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ALTERNATIVE INDICATORS OF CORE INFLATION FOR NORWAY*

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Alternative indicators of core inflation for Norway

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Abstract

This paper is an empirical assessment of different indicators of core inflation for Norway. In addition to investigating indicators that are already in use by the central bank of Norway, we present some new indicators that give less weight to, or exclude completely, prices that have been relatively volatile in the past. Our results show that no measure of core inflation performs well in all empirical tests. The policy implications we draw from this is that a central bank should monitor various measures of core inflation and not rely on only one indicator in the assessment of the underlying price pressure.

1 Introduction

Several central banks have an objective of maintaining low and stable inflation, and the numerical inflation targets are usually specified in terms of the headline consumer price indices (CPIs). But headline CPIs are typically subject to a number of transitory shocks and show substantial short-lived fluctuations. This is illustrated in figure 1, here we have graphed the 12 month growth in headline CPI for Norway in the period from 1993 to 2005. We note that there were particularly large fluctuations in headline inflation in the first years of this decade. This was due to substantial changes in VAT rates and extreme variations in electricity prices, but these developments only had a short run effect on headline inflation. A forward looking, inflation targeting central bank would be correct in disregarding these large fluctuations. But at a given moment in time, it is always difficult to determine which price developments that will persist, and which developments that will only have a temporary effect on headline inflation. For this reason a number of central banks focus on measures of core inflation - indicators that attempt to remove transitory noise from the headline inflation rates. Indicators of core inflation may also be helpful when evaluating past policy.

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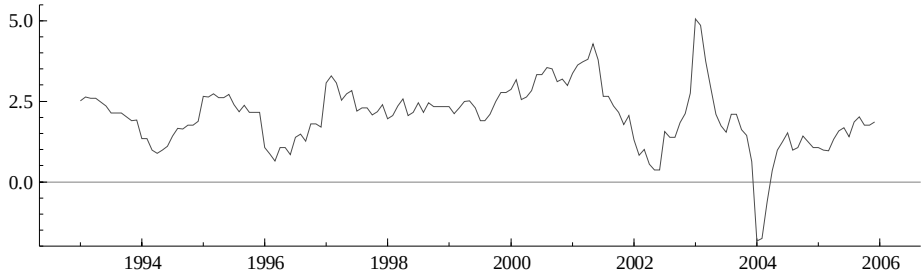
[3] All views expressed in this article are those of the authors and do not necessarily correspond with those of Norges Bank. We would like to thank seminar participants at Norges Bank for useful comments. We are particularly grateful to Statistics Norway and Lasse Sandberg for giving us access to an unpublished data set of 96 subindices in the CPI. All errors are of course our own responsibility.

Figure 1 12 month growth in headline CPI in Norway, 1993m1 - 2005m12



But even if it appears to be an agreement that measures of core inflation are useful, there is no consensus on what is to be understood as core inflation. In the literature core inflation has been defined in several ways. Eckstein (1981) originally defined core inflation as "... the trend increase in the cost of the factors of production". According to a definition presented in Bryan and Cecchetti (1993), core inflation is "... the long run, or persistent component of the measured price index, which is tied in some way to money growth". These definitions explicitly disregard cyclical movements in the inflation rate. Bryan et al. (1997) define core inflation as the inflation indicator that best track movements in smoothed average of headline inflation. Smith (2004) defines core inflation as the best forecaster of inflation.

Quah and Vahey (1995) define core inflation "... as that component of measured inflation that have no medium to long-term impact on real output". As monetary policy is considered to be neutral to output in the long run, core inflation will be that part of inflation which can be influenced by monetary policy. In a New Keynesian macroeconomic model with a flexible price sector and a sticky price sector, Aoki (2001) interpret core inflation as inflation in the sticky price sector; "Inflation in the sticky-price sector represents a relatively persistent component of aggregate inflation because it responds to smoothed expectations of future output gaps and relative price changes".

The main part of this paper is an empirical evaluation of different indicators of core inflation. The tests we have performed and the test results are described in section 4. But before we go into that, in the following section we present some desirable properties of a measure of core inflation and the various approaches that have been used when constructing an indicator of core inflation. The indicators we have studied are described in more detail in section 3. Our conclusion is presented in section 5.

2 Measures of core inflation

Roger (1998) and Wynne (1999) discuss several desirable properties of indicators of core inflation. The requirements they suggest can be summarized in five points.

A good indicator of core inflation should have the following properties:

- Be unbiased relative to the target measure of inflation.

- Be computable in real time. The measure should be available simultaneously with the headline inflation figure and should not be subject to revisions when new observations arrive. Measures of core inflation calculated by a two-sided filter are examples of measures that will not be computable in real time, as the value in period t depends on future observations.

- Be forward looking in the sense of having some predictive power for future headline inflation. Core inflation should be a good leading indicator of targeted inflation.

- Be credible in the sense that its calculation can be easily verified outside the central bank. If used to motivate and communicate monetary policy decisions, core inflation and its deviations from headline inflation ought to be easily understood by the public.

- Have some basis in monetary theory.

With a spectrum of definitions and desirable properties there will be several ways to measure core inflation. One approach is simply to take some kind of average of past inflation rates. Averaging reduces the volatility of the inflation series. When many central banks choose to focus on 12 month changes in the inflation rate rather than 1 month changes, this may be thought of as a measure of core inflation.

All prices are not equally informative about trend inflation. Several methods try to weigh price changes of single products and services according to their assumed information content.

1. Permanent exclusion of certain components. The components that are excluded may be chosen by some statistical criteria - e.g. the components that have been most volatile in the past - or the exclusion may be based more on subjective judgement. When a number of countries permanently exclude food and energy prices, it is probably because these prices have been volatile in the past, but also because food and energy prices are thought to be more influenced by supply side shocks than other prices in the CPI. In Norway, the consumer price index adjusted for tax changes and excluding energy products (CPI-ATE) is often used as a measure of core inflation. Permanent exclusion may be problematic if the information content of the different components changes over time.

2. Exclusion of components on a period-by-period basis. The exclusion may be based on a statistical criteria or more judgemental. An example of the second approach is the underlying inflation indicator published by the Reserve Bank of New Zealand until 1997, where it was corrected for shocks on a relatively ad hoc basis.[4] Frequently used core inflation measures as the trimmed mean and weighted median are examples of the first approach.

3. Less weight given to volatile components. No items are excluded under this approach. One example is the core inflation measure CPIW, published by the Canadian central bank, which assigns each of 54 components a weight inversely proportional to its variability.

[4] . This practice was discontinued in 1997, partly because the Reserve Bank felt uncomfortable with calculating the measure on which its performance was going to be judged.

4. Model based methods. These methods are based on some economic theory and are identified by econometric techniques. One example is the indicator suggested by Quah and Vahey (1995), where they use a structural VAR model for inflation.[5] Problems with core inflation estimates based on econometric techniques are among others that history may change every time a new observation is added, and that the measures are sensitive to model specifications. They are also difficult to understand for the general public.

3 Core inflation indicators used in this paper

We evaluate core indicators from the three first groups of indicators mentioned above in the next section. We have not studied any model based methods. We begin by describing the indicators from the first group, where certain elements are excluded permanently.

CPI-ATE belongs to the first group. An indicator that resembles CPI-ATE is CPI-AT, where prices on energy products are included, and the only adjustment is for tax changes.[6] We have chosen to study the empirical properties of this indicator, which is published monthly by Statistics Norway, due to the recent debate on whether it is appropriate to exclude energy prices permanently from measures of core inflation.[7]

Two inflation measures that are calculated and regularly published by Norges Bank in the Inflation Reports, but are normally not referred to as indicators of core inflation, is CPI-ATED, the "domestic" part of CPI-ATE, and CPI-ATEIMP, the "imported" part of CPI-ATE. CPI-ATED is included because some theoretical papers conclude that it may be optimal for a central bank in an open economy to stabilize domestic prices only.[8] CPI-ATEIMP is included mainly because we wanted to study its properties.

We also present a number of indicators where we have excluded the components that have been most volatile in the past. We have analysed as much as 15 new indicators based on this principle. The high number is because we have experimented with how much of the CPI-weights to remove, what measure of volatility to focus on, and which period to base the volatility measure on. We have excluded prices corresponding to from 5 to 30 percent of the CPI weights. The volatility measures we have employed are the standard deviation of the difference between the inflation rate of the respective subindice and headline inflation and the standard deviation of monthly changes in the inflation rates. Inflation is measured either as the change from the previous month (m/m) or as the change from the same month the year before (y/y). The first measure of volatility, V_1, singles out the subindices that have deviated the most from headline CPI, whereas the second measure, V_2, selects the subindices that is most volatile in itself. Fortunately, indices that are ranked among the most volatile according to one of the measure are usually also volatile according to the other measure.[9] We have estimated the volatility in the period from 1993 to 2005 and from 1999 to 2005.

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[5] Bjørnland (2001) has suggested a similar indicator for Norway.
[6] The official series for the 12 month growth in CPI-ATE and CPI-AT begins in August 2000, but we have used data back to January 1983 in this paper. The data prior to August 2000 is based on Norges Bank's own calculations.
[7] See for instance the February 2006 Inflation Report from the Bank of England, page 27.
[8] See for instance Clarida et al. (2001).
[9] The rank correlation between the two volatility measures based 12 month rates in the period from 1993 to 2005 is for instance as high as 0.92.

$$V_1 = sd(\pi_t^{CPI} - \pi_t^i) \quad V_2 = sd(\pi_t^i - \pi_{t-1}^i) \qquad (1)$$

In the tables the indicators are referred to as Excluded, and numbered from 1 to 15. The details about how much of the CPI weights that are excluded from each indicator, what measure of volatility the exclusion is based on and what period the volatility is estimated over, is given in the appendix. The overall 12 month inflation is calculated by taking a weighted arithmetic average of the 12 month inflation rates for the remaining subindices, see equation 2. We have studied 96 subindices in the CPI altogether. This is the complete set of subindices at the coicop4 level. The weights we have used in the aggregation are the standard CPI weights, of course readjusted to sum to 1 as some subindices are removed.

$$\prod_t = \sum_{i=1}^{K} \omega_i \pi_{it} \qquad (2)$$

We will not reproduce headline CPI exactly with this procedure, as the CPI is calculated as chained indices. But it is a good approximation in most cases.[10]

The next set of indicators we have examined belong to the second group mentioned above, where components are removed on a period-by-period basis. The three indicators in this group are the trimmed mean - 10 percent and 20 percent - and the weighted median. These indicators are based on 146 subindices in the CPI (the complete set of subindices at the coicop5-level). The trimmed mean (x percent) is calculated by ordering the respective inflation rates for 146 subindices each month in ascending order, from the prices that dropped the most to the prices that saw the largest increase. Then prices corresponding to x percent of the CPI weights in the upper and lower part of the distribution are removed. The price growth as measured by the trimmed mean is computed as a weighted average of the remaining price observations, using the formula in equation 2. Weighted median is a special case of the trimmed mean. Here we remove all price observations except the middle observation when the price changes each month are ranked in ascending order, taking the CPI weights into account. The trimmed means and weighted median is calculated by Statistics Norway, but published by Norges Bank.

The third set of indicators we have considered belong to the third group above. No components are excluded, but volatile items are given less weight. This is done in two different ways. In the first approach the standard CPI weights are simply replaced with weights that are inversely related to the components past volatility. We have estimated the volatility of the different subindices with the same methods, data and sample periods as for the indicators where we have excluded volatile components. This approach is sometimes described as an Edgeworth-index in the literature, as the general idea was vaguely formulated by Edgeworth in a number of papers in the late 1800s and early 1900s. A more precise formulation was presented by Diewert (1995). The consumer's budget share of the various goods and services has no influence on the weights under this approach.

In the second approach the CPI-weights are retained, but they are adjusted according to past volatility. This implies that prices that are economically important for the consumer will maintain some influence on the aggregate measure of inflation even if they have been very

[10] The mean absolute error when we tried to reproduce the 12 month growth in CPI over the period from 1980 to 2005 by aggregating the subindices like this was 0.08 percentage points, and the median absolute error 0.05.

volatile. This approach is sometimes described as doubleweighting. We take price on electricity as an example. The price on electricity is economically important for Norwegian consumers, but this is also a price that has fluctuated largely in recent years. In the CPI the electricity price had a weight of 4.0 percent in December 2005, but based exclusively on past volatility, electricity is only assigned a weight of 0.2 percent. When the CPI weights and volatility weights are combined, electricity is assigned a weight of 0.5 percent.[11] }

We have produced 12 indicators where volatile items are given less weight altogether, and they are referred to as Volatility 1 to Volatility 12 in the tables. Precise details about each indicator are given in the appendix.

4 How to assess an indicator of core inflation empirically?

Since there is no agreement in the literature on the proper definition of core inflation, there will be no consensus on which criteria that are most important in an empirical assessment of various indicators. Keeping that in mind we will focus on some tests that have been used by a number of other authors in this paper.[12]

We will study whether the various measures are unbiased indicators of headline inflation, investigate whether they are less volatile than headline inflation, check how they track trend inflation, and examine their ability to explain future developments in headline CPI.

[11] The volatility weights in these examples are based on the standard deviation of the difference between 12 month changes in the respective subindice and aggregate CPI. The weights mentioned are from the two indicators Volatility 1 and Volatility 3, respectively.
[12] See for instance Catte and Sløk (2005) and Rich and Steindel (2005).

Table 1 Mean difference from the CPI

	83-05	Rank 83	93-05	99-05
CPI-ATE	-0.18	26	-0.34	-0.32
CPI-ATED	0.34	33	0.42	0.89
CPI-ATEIMP	-1.56	34	-2.31	-3.26
CPI-AT	-0.07	15	-0.16	-0.01
Trimmed mean 20%	0.00	1	-0.04	0.15
Trimmed mean 10%	-0.06	10	-0.14	0.01
Weighted median	0.20	27	0.22	0.59
Exclude 1	-0.07	14	-0.15	-0.25
Exclude 2	-0.06	11	-0.17	-0.24
Exclude 3	-0.13	24	-0.28	-0.27
Exclude 4	0.09	17	0.05	0.22
Exclude 5	0.25	31	0.16	0.32
Exclude 6	0.15	25	0.13	0.37
Exclude 7	0.01	3	-0.01	-0.02
Exclude 8	0.06	9	0.01	0.15
Exclude 9	0.04	6	0.13	0.36
Exclude 10	-0.11	20	-0.26	-0.34
Exclude 11	-0.02	4	-0.09	0.00
Exclude 12	0.24	29	0.20	0.41
Exclude 13	0.09	18	0.15	0.17
Exclude 14	0.07	12	0.02	0.16
Exclude 15	0.24	30	0.17	0.33
Volatile 1	0.07	13	0.10	0.28
Volatile 2	0.12	22	0.25	0.57
Volatile 3	-0.05	8	0.09	0.10
Volatile 4	-0.10	19	0.08	0.17
Volatile 5	0.13	23	0.13	0.39
Volatile 6	0.28	32	0.35	0.82
Volatile 7	-0.08	16	0.09	0.17
Volatile 8	-0.04	7	0.21	0.51
Volatile 9	0.04	6	0.13	0.36
Volatile 10	0.03	5	0.19	0.05
Volatile 11	0.01	2	0.13	0.38
Volatile 12	-0.23	28	0.01	0.09

The table reports the mean difference between the 12 month growth in headline CPI and the various indicators. A negative number implies that the indicator has had a lower mean than CPI. The third column contains the relative rank of the indicator, measured according to the absolute mean difference in the period from 1983 to 2005. The indicators are described in section 3 and in the appendix.

4.1 Are the core indicators unbiased?

We now turn to the empirical analysis. The first question we address is whether the various possible measures of core inflation have been unbiased indicators of headline inflation. In table 1 we report the estimated difference in mean from headline cpi over different time periods. As in the rest of the paper, we have focused on 12 month growth rates.

We note that the indicator most frequently referred to by Norges Bank, CPI-ATE,[13] is among the indicators that have differed the most from headline CPI. Over the period where we have data for all indicators, 1983 to 2005, the mean 12 month inflation rate of CPI-ATE is 0.18 percentage point below that of CPI. The difference is caused by increases in the general tax level and energy prices. The difference between CPI and CPI-ATE has been even more pronounced in recent years. From 1993 to 2005 the growth in CPI was on average 0.34 percentage points above CPI-ATE.

Of the other indicators Norges Bank regularly publishes in the inflation reports, the trimmed mean (20%) stands out with an identical mean to CPI from 1983 to 2005. The trimmed mean (20%) is close to the CPI also in the more recent subperiods. The weighted median has generally been above the CPI. The domestic part of CPI-ATE, CPI-ATED, is not surprisingly the indicator that has had the highest growth. Imported consumer prices, CPI-ATEIMP, has the largest negative difference, due to the shift of Norwegian imports towards low-cost countries that begun in the mid 1990s.

Among the various indicators weighted by volatility or where volatile items are excluded, there is no clear picture. Some indicators have had a higher mean than CPI, whereas others have had a lower mean. But the majority have been closer to CPI than CPI-ATE.

4.2 Are the core indicators less volatile than CPI?

The next question we will address is whether the various measures we have considered are less volatile than CPI. We will focus on two measures of volatility: The standard deviation of the 12 month growth of the respective indicators, and a measure of volatility at a higher frequency - the standard deviation of the change in the 12 month inflation rate from month to month. The results are shown in table 2.

[13] Statistics Norway has only published official figures for the 12 month growth in CPI-ATE since August 2000. The data for CPI-ATE we have used prior to that are calculated by Norges Bank.

Table 2 Volatility of indicators of core inflation

	Sd 83 05	Sd 93 05	Sd m/m 83 05	Sd m/m 93 05
CPI-ATE	2.60	0.71	0.26	0.18
CPI-ATED	2.41	1.02	0.28	0.22
CPI-ATEIMP	3.61	1.55	0.52	0.46
CPI-AT	2.53	1.01	0.40	0.44
Trimmed mean 20%	2.39	0.69	0.28	0.25
Trimmed mean 10%	2.44	0.73	0.29	0.26
Weighted median	2.35	0.79	0.41	0.32
CPI-6				
Exclude 1	2.46	0.73	0.32	0.27
Exclude 2	2.55	0.66	0.29	0.24
Exclude 3	2.59	0.66	0.29	0.24
Exclude 4	2.49	0.64	0.28	0.23
Exclude 5	2.53	0.66	0.28	0.24
Exclude 6	2.43	0.67	0.28	0.23
Exclude 7	2.43	0.88	0.38	0.39
Exclude 8	2.48	0.64	0.27	0.21
Exclude 9	2.37	0.67	0.27	0.21
Exclude 10	2.58	0.65	0.28	0.23
Exclude 11	2.51	0.61	0.28	0.23
Exclude 12	2.54	0.68	0.28	0.22
Exclude 13	2.29	0.72	0.32	0.27
Exclude 14	2.50	0.64	0.28	0.23
Exclude 15	2.53	0.70	0.30	0.26
Volatile 1	2.31	0.66	0.28	0.25
Volatile 2	2.22	0.71	0.27	0.24
Volatile 3	2.24	0.63	0.25	0.21
Volatile 4	2.21	0.63	0.26	0.23
Volatile 5	2.33	0.69	0.27	0.24
Volatile 6	2.25	0.87	0.27	0.26
Volatile 7	2.23	0.57	0.25	0.20
Volatile 8	2.14	0.62	0.24	0.20
Volatile 9	2.34	0.67	0.30	0.25
Volatile 10	2.23	0.86	0.34	0.32
Volatile 11	2.34	0.67	0.31	0.26
Volatile 12	2.21	0.60	0.26	0.22

Sd is the standard deviation of the indicators, over the periods 1983 to 2005 and 1993 to 2005. Sd m/m is the standard deviation of the monthly change in the inflation rate, over the same time periods. The indicators are described in section 3 and in the appendix.

According to the first measure, the simple standard deviation, a number of the indicators we have studied have actually been more volatile than headline CPI. This is particularly the case if we look at the entire period from 1983 to 2005. We also observe that the standard deviation for all indicators in the subperiod from 1993 to 2005 is substantially lower than in the entire period. This is because inflation has been stable at low level since the early 1990s, whereas it was high and variable in the 1980s.

The second measure, the standard deviation of monthly changes in the 12 month growth for the various indicators, is probably a better measure of volatility for our purposes. According to this measure, CPI-ATE has been among the least volatile indicators, and from 1993 to 2005 it in fact had the lowest standard deviation of all indicators. Its standard deviation of monthly changes was only 39 percent of that of CPI in this period. Most of the indicators have by the way been substantially less volatile than CPI in this period. Two exceptions are CPI-ATEIMP, imported consumer goods, and CPI-AT, the CPI adjusted for tax changes. The standard deviations of monthly changes in these indicators were respectively 98 percent and 93 percent of that of the CPI. This illustrates that including energy prices and only adjusting for tax changes in a measure of core inflation would lead to an indicator that is very volatile. It is however important to remember that volatility in itself is not a bad characteristic of an indicator of core inflation. The key question is whether the volatility is a result of relevant new information or just reflects transitory disturbances. Simple measures of volatility cannot answer this question.

4.3 Do the core indicators track trend inflation?

The third empirical question we will discuss is which measure of core inflation that tracks trend inflation best. This corresponds to the definition of core inflation given in Bryan et al. (1997). An obvious question is of course how to calculate trend inflation. In this paper we have chosen to follow Catte and Sløk (2005) and interpreted trend inflation as the centered 25 month moving average of 12 month headline inflation rates.[14] We compare how different measures track the trend by comparing the respective mean square error (MSE) with the MSE of headline inflation itself. The MSE is given by

$$MSE = \frac{\sum_{t=1}^{T} \pi_t^{Core} - \pi_t^{Trend}}{T}. \qquad (3)$$

[14] In order to get a cross check of our results, we have performed the same test with with a HP-trend (lambda equal to 14 400) as the measure of trend inflation. The results are very similar.

Table 3 Mean square error between trend and core inflation

Indicator	Ma 83-04	Ma 93-04	Hp 93-04	Ma dm 93-04
CPI-ATE	0.42	0.30	0.29	0.18
CPI-ATED	0.63	0.88	0.86	0.71
CPI-ATEIMP	6.01	7.65	7.66	2.43
CPI-AT	0.55	0.70	0.69	0.68
Trimmed mean 20%	0.26	0.22	0.21	0.22
Trimmed mean 10%	0.29	0.24	0.24	0.22
Weighted median	0.55	0.52	0.48	0.47
Exclude 1	0.43	0.33	0.33	0.31
Exclude 2	0.43	0.29	0.26	0.26
Exclude 3	0.44	0.36	0.32	0.27
Exclude 4	0.41	0.31	0.27	0.31
Exclude 5	0.49	0.31	0.27	0.29
Exclude 6	0.42	0.31	0.28	0.30
Exclude 7	0.50	0.57	0.55	0.57
Exclude 8	0.39	0.27	0.24	0.27
Exclude 9	0.42	0.28	0.25	0.27
Exclude 10	0.43	0.32	0.29	0.25
Exclude 11	0.39	0.29	0.26	0.27
Exclude 12	0.56	0.34	0.30	0.30
Exclude 13	0.43	0.33	0.33	0.32
Exclude 14	0.41	0.29	0.26	0.29
Exclude 15	0.51	0.37	0.33	0.35
Volatile 1	0.28	0.27	0.24	0.26
Volatile 2	0.34	0.41	0.38	0.36
Volatile 3	0.28	0.19	0.16	0.19
Volatile 4	0.34	0.25	0.22	0.25
Volatile 5	0.31	0.33	0.30	0.32
Volatile 6	0.52	0.68	0.67	0.59
Volatile 7	0.31	0.19	0.16	0.19
Volatile 8	0.39	0.33	0.28	0.31
Volatile 9	0.46	0.34	0.32	0.33
Volatile 10	0.45	0.45	0.45	0.41
Volatile 11	0.53	0.39	0.35	0.38
Volatile 12	0.52	0.24	0.21	0.24

The table reports the MSE of the various indicators and trend inflation. Trend inflation is calculated as a moving average (ma) or by a HP-filter (hp). The last column contains the MSE when the series have been demeaned before their ability to track trend inflation are investigated. The indicators are described in section 3 and in the appendix.

The results are reported in table 3. Of the indicators that are already being used at Norges Bank, the trimmed mean (20%) does by far the best job in tracking trend inflation. This holds both in the period from 1983 to 2005 and in the shorter periled from 1993, and irrespective of whether the benchmark trend is a moving average or HP-trend. Some of the indicators with weights inversely related to past volatility have also been close to the inflation trend over time. This is in particular the case for the two indicators referred to as Volatility 3 and Volatility 7 in the table. They are constructed by replacing the CPI-weights with weights

inversely proportional to the standard deviation of the difference between the 12 month growth in headline CPI and the subindices, and the standard deviation of the monthly change in the 12 month inflation rate of the subindice, respectively. These two indicators belong to the class of core inflation indicators referred to as Edgeworth index above.

With an exception for CPI-ATED and CPI-ATEIMP, all the indicators we have considered track the inflation trend better than headline CPI. But some are only marginally better. This is particularly the case for CPI-AT. Among the core indicators currently used by Norges Bank, the weighted median does the worst job in tracking trend inflation.

The method we have chosen to assess how the various indicators track trend inflation will systematically punish indicators that have a different long run mean than trend inflation. As we noted above, CPI-ATE was one of the indicators that had differed the most from headline CPI in the period under consideration here. To get an idea of how important this is for the results we have obtained, we have demeaned all the series and recalculated the mean square error over the period from 1993 to 2005. The results are reported in the fifth column in table 3. We note that CPI-ATE now has the lowest MSE, whereas it ranked in the middle without demeaning the series. This implies that CPI-ATE has moved largely in line with trend inflation, but been biased downwards.

4.4 Do the core indicators explain future changes in headline?

The fourth empirical test we have performed is a test of whether the candidate measure of core inflation has the ability to predict future changes in headline inflation. This test is related to the definition of core inflation proposed by Smith (2004), that core inflation is the best forecaster of future inflation. We use a simple regression equation for this purpose, where we examine whether the deviation between headline CPI and the candidate core measure has had the ability to explain future changes in headline CPI. The regression equation is specified as follows.

$$(\prod_{t+h}^{CPI} - \prod_{t}^{CPI}) = \alpha + \beta(\prod_{t}^{CPI} - \prod_{t}^{Core}) + u_t \qquad (4)$$

If the core measure is a good forecaster of future headline inflation, and headline inflation is above core inflation in a given period, we would expect headline inflation to fall in the periods afterwards. If it has been like this historically, the estimated β will be negative. The empirical test here amounts to testing whether the coefficient β is negative and significant. By including a constant term in the regression, indicators that have had a different mean than headline CPI in the long run will not perform systematically worse in the test. In addition to testing the significance of β we rank the core indicators according to their explanatory power in the regression (R^2).

Table 4 Does core inflation explain future changes in headline?

	6 months		12 months		18 months		24 months		R^2-av.	Rank R^2-av.
	β	R^2	B	R^2	β	R^2	β	R^2		
CPI-ATE	-0.95	0.42	-1.45	0.58	-0.86	0.28	*-0.59*	0.17	0.36	6
CPI-ATED	-0.51	0.25	-0.79	0.34	-0.37	0.11	*-0.12*	0.01	0.18	30
CPI-ATEIMP	-0.23	0.11	-0.40	0.19	-0.34	0.18	-0.28	0.20	0.17	32
CPI-AT	*-0.49*	0.05	-1.05	0.13	*-0.36*	0.02	*0.30*	0.02	0.05	35
Tr.m.(20\%)	-1.05	0.33	-1.72	0.53	-0.94	0.22	*-0.36*	0.04	0.28	15
Tr.m.(10\%)	-1.19	0.35	-2.01	0.58	-1.06	0.23	*-0.39*	0.04	0.30	12
W.med.	-0.55	0.18	-0.98	0.34	-0.59	0.17	*-0.03*	0.00	0.17	31
CPI_-6	-0.14	0.02	-0.74	0.31	-0.73	0.38	-0.37	0.12	0.21	25
Excl. 1	-1.26	0.48	-1.65	0.47	-0.97	0.23	-1.14	0.38	0.39	4
Excl. 2	-1.10	0.42	-1.50	0.46	-1.02	0.30	-1.17	0.43	0.40	2
Excl. 3	-1.05	0.38	-1.46	0.42	-0.98	0.27	-1.02	0.34	0.35	7
Excl. 4	-0.91	0.34	-1.25	0.36	-0.74	0.18	-0.78	0.21	0.27	17
Excl. 5	-0.92	0.32	-1.32	0.38	-0.82	0.20	-0.81	0.21	0.28	16
Excl. 6	-0.86	0.30	-1.26	0.36	-0.76	0.18	*-0.64*	0.13	0.24	23
Excl. 7	-2.75	0.15	-3.98	0.19	-3.54	0.21	-5.39	0.24	0.20	26
Excl. 8	-0.96	0.35	-1.34	0.39	-0.80	0.20	-0.80	0.21	0.29	13
Excl. 9	-0.85	0.29	-1.30	0.39	-0.82	0.22	*-0.59*	0.12	0.26	19
Excl. 10	-1.10	0.42	-1.52	0.46	-1.04	0.30	-1.16	0.43	0.40	3
Excl. 11	-1.00	0.38	-1.35	0.39	-0.80	0.19	-0.90	0.26	0.31	11
Excl. 12	-0.83	0.29	-1.22	0.35	-0.75	0.19	-0.68	0.16	0.25	21
Excl. 13	-1.19	0.46	-1.52	0.43	-0.76	0.15	-0.94	0.24	0.32	10
Excl. 14	-0.96	0.35	-1.31	0.37	-0.78	0.18	*-0.86*	0.23	0.29	14
Excl. 15	-0.88	0.30	-1.21	0.32	-0.73	0.16	-0.77	0.19	0.25	22
Vol. 1	-1.17	0.36	-1.59	0.39	-0.92	0.18	*-0.72*	0.11	0.26	18
Vol. 2	-0.79	0.30	-1.08	0.32	*-0.52*	0.11	*-0.27*	0.03	0.19	29
Vol. 3	-1.17	0.36	-1.84	0.52	-1.33	0.38	-1.24	0.36	0.40	1
Vol. 4	-1.16	0.31	-1.86	0.45	-1.27	0.30	*-1.07*	0.25	0.33	9
Vol. 5	-0.92	0.28	-1.28	0.31	-0.72	0.14	*-0.46*	0.06	0.20	27
Vol. 6	-0.55	0.21	-0.76	0.23	*-0.34*	0.07	*-0.10*	0.01	0.13	34
Vol. 7	-1.07	0.35	-1.66	0.48	-1.17	0.34	-1.13	0.32	0.37	5
Vol. 8	-0.77	0.28	-1.20	0.38	-0.76	0.21	*-0.58*	0.13	0.25	20
Vol. 9	-0.97	0.28	-1.32	0.29	*-0.70*	0.11	*-0.56*	0.07	0.19	28
Vol. 10	-0.96	0.18	-1.51	0.26	-1.26	0.25	-1.12	0.24	0.23	24
Vol. 11	-0.87	0.24	-1.21	0.25	*-0.67*	0.11	*-0.54*	0.06	0.17	33
Vol. 12	-1.05	0.34	-1.54	0.42	-1.04	0.27	-1.15	0.32	0.34	8

The estimates of β and the respective R^2 are reported in table 4. *Italic letters* signifies that the estimated coefficient was not significantly different from zero. To account for possible heteroskedasticity and autocorrelation in the residuals, we have estimated the covariance matrix using the method proposed by Newey and West (1987) when performing the significance tests. We have further reported the relative ranking of the various core measures based on the average R^2 over all horizons. We have examined how the deviation between headline and core inflation has explained the change in headline inflation 6, 12, 18 and 24 months ahead (k=6, 12, 18, 24). The estimation period is January 1993 to December 2005.

To get a cross-check of our results, we have included the headline inflation rate six months ago as one of the candidate core measures. We get a significant and negative β with this indicator 12 and 18 months ahead, and the average explanatory power (R^2) over all horizons is 0.21. Core inflation indicators that are to be considered as useful tools in predicting future changes in headline inflation should at least do better than this.

For the horizons on 6, 12 and 18 months the estimated coefficients have the expected negative sign for all indicators, and nearly all estimates are significantly different from zero. The picture is more mixed with a horizon on 24 months. Of the indicators currently used by Norges Bank it is only CPI-ATEIMP, imported consumer goods, that is found to be significant. On the other hand, among the new indicators introduced in this paper, almost all of the indicators where volatile prices are excluded get significant coefficients. Among the indicators where all prices are included, but volatile prices are given less weight, there is an obvious difference based on the construction principles. All indicators based on doubleweighting are insignificant 24 months ahead, and a number of them are insignificant also with a horizon on 18 months. Of the indicators based on pure volatility weights, all indicators using weights related to the subindices' standard deviation are found to be significant at all horizons. The same is not the case for the indicators based on variance weights. Accordingly, if the aim is to construct a core inflation indicator that forecasts headline inflation well, and all items are included, but the more volatile have less weight, the lesson from this study is straightforward: One should use pure volatility weights based on the different subindices'
standard deviation.

If we look at the average explanatory power over all horizons, much of the same picture reemerges. The indicator named Volatility 3 has the highest average explanatory power, followed closely by a number of indicators where volatile subindices are excluded. Volatility 3 did also track trend inflation closely, its mean was not significantly different from that of CPI, and it was considerably less volatile than CPI. If we were to pick the best indicator of core inflation based on the tests performed here, Volatility 3 would be a strong contender. But as discussed above, the simple empirical test we have performed here cannot give a precise answer on what core inflation indicators a central bank should pay extra attention to. That is partly because a number of the features that usually are required of an indicator of core inflation cannot be tested empirically. In addition, even if the empirical tests performed here have been used by a number of other authors, they are clearly controversial. See for instance Robalo Marques et al. (2003) for a critical discussion. Two obvious drawbacks with Volatility 3 is that it is not easy to explain to the public, and the weights given to the various items in the index is not related to their economic importance. It is thus very different from the CPI.

CPI-AT performs relatively poorly as a core indicator. Its long run mean is not very different from CPI, but it is almost as volatile, it tracks trend inflation poorly, and it has explained very little of the future development in headline CPI. The weighted median did not perform very well either.

We would nevertheless argue that the main lesson from this study is that no mechanical indicator of core inflation can provide a reliable picture of the underlying price pressure under all circumstances. As we have seen, evaluated against different empirical criteria, different indicators have performed best, even if some indicators have performed better than others overall. The policy recommendation is therefore that a central bank should monitor a number of indicators of core inflation, and pay particular attention to the question of what the

underlying price pressure is at a given moment if the different indicators deviate substantially. This question can in any circumstance not be answered without using a lot of judgement.

5 Conclusion

We have presented some indicators of core inflation not used at present at the central bank of Norway, and evaluated new and traditional indicators empirically in this paper. Our main conclusion is that no indicator can be expected to provide an accurate picture of the true underlying inflation pressure under all circumstances. Therefore, the central bank should monitor several indicators, and pay particular attention to the question of what the true underlying inflation is if different indicators deviate substantially. The indicator that receives most attention in Norges Bank's Inflation Reports, the CPI-ATE, performs reasonably well in the empirical tests performed here, but has over time had a somewhat lower growth than headline CPI.

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Table A1 Description of indicators

Name	**Description**
CPI-ATE	CPI adjusted for tax changes and energy prices excluded
CPI-ATED	CPI-ATE from domestic sources
CPI-ATEIMP	Imported consumer goods in CPI-ATE
CPI-AT	CPI adjusted for tax changes
Trimmed mean 20%	See section 3
Trimmed mean 10%	See section 3
Weighted median	See section 3
Exclusion of volatile components	**Percent excluded, exclusion criteria, sample period**
Exclude 1	5%, standard deviation of 12 m growth relative to CPI, 1993-2005
Exclude 2	10%, sd of 12 m growth relative to CPI, 1993-2005
Exclude 3	15%, sd of 12 m growth relative to CPI, 1993-2005
Exclude 4	20%, sd of 12 m growth relative to CPI, 1993-2005
Exclude 5	25%, sd of 12 m growth relative to CPI, 1993-2005
Exclude 6	30%, sd of 12 m growth relative to CPI, 1993-2005
Exclude 7	10%, sd of 12 m growth relative to CPI, 1999-2005
Exclude 8	20%, sd of 12 m growth relative to CPI, 1999-2005
Exclude 9	30%, sd of 12 m growth relative to CPI, 1999-2005
Exclude 10	10%, sd of monthly changes in 12 m growth, 1993-2005
Exclude 11	20%, sd of monthly changes in 12 month growth, 1993-2005
Exclude 12	30%, sd of monthly changes in 12 m growth, 1993-2005
Exclude 13	10%, sd of 1 m growth relative to CPI, 1993-2005
Exclude 14	20%, sd of 1 m growth relative to CPI, 1993-2005
Exclude 15	30%, sd of 1 m growth relative to CPI, 1993-2005
Less weight to vol. components	**Weights**
Volatile 1	Doubleweighted, sd of 12 m growth relative to CPI
Volatile 2	Doubleweighted, variance of 12 m growth relative to CPI
Volatile 3	Sd of 12 m growth relative to CPI
Volatile 4	Var of 12 m growth relative to CPI
Volatile 5	Doubleweighted, sd of monthly changes in 12 m growth
Volatile 6	Doubleweighted, var of monthly changes in 12 m growth
Volatile 7	Sd of monthly changes in in 12 month growth
Volatile 8	Var of monthly changes in 12 m growth
Volatile 9	Doubleweighted, sd of 1 m growth relative to CPI
Volatile 10	Sd of 1 m growth relative to CPI
Volatile 11	Doubleweighted, sd of changes in 1 m growth
Volatile 12	Sd of changes in 1 m growth
