STAFF MEMO

# Indicators of underlying inflation in Norway

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MONETARY POLICY

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*Norges Bank operates a flexible inflation targeting regime. Under such a regime, monetary policy does not seek to steer current inflation towards the inflation target, but is oriented towards moving the forecasts for future inflation towards the target.*

*Under a flexible inflation targeting regime, the central bank seeks to "look through" temporary changes in inflation. At a given point in time, it can be difficult to determine which price changes are permanent and which changes are transitory. Indicators of underlying inflation can be helpful. The purpose of these indicators is to have a real-time measure of trend CPI inflation.*

*In this article, different indicators of underlying inflation are evaluated empirically. The conclusion is that there is no single indicator that fully measures underlying inflation, in the sense that it performs best in every category of the evaluation. This suggests that the central bank should monitor a range of indicators. Determining the rate of underlying inflation at any given point in time is ultimately a matter for the central bank's judgement.*

## The purpose of indicators of underlying inflation

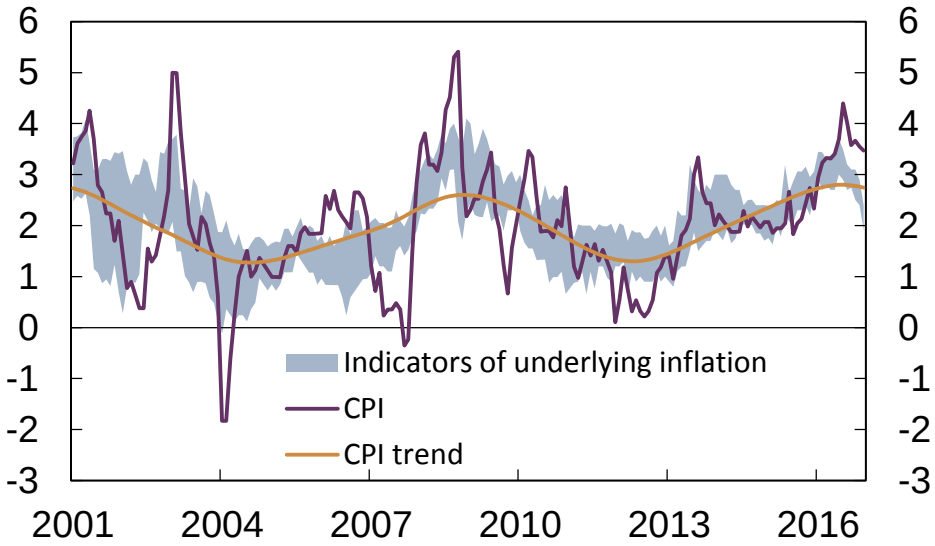
The Regulation on Monetary Policy in Norway states: "The operational target of monetary policy shall be annual consumer price inflation of approximately 2.5 per cent over time. In general, the direct effects on consumer prices resulting from changes in interest rates, taxes, excise duties and extraordinary temporary disturbances shall not be taken into account."

Norges Bank operates a flexible inflation targeting regime. Under such a regime, monetary policy does not seek to steer current inflation towards the inflation target, but is oriented towards moving the forecasts for future inflation towards the target.

Indicators of underlying inflation can be helpful in the conduct of monetary policy.[1] The purpose of the indicators is to look through transitory variation in inflation and serve as a real-time measure of trend CPI inflation. When transitory shocks occur, CPI inflation can be expected to gradually revert to its trend. It should therefore be possible to use an indicator that captures the trend as a tool in the assessment of the inflation outlook (Chart 1).

[1] See Jonassen and Nordbø (2006) for a more detailed review of different measures of underlying inflation.

**Chart 1 CPI, trend CPI inflation[1)] and indicators of underlying inflation[2)]. Twelve-month change. January 2001 – December 2016**




1) Trend CPI inflation (extended by projections in *Monetary Policy Report* 4/16) is given by a two-sided HP filter (λ=14400).
2) The shaded areas show the highest and lowest values per month for seven indicators of underlying inflation: CPI-ATE, weighted median, trimmed mean, CPIXE, CPIM, CPIXV and CPI-common. The indicators are described in detail on pages 9-11 of this article,

Sources: Statistics Norway and Norges Bank

In addition, an indicator of underlying inflation can be a useful tool in justifying and explaining the conduct of monetary policy to the public. If the 12-month change in the CPI temporarily deviates from the target, an indicator of underlying inflation can help to prevent doubts from arising with regard to the central bank's commitment to reaching the target. This could contribute to the stability of inflation expectations by reducing the risk that substantial but transitory shocks to inflation influence expectations.

It is international practice to use indicators of underlying inflation as cross-checks of inflationary pressures in the economy. While nearly all central banks monitor a number of indicators, it is customary to place particular emphasis on a single indicator in their communication. Recently, the Bank of Canada announced that it would replace a single preferred measure with three new indicators. The intention is to mitigate the risk of placing sole weight on a single indicator that subsequently proves to provide an incorrect picture of underlying inflationary pressures.[2]

[2] The Bank of Canada will replace the CPIX as its preferred measure with the CPI-common, CPI-trim and CPI median (see Bank of Canada (2016)). As part of the evaluation of indicators of underlying inflation, the Bank of Canada has conducted the same kind of tests as used in this article. They also look at the persistence of the indicators and their correlation with the output gap (see Bank of Canada (2015)).

## Properties of a good indicator of underlying inflation

Defining the properties that characterise a good indicator of underlying inflation depends on the indicator's intended role. The properties can be summarised as follows:[3]

- The main purpose of the indicators is to provide a real-time measure of trend CPI inflation. A good indicator must therefore be more stable than CPI inflation, but must not differ systematically from CPI inflation over time. It must be computable as soon as the CPI is published, and its history must not be revised when new data are added.

- An indicator that actually captures trend CPI inflation should also be able to contribute to predictions of future developments in the CPI.

Indicators that satisfy the criteria in the points above will be useful in the ongoing analysis of inflation developments.

- In addition, indicators to be used by the central bank in its external communication should be easy for the public to understand. These indicators can function as teaching tools in the bank's communication of monetary policy.

- It may also be an advantage if the indicator is produced and published independently of the central bank. If the indicator is produced by the central bank, its performance should be easy to evaluate. This would ensure confidence in the indicator.

## The indicators

Norges Bank monitors a range of indicators of underlying inflation. The following presents an evaluation of the extent to which the nine most widely used indicators satisfy the criteria listed above. The 12-month rise in the indicators is shown in Chart 2.

The indicators evaluated can be divided into three groups according to the method used to construct them:

### Indicators that permanently exclude certain subgroups of the CPI:

- *CPI-ATE*: the CPI adjusted for tax changes and excluding energy products. This indicator is well known to the public and is published by Statistics Norway.

[3] See Roger (1998) and Wynne (1999).

- *CPIXE*: the CPI adjusted for tax changes and excluding temporary changes in energy prices. This indicator is produced by Norges Bank.[4] It is constructed the same way as the CPI-ATE but takes account of the trend in energy prices instead of excluding these prices. The energy price trend is given by a centred moving average of historical energy prices and futures prices.

- *CPIXV*: the CPI excluding the eight most volatile subgroups.[5] The purpose of the indicator is to strip out prices that show frequent and substantial changes and that can therefore have a considerable impact on headline CPI inflation.

- *CPI-sticky prices*[6]*:* The construction of this indicator was motivated by the New Keynesian theory of optimal monetary policy[7], which gives the indicator a solid theoretical foundation. Nevertheless, as constructed, this indicator will not satisfy all the criteria for a good indicator of underlying inflation as listed above. This indicator includes the subgroups of the CPI for which prices changed less frequently than every 8.5 months in the period between 1999 and 2004. These subgroups account for about 25 percent of the weighting basis of the CPI. They are included in the indicator with their respective CPI weights, scaled to sum to 1. Since such a large portion of the weighting basis is excluded, the average change shown by this indicator differs, as expected, from the CPI. The indicator is produced by Norges Bank.

- *Domestic CPI-ATE*: a measure of the rise in prices for domestically produced goods and services. Norges Bank constructs the indicator by weighting together a number of CPI-ATE subgroups. Although not defined as an indicator of underlying inflation, it reflects domestic spare capacity more closely, both in theory and in practice, than headline CPI inflation. As a result, the indicator can capture the trend in headline inflation that comes from domestic price pressures.

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[4] See Hov (2009).
[5] The eight most volatile subgroups in the period January 2010 – July 2015 are completely excluded: electricity, air fares, household textiles, fruit, coffee, tea and cocoa, vegetables, fish, newspapers, books and office equipment.
[6] See Erlandsen (2014).
[7] In New Keynesian models, it takes time for all prices to adjust after shocks owing to nominal price rigidities. Many prices will therefore deviate from their optimal level and undesirable distortions in relative prices will arise, prompting inefficient resource allocation. Monetary policy can increase public welfare by steering towards a resource equilibrium that is fully in line with flexible prices. This is achieved by stabilising an index of underlying inflation that gives greater weight to sticky prices, ie the central bank stabilises prices that are adjusted, and are therefore probably misadjusted, while prices that change frequently can often be allowed to vary. See Woodford (2003).

Indicators that exclude subgroups on a period-by-period basis:

- *Trimmed mean (20%)*: this indicator is produced by Statistics Norway and measures the CPI excluding the subgroups with the highest and lowest rise in prices. This is an internationally established method of measuring underlying inflation. The subgroups of the CPI are ranked in ascending order each month according to the 12-month change in prices in these groups. The price series corresponding to the top and bottom 10 percent of the CPI weights are then removed. The inflation rate is given by the mean of the remaining price changes. The aim is to reduce noise.

- *Weighted median*: A special case of the trimmed mean is the weighted median, where inflation in a month is given by one subgroup. The subgroups of the CPI are ranked in ascending order according to the 12-month change in prices in these groups. Inflation measured by this indicator in a given month is defined as the change in prices for the fiftieth percentile ranked according to the CPI weights of the subgroups. The indicator is produced by Statistics Norway.

Indicators constructed using model-based methods:

- *CPIM*: The subgroups in the CPI are assigned new weights based on their historical accuracy in forecasting headline CPI inflation one month ahead. The more accurate the forecast, the higher the weight assigned. The indicator is produced by Norges Bank.[8]

- *CPI-common:* A measure of the common trend in price changes across price series in the CPI at group level. A factor model is used to filter out sector-specific price changes and find the common trend across all goods and services groups in the CPI. The indicator is produced by Norges Bank (Annex 1).

## Evaluation of the indicators

Whether the indicator is easy to understand and evaluate has been assessed based on judgement. Six of the indicators are assessed to be (relatively) easy for the public to understand. These indicators are constructed by excluding one or more subgroups of the CPI, in some cases in combination with replacing growth in one or more subgroups with trend growth for each subcomponent. The intuition behind these indicators is simple: the product groups that are excluded are those with the highest volatility, and the indicators are still

[8] See Hov (2005).

weighted according to the original consumption percentages of the CPI. The three indicators assessed to be less easy to understand are constructed by excluding subgroups on the basis of economic theory or by applying model-based methods. Understanding this type of indicator requires knowledge of the economic theory on which the exclusion of particular subgroups is based or of the model-based methods used.

All the indicators are produced using internationally established methods. Nevertheless they can be difficult to evaluate owing to a lack of available data.[9] None of the indicators are revised. Three of the nine indicators are produced by institutions other than Norges Bank.

In this assessment, empirical tests were used to establish whether the indicators have shown the same developments as the CPI over time, whether they have shown less volatility than the CPI over time and to what extent they can explain future developments in the CPI. The tests were conducted for the period 2002 – 2016.[10] The results are shown in Table 1 and in Annex Table 1. The indicators are ranked from first to last according to their performance in the various tests. The empirical tests are explained in the following section.

### Test 1: deviation from the CPI

Whether an indicator has shown systematic deviations from the CPI is evaluated along two dimensions. First, to what extent the indicator in the period as a whole has shown the same 12-month rise as the CPI; second, how well the indicator tracks trend CPI inflation.[11] The second test takes account of the fact that the indicator may be alternately above and below the CPI for long periods and thus show the same average rise as the CPI. The assessment is based on the root mean-squared error (RMSE), given by:

$$\sqrt{\frac{\sum_{t=1}^{T}\left(\pi_t^i - \pi_t^{ma}\right)^2}{T}}$$

[9] For some of the indicators, access to the CPI is required at a higher disaggregation level than the one published by Statistics Norway, in addition to real-time trend estimations.
[10] The reason for starting in 2002 is that this is when the CPIXE series starts. Alternatively, the test period could have started in 2001, ie the year the inflation targeting regime was introduced.
[11] Trend CPI inflation is unobservable in real time. For historical data, statistical methods can be used to identify the trend in the CPI. A drawback of using such methods in real time is that towards the end of the time series, the most recent observations have a disproportionate influence on the trend. The reason is that at the end point there are no future observations that can inform the trend. Here, we use a two-sided HP filter (λ=14400) to identify the trend in the CPI. We use actual data up to and including December 2016, extended by projections from *Monetary Policy Report* 4/16, thereby.avoiding the end-point problem. The reason that such statistical methods are not used in compiling indicators of underlying inflation is that the estimated trend in real time will depend on the projections on which future inflation is based.

where $\pi_t^i$ is the 12-month rise in indicator *i* in month *t*, $\pi_t^{ma}$ is trend CPI inflation and *T* is the number of months in the sample period. The higher the RMSE, the poorer is the indicator's performance in tracking trend CPI inflation.

For four of these indicators, the difference between the average rise in these indicators and average CPI inflation is not statistically significant (Table 1). The average rise of the indicator with the largest deviation is one percentage point higher than average CPI inflation. The indicators with an average rise closest to average CPI inflation are also close to trend CPI inflation.

### Test 2: volatility

The volatility of the indicators is measured by the standard deviation of year-on-year inflation rates. Many central banks monitor indicators of underlying inflation because the CPI fluctuates considerably from one month to the next. Such noise can make it difficult to assess developments in the CPI that are more indicative of a trend. If an indicator has a lower standard deviation than the CPI, this means that the year-on year rise in the indicator has historically changed less than the year-on-year rise in the CPI.

All the indicators are less volatile than the CPI. Of the indicators close to average and trend CPI inflation, several are relatively volatile.

### Test 3: predictive properties

The last empirical test is conducted to assess the indicator's predictive properties. When transitory shocks occur, the 12-month rise in the CPI will move away from trend CPI inflation. If an indicator of underlying inflation actually tracks trend CPI inflation, the difference between the 12-month rise in the CPI and the 12-month rise in the indicator today should therefore contain information about future developments in the 12-month rise in the CPI. This is tested in the equation:

$$\pi_{t+h}^{CPI} - \pi_t^{CPI} = \alpha + \beta\left(\pi_t^{CPI} - \pi_t^i\right) + \varepsilon_t$$

where $\pi_{t+h}^{CPI} - \pi_t^{CPI}$ is the difference between the 12-month rise in the CPI at time $t + h$ and time *t* and $\pi_t^{CPI} - \pi_t^i$ is the difference between the 12-month rise in the CPI and indicator *i* at time *t*. The hypothesis is that if $\pi_t^{CPI} > \pi_t^i$ inflation should fall ahead, so that $\beta < 0$ and significant. The constant, $\alpha$, allows the rise in the CPI and in the indicator of underlying inflation to differ in pace over time, and $\varepsilon_t$ is an error term assumed to be have normal distribution and constant variance. The test is a measure of the indicator's ability to look through transitory price shocks.

We assess the various indicators in terms of their ability to predict CPI inflation six, 12, 18 and 24 months ahead. The models are estimated recursively. The first estimation period is January 2001 – November 2003.[12] Projections from the estimated models are compared with actual developments in the CPI. Estimating the models recursively means that an extra observation is added in each subsequent step of the estimation and the model projections are again compared with actual developments.

The models are assessed against each other and compared with projections from a simple AR(1) model. The AR(1) model explains inflation by:

$$\Delta log(CPI_t) = \delta + \gamma \Delta log(CPI_{t-1}) + \varepsilon_t$$

where $CPI_t$ is the level of the CPI in period $t$ and $\Delta$ is a difference operator. A good model should have better predictive properties than an AR(1) model.

The estimated coefficients and the results of the predictive properties test are reported in Annex Table 1. The coefficients are without exception negative and significant at the one percent level. The performance of all the indicators is worse than that of the AR(1) model at the six-month horizon, but better than the AR(1) model at the 12, 18 and 24 month horizon.[13] On the whole, the longer the horizon, the better is the indicators' performance (compared with the AR(1) model). As a shock to the 12-month rise in the CPI will typically last for (at least) a year, it makes intuitive sense that the indicators' performance will be better at horizons of one year and above. Monetary policy feeds through to inflation with a lag. This suggests that the shortest horizon is less relevant in a policy context.

Several of the indicators that performed well in the first and second part of the empirical evaluation performed less well in the predictive properties test.

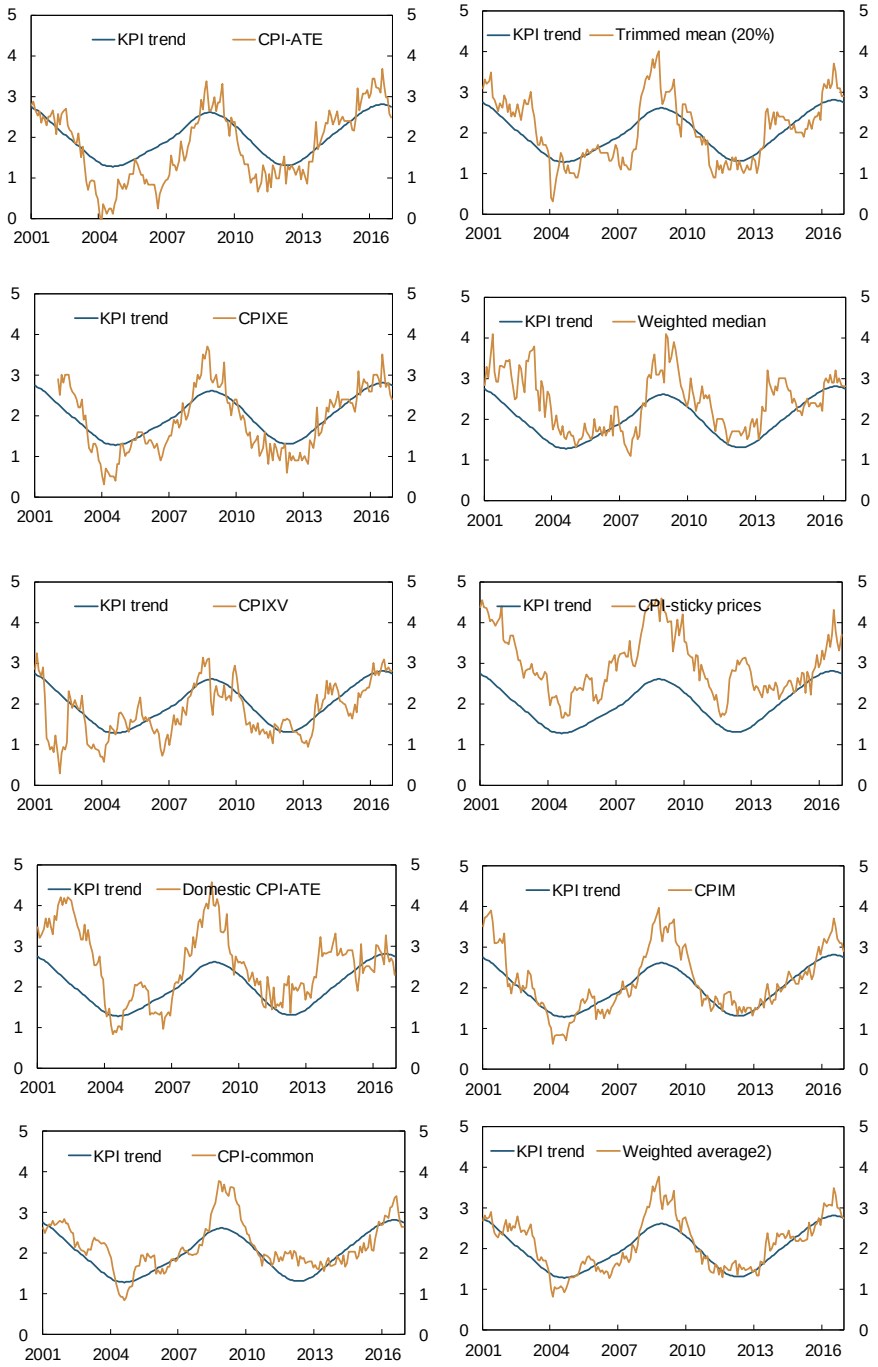
[12] Except the CPIXE model, where the estimation period starts in January 2002.
[13] Except CPI-common, which also performs worse than the AR(1) model at the 12-month horizon.

**Table 1 Ranking of indicators of underlying inflation. Based on data for the period January 2002 - December 2016**

| Indicator | Deviation from CPI | Deviation from trend CPI | Volatility | Predictive properties | Easy to understand | Produced by independent institution |
|---|---|---|---|---|---|---|
| | (i) | (ii) | (iii) | (iv) | (v) | |
| CPI-ATE | 6.(-0.23) | 6.(0.57) | 6.(0.27) | 3.(0.81) | Yes | Yes |
| CPIXE | **1.(-0.07)** | 3.(0.43) | 9.(0.35) | 5.(0.84) | Yes | No |
| CPIXV | **1.(-0.17)** | 4.(0.47) | 5.(0.26) | 8.(0.87) | Yes | No |
| Weighted median | 7.(0.42) | 7.(0.67) | 8.(0.30) | 9.(0.85) | Yes | Yes |
| Trimmed mean | **1.(0.05)** | 5.(0.48) | 4.(0.25) | 2.(0.80) | Yes | Yes |
| CPIM | **1.(0.13)** | 1.(0.39) | 2.(0.20) | 6.(0.84) | No | No |
| CPI-sticky prices | 9.(0.95) | 9.(1.07) | 3.(0.25) | 4.(0.83) | No | No |
| CPI-common | 5.(0.20) | 2.(0.42) | 1.(0.16) | 8.(0.86) | No | No |
| Domestic CPI-ATE | 8.(0.52) | 8.(0.83) | 7.(0.29) | 1.(0.80) | Yes | No |
| Average CPI | (1.94) | (0.97) | (0.56) | | | |

i) Average difference between 12-month CPI inflation and the various indicators. A positive number means that the indicator has over time risen more rapidly than the CPI, and vice versa. Numbers in **bold** indicate that the difference was not statistically significant. First place is shared between the indicators that do not show a statistically significant difference from the CPI.
ii) Deviation between the 12-month rise in the indicator and trend CPI inflation (given by the RMSE).
iii) The standard deviation for the monthly change in 12-month inflation.
iv) Average accuracy of predictions of CPI inflation 12, 18 and 24 months ahead. The model's RMSE is based on the indicator relative to the RMSE of the AR(1) process.
v) Judgement-based assessment.

**Chart 2 Inflation. Twelve-month change. Trend CPI inflation[1)] and indicators of underlying inflation. January 2001 - December 2016**




1) Trend CPI inflation defined as in Chart 1.
2) The weighted average of the nine indicators of underlying inflation. The individual indicators are weighted by their performance in the empirical tests presented in Table 1.

Sources: Statistics Norway and Norges Bank

## More on the results

- *CPI-ATE*: The indicator also well in the predictive properties test, but has a somewhat larger deviation from trend CPI than the average for the nine indicators. Other drawbacks of the indicator are its relative volatility and that it shows a lower average rise than the CPI. The deviation reflects the higher rise in energy prices relative to other consumer prices and illustrates the risk associated with indicators that permanently exclude a selection of subgroups in that they do not capture structural changes in the CPI.

- *CPIXE*: The indicator shows approximately the same average rise as the CPI, and shows relatively little deviation over time from trend CPI inflation. The indicator's performance in the predictive properties test is relatively poor and it is the most volatile of the indicators of underlying inflation.

- *CPIXV*: The indicator shows approximately the same average rise as the CPI and is reasonably close to trend CPI inflation. Compared with the indicators that do not exclude the volatile subgroups (such as the CPI-ATE and CPIXE), the CPIXV is less volatile. Nevertheless, it is not among the least volatile indicators. This indicator performs poorly in the predictive properties test.

- *CPI-sticky prices*[14]*:* Of all the indicators, CPI-sticky prices differs most from average CPI inflation and is least in line with trend CPI inflation. It is slightly less volatile than the average of the indicators of underlying inflation and has average performance in the predictive properties test. The indicator is produced by Norges Bank.

- *Domestic CPI-ATE*: The indicator performs reasonably well in the predictive properties test, although, not unexpectedly, it differs significantly from average and trend CPI inflation. Compared with the indicators of underlying inflation, the domestic CPI-ATE indicator is fairly volatile.

- *Trimmed mean (20%)*: The indicator shows approximately the same average rise as the CPI and performs best in the predictive properties test. Compared with the other indicators, it has average performance in tracking trend CPI inflation and an average level of volatility. One risk associated with indicators that exclude subgroups of the CPI is that they

[14] See Erlandsen (2014).

may not capture structural changes, for example a subgroup that shows a persistently strong rise in prices for a period.

- *Weighted median*: Its performance is relatively poor in all the empirical evaluations.

Indicators constructed using model-based methods:

- *CPIM*: CPIM has the next lowest volatility and is closest to trend CPI inflation. It also shows approximately the same average rise as the CPI. The indicator's performance in the predictive properties test is lower than the average.

- *CPI-common:* CPI-common has the lowest volatility and is next closest to trend CPI inflation. It is also close to average CPI inflation. The indicator's performance in the predictive properties test is poor at the shortest horizons, but is among the best at the longest horizon.

## Summary and conclusion

The exercises that have been performed provide useful new information about the use of indicators of underlying inflation. They confirm a number of the advantages of the most widely used indicator of underlying inflation, the CPI-ATE. The CPI-ATE performs well in the predictive properties test and is probably relatively easy to understand.

But the CPI-ATE also has a number of drawbacks: over time, it has risen significantly more slowly than the CPI and is relatively volatile. Evaluated along these dimensions, two other indicators, the CPI-common and the CPIM show by far the best performance. The disadvantages of the CPI-common and the CPIM, on the other hand, are that they are probably difficult for the public to understand, particularly because there is no clear relationship between the weight assigned to the individual subgroup in the indicator and the percentage of household consumption expenditure the subgroup accounts for. From a purely analytical standpoint, it is probably easier to understand an indicator where a subgroup is permanently excluded or trend-adjusted.

This review shows that no single indicator fully measures underlying inflation in the sense that it performs best in every category. This suggests that monetary policy should monitor a range of indicators of underlying inflation. Determining the rate of underlying inflation at any given point in time is ultimately a matter for the central bank's judgement.

**Annex Table 1 Model estimate and predictive properties test. Estimate of β-coefficient and RMSE. The coefficients are estimated for the entire sample (January 2001 - December 2016). The RMSE is from the recursive predictive properties test described in the text.**

| Forecast horizon: | 6 months | | 12 months | | 18 months | | 24 months | |
|---|---|---|---|---|---|---|---|---|
| | $\hat{\beta}$ | RMSE | $\hat{\beta}$ | RMSE | $\hat{\beta}$ | RMSE | $\hat{\beta}$ | RMSE |
| CPI-ATE | -0.90 | 0.96 | -1.48 | 0.93 | -0.98 | 1.09 | -0.72 | 1.10 |
| CPIXE | -1.03 | 0.95 | -1.58 | 0.97 | -0.95 | 1.15 | -0.66 | 1.12 |
| CPIXV | -1.11 | 0.97 | -1.62 | 1.03 | -1.08 | 1.17 | -1.05 | 1.17 |
| Weighted median | -0.79 | 0.94 | -1.45 | 1.09 | -0.95 | 1.05 | -0.72 | 1.10 |
| Trimmed mean | -1.19 | 0.94 | -2.00 | 0.93 | -1.20 | 1.08 | -0.83 | 1.09 |
| CPIM | -0.91 | 0.92 | -1.65 | 1.01 | -1.15 | 1.08 | -0.76 | 1.15 |
| CPI-sticky prices | -0.77 | 0.92 | -1.38 | 0.97 | -0.95 | 1.07 | -0.64 | 1.17 |
| CPI-common | -0.74 | 0.96 | -1.40 | 1.04 | -1.06 | 1.13 | -0.77 | 1.12 |
| Domestic CPI-ATE | -0.79 | 0.99 | -1.29 | 0.93 | -0.73 | 1.09 | -0.41 | 1.05 |
| AR(1) | | 0.78 | | 1.12 | | 1.29 | | 1.46 |

## Literature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## Annex 1 – calculation of the CPI-common

The CPI-common measures underlying inflation by the common variation in prices across groups of the CPI.

The CPI-common is based on a factor model. A factor model is a statistical method that describes the variation in a data set on the basis of one or more common factors and an idiosyncratic error term. Applied to the CPI, the factors capture (non-observable) underlying driving forces that may be common to all or some of the CPI groups, while the error term captures variation specific to certain groups.

Let the 12-month change in prices in component *i* at time *t* be given by $\pi_{it}$, and let $\boldsymbol{\pi_t} = (\pi_{1t}, \pi_{2t}, \dots, \pi_{Nt})$ be an $N \times 1$ vector for the rise in prices for the $N$ groups of the CPI included in the model. The linear factor model is then given by:

$$\boldsymbol{\pi_t} = \boldsymbol{\Lambda F_t} + \boldsymbol{u_t} \tag{1}$$

where the $k$ factors in the $k \times 1$ vector $\boldsymbol{F_t}$ capture common sources of price variations, the $N \times k$ matrix $\boldsymbol{\Lambda}$ consists of coefficients indicating how each component responds to the $k$ factors, while the $N \times 1$ vector $\boldsymbol{u_t}$ captures price variations that are specific to certain groups.

CPI-common is calculated in three steps. First, the 12-month change in prices across the 33 CPI components is normalised[15], ie the 12-month change in each component is centred around its historical average and divided by its historical standard deviation. The normalised figures for time *t* are included in $\boldsymbol{\pi_t}$ in the model in (1).

In the second step, principal component analysis is used to select the common factors in the model in (1). The method involves making 33 new variables, principal components, each of which explains some of the variation in the 33 CPI groups. Of these 33 principal components, the first is, by definition, the component that can explain most of the variation in the CPI series.

There are a number of ways to determine the number of principal components that will be used in the final model. Generally speaking, the objective is to explain as much as possible of the variance in the data set using as few principal components as possible. Tests based on information criteria[16] indicate

[15] The CPI comprises a total of 39 series at group level, but six of these have been omitted from the analysis due to inadequate data for the beginning of the estimation period.
[16] See Bai and Ng (2002).

that between one (BIC) and six (Akaike) principal components is adequate. Visual inspection (scree plot) indicates that two is an adequate number. The first two principal components explain 38 percent of the variation in headline CPI inflation and between 60 and 92 percent of the variation in the indicators of underlying inflation presented above.[17]

According to economic theory and empirical data, headline CPI inflation depends on imported inflation and domestic labour costs.[18] The first two principal components appear to follow developments in these two series relatively closely over time (Annex Charts 1 to 3). This suggests that an indicator based on the first two principal components probably captures the most important forces driving underlying inflation.

Thus, in step three, the indicator of underlying inflation is defined as:

$$\pi_t^F = \hat{\alpha} + \hat{\beta}_1 F_{1t} + \hat{\beta}_2 F_{2t} \quad (2)$$

where $\pi_t^F$ is the 12-month change in the CPI-common at time *t*, $F_{1t}$ and $F_{2t}$ are the first and second factor in $\boldsymbol{F_t}$ and $\hat{\alpha}$, $\hat{\beta}_1$ and $\hat{\beta}_2$ are the estimated coefficients in the regression:

$$\pi_t^{CPI} = \alpha + \beta_1 F_{1t} + \beta_2 F_{2t} \quad (3)$$

where $\pi_t^{CPI}$ is the 12-month change in the CPI at time *t.*

The model is estimated over the period January 1992 – March 2017. By starting in 1992, we avoid the period of high and variable inflation in the 1980s, basing our estimations instead on data for inflation that reflect similar developments as in the period following the introduction of inflation targeting.

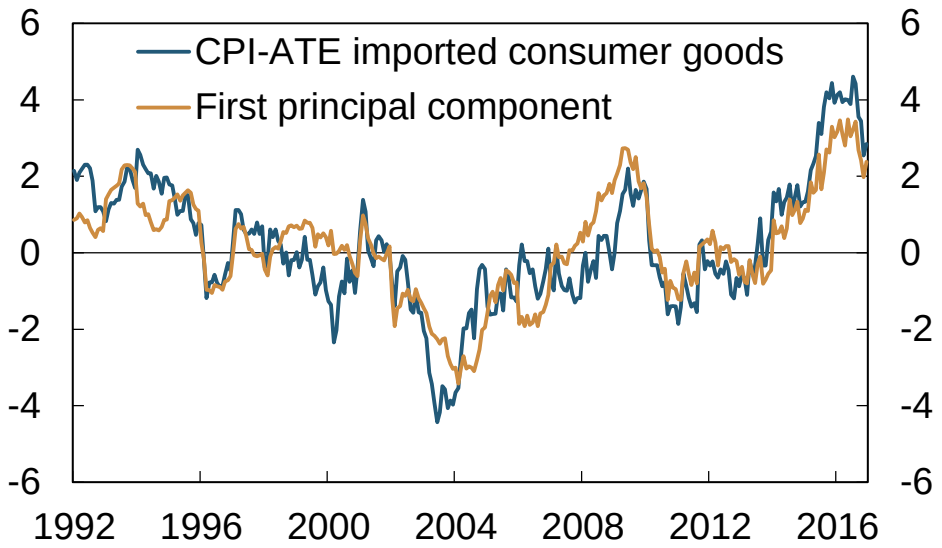
To produce a real-time series for the CPI-common, the three steps in the calculation are made recursively, ie the normalisation at time *t* is based on the historical average and standard deviation at time *t*. In the next step, principal components at time *t* are extracted from recursively normalised data at time *t*. With this approach, the principal components for time *t* do not change when new data are added to the model at time *t* +*h*. The coefficients are also

[17] Explained variation is given here by $R^2$ in a regression of the type $\pi_t^i = \alpha + \beta_1 F_{1t} + \beta_2 F_{2t}$ over the period January 2001 – December 2016, where $\pi_t^i$ is the 12-month rise in the indicator being tested and $F_{1t}$and $F_{2t}$ are the first and second factors in $\boldsymbol{F_t}$. The underlying indicators for which the principal components can explain least and most of their variation are, respectively, the *weighted median* (60 percent) and the *CPIM* (92 percent).

[18] See Hov, Naug and Stensland (2013).

estimated recursively in (3). The approach ensures that underlying inflation at time *t* is only based on data up to time *t* and does not change when new data are added, allowing a fairer comparison with other indicators of underlying inflation that are also real-time series.

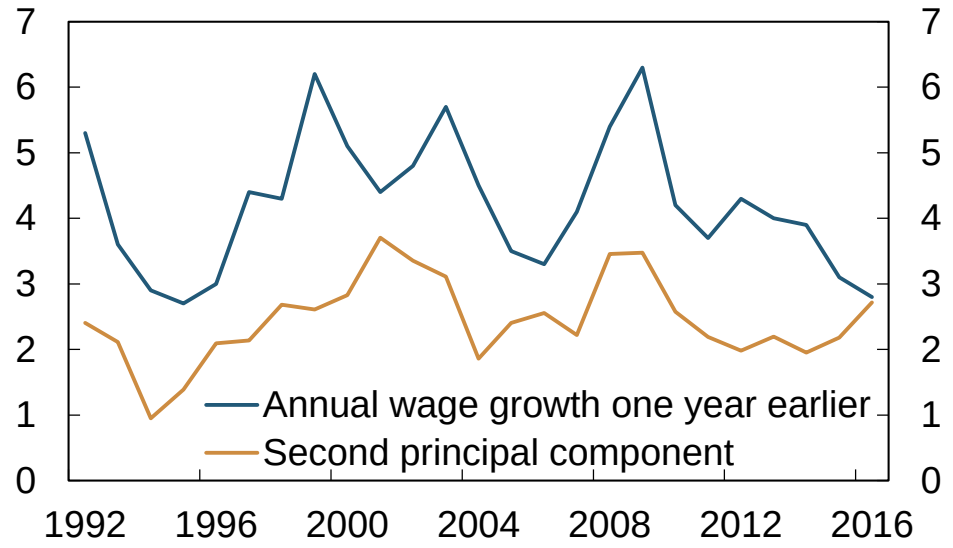
**Annex Chart 1 First principal component[1)] and 12-month rise in the CPI-ATE for imported consumer goods. January 1992 – December 2016**




1) The principal component shown here has not been calculated recursively. The principal component is scaled to fit the CPI-ATE for imported goods.

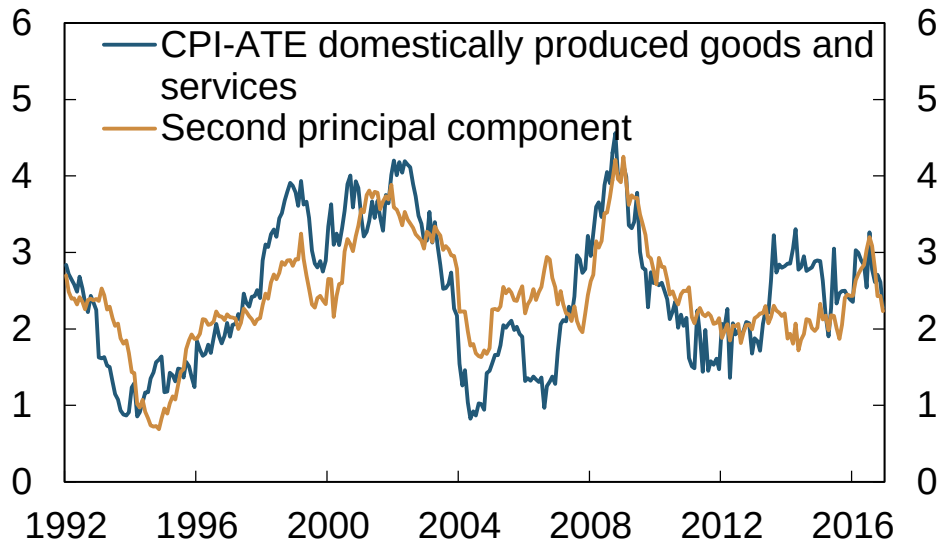
Sources: Statistics Norway and Norges Bank

**Annex Chart 2 Second principal component[1)] and annual wage growth one year earlier. Principal component for 1992 – 2016, annual wage growth for 1991 - 2015**




1) The principal component shown here has not been calculated recursively. The principal component is scaled to fit the CPI-ATE for domestically produced goods and services.
Sources: Statistics Norway and Norges Bank

**Annex Chart 3 Second principal component[1)] and 12-month rise in the CPI-ATE for domestically produced goods and services. January 1992 – December 2016**




1) The principal component shown here has not been calculated recursively. The principal component is scaled to fit the CPI-ATE for domestically produced goods and services.
Sources: Statistics Norway and Norges Bank