Methods explained

Methods explained is a quarterly series of short articles explaining statistical issues and methodologies relevant to ONS and other data. As well as defining the topic areas, the notes explain why and how these methodologies are used. Where relevant, the reader is also pointed to further sources of information.

Core inflation

Graeme Chamberlin

Office for National Statistics

SUMMARY

Core inflation attempts to capture the underlying inflationary pressures in the economy by excluding or down-weighting the more erratic and transitory components of consumer prices indices. Recent volatility in food and energy prices, along with the monetary policy regime of inflation targeting, has increased interest in these measures. However, the Office for National Statistics does not produce estimates of core inflation and neither does the Bank of England target them. This article outlines several ways in which core inflation can be calculated and discusses the issues and judgements involved.

The Office for National Statistics (ONS) produces two measures of consumer price inflation in the UK. Both the Retail Prices Index (RPI) and the Consumer Prices Index (CPI) are published each month and are based on the cost of a basket of goods and services for a representative household. Weights attached to each individual item generally reflect the share in total expenditure. Roe and Fenwick (2004) provides a good overview of the history, coverage and methodology of each index.

Core inflation, on the other hand, is a construct invented by economists to try and assess the more underlying inflationary pressures in the economy. It recognises that, in the short run, headline inflation rates may be driven by temporary supply shocks or seasonal effects that do not have a lasting impact and, as such, there is less imperative for policy makers to respond to these. Instead, as Blinder (1997) states, (monetary) policy should concentrate on the permanent or durable part of actual inflation that is likely to persist once the transitory or fleeting influences on price movements have worked through or been reversed.

ONS does not produce a specific measure of core inflation and the Bank of England does not explicitly target one. It is important to recognise at the outset that there are many ways of constructing such a measure and separating inflation into core and non-core parts in real time requires a strong element of judgement. Almost all methods are based on excluding or down-weighting the more erratic components of consumer prices indices based on the assumption that these provide little information about inflation in the medium term.

However, it may be the case that these are the exact components that are likely to pick up new inflationary developments. For example, the

Bank of England, as evidenced in the minutes of the Monetary Policy Committee (MPC), has been very concerned about possible second-round effects that can originate from one-off transitory shocks which become engrained in expectations and thus longer-term inflation rates. Core inflation measures are also contentious. By excluding or down-weighting items that matter to people in the 'real' world, they may be disregarded as unrepresentative by the public. So even though core inflation may be a useful indicator for policy makers, consideration should always be given to how it was produced and the judgements involved.

Recent interest in core inflation has been marked due to a combination of volatility in primary goods prices (food, energy and minerals) and the UK's monetary policy regime which puts a strong emphasis on the inflation outlook. This article, recognising the current context, sets out and discusses various methods for constructing core inflation and applies them to UK CPI inflation.

Recent volatility in UK CPI inflation

Interest in core inflation is particularly strong during times of volatile price movements, as has been the case in the UK and the rest of the world during the last two years. During 2008, CPI inflation in the UK, on an annual basis, peaked at 5.2 per cent in September before falling back to 3.1 per cent by the end of the year. As **Figure 1** shows, these trends have been largely driven by a few subaggregates of the overall price index.

Figure 1

CPI inflation

Percentage change, month on same month a year earlier

Source: Office for National Statistics

During 2008, the annual rate of food price inflation peaked at 14.8 per cent in August. Electricity and gas prices have risen substantially, by 31 and 51 per cent, respectively, during the course of the year. Transport fuel (petrol and diesel) has also exhibited large swings in prices connected with movements in global oil prices. In July, transport fuel prices were 25.7 per cent higher than in the same month a year earlier, but corresponding figures for December reported an 11.2 per cent fall.

Core inflation and UK monetary policy

The Bank of England Act (1998) established a new framework for the operation of monetary policy in the UK. Control of interest rates was passed from HM Treasury to the independent MPC at the Bank of England, whose remit was to maintain price stability in terms of an inflation target set by the Chancellor.

Initially, the target was RPI excluding mortgage interest payments (RPI-X) inflation of 2.5 per cent. However, in December 2003, the remit was changed to target CPI inflation at 2 per cent. The change was motivated by the wide belief that CPI was more methodologically sound and a better indicator of the UK inflationary pressures of concern to monetary policy makers. Roe and Fenwick (2004) provide the statistical perspective on the move to the new target.

Inflation targeting, by making the association between inflation outlook and the level of interest rates faced by households and firms more transparent, has heightened public awareness in price statistics. The Bank of England publishes the minutes of MPC meetings, a quarterly Inflation Report and MPC members themselves make speeches around the country and appear before the House of Commons Treasury Select Committee.

Although the Bank of England does not target core inflation, it is easy to understand why monetary policy makers might wish to consider these measures. It is widely accepted that interest rate changes take up to two years to fully feed through to output. Consequently, monetary policy is forward-looking, having to be set pre-emptively to maintain an inflation target in the medium term. As core inflation is the part of actual inflation that is expected to persist beyond the short run, it is potentially a useful indicator of the medium term and more persistent inflationary pressures in the economy that monetary policy should address.

While excluding or down-weighting the more erratic items can give an altogether cleaner measure, it runs the risk of discarding new information on emerging inflationary developments. The current UK policy regime reflects this by targeting headline inflation but allowing some short-term flexibility. If inflation departs from target by more than 1 percentage point in either direction, it triggers an open letter from the Governor of the Bank of England to the Chancellor explaining the reason for the deviation and how the target rate will be restored over the forecast horizon (approximately two years). This facility frees monetary policy from having to react to short-term influences on actual inflation as long as the target is on course to be met in the medium term. So, even though the Bank of England does not explicitly target a core inflation measure, it is clear that the underlying principles have been figured into the monetary policy regime.

Measuring core inflation

There are a plethora of different techniques for constructing measures of core inflation. These differ in part depending on how core inflation is actually defined but in essence most are built on the same underlying principles.

If core inflation is viewed as actual inflation once extreme or erratic prices are removed from the index, then the standard approach taken is to extract the general noise to leave a cleaner measure of current price changes. Here, statistical approaches such as excluding the most volatile subcomponents or reweighting the index based on the respective variances of the subcomponents are often adopted.

Alternatively, if the aim is to capture the true underlying price pressures in the economy, then the methods used might give higher weights to the components that exhibit greater persistency or are better predictors of future inflation. However, it is unlikely an item which exhibits erratic price movements will also show strong persistency or be a good predictor of future inflation. Hence, these techniques would be expected to produce similar answers to those based on variance weights.

Finally, economists have developed a fairly strong sense of the long-run determinants of inflation and this laid the foundation of model-based estimates of core inflation. These are slightly different from the more statistical methods, but again it is not too difficult to reconcile the views and approaches of economists and statisticians.

A number of desirable properties of core inflation measures have been suggested (see Wynne 1999).

- **Timeliness:** the measure should be computable in real time and available alongside the headline figures
- **Unbiased:** as core inflation measures seek only to remove transitory and/or reversible components from the price index, the long-run average of core measures should be similar to the actual or headline rate
- **Once constructed,** core measures should not then be revised unless there are revisions to the underlying data
- **Verifiable:** techniques should easily be understood by the general public and, if necessary, reproducible with limited resources
- **Forward-looking:** a key element of core inflation measures is their success in predicting future inflation trends
- **Economic basis:** a theoretical rationale may be beneficial given the use of any measure is likely to be in economic policy making or analysis

This article now seeks to demonstrate several of these methods applied to UK CPI inflation since the new inflation target was introduced in December 2003.

Exclusion methods

These are the simplest and the most widely applied measures of core inflation. Certain parts of an aggregate price index are considered very prone to short-term supply-side shocks or strong seasonal movements which have little effect on the long-term outlook

for inflation and can therefore be excluded altogether. The most common suspects appear to be food and energy items.

ONS publishes a number of consumer price indices where certain special aggregates are excluded, although they are not referred to as core inflation measures. These are typically known as CPI-X, where the X refers to the item or items omitted, and can be found in the monthly Focus on Consumer Price Indices release.¹ As an illustration, **Table 1** presents the different CPI-X measures for September 2008 when the aggregate CPI inflation rate peaked at 5.2 per cent.

Figure 2 plots UK CPI inflation along with a measure that excludes energy and one that excludes energy as well as food, beverages and tobacco. Looking at the three time series gives a very different perspective on UK consumer price inflation during 2008. All three measures peaked during September but, while overall CPI inflation was 5.2 per cent, the exclusion of energy saw it peak at a lesser 3.4 per cent and the further exclusion of food, alcoholic beverages and tobacco saw a peak of only 2.2 per cent. So, while headline inflation rates increased significantly, rates based on the exclusion of energy and food-related items suggested inflationary pressures were much closer to target.

Table 1
Exclusion of special aggregates and inflation, September 2008

Special aggregate (X)	CPI-X weight (per 1000)	CPI-X inflation rate (per cent)
CPI	1,000	5.2
Energy	927	3.4
Energy, food, alcoholic beverages and tobacco	776	2.2
Energy and unprocessed food	877	2.8
Seasonal food	971	5.1
Energy and seasonal food	898	3.2
Tobacco	976	5.2
Alcoholic beverages and tobacco	958	5.3
Liquid fuels, vehicles fuels and lubricants	960	4.6
Housing, water, electricity, gas and other fuels	885	3.9
Education, health and social protection	947	5.2

Source: Office for National Statistics

Source: Office for National Statistics

Another class of exclusion-based measures concerns one-off and known shocks. In UK economic policy making, RPI-X has been the measure of choice for many years and this is a form of core inflation by excluding mortgage interest payments from the overall index. It was not considered particularly helpful that an increase in interest rates designed to curb inflationary pressures might actually transmit into higher RPI inflation through mortgage interest payments, so a better underlying impression of true inflationary pressures would result from its omission. RPI-Y is another exclusion-based measure, not only stripping out mortgage interest payments but also indirect taxes from the index.

Mortgage interest payments along with a number of other housing-related items such as depreciation do not form part of the CPI. However, indirect tax changes can still have an important impact on measured price inflation even though they are not part of the underlying demand and supply pressures in the economy. ONS produces two estimates of CPI inflation that exclude the effects of indirect taxation (**Figure 3**). CPI-Y excludes VAT, duties, insurance premium tax, stamp duty on share transactions and air passenger duty. CPI-CT is simply the consumer price index at constant tax rates. Differences between the series predominately reflect weightings due to taxes being excluded in one measure, but included at constant rates in the other.

Looking at the history of CPI inflation, for the most part, indirect tax changes have had a small impact. In general, indirect tax rates have increased in recent years. Excise duties normally go up rather than down, especially fuel duties which, for a period of time, were driven by the fuel price escalator. There have also been notable increases in vehicle excise duty and air passenger taxes. Despite these trends, the latest impact of indirect tax changes on CPI inflation rates has been downwards.

In the 2008 Pre-Budget Report, the Chancellor announced a temporary 2.5 percentage point reduction in the rate of VAT, although the impact on alcohol, fuel and tobacco was to be offset by excise tax increases. These measures, implemented in December of that year, have had a big impact on CPI inflation. Headline rates for December reported a 3.1 per cent increase in prices relative to the same month a year earlier. However, the CPI-Y and CPI-CT rates were much higher, at 4.6 and 4.1 per cent, respectively. Hence, much of the reduction in UK inflation in that month was due to policy changes rather than a marked shift in inflation trends.

Core inflation measures based on the exclusion method are popular and tick many of the desirable boxes listed before. **Table 2** presents some cross-country comparisons of core inflation measures and all are based on this approach. Certainly they are easy to compute and the public has a good understanding of what they portray. But they have attracted criticism on two grounds. First, a once and for all judgement about what is in and what is out is required. Second, the blanket approach to exclusion may not always be considered helpful. For example, excluding all food items from the index implies that all food price movements are simply transitory whereas there may be useful underlying information inherent in certain subparts of the food category.

Figure 3
CPI inflation excluding the effects of indirect taxes

Percentage change, month on same month a year earlier

Source: Office for National Statistics

Table 2
Cross-country comparisons of core inflation measures

Country	Core inflation measure
Canada	CPI excluding food, energy and indirect taxes
Australia	Treasury underlying CPI
New Zealand	CPI excluding interest charges
Japan	CPI excluding fresh food
US	CPI excluding food and energy
Germany	CPI excluding indirect taxes
Spain	CPI excluding energy and unprocessed food
Netherlands	CPI minus fruits, vegetables, and energy
Ireland	CPI less mortgage interest payments (MIPs); CPI excluding MIPs, food and energy
Portugal	CPI less unprocessed food and energy

Source: Office for National Statistics

Weighted variance methods

Exclusion methods omit an entire class of items from the price index based on a prior judgement that their impact on inflation rates is erratic and non-lasting. A refinement of this approach would be to simply recalculate the price index based on a measure of volatility. Therefore, non-volatile items within a class of otherwise excluded items can still be allowed to influence the measurement of core inflation. And erratic components in other non-excluded item classes can have their influence diminished. Naturally, a downside is the less simplistic and clear-cut approach, although the computations involved are hardly complex.

Weighting individual components according to past volatility can be done in a number of ways, but a generally accepted approach proposed by Dow (1994) is to allocate weights inversely related to the standard deviation of individual prices. Therefore, for each of the 85 item categories making up the CPI, the respective weight is given by:

$$w_i = \frac{(1/\sigma_i)}{\sum_i (1/\sigma_i)}$$

where σ_i is the standard deviation of monthly inflation rates for each item over the past five years.

Figure 4 plots the core inflation rate calculated where the weights are updated each year using this methodology, alongside the headline rate. It is evident that, over the sample January 2004 to December 2008, the volatility of the core rate is lower. In particular, the inflation peak in the summer of 2008 is reduced, but also the core measure exceeds the low CPI measures at the beginning of the sample period.

A comparison of the standard deviation-based weights and the CPI expenditure-based weights at a more aggregated 12-item classification and pertaining to 2008 are presented in **Figure 5**. Note that the weights applied during 2008 were formulated over the previous five-year period (2003 to 2007), so the significant volatility in food and home-energy prices during that year would yet to be fully reflected. However, it is evident that previous volatility in transport fuel prices had an impact, meaning its lower weight in the core inflation measure fed through to a lower peak rate in September 2008. Higher core rates at the beginning of the sample might reflect the lower weights attached to clothing and footwear items where prices have generally fallen over the last decade. These items tend to exhibit seasonal volatility so it is no surprise that past inflation rates, month on month, report a relatively high standard deviation.

Some understanding of how the volatility of certain item prices might be changing over the sample period can be taken from

Figure 4

Core inflation based on weights inversely related to the past standard deviation of price movements

Percentage change, month on same month a year earlier

Source: Office for National Statistics

Figure 5

Standard deviation-based weights and CPI weights, 2008

Weights (parts per thousand)

Source: Office for National Statistics

Figure 6 which shows a comparison of standard deviation-based weights for 2004 and 2008. Clearly, the weights of food and home-energy items are beginning to fall.

This reflects one of the disadvantages of the method, that the weights are backward looking, so the calculation can be sensitive to regime changes in price movements. Using a shorter rolling sample would make the weights more responsive to recent inflation volatility but, obviously, assumes the risks of using a smaller sample of observations. Hence a judgement has to be made: should the weights reflect longer-term trends in volatility or be more able to respond quickly to sudden changes?

Persistence-weighted methods

If an important feature of core inflation is the accurate prediction of future headline rates, then the persistency of individual price movements may be informative. This approach was investigated

Figure 6

Standard deviation-based weights

Weights (parts per thousand)

Source: Office for National Statistics

by Cutler (2001) in an MPC working paper. Her suggestion was to reweight price movements in monthly inflation rates using the coefficients from a simple first-order autoregressive model.

For each of the 85 items making up the CPI, the following simple regression was estimated:

$$\pi_{it} = a_i * \pi_{it-1} + e_{it}$$

where π_{it} is the individual inflation rate of a particular item at time t , a_i the autoregressive coefficient and e_{it} an error term.

The reasoning behind this approach is fairly intuitive. If the coefficient a_i is negative, then it suggests that previous price movements are quickly reversed and the item is given a zero weight. This is likely to correspond to items where seasonal factors are important. The larger the coefficient a_i , the stronger the effect of previous price movements on current inflation. Hence, a persistency-weighted index can be constructed where each item is given the weight:

$$w_i = \frac{a_i}{\sum_{i=1}^{85} a_i}$$

In **Figure 7**, this method is applied to produce a UK CPI core inflation measure between 2004 and 2008. Weights are updated annually and the regression is run over a five-year rolling sample with the monthly inflation rate as the dependent variable. The surprising result is that the core inflation rate calculated using this method is actually more volatile than the headline rate.

A comparison of persistence and general CPI weights in 2004, at the 12-item level of aggregation, is presented in **Figure 8**. These results are plausible, especially the low persistence weights attached to the food, drink and tobacco segments where monthly price movements are driven by strong seasonal factors and are quickly reversed.

Figure 7

Core inflation based on persistence weights

Percentage change, month on same month a year earlier

Source: Office for National Statistics

Figure 8

Persistence-based weights and CPI weights, 2004

Weights (parts per thousand)

Source: Office for National Statistics

Comparing the 2004 and 2008 weights shows how the persistence weights have changed over time (Figure 9). Note that the food and household energy weights have increased markedly during this time reflecting the recent sustained increases in these prices. Once again, these results will not capture the strong volatility in 2008, as the weights applied to price movements in that year were taken from regressions run over the five-year period January 2003 to December 2007.

Applying this methodology produces a core inflation measure that actually amplifies the movements in the headline rates. This must be because the items that are exhibiting high inflation have also been exhibiting sustained movements in inflation. While this approach is probably quite good at giving low or zero weights to very seasonal price movements, it is generally poor at dealing with jumps or large movements in time series. In this case, the coefficient in the autoregressive model will be quite sensitive, as is evident in the shifting weight patterns for the food and the housing, water and fuels categories in Figure 9.

Figure 9

Persistence-based weights

Weights (parts per thousand)

Source: Office for National Statistics

However, this example does underline an important principle. It is not implausible for core inflation measures to show stronger movements than the headline index for short periods, even though conventional wisdom is that the former are generally just smoothed versions of the latter. This is particularly likely when the extreme price movements in the distribution of all individual prices are sustained for several periods. This effect is further strengthened by the backward-looking nature of the calculation which assumes that sustained price movements in the past will continue.

Trimmed-mean methods

Both the CPI and RPI are based on a weighted basket, where the weights reflect the typical expenditure share of each item for a representative consumer. RPI inflation is calculated as the arithmetic mean of price relatives, but this is only the best estimator if the distribution of price changes follows a normal distribution.

In reality, most price distributions are considered to be non-normal in two ways. First, the distribution of price movements tends to be asymmetric in exhibiting positive skewness. This means that large positive price movements tend to be more common than negative price movements of the same magnitude. Second, the distribution of price movements is leptokurtic with fat tails (that is, having a higher probability of extreme values), implying that very large price movements are actually far more common than the normal distribution would imply. If a distribution were skewed, then the arithmetic mean would be a biased estimator of central tendency. And if the distribution were leptokurtic, it would be an inefficient estimator in that a better indicator of the central tendency could be achieved by giving less weight to the large price changes at the extremes of the distribution (see Roger 2000 for a useful account of the importance of the distribution of price changes).

These problems are slightly mitigated in the calculation of CPI inflation rates, which are based on the geometric mean of price

movements. A geometric mean is essentially the arithmetic mean of a log-normal distribution, and the effect of a log-transformation is to generally reduce the impact of the more extreme observations.

If the distribution of price changes is leptokurtic, then trimmed means, where a certain percentage of the largest and smallest price changes are excluded, are regarded as a more efficient estimator. Judgement, though, is required concerning the proportion of the distribution that should be trimmed. Bakhshi and Yates (1999) suggest a 15 per cent symmetric trim for the UK RPI-X. According to their analysis, this approach produces a core inflation measure with similar properties to a 37-month moving average of the actual RPI-X inflation rate. Judgement is also required on whether the

applied trim should be symmetric or focused on tackling any skewness in the distribution of individual price changes.

Figure 10 presents a trimmed-mean core inflation estimate for the UK CPI. This has been calculated by removing for each month the 15 per cent largest and smallest monthly price changes over the period 2004 to 2008. Also presented in Figure 10 is the median rate of CPI inflation. A median is basically the same as a 50 per cent symmetric trim and exhibits the useful property of being a much more robust indicator of central tendency than the mean. **Table 3** reports the top 15 and bottom 15 most excluded items in the 60 monthly periods.

The most often trimmed items are passenger transport by air

Figure 10
Trimmed mean and median estimates of core inflation

Percentage change, month on same month a year earlier

Source: Office for National Statistics

Table 3
Top 15 most and least often trimmed items

Top 15 trimmed items			Bottom 15 trimmed items		
Item		Percentage of months trimmed	Item		Percentage of months trimmed
07.3.3	Passenger transport by air	98.3	07.1.1A	New cars	0.0
07.3.4	Passenger transport by sea and inland waterway	91.7	09.2.1	Major durables for recreation	1.7
04.5.3	Liquid fuels	90.0	11.1.1	Restaurants and cafes	1.7
05.1.1	Furniture and furnishings	86.7	12.1.1	Hairdressing and personal grooming establishments	1.7
09.1.2	Photographic, cinematic and optical equipment	86.7	04.3.2	Services for maintenance and repair	6.7
09.1.3	Data processing equipment	83.3	09.1.5	Repair of audiovisual equipment	6.7
01.1.6	Fruit	81.7	04.4.1	Water supply	8.3
07.2.2	Fuels and lubricants	80.0	04.4.3	Sewage collection	8.3
09.1.1	Reception and reproduction of sound and pictures	75.0	05.3.3	Repair of household appliances	8.3
09.5.1	Books	75.0	05.6.2	Domestic and household services	8.3
05.1.2	Carpets and floor coverings	70.0	06.1.2	Other medical equipment	8.3
05.2	Household textiles	70.0	09.4.1	Recreational and sporting activities	8.3
09.1.4	Recording media	68.3	09.5.2	Newspapers and periodicals	8.3
01.2.1	Coffee, tea and cocoa	65.0	11.1.2	Canteens	8.3
09.3.1	Games, toys and hobbies	65.0	12.4	Social protection	8.3

Source: Office for National Statistics

and water, where seasonal factors play a key role in driving price movements. Other items typically excluded are a general class of electrical goods (audiovisual, computers and photography), household furniture and carpets. Again, these are items that may follow fairly regular discount periods, such as biannual sales. It is little surprise that liquid fuels, fruit, and coffee, tea and cocoa are also regularly trimmed given the sensitivity of prices to supply shocks.

In terms of the least often trimmed, the goods and services which report relatively stable monthly price movements, new cars were never excluded. Repair and maintenance expenditure; cafes, restaurants and canteens; recreational, domestic, household and personal services; and water and sewage utilities also showed evidence of relative price stability.

The basic justification for trimming is that prices at the extreme of the distribution carry less information about the currently prevailing inflationary pressures in the economy. However, Zeldes (1994) argues that, in certain situations, it is the large price movements at the ends of the distribution that actually contain the true news on general price pressures. For example, there is a great deal of anecdotal evidence that prices are sticky so, for a firm that faces costs in changing prices, it is possible for a wedge to open up between its actual and desired price. If, following a demand shock, this wedge reaches a critical level for some companies and not others, the firms that actually change price will be those that are responding to the underlying price information. A trimming procedure though may well delete these items from the core inflation estimate even though they contain new information about future price movements.

Common component methods

When observing price movements in real time, the difficulty is identifying the relative importance of the permanent and transitory parts. In this sense, measuring core inflation is a signal extraction problem, in that true or underlying price movements are embedded in the noisier observed data.

Signal extraction problems are commonplace in economic and statistical analysis. For example, the permanent income hypothesis argues that households base their consumption decisions not on actual income but on a longer-term view or permanent income. Therefore, transitory changes in income would have little impact on spending. Another example concerns the rate of unemployment, where inflationary pressures are likely to be neutral, known as the Non-Accelerating Inflation Rate of Unemployment or NAIRU. In both cases, it is not the observed data that matter, whether household income or unemployment, but the signal within that data referring to the permanent innovations in the data.

Deducing the underlying variable of interest (core inflation) from the measured data (headline inflation) can be achieved by writing the signal extraction problem in state space form and applying the Kalman Filter. State space form consists of two sets of equations.

The measurement equations define the relationship between the observed data, the state variable(s) and an idiosyncratic component.

Using a broader 12-item disaggregation of CPI inflation, the measurement equations can be written as follows:

$$\begin{aligned}\pi_{1t} &= S_t + e_{1t} & \text{Var}(e_{1t}) &= \sigma_1^2 \\ \pi_{2t} &= S_t + e_{2t} & \text{Var}(e_{2t}) &= \sigma_2^2 \\ &\vdots & &\vdots \\ \pi_{12t} &= S_t + e_{12t} & \text{Var}(e_{12t}) &= \sigma_{12}^2\end{aligned}$$

Hence, the recorded inflation rate of each item (π_{it}) consists of a common component (core inflation) represented by the state variable (S_t) and an individual idiosyncratic factor (e_{it}) that is allowed to take its own variance (σ_i^2).

The second set of equations, known as the state equations, define a law of motion for the state variable(s). This could feasibly be any type of linear model although, for simplicity, this example uses a basic first-order autoregressive model.

$$S_t = \rho S_{t-1} + v_t \quad \text{Var}(v_t) = 1$$

Having expressed the signal extraction problem in state space form, an estimate of core inflation can be found using the Kalman Filter (see Harvey 1991 for a good exposition). This is a recursive algorithm which at each point in time, based on the history of the data, determines how much of an innovation in measured inflation is accounted for by the core element and the non-core or idiosyncratic element. For example, if the past data are particularly volatile, then the algorithm would be expected to allocate a larger proportion of current and future inflation innovations in that item to the idiosyncratic rather than the common component. The results from this procedure are shown in Figure 11.

The Kalman Filter is often used in trend analysis and, here, core inflation is estimated as the general underlying trend in a cross-section of individual inflation rates. A key element of the procedure is the signal-to-noise ratio. If the variance of the error term in the state equation is normalised to unity, then this will be given by the inverse of the variance of the idiosyncratic terms in each of the measurement equations ($1/\sigma_i^2$).

The lower the signal-to-noise ratio, the greater the contribution of

Figure 11
A Kalman Filter approach to core inflation

Percentage change, month on same month a year earlier

Source: Office for National Statistics

Figure 12

A comparison of CPI expenditure weights and signal-to-noise ratios

Weights (parts per thousand)

Source: Office for National Statistics

specific rather than common factors in accounting for inflation. As the signal-to-noise ratio increases, core inflation plays a larger role in accounting for the measured inflation of that item. Therefore, this method is closely related to the variance-weighted approach. By normalising the calculated signal-to-noise ratios so that they sum to 1000, they can be compared with the actual CPI expenditure weights (Figure 12).

The signal-to-noise ratios were estimated over the period 1996 to 2008 so, being based on a much longer sample, may not exactly compare with weights calculated through other methods. The most significant result is the large weight attached to hotels and restaurants, implying that inflation in this category has been strongly representative of underlying inflationary pressures in the whole economy over this longer time period. This corresponds with the evidence in Table 3 where this category was infrequently excluded when calculating a trimmed mean of price changes. Lower weights attached to food, housing fuels and transport prices are indicative of the frequent supply shocks that affect these items. Also, the clothing and footwear, household furniture, and recreation and culture (which includes computers and audiovisual goods) categories would have a lower signal-to-noise ratio due to frequent periods of discounting, adding volatility to the time series.

The example used here is close in spirit to the dynamic factor model outlined in Bryan and Cecchetti (1993). Another approach, based on similar principles, is the use of generalised dynamic factor analysis in Cristadoro *et al* (2001) which has the advantage of being able to deal with a much larger cross-section of data. While methods based on extracting common components from the data are fairly intuitive, and flexible in that almost any type of linear model can be represented in state space form, they are generally more complex than other approaches. This might be expected to hinder public understanding and acceptance of such measures.

A further problem connected with filters is that past estimates will tend to be revised, even if the underlying data remain the same, once the time series rolls forwards. Data at the end of the sample are the most prone, an issue known as the end-point problem. Unfortunately, the recent data also tend to be of most interest, so revisions to core inflation measures may undermine people's trust in them.

Economic model-based methods

According to economic thought, there are two sources of price changes in an economy. The first are relative price changes resulting from shifting demand and supply. For example, a sharp rise in oil prices would, if everything else were held constant, lead to a fall in real incomes and subsequently falling demand and prices elsewhere in the economy. Although relative prices have changed, the overall price index would remain unchanged. Movements in relative prices may well be far from painless and have differential impacts on certain groups of people but, in aggregate, they are neutral and thus require no monetary policy response under a regime of inflation targeting. Even if relative price changes did have a non-neutral impact, it would be expected to be a one-off effect on the price level rather than the rate of inflation (the growth rate of the price level).

When economists talk about inflation, they are really referring to a fall in the purchasing power of money caused by a mismatch between the money supply and the level of output. When the growth of the money supply exceeds the growth of output, the relative increase in money causes prices to be bid upwards, hence each unit of money has less power to be exchanged for goods and services. The general creep in prices that this causes is identified as the long-term root cause of inflation. Relative price changes only have permanent effects to the extent they are accommodated by the money supply. For this reason, Milton Friedman famously stated inflation as being everywhere a monetary phenomenon.

In real time, it is immensely difficult to separate out the relative price and monetary mismatch effects in measured inflation. For this reason, the approaches used by statisticians can serve as a good proxy. Relative price movements are assumed to have a more erratic and shorter-term impact on aggregate price movements so, if removed or down-weighted, a measure based on more persistent inflationary trends results.

If core inflation is defined as the long-run consequence of excessive monetary growth, then it provides a basis for economists to model core inflation. Despite this, the literature has remained fairly sparse and it has been hard to find much empirical correlation between growth in the money supply and the trend in inflation as theory predicts. Quah and Vahey (1995) is the most cited work to date, and they identify core inflation as the component of measured inflation with no medium- to long-run effect on output and produce an estimate for UK RPI-X.

Final remarks

Core inflation measures seek to provide an estimate of the underlying and persistent component of inflation, recognising that price indices can be affected by erratic and transitory components in the short run. As an explicit measure, it can guide in the setting of monetary policy and in helping the public to establish inflation expectations.

This article has discussed a number of approaches to measuring core inflation. The most commonly applied is the exclusion approach, favoured for its simplicity and for the ease with which it can be verified by the public. Food (seasonal) and energy prices are the most commonly omitted as these items are particularly prone to supply shocks that have temporary effects on the rate of inflation.

However, it has been questioned whether central banks should just concentrate on core inflation, as households care about the prices of all the items they buy. By living in a world where people do not eat or drive, monetary policy makers might be accused of being out of touch so, for the benefit of public accountability, it is sensible to target headline inflation as well.

A dual approach takes into account the possible interactions that exist between headline and core inflation. Changes in core inflation are less likely to be reversed, and by providing a cleaner measure of the underlying inflationary pressures in the economy, is a useful indicator for the future path of headline inflation. Correspondingly, sharp movements in relative prices can also feed through into core inflation, especially if the initial bout of inflation they cause becomes engrained in inflationary expectations. The potential for these second-round effects has been an important consideration to the Bank of England, as recorded in the MPC minutes.

Notes

1 See www.statistics.gov.uk/statbase/product.asp?vlnk=867

CONTACT

✉ elmr@ons.gsi.gov.uk

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