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Abstract

In this paper, the authors propose a measure of underlying inflation for Canada obtained from estimating a monthly factor model on individual components of the CPI. This measure, labelled the common component of CPI, has intuitive appeal and a number of interesting features. In particular, it is not affected by sector-specific price movements that can distort the signal in many other measures of underlying inflation, and appears to capture price movements that are indicative of aggregate demand fluctuations in the Canadian economy. This indicator may serve as a useful complement to existing measures of underlying inflation monitored by the Bank of Canada.

JEL classification: C1, E31, E32, E52, E58
Bank classification: Econometric and statistical methods; Inflation and prices; Business fluctuations and cycles; Monetary policy framework

Résumé

Les auteurs proposent une mesure de l'inflation sous-jacente au Canada qu'ils obtiennent en estimant, à partir de données mensuelles, un modèle factoriel des variations des composantes individuelles de l'indice des prix à la consommation (IPC). La mesure, dénommée composante commune de l'IPC, présente un attrait intuitif et un certain nombre de caractéristiques intéressantes. En effet, elle n'est pas influencée par les mouvements sectoriels de prix qui peuvent brouiller le signal envoyé par un bon nombre d'autres mesures de l'inflation sous-jacente, et elle semble capter les mouvements de prix associés aux fluctuations de la demande globale dans l'économie canadienne. Cet indicateur pourrait être un complément utile des mesures de l'inflation sous-jacente qui font l'objet d'un suivi régulier de la part de la Banque du Canada.

Classification JEL : C1, E31, E32, E52, E58
Classification de la Banque : Méthodes économétriques et statistiques; Inflation et prix; Cycles et fluctuations économiques; Cadre de la politique monétaire

1. Introduction

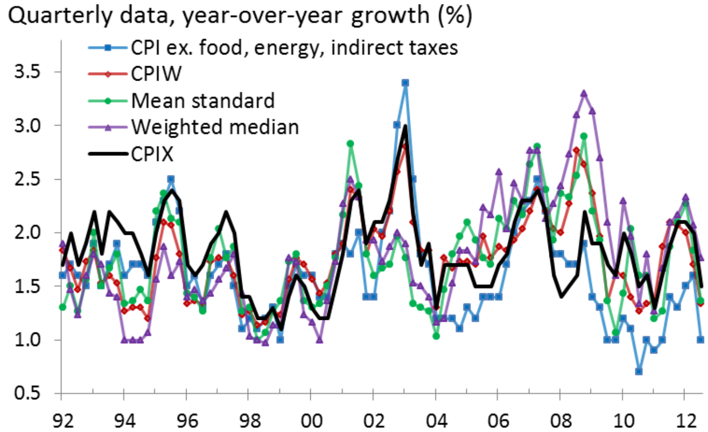
For an inflation-targeting central bank such as the Bank of Canada, assessing underlying inflationary pressures in the economy is central to the conduct of monetary policy. Although the inflation target in Canada is specified in terms of the annual rate of increase in the consumer price index (CPI), the high-frequency noise in this measure motivates the use of "core" inflation as a short-term guide for monetary policy. The Bank's preferred measure of core inflation (CPIX) excludes eight of the most volatile components of the CPI and removes the effects of changes in indirect taxes from the remaining components. By excluding price movements that are likely transitory, subject to frequent supply shocks or influenced directly by movements in monetary policy (mortgage interest cost), this measure is intended to provide a clearer signal of the underlying trend in inflation than can be inferred from total CPI inflation.[1]

In addition to CPIX, the Bank also monitors a set of alternative measures of underlying inflation. This includes measures that exclude a fixed set of volatile components from the CPI basket (CPI ex. food and energy), attribute a relatively lower weight to volatile components (CPIW), remove extreme price movements in a given month (mean standard), and focus on the median of price changes (weighted median).[2] These alternative measures generally provide a message relatively consistent with CPIX, but they can sometimes diverge substantially (see Figure 1), making the task of identifying underlying inflation challenging. Moreover, these measures can be affected by sector-specific disturbances. For instance, the elevated levels of some of them in 2002–03 largely reflect the run-up in one component of the CPI: automobile insurance premiums.

In this paper, we seek to expand the set of core inflation measures monitored by the Bank of Canada by drawing on the growing application of factor models to gauge underlying inflation. Estimating a factor model using disaggregated monthly CPI data, we extract the component of inflation that is common across the individual series that comprise the CPI. We label this measure the "common component of CPI" and note a number of interesting features. In particular, contrary to most other measures of underlying inflation, the common component of CPI is not affected by sector-specific price movements. Empirical analysis also establishes that the common component of CPI moves with key macroeconomic variables, most notably the output gap. Hence, this measure appears to capture price movements that are indicative of aggregate demand fluctuations in Canada.

Figure 1. Alternative measures of underlying inflation can provide contrasting messages

Quarterly data, year-over-year growth (%)



The remainder of this paper is organized as follows. Section 2 provides a general overview of factor models, the intuition behind their application to measuring underlying inflation and a description of the

[1]The eight excluded components are: fruits, vegetables, gasoline, fuel oil, natural gas, tobacco products, intercity transportation and mortgage interest cost. See Macklem (2001) for more details on CPIX.

[2] See Hogan, Johnson and Lafleche (2001) for details on the construction of these alternative measures.

relevant literature. Section 3 describes the data and estimation procedure used to extract the common component of CPI. Section 4 details the empirical results. These include how the common component of CPI relates to other measures of inflation, the individual CPI components used in its construction and key macroeconomic variables typically used to analyze inflation dynamics. Section 5 examines the robustness of the common component and addresses some practical issues related to its construction. Section 6 offers some conclusions.

2. Factor Models and Their Application to Measuring Underlying Inflation

A factor model is a statistical procedure that represents the variation in a set of variables as the sum of one or more factors representing co-movements across variables, and an idiosyncratic term capturing the part unexplained by co-movement in the panel. The technique and its applications to macroeconomic issues have been studied and developed extensively by Stock and Watson (1989, 1998, 2002a and b, 2005) and Forni et al. (2000, 2005). To see how the factor methodology relates to the issue of underlying inflation measurement, one can think of the individual prices comprising the Canadian CPI as being driven by a common source of variation as well as unrelated sector-specific events. It is important that monetary policy-makers be able to distinguish between these sources of price movements, since common movements in prices are more likely to reflect underlying inflationary pressures related to aggregate demand than sector-specific disturbances. A factor model is well suited to this decomposition of inflation. Specifically, let $\pi_{i,t}$ denote the rate of inflation of the *i*-th component of the CPI. Then, the general form of the factor model can be expressed as

$$\pi_{i,t} = \Lambda_i F_t + \varepsilon_{i,t}, \tag{1}$$

where each individual inflation rate is related to a common factor, F_t, through Λ_i (factor loadings), and $\varepsilon_{i,t}$ is an idiosyncratic term representing sector-specific disturbances that are uncorrelated with F_t.[3] Hence, underlying inflation in this context ($\tilde{\pi}_t$) is defined as

$$\tilde{\pi}_t = \Lambda F_t, \tag{2}$$

where Λ is the matrix of factor loadings. Note that the framework presented above is static; i.e., $\tilde{\pi}_t$ in equation (2) is identified as the common source of price variation that is uncorrelated with sector-specific shocks *contemporaneously.* Dynamics can be introduced to this system by expressing the panel of inflation data as a distributed lag of the common factor plus an idiosyncratic term, and positing time-series processes for both of these components. In that case, the common component of CPI would be identified as the common source of price variation that is uncorrelated with sector-specific shocks at all leads and lags.

Variants of the above framework have been applied extensively in the measurement of underlying inflation. Kapetanios (2002) employs a state-space representation of a dynamic factor model and uses subspace algorithms to extract a factor representing core inflation in the United Kingdom. Cristadoro et al. (2005) compute a measure of core inflation for the euro area by estimating a dynamic factor model on a large panel of inflation indicators encompassing both euro and national data. Similarly, Giannone and Matheson (2007) estimate a measure of core inflation for New Zealand using a dynamic factor

[3] In principle, more than one factor can be extracted, but this is rare in applications to measure underlying inflation. We explore this possibility further in section 5.1.

model with disaggregated CPI data, while Tekatli (2010) does so for Turkey. Kirker (2010) also uses a dynamic factor approach to measure core inflation in New Zealand, but employs an identification scheme that allows the core inflation measure to be a function of two factors: one for tradable and the other for non-tradable components of the CPI. For the United States, Reis and Watson (2007) use a dynamic factor approach to identify "pure inflation," the common component of inflation that has an equiproportional effect on all prices of the personal consumption deflator (PCE), while being uncorrelated with relative price changes at all horizons. Amstad and Potter (2009) also develop measures of underlying inflation for both the CPI and PCE in the United States using a dynamic factor model.

Our work draws on this literature to compute a measure of underlying inflation for Canada.

3. Data and Estimation

The common component of CPI is extracted over the period starting in January 1990 (to October 2012 in this study), using 54 monthly Canadian CPI series.[4] These 54 series cover 100 per cent of the CPI basket, are adjusted to remove the effect of changes in indirect taxes and are expressed on a year-over-year basis. This data set is thus identical to the one used to construct other measures of core inflation at the Bank of Canada, which facilitates a direct comparison across measures. The use of year-over-year growth rates also eliminates concerns regarding the need to seasonally adjust the CPI data.[5]

The factor model outlined in equation (1) is estimated by the method of principal components, following Stock and Watson (2002a and b).[6] All series are standardized prior to estimation, as required by the factor model. In this case, the common component of CPI is extracted by exploiting only the contemporaneous variance-covariance matrix of the inflation data panel (static approach). We favour this method for its relative simplicity compared to other estimation procedures that have been suggested in the literature. In section 4.1, however, we test the robustness of our estimate to using more complex dynamic approaches and find that the results do not differ substantially.

One source of contention in the literature on factor models is the number of factors that should be extracted from the data set. Our choice to focus on the first common factor is motivated by the intuition that there should, in principle, be only one component common to all items in the CPI. However, we have also applied the selection criterion suggested by Bai and Ng (2002) and found the procedure to recommend one factor.

Since the factor model is estimated on standardized data, the common component is scaled to be comparable to the original CPI data. This is done by multiplying the common component by the standard deviation of total CPI inflation and adding back the sample mean, as is standard practice in the previously cited literature. Therefore, the common component will by construction have the same

[4] This time period balances our aim to focus on the inflation-targeting regime while having a sufficiently long sample to conduct empirical analysis. The 54 CPI series used are listed in Table 2.

[5] Statistics Canada does not publish disaggregated CPI data on a seasonally adjusted basis, so in that case we would have to seasonally adjust the data ourselves. Seasonal adjustment procedures can be unreliable near the end of the sample, and are subject to historical revisions.

[6] The principal component estimator is $(X'\hat{\Lambda}/N)$, where X is the panel of data, $\hat{\Lambda}$ is the estimated matrix of factor loadings and N is the number of data series (54, in this case). The first principal component corresponds to the eigenvector associated with the higher eigenvalue in the data panel.

average progression as total CPI inflation (1.9 per cent over this sample). Note that the scaling of the common component of CPI facilitates a comparison across inflation measures and does not alter any of the main results in this paper.

4. Results

4.1 Statistical properties

Figure 2 shows the extracted common component of CPI, along with total CPI (excluding indirect taxes) and CPIX inflation since 1992 (post-inflation targeting sample). The common component is noticeably smoother than both inflation series. Although the common component and CPIX inflation are positively correlated, significant divergences have occurred over time. This is especially the case in 2002–03, when the common component remained close to 2.0 per cent, while both total CPI and CPIX inflation increased significantly following the run-up in automobile insurance premiums. This illustrates the ability of the common component to filter through idiosyncratic shocks. In fact, we find that the common component of CPI explains only about 20 per cent of the total variance of the 54 CPI components (see Table 2). This suggests that a majority of movements in total CPI inflation are component-specific rather than reflecting movements common across CPI components. This finding is also consistent with the results of Reis and Watson (2007) and Boivin, Giannoni and Mihov (2009), which show the dominance of sector-specific shocks in explaining the variability of inflation in the United States.

Figure 2. The common component of CPI

Monthly data, year-over-year growth (%)

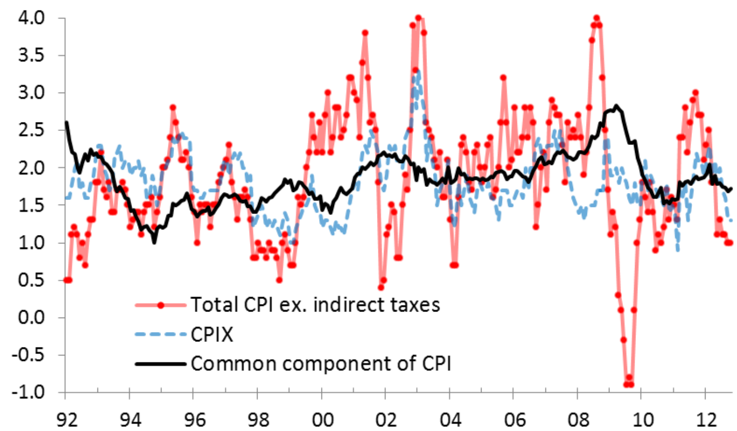


Table 1 provides descriptive statistics consistent with these observations. As measured by the standard deviation of year-over-year changes, the common component of CPI is less volatile than both CPI and CPIX inflation. This low volatility reflects the aforementioned fact that most of the variance in prices is found to be driven by sector-specific developments that do not influence the common component of CPI. Table 1 also shows that the common component of CPI is only weakly positively correlated with CPI and CPIX inflation. For instance, the contemporaneous correlation between total CPI inflation excluding indirect taxes and the common component is only 0.02. Even when eight of the most volatile components are excluded (CPIX), the correlation remains relatively weak (0.21). This suggests that the common component of CPI may contain information that is masked by the dominance of sector-specific shocks in these other measures of inflation. The information content of the common component of CPI is further explored in the following sections.

Table 1. Descriptive statistics

1992m1-2012m10 *y/y inflation*	Standard deviation	Correlation with common component
Total CPI	0.92	0.11
Total CPI ex. indirect taxes	0.85	0.02
CPIX	0.40	0.21
Common component of CPI	0.34	-

4.2 Relationship between the common component and individual CPI components

Table 2 shows the contemporaneous correlation between the year-over-year inflation rates of individual CPI components and the common component of CPI. It also shows the share of the variance of these individual inflation rates that is explained by movements in the common component.[7] These statistics help determine how different prices respond to common sources of variation, as well as the extent to which movements in individual prices are indicative of co-movements across the CPI basket.

The inflation rates of a vast majority of the CPI components (41 of 54, comprising 69 per cent of the basket) are positively correlated with the common component of CPI, suggesting a similar directional response of most consumer prices to common sources of variation. At the same time, the common component of CPI explains a relatively low share of the variance of most of these prices, which is again consistent with the dominance of sector-specific shocks driving the variance of inflation in Canada.

[7] This is the R-squared obtained from a regression of each individual component's inflation rate on the common component of CPI over the full estimation sample.

Table 2. Relationship between common component and individual components of the CPI

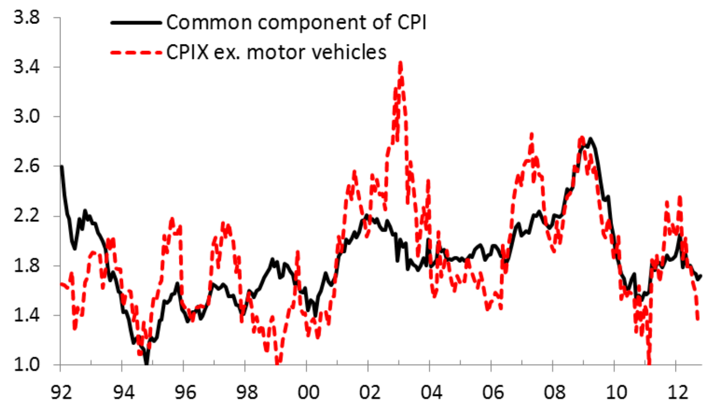
CPI components (y/y)	Correlation	% of explained variance
Alcoholic beverages served in licensed establishments	0.86	0.74
Food purchased from restaurants	0.82	0.68
Personal care services	0.81	0.66
Rented accommodation	0.80	0.64
Clothing material notions and services	0.73	0.53
Health care services	0.70	0.49
Alcoholic beverages purchased from stores	0.68	0.47
Health care goods	0.68	0.46
Property taxes	0.68	0.46
Mortgage interest cost**	0.66	0.43
Water	0.65	0.42
Tobacco products and smokers' supplies**	0.62	0.39
Child care and domestic services	0.62	0.38
Other cultural and recreational services	0.56	0.32
Fruit, fruit preparations and nuts**	0.55	0.31
Other household goods and services	0.55	0.30
Local and commuter transportation	0.50	0.25
Household chemical products	0.45	0.21
Electricity	0.42	0.18
Personal care supplies and equipment	0.42	0.18
Education	0.41	0.17
Clothing accessories and jewellery	0.39	0.15
Dairy products and eggs	0.38	0.14
Passenger vehicle parts maintenance and repairs	0.35	0.12
Services related to household furnishings and equipment	0.34	0.11
Recreational equipment and services (excluding recreational vehicles)	0.31	0.10
Footwear	0.29	0.08
Operation of recreational vehicles	0.29	0.08
Intercity transportation**	0.27	0.07
Other owner accommodation expenses	0.25	0.06
Clothing	0.25	0.06
Meat	0.22	0.05
Homeowners' maintenance and repairs	0.22	0.05
Reading material and other printed material (excluding textbooks)	0.21	0.05
Bakery and cereal products (excluding infant food)	0.20	0.04
Household textiles	0.17	0.03
Furniture	0.16	0.03
Vegetables and vegetable preparations**	0.14	0.02
Other passenger vehicle operating expenses	0.14	0.02
Fish, seafood and other marine products	0.13	0.02
Household equipment	0.03	0.00
Fuel oil and other fuels**	-0.01	0.00
Paper, plastic and foil supplies	-0.03	0.00
Leasing of passenger vehicles	-0.03	0.00
Other food products and non-alcoholic beverages	-0.04	0.00
Gasoline**	-0.06	0.00
Home entertainment equipment parts and services	-0.07	0.01
Travel services	-0.13	0.02
Natural gas**	-0.14	0.02
Communications	-0.17	0.03
Homeowners' home and mortgage insurance	-0.22	0.05
Replacement cost	-0.24	0.06
Purchase of recreational vehicles	-0.25	0.06
Purchase of passenger vehicles	-0.33	0.11
Average	**0.30**	**0.19**

** Excluded from CPIX

The 13 CPI components whose price movements are negatively correlated with the common component comprise 31 per cent of the CPI basket, and contain three of the eight components that are excluded from CPIX (all three of these are energy prices).[8] Notably, movements in motor vehicle prices, which have a weight of 7 per cent in CPI, are negatively correlated with the common component of CPI. This partly explains why the correlation between CPIX inflation and the common component is so weak: in fact, when excluding motor vehicles from CPIX, the correlation between this modified measure of core inflation and the common component jumps from 0.21 to 0.63 (Figure 3). The correlation has been particularly strong over the past four years.

Figure 3. Motor vehicle prices mask some of the correlation between the common component and CPIX

Monthly data, year-over-year growth (%)



Another interesting observation is that the CPI components most positively linked to the common component of CPI, such as served food and alcohol, personal care services, and rent, are concentrated in the service sector. Over half of the variation in these prices is explained by movements in the common component of CPI. As Table 3 shows, the common component is indeed highly positively correlated with inflation in the CPI for services. This relationship is less pronounced for the CPI for goods, and is negative for the energy subaggregate of the CPI. This is consistent with the result of Kirker (2010), who shows that a factor model-based estimate of core inflation for New Zealand is more closely linked to prices for non-tradable than tradable items. One reason movements in services prices may be more representative of common price pressures is that many goods are traded globally and hence are influenced by factors such as exchange rate movements and foreign macroeconomic developments.

Table 3. Correlation between common component and subaggregates of the CPI

1992m1-2012m10 y/y inflation	Correlation coefficient
Goods ex. energy	0.10
Services	0.55
Energy	-0.20

4.3 Relationship between the common component and macroeconomic variables

In this section, we examine the relationship between the common component of CPI and macroeconomic variables typically used to explain inflation dynamics. As shown by Demers (2003), identifying a statistical relationship between CPIX inflation and aggregate demand indicators (the Phillips curve) has become increasingly difficult since the adoption of inflation targeting in Canada. This is likely due in part to the success of monetary policy in keeping inflation low and stable. However, this apparent lack of relationship could also be partly driven by the dominance of sector-specific shocks masking the component of inflation that is related to macroeconomic fundamentals. To investigate whether the common component of CPI helps reveal this relationship, we estimate the following regression using quarterly data, from 1992 to 2012:

[8] Excluding these 13 components when extracting the common component yields a very similar measure (correlation of 0.99).

$$CC_t = \alpha + \beta_1 Ygap_{t-5} + \sum_{i=1}^{11} \gamma_i \Delta ULC_{t-i} + \sum_{j=1}^{2} \delta_j \Delta CanUsExch_{t-j} + e_t, \tag{3}$$

where CC_t is the common component of CPI (in y/y terms), $ygap_t$ is the Bank of Canada's conventional estimate of the output gap, ULC_t is unit labour costs for the total economy, and $CanUsExch_t$ is the Canada-U.S. nominal bilateral exchange rate (an increase in this series represents a depreciation of the exchange rate).[9] The output gap represents aggregate demand conditions, unit labour costs capture wage pressures while controlling for changes in productivity, and the exchange rate accounts for possible pass-through effects from variations in the price of imported goods. Δ denotes the first difference of the natural logarithm of the series. The lag structure is selected using the Schwarz information criterion and Table 4 provides estimation results.

We find that all variables entering the equation are statistically significant at the 5 per cent level. Strikingly, these variables account for 90 per cent of the variation in the common component of CPI.[10] Of particular interest is the statistical significance of the output gap in explaining movements in the common component. Contrary to previous findings for Canada, we do find evidence of an inflation-output relationship. The estimated coefficient on the output gap suggests that a 1 percentage point increase in the output gap boosts the common component by about 0.1 percentage points after 5 quarters. Hence, the common component of CPI appears to capture (with a lag) movements in prices that are indicative of aggregate demand pressures in the Canadian economy. Figure 4 shows that movements in the common component have generally mirrored those of the business cycle. Admittedly, the estimated coefficient on the output gap is quite small and therefore consistent with the broader finding of a flattening of the Phillips curve under Canada's inflation-targeting regime.

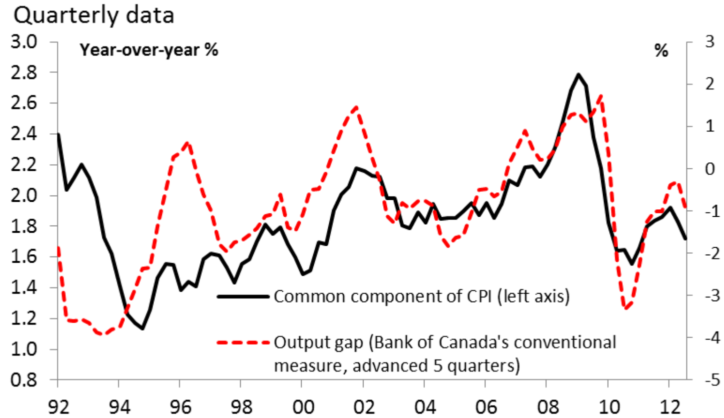
Table 4. Regression Results – equation (3)
Sample 1992Q1–2012Q3

Variables	Coefficient	*p-value**
Output gap (5th lag)	0.11	0.00
Changes in unit labour costs (sum of 11 lags)	0.71	0.00
Changes in the exchange rate (sum of 2 lags)	0.02	0.00
Adjusted-R^2	0.88	
Durbin-Watson statistic	0.75	

*Using Newey-West HAC standard errors

Figure 4. Movements in the common component of CPI are indicative of aggregate demand fluctuations

Quarterly data



[9] The Bank of Canada's conventional estimate of the output gap is available on the Bank of Canada's website (http://www.bankofcanada.ca/rates/indicators/capacity-and-inflation-pressures/product-market-definitions/product-market-historical-data/), while the bilateral exchange rate and unit labour costs series are taken from Statistics Canada's CANSIM database (series v37426 and v29509282, respectively).

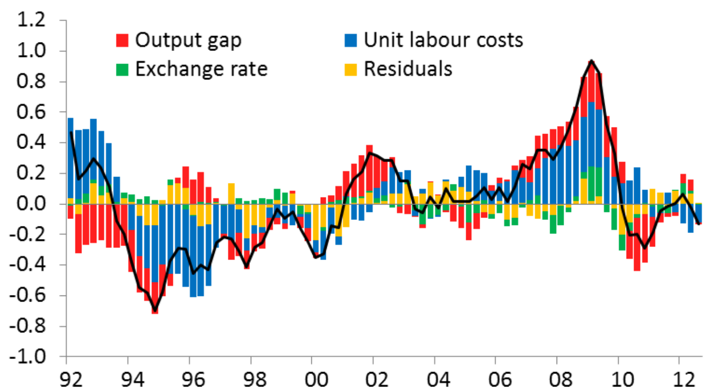
[10] The high R^2 is somewhat boosted by the persistence introduced from expressing the common component on a year-over-year basis. This is also why the Durbin-Watson statistic shows the residuals to be serially correlated. This can be addressed by augmenting equation (3) with moving-average terms, which we find does not alter any of the main results. The regression results also hold using quarter-over-quarter inflation (with an adjusted R^2 of about 0.65).

The lag selection of unit labour costs indicates that wage pressures are only gradually reflected in the common component, whereas the relatively low estimated coefficient on the exchange rate is consistent with the weak exchange rate pass-through documented in previous research for Canada.[11]

Using the estimated coefficients from Table 4, the common component can be decomposed into its main drivers. As Figure 5 shows, the common component was at its historical trough in in the mid-1990s, a period when unit labour costs were a particularly large drag on underlying inflation. The common component then hovered around its average over the early to mid-2000s, before being driven up considerably by both demand and cost pressures. Following the recent recession, the common component fell sharply as labour cost pressures eased and economic slack emerged.

Figure 5. Decomposing the common component of CPI

Contributions to the deviations of the common component of CPI from its average (in percentage points)



Note that the regression results reported in Table 4 were found to be robust across various measures of the output gap, wages and the exchange rate, including specifications that use real-time data. Variables that were tested but not found to be significant in explaining movements in the common component of CPI include oil and other commodity prices, global inflation, and the global output gap.

5. Sensitivity Analysis

In this section, we examine the robustness of the extracted common component to different assumptions regarding model specification and estimation, the data used in the model, and real-time versus full-sample estimation.

5.1 Static versus dynamic factor model

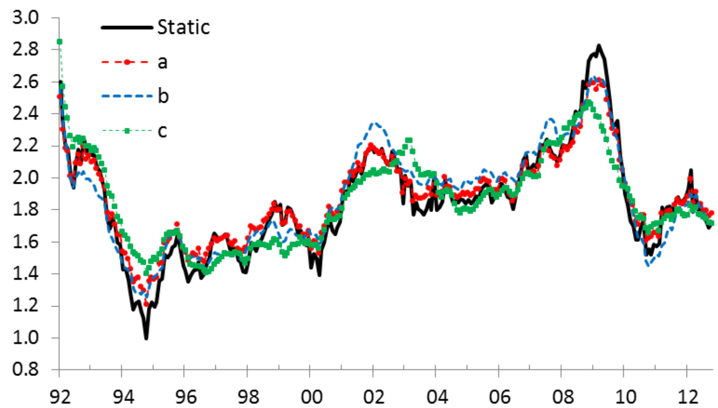
As previously mentioned, our decision to extract the common component of CPI using a static factor model is motivated in part on practical grounds. Dynamic factor models are more complex, computationally more intensive and in other applications have not been found to have obvious advantages over a simpler, static approach (Boivin and Ng 2005). Furthermore, it is critical for the conduct of monetary policy that measures of underlying inflation can be easily communicated. Naturally, moving to a dynamic model makes this task increasingly more challenging. Nevertheless, it remains important for policy analysis that the common component be robust to some of these alternative specifications.

[11]See Murchison (2009) for a discussion of exchange rate pass-through for Canada.

To test the robustness of the common component to adopting a dynamic approach, we estimate three variants of a dynamic factor model:[12]

Figure 6. The extraction technique does not materially affect the obtained common component

Monthly data, year-over-year growth (%)



a. The generalized dynamic factor model of Forni et al. (2000, 2005).
b. A state-space representation in which the dynamic factor model is estimated by maximum likelihood, using a Kalman filter to extract the common component of CPI (similar to Stock and Watson 1989).
c. The same procedure as in (b) except we extract two factors. The first is restricted to only load on goods components of the CPI and the second to only load on services components. The common component of CPI is the weighted sum of the two factors, as in Kirker (2010).[13]

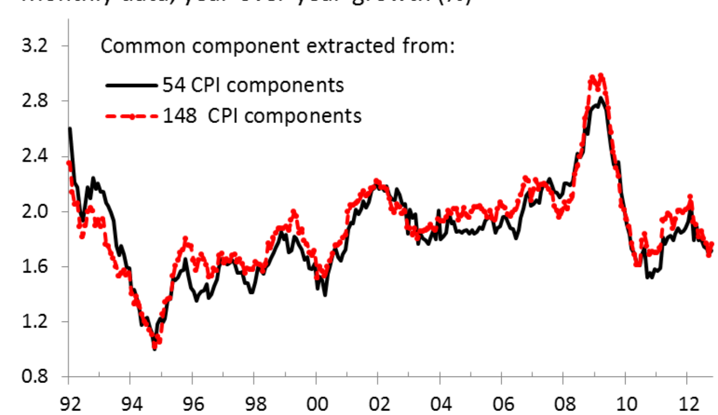
As Figure 6 shows, applying these different methods of estimating a dynamic factor model yields very similar measures to the one extracted using a static approach (common component of CPI). In fact, over most of the sample the alternative estimates are visually indistinguishable. This further supports our preference for a static approach, since moving to a more complex framework does not materially affect our results.

5.2 Lower level of aggregation

The reason the common component and other measures of underlying inflation in Canada are computed using 54 CPI components is based primarily on data availability and basket coverage. As mentioned, these 54 series cover the entire CPI basket and are all available since 1990 on a monthly basis. At the most disaggregated level, Statistics Canada publishes price series for 170 basic product classes. These classes are very detailed; for instance, for vegetables (one of the 54 components), the basic product classification distinguishes between potatoes, tomatoes, lettuce, other fresh vegetables, frozen and dried vegetables, and canned vegetables and other vegetable

Figure 7. Using a more disaggregated data set leads to a relatively similar common component

Monthly data, year-over-year growth (%)



[12] Refer to the technical appendix for more details on these dynamic approaches.

[13] This framework is not inconsistent with our prior argument for extracting one factor, since in this case the two factors are restricted to load on subsets of the data that collectively account for 100 per cent of the CPI basket. If no such restrictions were placed, multiple factors would capture the idiosyncratic components we wish to exclude.

preparations. However, the problem posed by using this level of aggregation is that some CPI series (22 of them) are not available over the entire sample period. These include items that were reclassified over time (such as wine served in restaurants) and newly introduced items (such as cellular phones and electronic tablets). In practice, these 22 components could be excluded from the list of series from which the common component is extracted, but these components jointly account for about 10 per cent of the latest CPI basket, making the data set used to construct the measure not fully representative of items consumed by Canadians. Nevertheless, as Figure 7 shows, extracting a common factor on the remaining 148 series yields a series that is broadly similar to the common component of CPI obtained with 54 components (the correlation is 0.94).

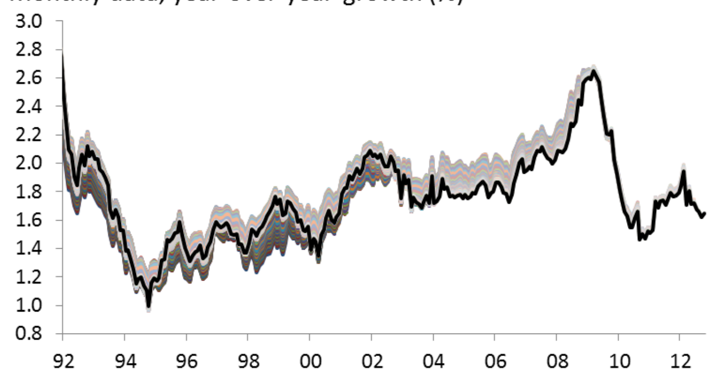
5.3 Real-time extraction of the common component

The common component of CPI is extracted using an econometric procedure, so historical estimates may change each time more data become available and the factor model is re-estimated. Furthermore, since the extracted common component is then scaled by total CPI inflation, changes in the statistical properties of inflation are a further potential source of revision to the common component. This is important, since the CPI and alternative measures of core inflation monitored by the Bank of Canada are not subject to historical revisions. Indeed, Wynne (2008) makes this criticism of factor model-based approaches to measuring underlying inflation, but acknowledges that the criticism would lose its force if historical revisions were found to be trivial.

Figure 8. The common component of CPI is subject to historical revisions

Real-time estimates of the common component of CPI

Monthly data, year-over-year growth (%)



To investigate this matter, we conduct the following real-time exercise. We start by extracting the common component using 10 years of data starting in 1990. The sample is then expanded one month at a time, with the common component being extracted and scaled each month. This continues until October 2012, at which point we obtain the full-sample common component of CPI discussed in section 3. This process results in the extraction of 154 time series, shown in Figure 8.

Historical revisions to the common component are found to be quite small, averaging 0.1 percentage points in absolute terms. These revisions are noticeably larger in the earlier part of the sample (the maximum revision is 0.4 percentage points), while revisions over the past four years have been negligible. This result is driven by the fact that the real-time estimation is initiated with a relatively small sample (10 years), so the mean and variance of inflation, by which the common component is scaled, are initially more sensitive to additional observations.[14] Naturally, the influence of this phenomenon decreases over time, and explains why revisions in recent years have been so small. Hence, in the

[14] Indeed, we find that revisions coming solely from the re-estimation of the factor model are small over the entire sample. Hence, mean and variance shifts in total CPI inflation are the dominant sources of revision to the common component of CPI.

absence of significant changes to the time-series properties of inflation, we do not believe that potential future revisions to the common component of CPI are a cause for concern.

6. Conclusion

This paper introduces a measure of underlying inflation for Canada, the common component of CPI. The methodology used to construct this measure exploits co-movements between individual prices comprising the Canadian CPI and minimizes the impact of sector-specific disturbances in extracting the signal in total CPI inflation.

Empirical analysis establishes that the common component of CPI moves with key macroeconomic variables, notably the output gap. Hence, this measure appears to capture price movements that are caused by aggregate demand fluctuations in Canada. We also find that the common component is robust to alternative specifications of a factor model, as well as the level of aggregation of the data used in the model. Furthermore, historical revisions to the measure are trivial, averaging 0.1 percentage points.

These results suggest that the common component of CPI may serve as a useful complement to existing measures of underlying inflation monitored by the Bank of Canada.

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TECHNICAL APPENDIX

The generalized dynamic factor model of Forni et al. (2000)

This method seeks to identify a dynamic structure of the factor model by relying on the sample autocovariances of the times series. The estimators of the dynamic factors are obtained from an eigenvalue decomposition of the spectrum smoothed over different frequencies. As presented in Boivin and Ng (2005) and Schumacher (2005), the estimated spectral density of $\widehat{\Gamma}_k$ can be expressed as follows:

$$\widehat{\Sigma}(\theta_h) = \sum_{k=-M}^{M} \widehat{\Gamma}_k \, \omega_k e^{-ik\theta_k}, \tag{A1}$$

where $\omega_k = 1 - |k|/(M+1)$ represents the triangular Bartlett lag window of size M. At each frequency $\theta_h = 2\pi h/(2M+1)$, $h = 0 \dots 2M$, an eigen decomposition is then performed to get both the dynamic eigenvalues and eigenvectors from $\widehat{\Sigma}(\theta_h)$ and arrange the latter in decreasing order of magnitude. To obtain the eigenvectors in the time domain, the inverse discrete Fourier transform is then applied:

$$\widehat{\mathrm{P}}_j(L) = \sum_{k=-M}^{M} \left(\frac{1}{2M+1} \sum_{h=0}^{2M} \widehat{\mathrm{P}}_j(\theta_h) \, e^{-ik\theta_k} \right) L^k, \tag{A2}$$

for $k = -M \, \dots \, M$ and $j = 1 \dots q$, with *q* corresponding to the number of dynamic factors and *L* the lag operator. These factor loadings $\widehat{\mathrm{P}}_j(L)$ contain leads and lags and allow for dynamic relationships between the indicators at various points in time. The dynamic common components $F_t = X'\widehat{\mathrm{P}}_j(L)$ are simply a projection of the indicators X_t on leads and lags of the factor loadings.[15] In the case of the dynamic factors model, not only the factor space (*q*) has to be determined but also the number of lags used in the sample autocorrelation (M). [16]

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[15]Although these estimators of the dynamic common components are consistent as T and $N \rightarrow \infty$N →∞, the reliance on spectral-based estimators leads to two-sided filters, which leads to problems in a forecasting exercise or in a real time environment. To circumvent this problem, we used the one-sided estimates of the factors derived in Forni et al. (2005).

[16] For q, we used Bai and Ng (2007) selection criteria; for the choice of M, Monte Carlo simulation results from Forni et al. (2000) suggest opting for $round(2T^{1/3}/3)$. In this note, the number of both dynamic factors (q) is equal to 1, while the number of lags selected (M) is equal to 4.

The state-space representation

The state-pace model is estimated by maximum likelihood and used in conjunction with the Kalman filter, following Stock and Watson (1989) as follows:

$$\Pi_t = \gamma C_t + v_t, \tag{A3}$$

$$\phi(L)C_t = \eta_t, \tag{A4}$$

$$D(L)v_t = \varepsilon_t, \tag{A5}$$

where:

- Π_t is an *n* X 1 vector of inflation rates for individual components of the CPI.
- γ is the matrix of factor loadings relating the individual inflation rates to an unobserved common factor.
- C_t corresponds to the common factor where the diagonal element of the matrix of variance covariance of the process (η) is assumed to equal one as series have been normalized prior to the estimation. The common factor is assumed to follow a first-order autoregressive process.
- V_t represents the idiosyncratic movements of the inflation series and measurement error.
- L denotes the lag operator, and $\phi(L)$ and $D(L)$ are, respectively, scalar and matrix lag polynomials.