Indicators of underlying inflation in Norway

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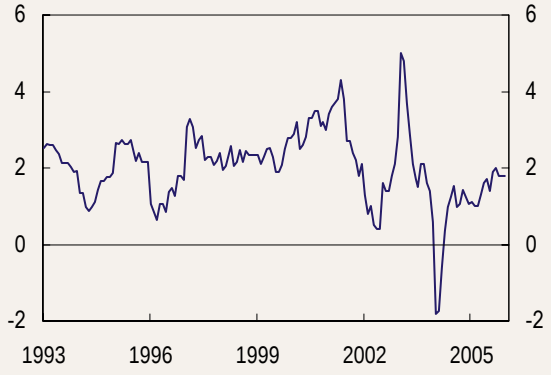
A central bank that is to steer inflation ahead in time seeks to exclude temporary price variations when setting policy rates. At a given point in time, it is not that easy to determine which price changes are permanent and which changes are temporary. Indicators of underlying inflation can be useful in this context. In this article, we make an empirical evaluation of various indicators of underlying inflation in Norway. Our conclusion is that there is no one indicator that is a perfect measure of underlying inflation at all times. A central bank should therefore follow developments in several indicators of underlying inflation.

1 Introduction

Low and stable inflation is a central objective of monetary policy in many countries. In countries where monetary policy is operated using an explicit inflation target, a quantified inflation target is often linked to the consumer price index (CPI). In Norway, for example, the Regulation on Monetary Policy of 29 March 2001 states that "the operational target of monetary policy shall be annual consumer price inflation of close to 2.5 per cent over time".

In periods, the CPI may be influenced by temporary changes in one or several prices. This is illustrated in Chart 1, which shows the year-on-year rise in the CPI in Norway in the period January 1993 to December 2005. The degree of variability in the rise in prices was particularly high between 2001 and 2004, primarily reflecting pronounced changes in VAT rates and wide variations in electricity prices. These factors only had a short-term impact on headline inflation.

Chart 1 CPI. 12-month change. Per cent. Jan 93 – Dec 05



Source: Statistics Norway

In interest rate setting, the central bank seeks to ignore such short-term price variations. The Regulation on Monetary Policy in Norway also states that in general "direct effects on consumer prices resulting from changes in interest rates, taxes, excise duties and extraordinary temporary disturbances shall not be taken into account". At a given point in time, it is not that easy to determine which price changes will persist and which changes will only have a temporary effect on headline inflation. Indicators of underlying inflation that seek to remove temporary noise and show the more persistent trend in price developments may be useful in this context. A number of central banks therefore follow developments in indicators of underlying inflation.

In this article, we first take a close look at the uses of indicators of underlying inflation and the definition of "underlying inflation" in the literature. Section 3 provides a brief overview of the various methods proposed for estimating underlying inflation. The main contribution in this article can be found in Section 4, which presents an empirical evaluation of various indicators of underlying inflation for Norway.[2] We evaluate both new indicators presented in this article and indicators that are already in use in Norges Bank. The final section provides a summary of this article.

2 Uses of indicators of underlying inflation

Indicators of underlying inflation can be used for different purposes. The indicator's purpose may have implications for its construction and properties. An indicator of underlying inflation can be constructed with a view to evaluating monetary policy. Such an indicator should not incorporate prices that the central bank has little

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[2] See Bråten and Olsen (1997) and Johansen et al. (2006) for other studies of empirical properties of different indicators of underlying inflation in Norway. Silver (2006) provides a general account of methods for measuring underlying inflation and concept use.

scope for influencing. In Norway, for example, electricity prices are largely determined by temperature and water reservoir levels, and electricity price swings may result in wide fluctuations in the CPI. A central bank has little scope for countering such fluctuations in the CPI.

The indicators can also be used to assess the inflation outlook. Monthly CPI figures are influenced by short-term fluctuations in certain prices. An indicator of underlying inflation used in this context should only capture persistent changes in inflation. An increase in electricity prices that is perceived as permanent may gradually lead to a higher rate of increase in other prices because producers seek to compensate for higher electricity costs (second-round effects) or because it has an influence on economic agents' inflation expectations. Such a change in electricity prices should not be disregarded when making inflation forecasts.

It has been argued that an indicator of underlying inflation is not necessary when the central bank is conducting a forward-looking monetary policy. Temporary disturbances will not affect inflation 2–3 years ahead, and projections for underlying and headline inflation will have converged.[3] The projected level of inflation 2–3 years ahead will, however, depend on how high the central bank judges the "persistent" part of inflation to be when the projection is made. Indicators of underlying inflation are useful in determining the correct starting point for the projection.

An indicator of underlying inflation can also be a useful tool in justifying and explaining the conduct of monetary policy to the general public. If the rise in the CPI temporarily deviates from the inflation target, an indicator of underlying inflation can contribute to preventing doubts as to the central bank's commitment to reaching the target. It will minimise the risk that temporary shocks to price trends influence inflation expectations. At the same time, when the general public uses an indicator that varies less than the CPI as a reference, this may contribute to more stable inflation expectations. An indicator of underlying inflation that is established and well-known by the general public can have this function.

Disagreement about what underlying inflation really is, is one reason why indicators of underlying inflation have different purposes. In the literature, definitions vary. Eckstein (1981) defined underlying inflation as "trend increase in the cost of factors of production". Underlying inflation is the level of inflation prevailing when the economy is in long-term equilibrium, i.e. in the absence of shocks and when actual output is equal to potential output. This definition of underlying inflation is closely linked to economic agents' long-term inflation expectations. Inflation caused by cyclical factors is not considered as a component of underlying inflation according to this definition.

Quah and Vahey (1995) defined underlying inflation as the component of inflation that is due to shocks that do not affect output in the long run. The definition in Quah and Vahey (1995) includes Eckstein's (1981) concept of underlying inflation, but also incorporates price rises caused by cyclical factors. Inflation caused by permanent supply-side shocks is not included in underlying inflation.

Other definitions of underlying inflation are more related to how one should in practice choose the best underlying indicator among several candidates. Bryan et al. (1997) defined underlying inflation as the indicator that tracks a moving average of headline inflation most closely. Smith (2004) defined underlying inflation as the indicator that is the best forecaster of inflation. This definition was inspired by Blinder (1997), who defined underlying inflation as the "persistent component" of inflation.

3 Different measures of underlying inflation

Numerous methods for constructing an indicator of underlying inflation have been proposed. This reflects varying concepts of underlying inflation, but it is also because indicators of underlying inflation can have different purposes. The various methods can be broadly divided into four groups:

- **Exclude fixed components from the CPI.** This is the most common method, and the calculation in Norway of the CPI-ATE (the consumer price index adjusted for tax changes and excluding energy products) is an example. The choice of components to be excluded can be based on statistical criteria – for example, exclude the most volatile price index components – or can be based on a greater element of discretion. In a number of countries, food and energy prices are excluded. This is often justified by the highly volatile nature of these prices, and that variations are caused by supply-side changes rather than changes in demand. A simple example is that bad weather can lead to a sharp rise in prices of certain food products.

- **Exclude different components of the CPI from one period to another.** The choice of the components that are excluded can be based on statistical criteria or discretion. The indicators trimmed mean and weighted median, which are regularly published by Norges Bank, are two examples where components are excluded based on statistical criteria. Up to 1997, the central bank of New Zealand made adjustments for various shocks on a discretionary basis. But this approach was discontinued as the central bank considered it awkward to estimate the indicator monetary policy would be judged by.[4]

[3] See Nessen and Soderstrom (2000).

[4] See press release of 15 December 1997 from the Reserve Bank of New Zealand (http://www.rbnz.govt.nz/news/1997/0092611.html)

- **Reweighting of CPI components.** In this method, no component is completely excluded from the estimation of underlying inflation, but the weight that is assigned to each sub-group will depend on the sub-group's historical time-series properties. An example is the indicator published by the Bank of Canada, which gives less weight to prices for goods and services that have shown wide historical variations.[5]

- **Model-based methods.** These methods are somewhat different from those above. An example is the indicator of core inflation that was proposed by Quah and Vahey (1995). This indicator is based on a structural VAR model of inflation. Another example is the indicator that was introduced by Cristadoro et al. (2005). They use a factor model to calculate underlying inflation based on developments in a large number of time series.

4 Empirical evaluations of different indicators

Since there is no agreement on the definition of underlying inflation, there is no agreement on the weight to be given to various criteria when evaluating different indicators. Roger (1998) and Wynne (1999) discuss several criteria that an indicator of underlying inflation should satisfy. The criteria can be summed up in six points:

(a) The indicator of underlying inflation should not systematically deviate from the CPI over a longer period.

(b) It should be possible to estimate the indicator of underlying inflation at the same time as the total CPI is published, and previously published observations should not be revised when new data are released.

(c) The indicator of underlying inflation should be able to contribute to predicting future developments in headline inflation.

(d) To avoid doubts as to whether the central bank manipulates the indicator of underlying inflation, it should be calculated by other institutions than the central bank.

(e) The indicator of underlying inflation should be easy for the public to understand.

(f) The indicator should be founded in economic theory.

The criteria applied to an indicator of underlying inflation will depend on its intended purpose. An indicator of underlying inflation that is to play a central role in communicating monetary policy must necessarily be easy for the general public to understand. It is not natural to apply the same criteria to an indicator that is used internally in the central bank as an aid in assessing the inflation outlook.

All the indicators examined in this article satisfy the criterion in point (b). An example of an indicator that does not satisfy the criterion is when underlying inflation is estimated using a two-sided filter, for example, the well-known HP-filter. The criterion in point (d) has, in many countries, been satisfied by leaving the task of estimating underlying inflation to the statistical agency. Point (e) and (f) can only be evaluated on a discretionary basis. Indicators where fixed components have been excluded, such as the CPI-ATE and the traditional indicators excluding food and energy will typically be more easily understood by the general public than the other measures of underlying inflation mentioned above. Few of the model-based measures will be easy to explain to the general public. On the other hand, only some of the model-based methods can be said to be clearly founded in economic theory. One example is the indicator proposed by Quah and Vahey (1995), based on the notion that the long-run Phillips curve is vertical. None of the indicators examined in this article have a direct foundation in economic theory.

Among the points mentioned above, only points (a) and (c) are relevant in terms of empirical testing, and it is the empirical evaluation that we emphasise in this article. We do not seek to give a complete answer to the question about which indicators are "good" or "poor".

The empirical tests in this article are partly related to the criteria in points (a) and (c). The tests have been used in a series of international studies of underlying inflation, see for example Rich and Steindel (2005), Catte and Sløk (2005) and Clark (2001). The tests examine whether the different indicators of underlying inflation have:

- had the same average as the CPI over time
- been less volatile than the CPI
- tracked a moving average of the CPI over time
- contributed to explaining future developments in the CPI

In the following, indicators from the first three groups above are examined. Model-based methods are not studied. In the group of indicators that excludes permanent CPI components, the following indicators are tested:

- CPI-ATE – consumer price index adjusted for tax changes and excluding energy products
- CPI-AT – consumer price index adjusted for tax changes, but including energy products
- CPI-AE – consumer price index excluding energy products, but including tax changes
- CPI-ATED – domestically produced goods and

[5] See Bank of Canada May 2001: Renewal of the Inflation-Control Target, Background Information (http://www.bankofcanada.ca/en/press/background.pdf)

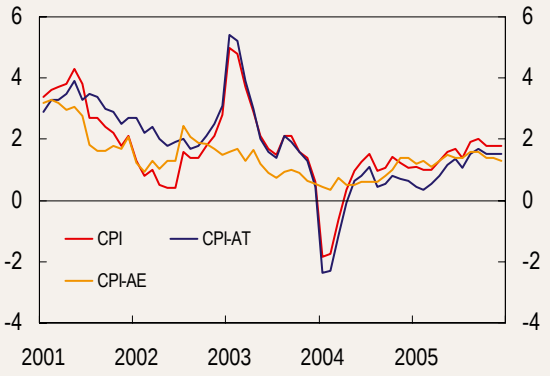
services adjusted for tax changes and excluding energy products, i.e. the domestic component of the CPI-ATE

These are indicators that Norges Bank uses in its assessment of inflation developments. With the exception of the CPI-ATED, calculated by Norges Bank, all the indicators are calculated and published monthly by Statistics Norway (see Charts 2 and 3).

We have also constructed new indicators, using 96 sub-groups of the consumer price index. Two of the new indicators belong to the class of indicators in which certain product groups are permanently excluded. We have removed the sub-groups with the highest volatility in the period January 1993 to December 2005.[6] In the indicator "excluding the most volatile 10 per cent", product groups corresponding to 10 per cent of the weighting basis are excluded. In the indicator "excluding the most volatile 20 per cent", product groups corresponding to 20 per cent of the weighting basis in the CPI are excluded (see Chart 4). The reason why we have looked at these indicators is that there are also products other than energy products that vary widely from one period to the next, and that can contribute to short-term swings in the CPI. Air travel, tele-equipment (mobile phones), fruit, vegetables, and some clothing articles are among the product groups excluded.

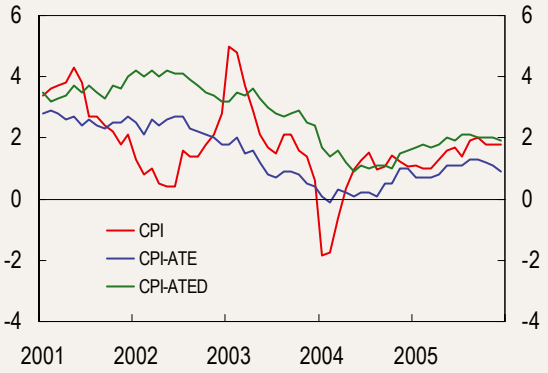
In the group of indicators where different components are excluded from one period to the next, the two indicators weighted median and trimmed mean are examined. These two indicators are based on 146 sub-groups of the CPI. The indicators are calculated by ranking the 12-month price rise for the different sub-groups in ascending order from the strongest price fall to the highest price rise. In "trimmed mean (20 per cent)", the price changes corresponding to 10 per cent of the rise in the CPI, in the upper and lower end of the distribution, are excluded. All in all, 20 per cent of the weighting basis is excluded. The rise in prices is based on the remaining

Chart 2 CPI and indicators of underlying inflation based on exclusion. 12-month change. Per cent. Jan 01 – Dec 05



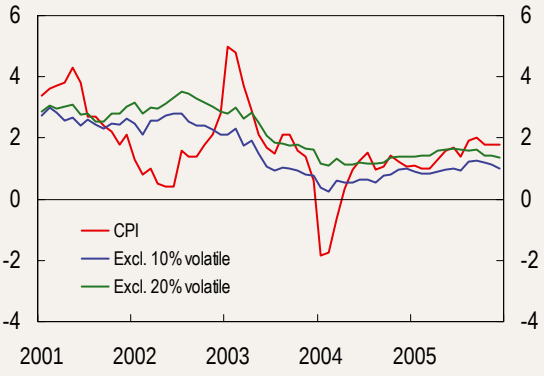
Source: Statistics Norway

Chart 3 CPI and indicators of underlying inflation based on exclusion. 12-month change. Per cent. Jan 01 – Dec 05



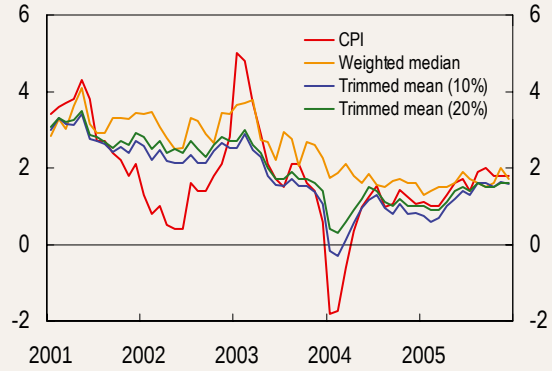
Sources: Statistics Norway and Norges Bank

Chart 4 CPI and indicators of underlying inflation excluding volatile components. 12-month change. Per cent. Jan 01 – Dec 05



Sources: Statistics Norway and Norges Bank

Chart 5 CPI, weighted median and trimmed mean. 12-month change. Per cent. Jan 01 – Dec 05



Source: Statistics Norway

[6] The volatility measure used is the standard deviation of the monthly difference between the 12-month rise in the CPI and the 12-month rise in the respective sub-index, $Vol = sd(\Pi_t^{CPI} - \Pi_t^i)$. ($\Pi$ denotes 12-month rise) We have also tested other volatility measures, but do not present the results here. We refer the reader to an earlier edition of this article: Jonassen and Nordbø (2006).

observations. In "trimmed mean" (10 per cent)", 10 per cent of the weighting basis is excluded. The weighted median is a special case of trimmed mean, where all the price observations are excluded with the exception of the middle one, when the product group's weight in the CPI is taken into account (see Chart 5).

In the group of indicators where the different components' weight depends on historical time-series properties, we have looked at three new indicators. All the indicators are calculated based on 96 CPI sub-groups. Unlike the indicators above, no product group is excluded from these indicators. The idea behind the construction of the indicators is that the historical time-series properties of each sub-group provide an indication of the information content of the sub-group's price observations. This again determines the weight to be given to the sub-group in estimating total inflation.

In two of the indicators, the weight of each sub-group depends on the historical volatility of the sub-group. In the first indicator, a volatility-weighted indicator, the weight of the sub-index is determined solely by its historical volatility.[7] Little weight is given to the most volatile sub-indices, whereas the least volatile are given considerable weight. The product group's weight in the consumer price index has no bearing on the weight it is given in this indicator.

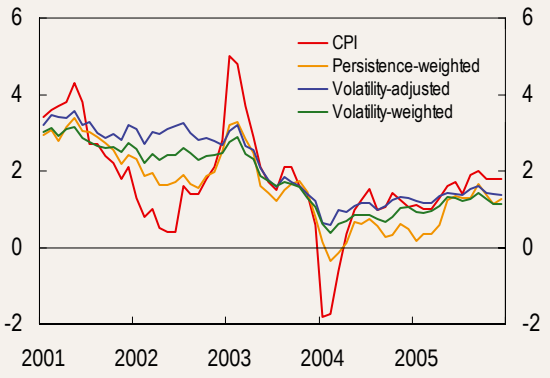
The other indicator, a volatility-adjusted indicator, differs from the volatility-weighted indicator in that the weights of the different sub-indices are a combination of the original CPI weights and the weights used in the volatility-weighted indicator. Energy prices, which have traditionally been very volatile, have been given somewhat higher weights in the volatility-adjusted indicator than in the volatility-weighted indicators. In both indicators, the weight given to energy prices is considerably lower than in the CPI.[8]

In the third indicator, a persistence-weighted indicator, it is the historical "inflation persistence" that determines each sub-group's weight.[9] Inflation persistence is a measure of how slowly the inflation rate in the respective sub-groups changes. Cutler (2001) has looked at a similar indicator for the UK. Her work was inspired by Blinder (1997). The most persistent sub-groups are given the highest weight, while the least persistent sub-groups are given the lowest weight. Like the volatility-weighted indicator, each sub-group's economic importance has no bearing on its weight in this indicator (see Chart 6).

4.1. Have the different indicators had the same average as the CPI?

In this section we examine if the different indicators have over time risen at the same pace as the CPI. If an indicator has deviated substantially from CPI inflation over a longer period, it means that not only temporary price disturbances, but also more permanent developments have been stripped out of the calculation of underlying inflation. This is tested by examining if the difference between the average 12-month rise in the CPI and the underlying indicator has been different from

Chart 6 CPI and indicators of underlying inflation based on reweighting. 12-month change. Per cent. Jan 01 – Dec 05



Sources: Statistics Norway and Norges Bank

Table 1. Difference between average 12-month rise in the various indicators and CPI inflation. Percentage points

	1983 – 2005	1993 – 2005	1999 – 2005
CPI-ATE	**–0.18**	**–0.34**	–0.32
CPI-ATED	**0.34**	**0.42**	**0.89**
CPI-AT	–0.07	–0.16	–0.01
CPI-AE	–0.11	**–0.21**	**–0.34**
Trimmed mean (20 %)	0.00	–0.04	0.15
Trimmed mean (10 %)	–0.06	–0.14	0.01
Weighted median	**0.20**	0.22	**0.59**
Exclu. most volatile (10 %)	–0.06	–0.17	–0.24
Exclu. most volatile (20 %)	0.09	0.05	0.22
Volatility-adjusted	0.07	0.10	0.28
Volatility-weighted	–0.05	0.09	0.10
Persistence-weighted	–0.04	0.06	–0.11
CPI average	3.65	2.03	2.03

The table shows the average difference between the 12-month rise in the CPI and the different indicators of underlying inflation in the period from January 1983, January 1993 and January 1999, respectively, to December 2005. Figures in bold type mean that the difference is statistically significant. A positive figure denotes that CPI inflation has been lower than the indicator over time, and a negative figure that CPI inflation has been higher.

[7] The volatility measure used is the same as the indicators where we have excluded the most volatile components: The standard deviation of the monthly difference between 12-month CPI inflation and the 12-month rise in the respective sub-index. The rate of increase of each sub-group is updated annually and is based on the volatility recorded for the previous 10 years. We have also studied indicators based on other volatility measures, but the results are not reported here. The reader is again referred to Jonassen and Nordbø (2006).

[8] Electricity prices can serve as an example. In the consume price index, electricity prices are given a weight of about 2 per cent. In the volatility-adjusted indicator, the weight is 0.5 per cent, while the weight in the volatility-weighted indicator is 0.2 per cent.

[9] The persistence of the sub-group is given here by the autoregressive coefficient ρ^i in an AR(1) model of the 12-month rise in the respective sub-group, $\Pi_t^i = \alpha + \rho^i \Pi_{t-1}^i + \varepsilon_t$. The weight of each sub-group is equal to the autoregressive coefficient (ρ), normalised so that the sum of the autoregressive coefficients for the 96 sub-groups is equal to 1. The weights are updated annually and determined by the persistence in the previous 10 years.

zero over different periods. The results are reported in Table 1. Bold figures mean that the average difference was statistically significant.[10, 11]

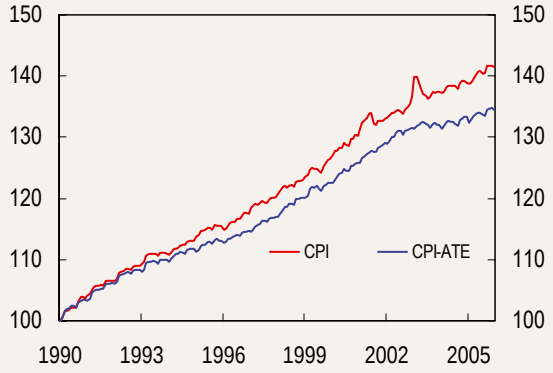
The average 12-month rise in the CPI-ATE was below the average 12-month rise in the CPI in all the time periods in Table 1. The difference is largest in the period January 1993 to December 2005 (see Chart 7). In this period, 12-month CPI-ATE inflation was on average 0.34 percentage point lower than CPI inflation. This difference was also statistically significant. The difference has been approximately the same in the period January 1999 to December 2005, whereas it was somewhat smaller from January 1983 to December 2005.

The difference between CPI and CPI-ATE is partly due to the rise in the general level of indirect taxes, but also to a higher rise in energy prices over time than in other prices in the CPI. In the period 1999–2005, energy prices, and electricity prices in particular, account for the difference between the two indices. The total contribution from tax changes to the difference between the CPI and the CPI-ATE is close to zero in this period. The indicator where only energy prices are excluded and tax changes are included, the CPI-AE, deviated only slightly more from the CPI than the CPI-ATE during this period. The CPI-AE was significantly lower than the CPI during the two last periods, but the difference was not significant for the period 1983 to 2005. The period where energy prices show a clearly higher rate of increase than other prices has in other words not been very long.

Not unexpectedly, the domestic component of the CPI-ATE, CPI-ATED, has generally risen at a faster pace than the CPI. This is because total inflation has been pushed down by low imported inflation since the mid-1990s. Low imported inflation partly reflects a rising share of imports from low-cost countries to Norway.

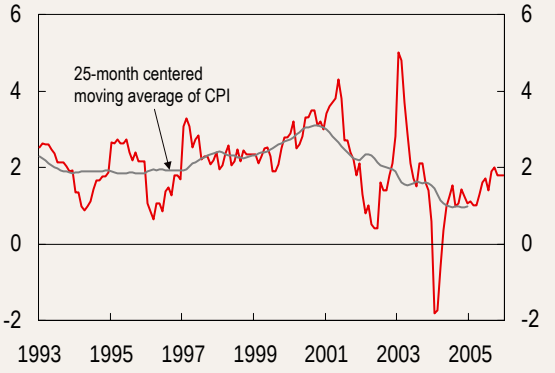
Inflation measured by a weighted median has been somewhat higher than inflation measured by the CPI, particularly in very recent years. The fact that the weighted median has been higher than the CPI, which is a weighted average, indicates that the largest price changes have been negative. The other indicators in Table 1 have been closer to the CPI over time, and none of them has been significantly different from the CPI in any of the periods.

Chart 7 CPI and CPI-ATE. Index. 100 = Jan 90.
Jan 90 – Dec 05



Sources: Statistics Norway and Norges Bank

Chart 8 CPI and 25-month centered moving average.
12-month change. Per cent. Jan 93 – Dec 05



Sources: Statistics Norway and Norges Bank

4.2 Has the indicators tracked a moving average of CPI inflation?

The next question we explore is how the indicators have tracked a moving average of CPI inflation over time. This corresponds to the definition of underlying inflation given by Bryan et al. (1997). In accordance with Catte and Sløk (2005), the moving average is calculated here by applying a moving centred 25-month average of 12-month CPI inflation.[12] Chart 8 shows the development in the moving average and total CPI inflation.

Table 2 shows how the different measures of underlying inflation have tracked the moving average of CPI inflation. This is measured by looking at mean square error (MSE) between the moving average of the CPI and the different indicators. MSE is expressed as

$$\frac{\sum_{t=1}^{T}(\Pi_t^i - \Pi_t^{ma})^2}{T}$$

where Π_t^i and Π_t^{ma} are respectively the relevant indicator and the moving average in period t.

With the exception of domestic CPI-ATE, all the indicators have tracked the moving CPI average more closely than the CPI. The CPI-AT only performs marginally better than the CPI.

[10] That the difference is statistically significant means here that the constant term in the regression $(\Pi_t^{CPI} - \Pi_t^U) = \alpha + \varepsilon_t$ is found to be different from zero at a significance level of 5 per cent. The covariance matrix of the residual terms is estimated by the method proposed by Newey and West (1987).

[11] We have looked at figures for the various indicators dating back to 1983. The official series from Statistics Norway do not date back as far. The CPI-AE index starts in August 1995 and the CPI-ATE and CPI-AT indicators start in December 2002. However, Statistics Norway has published figures for the 12-month rise in the CPI-AT and the CPI-ATE since August 2000. The figures used for the indicators prior to this are estimated by Norges Bank.

12 As a cross-check, we also smoothed inflation using an HP-filter (λ=14 400). The results were very similar to those obtained by applying a 25-month moving average. See Jonassen and Nordbø (2006).

Table 2. Deviation (MSE) from a moving average of CPI inflation

	1983 – 2004	1993 – 2004	Same average 1993–2004
CPI-ATE	0.42	0.30	0.18
CPI-ATED	0.63	0.88	0.71
CPI-AT	0.55	0.70	0.68
CPI-AE	0.44	0.33	0.31
Trimmed mean (20 %)	0.26	0.22	0.22
Trimmed mean (10 %)	0.29	0.24	0.22
Weighted median	0.55	0.52	0.47
Exclu. most volatile (10 %)	0.43	0.29	0.26
Exclu. most volatile (20 %)	0.41	0.31	0.31
Volatility-adjusted	0.28	0.27	0.26
Volatility-weighted	0.28	0.19	0.19
Persistence-weighted	0.38	0.37	0.36
CPI	0.58	0.72	0.72

The table shows the mean square error (MSE) between the 12-month rise in the different indicators of underlying inflation and a 25-month moving average of 12-month CPI inflation. We have calculated MSE for the period from January 1983 and January 1993, respectively, to December 2004. In the last column, the series are adjusted so that they have the same average before MSE is calculated.

Table 3. Volatility of the various indicators and CPI inflation

	1983– 2005	1993– 2005
CPI-ATE	0.26	0.18
CPI-ATED	0.28	0.22
CPI-AT	0.40	0.44
CPI-AE	0.29	0.25
Trimmed mean (20 %)	0.28	0.25
Trimmed mean (10 %)	0.29	0.26
Weighted median	0.41	0.32
Exclu. most volatile (10 %)	0.29	0.24
Exclu. most volatile (20 %)	0,28	0.23
Volatility-adjusted	0.28	0.25
Volatility-weighted	0.25	0.21
Persistence-weighted	0.33	0.29
CPI	0.43	0.47

The volatility is calculated as the standard deviation of monthly change in the 12-month rise of the various indicators. We have looked at the volatility from January 1983 and January 1993, respectively, to December 2005.

Of the indicators used by Norges Bank, the trimmed mean (20 per cent) has been closest to the moving average both in the entire period from January 1983 to December 2004 and in the shorter period from January 1993 to 2004. Among the new indicators, the volatility-weighted indicator has tracked the moving average very closely. In the period from 1993 to the end of 2004, this indicator has the lowest MSE of all the indicators. The deviation between the weighted median and the moving average has been considerably wider.

With this test, indicators that have a lower average than the CPI over time will be systematically punished. From Section 4.1 we already know, for example, that CPI-ATE inflation has been lower than CPI inflation over time. For this reason, it is interesting to examine if the different indicators have deviated from the moving average of CPI inflation over time only because their average has been different over time, or because they also have a different profile. We have therefore re-calculated the MSE after demeaning all the series. The results are shown in the last column of Table 2. Of all the indicators, the CPI-ATE performs best now. This can be interpreted to mean that CPI-ATE inflation has moved fairly closely in tandem with the moving average, but has often been somewhat lower.

4.3 Have the indicators varied less than CPI inflation?

The reason why many central banks focus on indicators of underlying inflation is that the CPI can show wide monthly swings. Consequently, an indicator of underlying inflation should be less volatile than the CPI. The volatility measure we have used to examine if this actually applies is the standard deviation of the monthly change in the 12-month rise in the respective indicators (see Table 3).

Most of the indicators in Table 3 have varied considerably less than the CPI both in the periods from January 1983 to December 2005, and in the period from January 1993 to December 2005. An exception is the CPI adjusted for tax changes, CPI-AT, which has only been marginally less volatile than the CPI in both periods. On the other hand, if only energy products are excluded, as in the CPI-AE, volatility is substantially lower. This illustrates that the price rise for energy products has contributed more to short-term variations in the CPI than changes in taxes.

The indicator adjusted both for tax changes and energy prices, the CPI-ATE, is the one that has varied the least from month to month of all the indicators in the period from 1993 to 2005. Of the indicators already used in Norges Bank, the weighted median has shown wider monthly variations than all the others. Among the new indicators, the volatility-weighted indicator has varied the least from month to month.

Sometimes an indicator of underlying inflation varies widely from one month to another. This may be due to temporary noise, but it may also change because the fundamental factors that determine inflation have changed. That an indicator typically shows small monthly variations does not necessarily mean that it is an accurate indicator of underlying inflation. The central question is if it is only noise, or also relevant information that is removed. The simple volatility measure we have used here cannot answer this question. In the next section we will attempt to shed further light on the different indicators' ability to strip out temporary disturbances.

4.4 Can the indicators predict future changes in CPI inflation?

As mentioned, Smith (2004) defined underlying inflation as the indicator that is the best forecaster of inflation. We have therefore tested to which extent the different indicators can contribute to predicting inflation. This is done by analysing if the deviation between underlying inflation and CPI inflation can at a given time explain future changes in CPI inflation.

In accordance with Catte and Sløk (2005), we estimate the coefficients α and β in the following equation:

$$\Pi_{t+k}^{CPI} - \Pi_t^{CPI} = \alpha + \beta(\Pi_t^{CPI} - \Pi_t^U) + \varepsilon_t \qquad (1)$$

We expect that the coefficient in front of the deviation between CPI inflation, Π^{CPI}, and underlying inflation, Π^U, in period t, will be negative and significant. The background for this is that if CPI inflation caused by a temporary shock is higher than underlying inflation at a given time, CPI inflation will fall in the following period. Therefore, the test indicates to what extent the underlying indicator neglects temporary disturbances and captures relevant new developments, as an accurate indicator of underlying inflation should. By allowing a constant term in the regression equation, α, it becomes possible for the CPI and underlying inflation to increase at a systematically different pace over time.[13] Ideally, the coefficient β should be equal to –1. This means that if, for example, total inflation is pushed up by a temporary disturbance in period t, the deviation between total and underlying inflation will be back to the average level k periods later.

We evaluate the different indicators according to the degree to which the difference between CPI inflation and underlying inflation explains the changes in CPI inflation 6, 12, 18 and 24 months ahead. This is measured by the different indicators' explanatory power, measured by R^2 in the estimated regression equation.[14]

In Table 4, the coefficient β and explanatory power R^2 are reported by the different horizons. We also report the average explanatory power over all horizons. Figures marked with * denote that the coefficient estimate was not significantly different from zero.[15]

The estimated coefficients were negative and significant for all the indicators, except the CPI-AT, 6, 12, and 18 months ahead. For the CPI-AT, the estimated coefficient was only significant at a horizon of 12 months, and the explanatory power of this indicator is generally lower. We see that particularly 6 months ahead many coefficients were near –1, while the estimates vary more with longer horizons.

At a horizon of 24 months, the following indicators had a significant correlation with the changes in CPI inflation: The indicators where the 10 and 20 per cent most volatile sub-groups in the CPI were excluded, the volatility-weighted indicator, the persistence-weighted indicator and the CPI-AE.

If we look at the average explanatory power at all horizons, as shown in the last column of Table 4, two of the new indicators perform best together with the CPI-AE. The volatility-weighted indicator and the indicator where the 10 per cent most volatile sub-groups are excluded both have an average explanatory power of 0.4. The two indicators perform consistently well in explaining future changes in CPI inflation for all time-horizons. The same applies to the CPI-AE.

The CPI-ATE has on average ranked fourth in terms of explanatory power. The CPI-ATE is particularly accurate 6 and 12 months ahead, and none of the other indicators perform better at these horizons. However, its explanatory power is somewhat weaker at the 18- and 24-month horizon.

Table 4. Estimates of coefficient β and explanatory power (R^2) in the regression equation.

	6 months		12 months		18 months		24 months		Average
	β	R^2	β	R^2	β	R^2	β	R^2	R^2
CPI-ATE	–0.95	0.20	–1.45	0.58	–0.86	0.28	–0.59*	0.17	0.36
CPI-ATED	–0.51	0.25	–0.79	0.34	–0.37	0.11	–0.12*	0.01	0.18
CPI-AT	–0.49*	0.05	–1.05	0.13	–0.36*	0.02	0.30*	0.02	0.05
CPI-AE	–1.07	0.41	–1.49	0.46	–1.00	0.29	–1.13	0.45	0.40
Trimmed mean (20 %)	–1.05	0.33	–1.72	0.53	–0.94	0.22	–0.36*	0.04	0.28
Trimmed mean (10 %)	–1.19	0.35	–2.01	0.58	–1.06	0.23	–0.39*	0.04	0.30
Weighted median	–0.55	0.18	–0.98	0.34	–0.59	0.17	–0.03*	0.00	0.17
Exclu. most volatile (10 %)	–1.10	0.42	–1.50	0.46	–1.02	0.30	–1.17	0.43	0.40
Exclu. most volatile (20 %)	–1.05	0.34	–1.25	0.36	–0.74	0.18	–0.78	0.21	0.27
Volatility-adjusted	–1.17	0.36	–1.59	0.39	–0.92	0.18	–0.72*	0.11	0.26
Volatility-weighted	–1.17	0.36	–1.84	0.52	–1.33	0.38	–1.24	0.36	0.40
Persistence-weighted	–1.05	0.23	–1.65	0.32	–1.34	0.30	–1.23	0.30	0.29

In the table, the coefficient estimates and explanatory power (R^2) are reported for the different indicators in the regression equation in (1). We have estimated the equation at a horizon of 6, 12, 18 and 24 months. The last column shows estimated average explanatory power over all horizons.

[13] We have examined whether the different indicators have risen at the same rate as the CPI in section 4.1.

[14] R^2 is a measure of the degree to which the variable on the right-hand side of the equal sign in the regression equation explains the variation in the left-hand side variable. R^2 will always be between 1 and 0, with 0 as minimum and 1 as maximum.

[15] In order to take account of possible heteroskedacity and autocorrelation in the residuals, we have estimated the covariance matrix using the method proposed by Newey and West (1987).

Once again, the weighted median performs relatively poorly, with an average explanatory power of 0.17, which is lower than half of the average explanatory power of the best indicators.

4.5 Comparisons with international studies

The indicators that perform best in the tests in similar international studies vary from country to country and from one period to another.

Catte and Sløk (2005) find that the indicators where volatile components were given less weight are closest to trend inflation[16] in the US and Japan, while the trimmed mean has been closest to trend inflation in the euro area and the UK. Rich and Steindel (2005) only look at US figures and find that a weighted median that is exponentially smoothed[17] has been closest to trend inflation.

When Catte and Sløk (2005) tested whether the deviation between core inflation and total inflation can predict future changes to aggregate inflation, the traditional indicators excluding food and energy performed best in the US. In the euro area the weighted median performs best, and in the UK the trimmed mean and a volatility-weighted indicator produce the best results. Rich and Steindel (2005) concluded that the weighted median and a weighted median that is exponentially smoothed have the greatest explanatory power in the US.[18]

5 Summary

The volatility-weighted indicator has generally performed well in the empirical tests in this article. The indicator has increased at approximately the same rate as the CPI. It has been among the least volatile of the indicators we have examined and has been closest to a moving average of the CPI. None of the other indicators has made a greater contribution to accounting for future changes in CPI inflation.

However, the volatility-weighted indicator also has clear weaknesses. First, it is constructed in a fundamentally different way to the consumer price index in that there is no relationship between the weight each sub-group is given and the sub-group's share of a typical household's expenses. Second, the volatility-weighted indicator is more difficult to understand intuitively than indicators where, for example, certain product groups are permanently excluded.

Nor is there any agreement in the literature as to whether the empirical tests that we have carried out are the "proper" tests (see Robalo Marques et al. (2003) for a further discussion). This suggests that one should be cautious about placing too much emphasis on the results. Nevertheless, we believe that this study has produced a number of useful answers. The indicator that has been most frequently used by Norges Bank, the CPI-ATE, performs reasonably well in the majority of the tests but, over time, it has increased at a slower rate than the total consumer price index. Advantages of the CPI-ATE are that it is relatively simple for the general public to understand, and that it is already established and recognised as an indicator of underlying inflation. The trimmed mean (both 10 and 20 per cent) also produced relatively good test results, while the results for the weighted median were less satisfactory.

The indicator that was only adjusted for tax changes, the CPI-AT, was very volatile. It did not track the moving CPI average well, and it made a limited contribution to explaining future changes in CPI inflation. This indicates that an indicator of underlying inflation where components are excluded permanently should be adjusted for more than only tax changes.

Our conclusion is that there is no single indicator that can be a perfect measure of underlying inflation at all times. Different indicators perform best in different tests. For example, the CPI-ATE followed the moving CPI average closest when we demeaned the series, while the volatility-weighted indicator was among the best in terms of explaining future changes in CPI inflation. The results of this study have also shown that the choice of time period may be of significance for an indicator's performance in the different tests. For example, for the entire period from1983 to 2004 it was the trimmed mean (20 per cent) that was closest to the moving CPI average, but this indicator did not perform as well during the period from 1993 to 2004.

Since the information content of the different indicators may vary over time, a central bank should follow several indicators of underlying inflation. If the various indicators provide fairly unambiguous signals about underlying inflation at a given point in time, it may indicate that the degree of uncertainty is low. If the different indicators deviate considerably, it is a sign that the uncertainty surrounding underlying inflation is greater. The central bank should then place additional emphasis on understanding the deviations between the different indicators. In order to illustrate that underlying inflation is uncertain at a given point in time, an uncertainty interval for underlying inflation was introduced in Norges Bank's *Inflation Report 2/06*.

The level of underlying inflation at a given point in time ultimately becomes a matter that must be decided with the help of the central bank's discretion. Various mechanically measured indicators can be useful aids in exercising this discretion.

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17 See Cogely (2002) for an introduction to this method.

18 Rich and Steindel (2005) analyse data back to 1960. Catte and Sløk only look at figures dating back to 1984.

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