewert & Lawrence (1999)	UK Cunningam (1996)	US Boskin Report (1996)	US U.S. GAO Update (2000)	US Lebow & Rudd (2003)
Commodity substitution	0.15	0.10	0.05 – 0.10	0.10	0.05 – 0.15	0.05 – 0.10	0.40	0.08 – 0.20	0.35
Outlet substitution	0.08	0.07	0.05 – 0.15	0.10	0.25	0.10 – 0.25	0.10	0.10	0.05
Subtotal	**0.23**	**0.17**	**0.10 – 0.25**	**0.20**	**0.30 – 0.40**	**0.15 – 0.35**	**0.50**	**0.18 – 0.30**	**0.50‡**
Quality change	0.15	0.10	n/a	0.50	} 0.35 – 0.60	0.20 – 0.30	} 0.60	} 0.48 – 0.60	} 0.37
New goods	0.20	0.20		0.10		0.00 – 0.15			
Total	**0.58**	□ **0.50**	**n/a**	**0.75***	**0.65 – 1.00**	**0.35 – 0.80**	**1.10**	**0.73 – 0.90†**	**0.87**

* Author's total (does not correspond to sum of components).
† Because the subcomponent figures are the range of independent estimates given by four individuals, the total range does not correspond to the sums of the minimum and maximum values.
‡ Includes 0.10 p.p. for "Weighting Bias."

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