A statistical measure of core inflation

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A STATISTICAL MEASURE OF CORE INFLATION

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ABSTRACT

This paper examines alternative statistically-based measures of core inflation in Ireland over the period 1976-1999. A highly disaggregated (approximately 500 price series) dataset from the Irish HICP is used. The distribution of quarterly price changes is shown, in common with other international studies, to be highly kurtotic (i.e., fat-tailed) and right skewed. This would suggest there is considerable 'statistical noise' in the measured inflation rate, motivating the use of 'limited influence' estimators of central tendency over the mean measure on the grounds of statistical efficiency. It is found that even a relatively small amount of trim from both ends of the distribution of price changes results in considerable improvement in root mean square error (RMSE) relative to a benchmark measure of core inflation. This improvement is even larger when monthly data are examined.

INTRODUCTION

Monetary authorities generally have the explicit mandate to maintain a low and stable rate of price inflation. The European Central Bank (ECB) is committed to a monetary policy which has the primary objective of maintaining price stability throughout the eleven euro-area countries as a whole. Price stability has been defined "as a year-on-year increase in the harmonised index of consumer prices (HICP) for the euro area of below 2 per cent."[1] A main element of this monetary strategy will be a broadly based assessment of the outlook for price developments. Given the goal of price stability, as defined above, it is important to be able to distinguish between movements in price trends and noisy shocks to inflation data. In other words, with each new observation of inflation the question the central banker must ask is how much is new information allowing them to forecast near- and medium-term price developments (Blinder 1997) and how much is merely a temporary fluctuation which will be reversed relatively quickly. This is the well known 'signal versus noise' problem. Attempts to measure core inflation are attempts to extract the 'core inflation' signal from noisy inflation data.

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1 At first glance, it appears contradictory to define price stability as a year-on-year increase in prices of below 2 per cent. Price stability would appear by definition to require a year-on-year increase of zero. However, there has been much work recently on biases in inflation measurement, see, for example, Hoffmann (1998), Baxter (1997) and Boskin et al (1996). This work has highlighted how issues such as product substitution bias, quality change bias, new product bias and outlet substitution bias can mean that the measured increase in the price of a basket of goods can be overstated. Unfortunately the exact degree of bias is unknown, therefore, price stability tends to be defined on a range between zero and two per cent. If inflation is used to measure increases in the cost of living then bias is a problem, however, if it is used for the purposes of monetary policy then this need not necessarily be the case. This issue is discussed further below.

This paper focuses on one approach to the issue of measuring core inflation. This approach is essentially statistical in nature. It views commonly used measures of inflation such as the HICP or the Consumer Price Index (CPI) as being samples from the entire universe of goods and services. Individual items are subject to both price pressures common to all goods and services and idiosyncratic shocks. Examining the distribution of the price changes in the sample basket of goods yields estimates of the underlying properties of price changes. If the distribution is sufficiently different from a normal distribution, then a mean measure of inflation may no longer be the most efficient measure of core inflation.

It is shown that, in common with other countries, the distribution of quarterly price changes in Ireland is highly kurtotic (i.e., fat-tailed) and is right skewed. This motivates the use of 'limited influence' estimators of central tendency over the mean measure on the grounds of statistical efficiency. The extreme kurtosis of the distribution of price changes means that even a relatively small amount of trim from the distribution of price changes results in significant improvement in root mean square error (RMSE) relative to a benchmark measure of core inflation. This improvement is even larger when monthly data are examined.

The outline of the paper is as follows: Section 1 discusses two alternative concepts of inflation, the cost of living approach and the monetary approach. Noise in measured inflation data motivates the use of a statistically based measure of core inflation. Other measures of core inflation are also summarised. Section 2 presents an analysis of the statistical properties of the distribution of quarterly price changes in the

Irish HICP over the period 1976-1999. Section 3 considers a range of 'limited influence' estimators of core inflation. Section 4 examines the forecast performance of the constructed measure of core inflation. Section 5 considers measuring core inflation using monthly data available since January 1997. Section 6 evaluates some of the relative advantages and disadvantages of statistical measures of core inflation. Section 7 concludes.

1. MEASURING CORE INFLATION

Although price stability has been explicitly defined above, it is not immediately clear what is the correct measure of inflation for monetary authorities for use in the pursuit of price stability.[2] For the purpose of the ECB's monetary policy strategy, the HICP was chosen over national CPIs as it is harmonised across the euro area. However, the HICP and CPI are merely the price of a specific basket of goods and services, constructed so as to reflect patterns of private consumption. Although they reflect to some degree living costs they are not 'cost of living' indicators. When monetary authorities are concerned with inflation they should be concerned with the common price pressures acting across all items (i.e., core inflation) arising from their monetary stance.[3] This is the monetary concept of inflation as opposed to the cost of living approach which is based on micro-economic foundations of welfare optimisation.

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[2] See Bryan (1997) for an interesting discussion on "the origin and evolution of the word *'inflation'*."

The so-called monetary concept of inflation perhaps follows most evidently from Friedman's (1969) formulation of the quantity theory of money which states that demand for money balances, M, is proportional to nominal transactions (which is made up of the price level, P, and the level of transactions or volume of output, Y). The proportionality between money demand and nominal transactions can be defined as the velocity of money, V, which need not be constant over time nor invariant to monetary policy actions.[4] Thus monetary inflation can be thought of as the price pressure common to all goods brought about by the stance of monetary policy.

$$M * V \equiv P * Y \qquad (1)$$

In contrast, the cost of living approach to price measurement calculates the price level as the minimum cost of attaining a baseline level of utility, U^0. This can be defined as follows:

$$COL_t = \underset{q_i}{Min} \sum_{i}^{N} p_{it} q_{it} \quad s.t. \quad U(q_{it}) = U^0 \qquad (2)$$

Thus the change in the cost of living can be measured as the change in the cost of achieving the same baseline level of utility (i.e., COL_{t+1} - COL_t). Note that traditional measures of inflation such as the CPI or the HICP are flawed measures of the cost of living. For example, given that they are constructed using Laspeyres formula (i.e., q_i is fixed between

[3] This intuitively appealing concept is subject to the criticism that, unlike the 'cost of living' index, it is not ground out in optimising behaviour.

base periods), they will not take into account substitution away from relatively more expensive goods and will thus tend to overstate increases in the cost of living - the well-documented substitution bias effect.

In this paper, we subscribe to the monetary concept of inflation as being the price pressure common to all goods arising from the monetary position. At any given time, different sectors will be subject to idiosyncratic shocks which mean that price changes for individual items can be above or below the core or monetary inflation rate. Cecchetti (1997) decomposes an individual item's price change (π_{it}) into two components: a price change common to all items (core inflation - ΔP_t) and an idiosyncratic price change (Δp_{it}). Thus at any given time some prices are rising significantly relative to core inflation whilst others are falling significantly relative to core inflation.[5]

$$\pi_{it} = \Delta P_t + \Delta p_{it} \qquad (3)$$

When monetary authorities respond to price developments it is the price change common to all goods, ΔP_t, that they should be concerned with. Unfortunately this measure is not directly observable. Only the overall change in a specific basket of goods and services, π_t, (which is, in turn, the weighted sum of individual price changes, π_{it}) is observable.

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[4] Given the definition of the velocity of money this equation is tautological and not of too much use to policy makers.

[5] In the quarter to November 1998, one price series in the HICP fell by approximately 40 per cent whilst another rose by in excess of 20 per cent. The mean rate of inflation was 0.1 per cent.

$$\pi_t = \sum_i^n \left(w_{it} * \pi_{it}\right) \tag{4}$$

where,

n is the number of items in the price basket,

w_{it} is the weight of item i in time period t, and

$\sum_i^n w_{it} = 1$.

It is possible, with idiosyncratic shocks and sampling errors, that the observed overall price change, π_t, and the core price change, ΔP_t, can differ at any given time. Using equations 3 and 4, and the fact that $\sum_i^n w_{it} = 1$, then

$$\pi_t - \Delta P_t = \sum_i^n \left(w_{it} * \Delta p_{it}\right) = \eta_t \tag{5}$$

where η_t is 'noise' in measured inflation and is assumed zero mean stationary.

If the idiosyncratic price change, Δp_{it}, is normally distributed $N(0, \sigma_t^2)$ it is possible to show (Wynne, 1997) that the maximum likelihood estimator of the core price change, ΔP_t, is given simply by the **unweighted** average of the individual price changes. However, it is shown below that the distribution of individual price changes does not appear to be normal. Thus an alternative measure of central tendency could be optimal. The first four central moments of a distribution (i.e., the mean, variance, skew and kurtosis) yield valuable information in determining the most efficient measure of central tendency.[6]

The standard normal distribution has a mean of zero, standard deviation of unity, zero skew and kurtosis of three. A distribution which is flatter than a normal distribution (i.e., has more weight in the tails) is called a leptokurtic distribution. If the distribution is sufficiently flat (leptokurtic) then the mean may no longer be the most efficient measure of central tendency. An intuitive explanation is a follows: if the distribution is very flat, then the probability of getting a sample observation containing prices very far away from the mean is relatively high compared to a normal distribution. Therefore the probability of the sample mean being biased by an outlier is relatively high, thus the mean might no longer be the most efficient measure of central tendency. Bryan *et al* (1997) show, using Monte Carlo techniques, that as the degree of kurtosis rises then the mean becomes a less efficient measure of central tendency.

What is the alternative to the mean? A general class of alternative measures of central tendency are known as trimmed mean estimators. Trimmed mean estimators seek to overcome the difficulty of large tails by trimming or removing some of the price changes at either end of the distribution. An extreme version of the trimmed mean is the median, which involves removing 100 per cent of the tails (50 per cent from

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[6] The mean is the most commonly used measure of central tendency, although other measures exist such as the mode, median or trimmed means. The variance is a measure of dispersion. Skewness and kurtosis are **scaled** measures of the third and fourth central moments respectively. The skew is a measure of how asymmetric is the distribution. Kurtosis is a measure of the 'peakiness' of a distribution.

either side), so that only the central price change remains. Thus the median gives no weight to observations apart from the central observation. For certain classes of distributions it is possible to show that the median is the most efficient estimator of central tendency.

An additional issue arises in how to weight the individual price changes in the distribution. If the idiosyncratic price changes are normally and independently distributed $N(0, \sigma_t^2)$, then an unweighted mean is optimal. However, it is shown that this is not the case. Wynne (1997) argues that there is a fundamental contradiction in using 'cost of living' weights to construct a 'monetary' measure of inflation. Clements and Izan (1987) support the use of cost of living weights arguing that the more important an item is to consumers the less scope there is for significant relative price shifts.

Cecchetti (1997, pg. 144) constructs a dynamic factor index (DFI) "in which a measure of the aggregate price level is constructed by weighting (in a time varying manner) commodities based on the strength of a common inflation signal." This approach reduces bias in the inflation measure but does not eliminate noise. An alternative approach weights an individual price series inversely proportional to the volatility of that series. See Dow (1994) and Laflèche (1997) for examples of this approach. Blinder (1997) proposes weighting each series according to the ability of that series to forecast future inflation.

1.1 Alternative Measures of Core Inflation

Roger (1998) outlines some of the desirable properties of a measure of core inflation. These properties are essential if the measure of core inflation is to be acceptable for public policy purposes. First, the measure must be available on a timely basis, ideally simultaneous with the publication of the actual inflation data. If there is a considerable time lag before some required variables are available or if some variables must be estimated to construct the measure of core inflation, this reduces its use to policy makers. Second, the underlying rationale for the measure must be relatively easily understood. Inflation is an important economic variable that enters into a wide range of economic decisions such as investment and wage negotiations. If the underlying rationale is open to different interpretations, economic agents may not accept an alternative measure of inflation. Third, the measure should be free from revisions. Inflation data is relatively unique amongst economic indicators in that it is not subject to frequent and considerable revisions. Retrospective revisions to a measure of core inflation would again undermine its acceptability. Finally, and importantly, a measure of core inflation should not differ significantly from measured inflation in the medium-term. If the medium- or long-run values differ then different interest groups will accept or reject the measure depending on their strategic interests.

A wide range of alternative measures of core or underlying inflation are to be found both in the literature and in use by different monetary authorities. Bryan and Cecchetti (1999) present some of the alternative measures used in sixteen different countries. These encompass all of the alternatives outlined below with the exception of structurally based measures of core inflation.

Smoothing

Smoothed measures of inflation can range from simple moving averages to the fitting of trend lines such as the Hodrick-Prescott filter. The centred moving average approach violates the timeliness criterion discussed above. The fitting of time trends are subject to the well-known end-of-sample problems.

Exclusion

A far more common approach is to exclude specific items from the measure of core inflation on the basis that the excluded items are subject to far more idiosyncratic noise than other components of measured inflation. Measured inflation excluding seasonal food and energy is a frequently used measure. Other measures exclude items such as mortgage interest rates on the grounds that interest rates are controlled by the monetary authorities and are usually moved to counteract inflationary trends. Bryan *et al* (1997, pg. 1) criticise the exclusion based measures querying whether "it is truly the case that food and energy price changes never contain information about trend inflation." The relative performance of the excluding seasonal food and energy index in considered below.

Specific Adjustment

This approach adjusts the measured inflation rate for specific events having a once-off impact on the rate of inflation. Examples include extreme weather-related price movements and changes in indirect taxes or other government tariffs. The subjectivity involved and the difficulty in identifying shocks make this measure undesirable based on the criteria outlined above.

Statistical

Monetary authorities in a significant number of countries have constructed statistically based measures of core inflation. These include Canada (Laflèche, 1997), Portugal (Coimbra and Neves, 1997), UK (Bank of England, 1996), Japan (Mio and Higo, 1999), New Zealand (Roger, 1997), US (Bryan *et al*, 1997) and Australia (Kearns, 1998).

Structural

An alternative approach is the structural VAR (SVAR) approach taken by Quah and Vahey (1995). Their approach is grounded in economic theory, unlike the relatively *ad hoc* statistical approach. They define core inflation to be that component of measured inflation which has no long-run impact on output. A simple two-variable VAR model is estimated. The long-run neutrality condition and restrictions imposed on the residuals are sufficient to ensure unique identification. The main advantage of this approach is that it has a clear economic interpretation. Economic agents are assumed to incorporate core inflation into their actions, thus core inflation has no long-run impact on output. Extensions to Quah and Vahey model have been proposed by Gartner and Wehinger (1998) and Dewachter and Lustig (1997). However, as this approach is based on the estimation of a VAR model, revisions will be made to the entire series of core inflation estimates as new observations become available.

2 A STATISTICAL SUMMARY OF THE HICP

This section presents results from calculating the sample central moments of the cross sectional distribution of prices changes in the HICP. There are four different base periods over which the data are collected. The number of price series collected varies depending on the base period. Table 1 illustrates the number of price series available for each base period.[7]

Table 1 - No. of Price Series in HICP

Base Period	Number of Series
November 1996	529
November 1989	472
November 1982	447
November 1975	431

The central moments of the distribution of price changes can be constructed as follows:

The sample mean is simply the weighted sum of the individual price changes. As the price level is constructed using a Laspeyres arithmetic formula, the weights are time varying. The weights are a function of the base period weights and the individual price level relative to the overall

[7] The level of disaggregation available for this study is considerably greater than that for other international studies. For example, Kearns (1998) uses approximately 100 categories to examine the distribution of Australian price changes. Laflèche (1997) uses 54 series examining Canadian price data. Bryan and Cecchetti (1997) use 36 components of the US CPI. Generally semi-aggregated data will impact significantly on the properties of the distribution of price changes compared to more disaggregated data.

price level in the period prior to which the weights are being calculated. This is the same as equation 4 illustrated above.

$$\pi_t = \sum_{i}^{n}\left(w_{it} * \pi_{it}\right) \qquad (6)$$

where,

$$w_{it} = w_{io} * \left({p_{it-1}}/{P_{t-1}} \right) \qquad (7)$$

n is the number of price series in the overall index,

w_{i0} is the base period weight for item i,

P_{t-1} is the overall price level at time t-1,

P_{it-1} is the price level of series i at time t-1,

π_t is overall inflation, and

π_{it} is series i inflation.

Higher order sample central moments are calculated as follows:

$$m_t^r = \sum_{i=1}^{n} w_{it} * \left(\pi_{it} - \pi_t\right)^r \qquad (8)$$

The second moment, m_t^2, is simply the variance of the distribution, σ^2, and is a measure of the dispersion of the distribution. The standard deviation is the square root of the variance. This measure is used to scale the third and fourth moments, to obtain measures of the skewness and kurtosis of the distribution.

Skewness, S_t, can help summarise the shape of the distribution. It is closely related to, but not identical, to the idea of symmetry. A symmetric distribution (i.e., the distribution is a mirror image around the mean) automatically has a skewness of zero, although a skewness of zero does not necessarily mean that the distribution is symmetric. If the skewness is positive, this means the distribution is skewed to the right (i.e., the right-hand tail is longer than the left-hand tail). Alternatively if the skewness is negative, the distribution is skewed to the left.

$$S_t = \frac{m_t^3}{\sigma_t^3} \qquad (9)$$

Kurtosis, K_t, is an alternative summary statistic and captures the weight of the distribution in the tails. A distribution with high kurtosis has a relatively large weight in the tails of the distribution. This means that one is relatively more likely to obtain a sample from the tails of the distribution. A normal distribution has a kurtosis of three (a mesokurtic distribution). A distribution with a kurtosis larger than three is known as a leptokurtic distribution and has a relatively larger weight in the tails. A distribution with a kurtosis smaller than three is known as a platykurtic distribution.

$$K_t = \frac{m_t^4}{\sigma_t^4} \qquad (10)$$

Table 2 below presents a summary of the moment statistics for the overall period, 1976-1999 and each of the four subperiods. It is evident that the measured rate of inflation was significantly higher during the period prior to 1984, than during the period 1984-1999. The mean rate of quarterly inflation fell from 3.5 per cent over the period 1976-1983 to 0.7 per cent for the period 1984-1999. Across all subperiods the median was below the mean indicating skewness in the price distribution.

Table 2 - Summary of Price Change Moments

Period	Mean	Std. Dev.	Skew	Kurtosis	Median	Percentile
Overall	1.7%	4.2%	0.8	41.5	1.2%	57.6%
Nov. 1976	3.6%	5.7%	0.8	25.7	2.8%	58.5%
Nov. 1982	1.2%	3.7%	1.6	35.3	0.8%	58.1%
Nov. 1989	0.6%	3.5%	0.1	45.4	0.3%	58.5%
Nov. 1996	0.4%	3.6%	1.0	98.2	0.3%	50.2%
1976 - 1983	3.5%	5.7%	1.4	33.2	2.6%	59.5%
1984 - 1999	0.7%	3.4%	0.5	45.9	0.5%	56.6%

There was a decline in the average standard deviation from 5.7 percentage points in the earlier period to 3.4 percentage points for the period 1984-1999. In the latter period the standard deviation was quite large relative to the mean, indicating the high degree of noise in the data.

The degree of skew varies considerably quarter on quarter, but is, however, positive on average. Thus, on average, the distribution of price changes is skewed to the right. Over the entire period the skew was 0.8 which is above the skew of 0.2 found by Bryan *et al* (1997) for US price changes and the skew of 0.7 found by Kearns (1998) for New Zealand price changes. However, both of these studies use more aggregated data, which could account for the lower skew. Bryan *et al* argue that the degree of skew in US price changes implies that the distributions are "nearly symmetric on average". However, Kearns using a dataset, more disaggregated than Bryan *et al*, with a degree of skew similar to the Irish price changes, takes the asymmetry of the distribution into consideration when constructing his measure of core inflation. The direction of skew can, however, vary significantly.

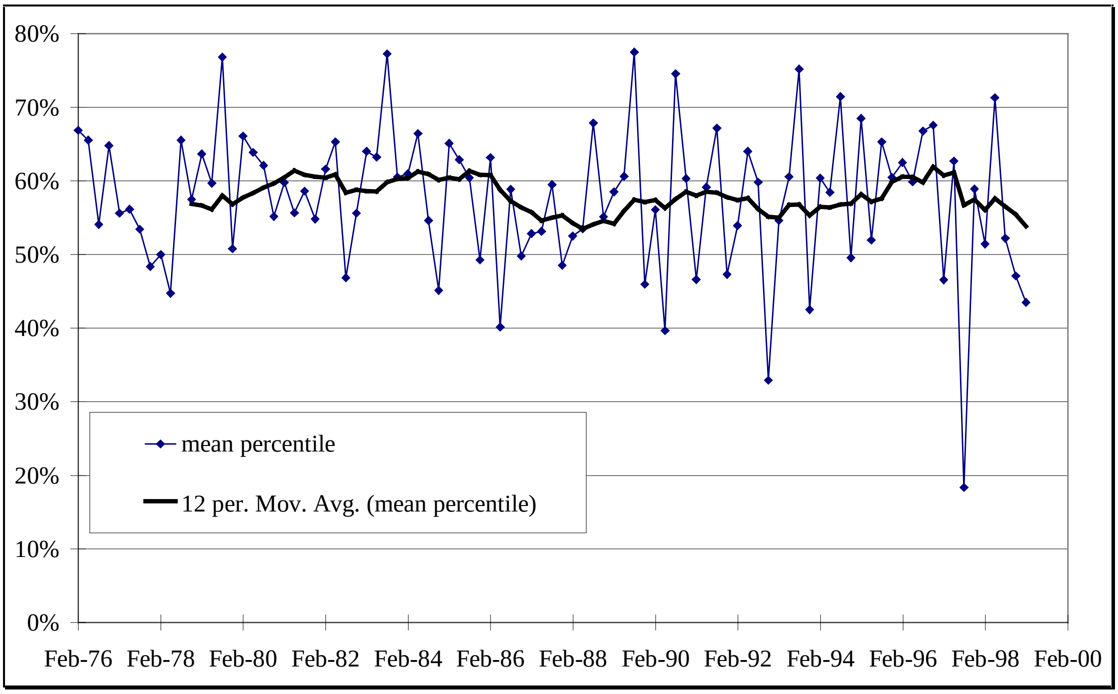
Over the entire period under consideration the skew was positive 58 times and negative 35 times. The degree of skewness has significant implications for which measure of central tendency is unbiased. If the distribution has zero skewness, the mean and the median coincide and both are unbiased. However, if the distribution is skewed, then the mean and median diverge, and the median will be a biased estimator of the central tendency of the distribution. For example, if the distribution is positively (i.e., right) skewed, then the median will lie below the mean. To obtain an unbiased measure one must select a skewed median rather than the median centred at 50 per cent. For example, if the distribution is positively (right) skewed then a percentile above the 50th percentile (e.g., 60th) might be an unbiased estimator of central tendency. However, although the mean and the 60th percentile are now both unbiased estimators, the most efficient estimator depends on the degree of kurtosis of the distribution.

The kurtosis of the price change distribution is always larger than three in the Irish case over the period 1976-1999. This indicates that the distribution of price changes has considerably fatter tails than a normal distribution. This has important implications for which measure of central tendency is the most efficient. As highlighted above, if the distribution can be adequately represented by a normal distribution then the mean is the most efficient unbiased measure of central tendency.

However, if the distribution is sufficiently leptokurtic, the mean may no longer be the most efficient measure of central tendency. Over the entire period 1976-1999 the average degree of kurtosis in the distribution of price changes was 41.5, indicating considerable excess kurtosis compared to a normal distribution. The degree of kurtosis increased from 33.2 for the period prior to 1984 to 45.9 for the period 1984-1999. Bryan *et al* (1997) show that for a specific class of distributions that a kurtosis in excess of 10 is sufficient for trimmed mean estimators to be more efficient measures of central tendency than the mean.

Another indication of the degree of skew in the distribution is to consider which percentile of the distribution contains the mean. As stated above, if the distribution is positively (right) skewed then the median lies below the mean, or alternatively, the mean lies above the 50th percentile. Figure 1 plots the percentile containing the mean over the period 1976-1999. The mean is above the 50th percentile in 73 out the 93 period distributions. On average the mean is contained in the 58th percentile. This was quite consistent for the first three base periods. However, for the 9 quarters since November 1996, the mean has dropped to the 50th percentile on average. Whether this is due to the impact of outliers with a relatively small number of periods or reflects a permanent change in the distribution of price changes is unclear. Eliminating a single outlier moves the average from the 50th percentile to the 54th percentile, which is closer to the average for the three base periods prior to November 1996.

Fig. 1 - Percentile of Price Distribution Containing Mean, 1976 - 1999



2.1 *CORRELATION BETWEEN MOMENTS*

An issue worth considering briefly is whether there is any correlation between the different moments. This is of importance especially when we come to consider whether the skewness and kurtosis are independent of the mean of the distribution of price changes.[8]

From Table 3 it can be seen that there was a correlation of 0.55 between the mean of and the standard deviation of the distribution of price changes. However, when examined over subperiods most of the correlation disappears, especially in the period 1984-1999.[9] This might

[8] Note that correlation does not imply causation. We are only interested whether there is, on average, correlation between different moments of the distribution.
[9] The lower diagonal elements of the bottom part of Table 3 contain the correlation between the moments of the distribution of price changes over the period 1976-1983.

suggest that within the two broad sample periods there was little correlation between the mean and standard deviation but that across the two periods there was a shift in both the mean and the standard deviation of the distribution of price changes.

Table 3 - Correlation Between Sample Moments

Correl.	1976_1999	mean	std. dev.	skew	kurtosis
mean		1.00	0.55	0.27	-0.21
std. dev.			1.00	-0.02	0.22
skew				1.00	0.24
kurtosis					1.00

Correl.	1984_1999	mean	std. dev..	skew	kurtosis
mean1976_1983		1.00	0.09	0.40	-0.16
std. dev.		0.28	1.00	-0.13	0.42
skew		0.29	-0.07	1.00	0.19
kurtosis		-0.28	0.29	0.44	1.00

The mean appears to be positively correlated with the skewness of the distribution both within the two time periods and over the whole sample.[10] This is consistent with Ball and Mankiw's (1995) menu costs model.[11] Assuming firms are subject to idiosyncratic symmetric shocks and that it is costly to adjust prices, then, if the core rate of inflation is positive, firms with reinforcing shocks will increase their prices. However, firms with counteracting shocks will find that their net position is close to zero and that it is not worthwhile changing prices given the positive costs of doing so, giving rise to a positive correlation between

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The upper diagonal elements contain the correlation between the moments over the period 1984-1999.

[10] A positive correlation between the mean and the skewness has also been noted in the US (Bryan and Cecchetti, 1997) and in New Zealand (Kearns, 1998).

the mean and skewness.[12] However, as the core inflation rate moves towards zero, firms' net positions will be symmetric around zero and price changes will become more symmetric around zero. It is also probable that the peak at zero will become more accentuated. The percentage of observations close to zero (within 0.01% of zero) has increased over the sample period, from 3.6 per cent to 6.0 per cent, although this would also occur without menu costs as the mean got closer to zero. The positive correlation between the mean and skewness of the distribution has implications for the construction of a statistical measure of core inflation and is discussed further below.

The kurtosis of the distribution appears to be negatively correlated with the mean. This would imply that as the mean rate of inflation drops, trimmed mean estimators become relatively more efficient estimators of central tendency than the mean.

In summary, in the Irish data, there are two distinctive features of the distribution of price changes which need to be considered when constructing a statistically-based measure of core inflation. First, the distribution of price changes is positively (right) skewed. Second, the distribution displays a degree of kurtosis significantly larger than a normal distribution. The distribution of price changes was tested for

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[11] Balke and Wynne (1996) posit an alternative model to explain the positive relationship between the mean and skew. Their model rests on the assumption that there is an asymmetric input-output relationship between sectors.

[12] Bryan and Cecchetti (1996) argue that the positive correlation between the mean and skewness found for US data is as a result of small-sample bias, countering evidence in support of the models posited by Balke and Wynne (1996) and Ball and Mankiw (1995). Frain (forthcoming) argues that the relationship between the mean and skew is not merely a small-sample bias but will hold right up to the limit.

normality in each time period.[13] The null hypothesis of normality was rejected in each of the 93 time periods.[14] The next section considers the construction of a statistically-efficient measure of core inflation given the high degree of kurtosis in the price change distribution whilst correcting for skewness in the distribution as well.

3. CONSTRUCTING A MEASURE OF CORE INFLATION

'Trimmed mean' or 'limited influence' estimators are attempts to arrive at more efficient measures of central tendency when significant kurtosis is a problem. They work by eliminating a proportion from the tails at either end of the distribution. For example, a symmetric 10 per cent trimmed mean removes the observations in both the upper and lower 5 per cent of the distribution and takes the mean of the remainder. By removing a portion of the tails it is hoped that the impact of substantial outliers is reduced. The median is a special type of trimmed mean with 100 per cent of the tails removed, leaving only the central observation left. The mean is another special case with zero trim removed.

To consider which trimmed mean is the best measure of core inflation we require a benchmark measure. Following Kearns (1998) and Cecchetti

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13 The test statistic used is $N\left[\frac{1}{6}S_t^2+\frac{1}{24}\left(K_t-3\right)^2\right]$, which under the null hypothesis is χ^2 with two degrees of freedom.

14 This result should not be too surprising. Bryan *et al* (1997) show that combining normally distributed variables with differing variances can produce highly leptokurtic distributions, thus violating normality even though the underlying variables are normally distributed.

(1997) we use a centred moving average of the actual CPI as a benchmark measure of core inflation.[15] A seven-quarter centred moving average is used in this paper. Alternative moving averages of three, five and nine quarters were examined and were found not to alter the results significantly. The strategy adopted was to construct a range of trimmed mean estimators with trim varying from zero (the mean) to 100 (the median) per cent in steps of five per cent. To allow for the skewness found in the distribution, the degree of trim was skewed across a range of 40 to 70 per cent, in steps of one per cent. Thus, for a trim of 50 per cent and a skew of 60 per cent, 20 (i.e., 0.50 * [1-0.60]) per cent was removed from the lower half of the distribution and 30 (i.e., 0.50 * 0.60) per cent from the upper half of the distribution.

Figure 2 shows the RMSE against the seven-quarter centred moving average for each of the alternative measures of core inflation over the period 1976-1999. The zero per cent trimmed mean had a RMSE of 0.777 per cent compared to the benchmark measure of core inflation. The measure of core inflation with the lowest RMSE (of 0.594 per cent) was the 100 per cent trimmed mean with a skew of 56 per cent (or alternatively the 56th percentile median). In other words the alternative measure of core inflation reduces the RMSE by 24 per cent compared to the unadjusted (zero trim) mean.[16]

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[15] The centred moving average is used as a benchmark measure of core inflation as it is a proxy for long-run inflation. It is not suitable as a contemporaneous measure of core inflation as it is only available with a long lag.

[16] In comparison, using the traditional measure of core inflation (the HICP index excluding unprocessed foods and energy) only reduces the RMSE from 0.777 per cent to 0.770 per cent, or by less than one per cent.

Fig. 2 - RMSE of Alternative Measures of Core Inflation, 1976-1999

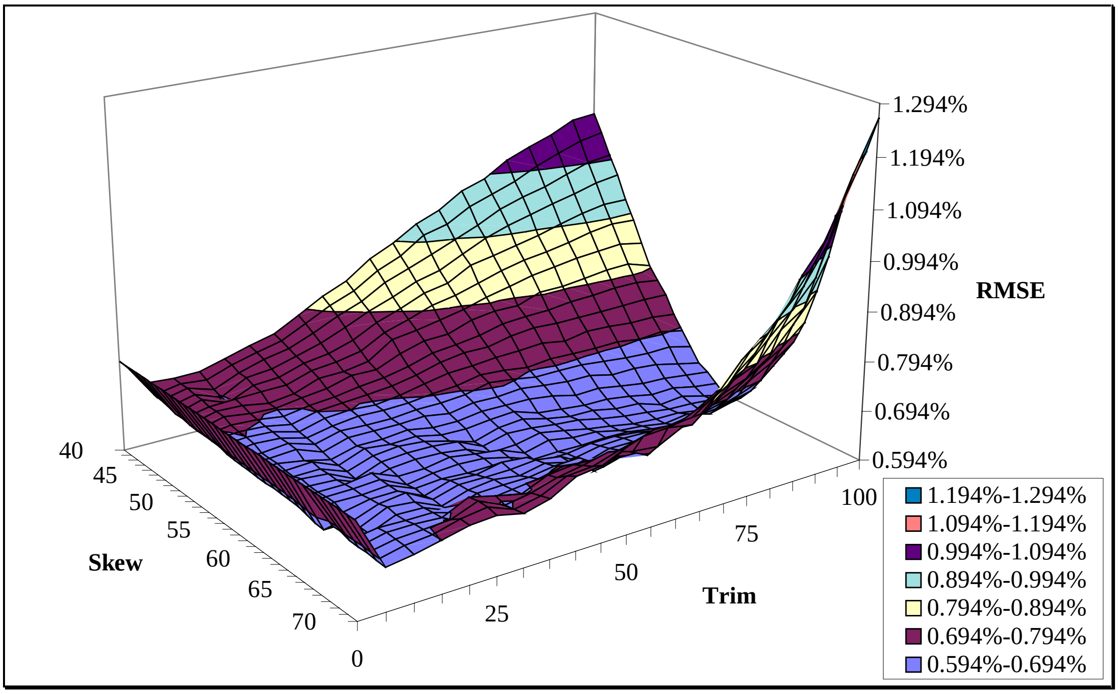
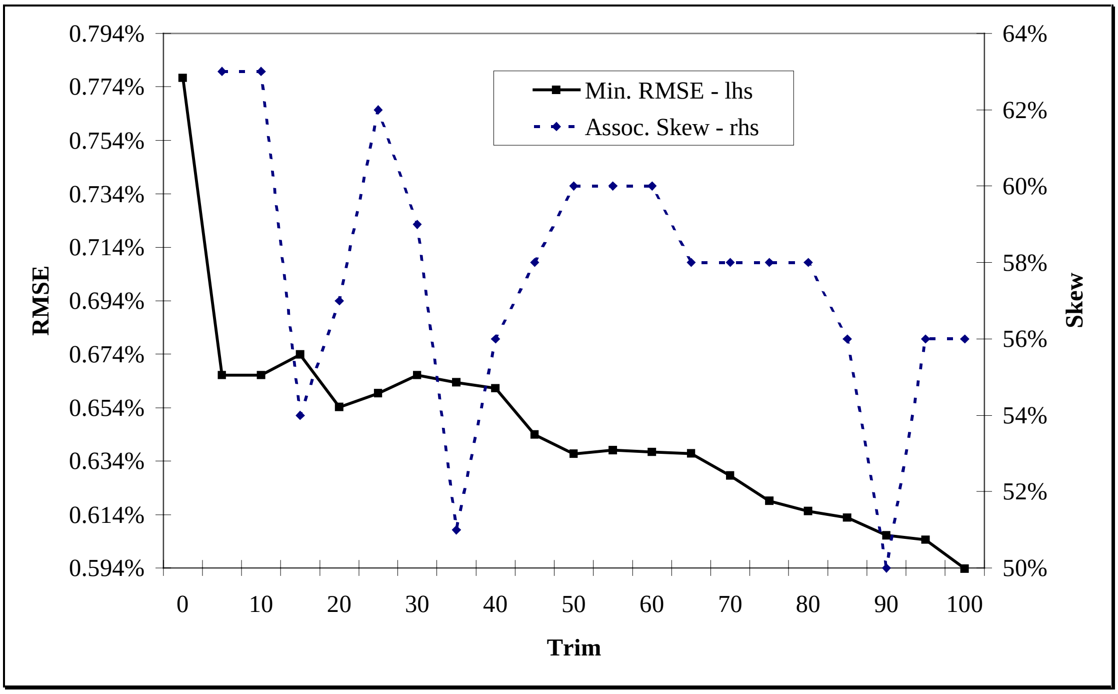


Figure 3 shows a cross sectional slice of Figure 2. It plots the minimum RMSE measure of core inflation at each degree of trim along with the associated degree of skewness. A significant point to note is that it requires only a small amount of trim to bring about a significant reduction in the RMSE. Moving from zero trim to five per cent trim reduces the RMSE by 14 per cent or by 61 per cent of the overall reduction in the RMSE. Further increases in trim reduce the RMSE but more slowly. A second point to note is that the associated skew, whilst not constant, is generally around the range of 56-60 per cent.

Fig. 3 - Min. RMSE (& associated skew) by Degree of Trim, 1976-99



The RMSE were also calculated over a range of alternative time periods. As shown in Table 2 the mean rate of inflation changed significantly in the period after 1984. Figure 4 presents the results using the period 1984-1999. Again, it is clear that the zero per cent trimmed mean is not the best measure of core inflation. The zero per cent trimmed mean had a RMSE against the benchmark core inflation measure of 0.482 per cent. The best performing alternative measure was not the 100 per cent trimmed mean in this case but the 50 per cent trimmed mean with a skew of 59 per cent with a RMSE of 0.273 per cent. This represents a 43 per cent improvement on the regular (zero trim) mean.[17]

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[17] In contrast to the overall period results using the overall HICP series excluding unprocessed food and energy actually increases the RMSE for the period 1984-1998 compared to the overall series from 0.482 per cent to 0.540 per cent, an increase of 12 per cent.

Fig. 4 - RMSE of Alternative Measures of Core Inflation, 1984 - 1999

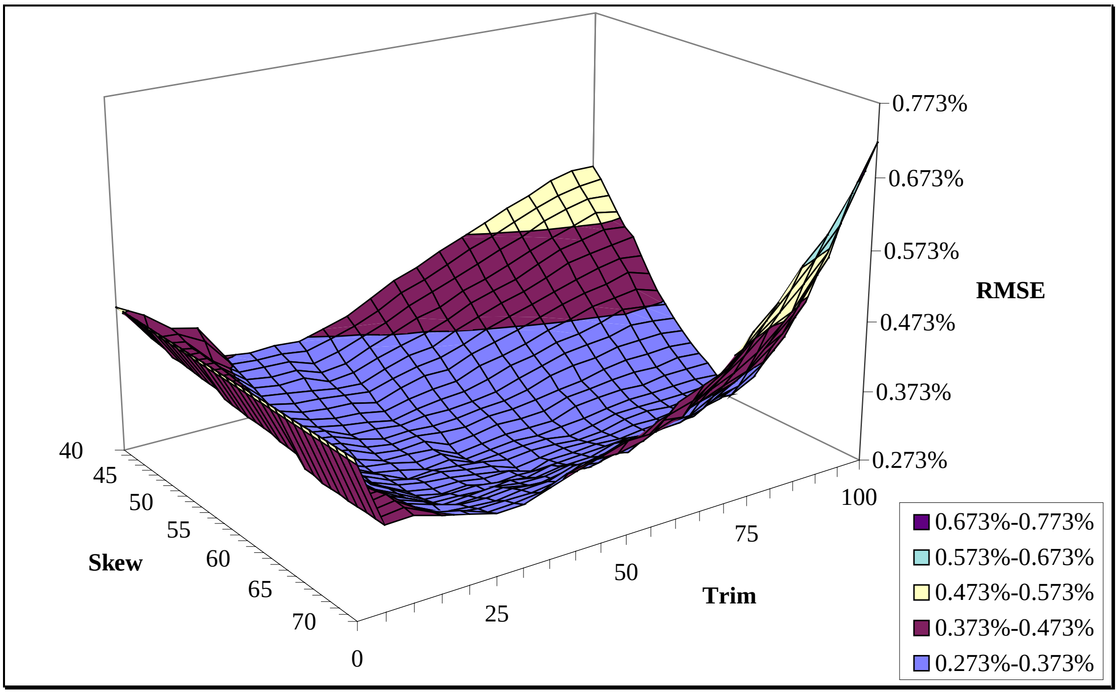
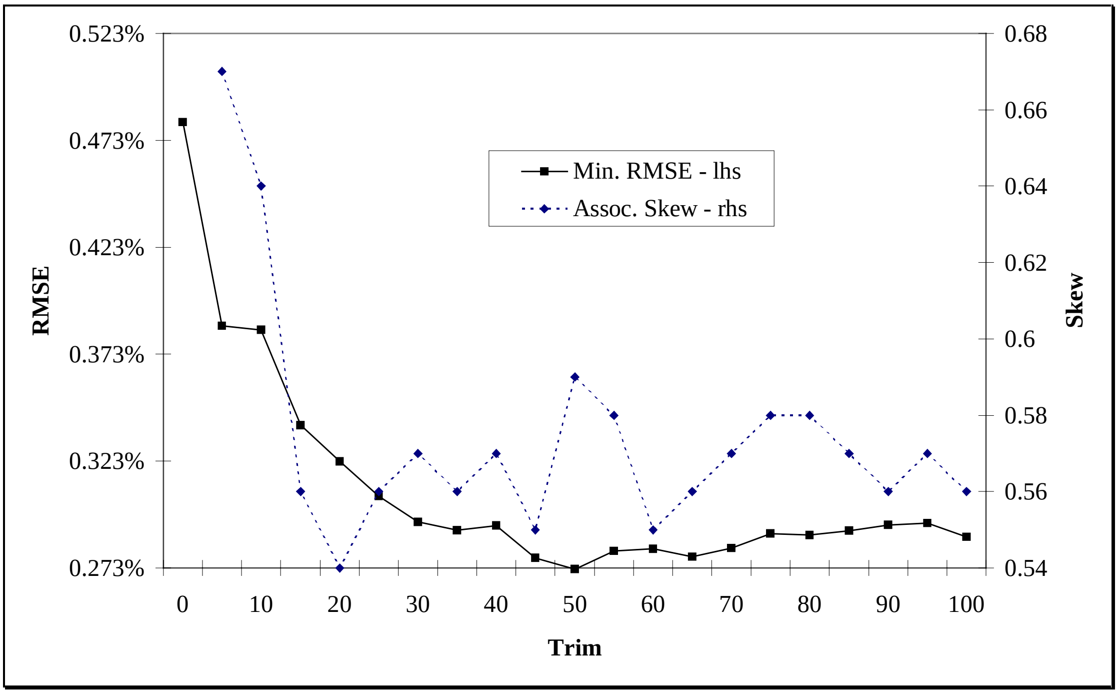


Figure 5 presents a cross-sectional view of Figure 4. Similar to the results for the overall period, only a small increase in trim is required to bring about a large reduction in the RMSE. Increasing the trim from zero per cent to five per cent reduces the RMSE by 20 per cent, or by 46 per cent of the overall reduction in the RMSE. In contrast to the overall period, however, the minimum RMSE is not at 100 per cent trim, but at 50 per cent trim. Increasing the trim beyond 50 per cent leads to a slight increase in the RMSE. Once the trim increases beyond 15 per cent the associated degree of skewness is relatively constant around 56-58 per cent.

Fig. 5 - Min. RMSE (& associated skew) by Degree of Trim, 1984-99



For the period 1984-1998, the 50 per cent trimmed mean with a skew of 59 per cent minimised the RMSE against the benchmark core inflation measure. Figure 6 plots this measure of core inflation against the actual HICP inflation rate over the period. The mean rates of inflation are essentially identical at 0.70 per cent for actual inflation and 0.69 per cent for the core inflation measure. However, the standard deviation over the period is considerably lower for the core inflation measure at 0.38 per cent compared to 0.56 per cent for actual inflation.

Fig. 6 - Measured vs. Constructed Core HICP inflation, 1984-1999

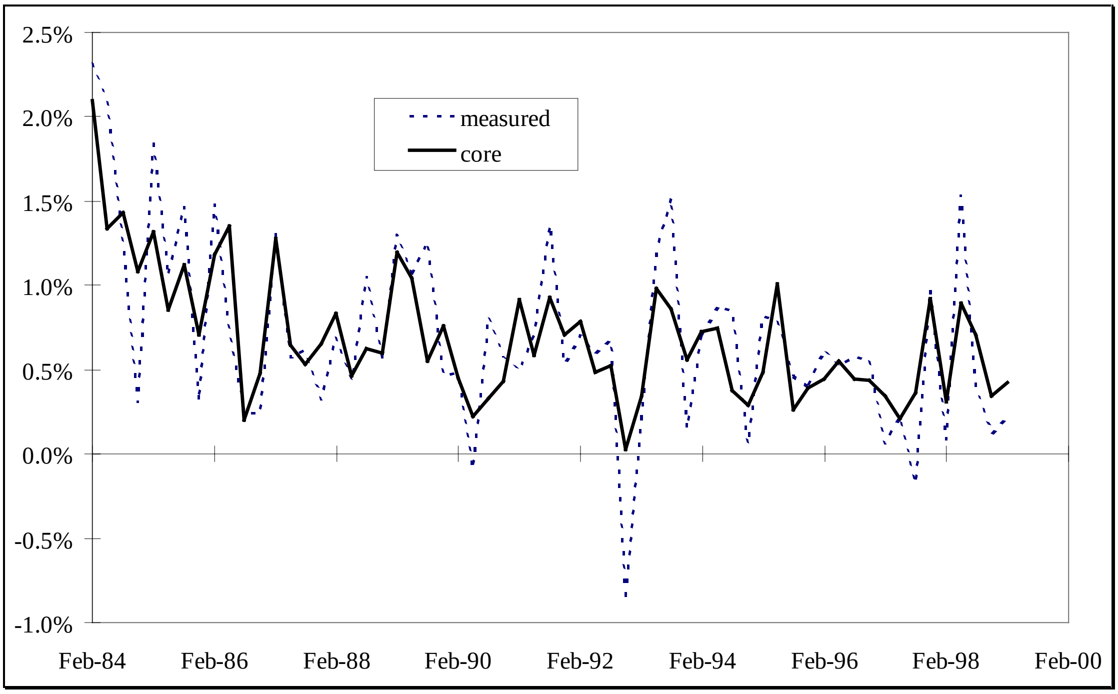
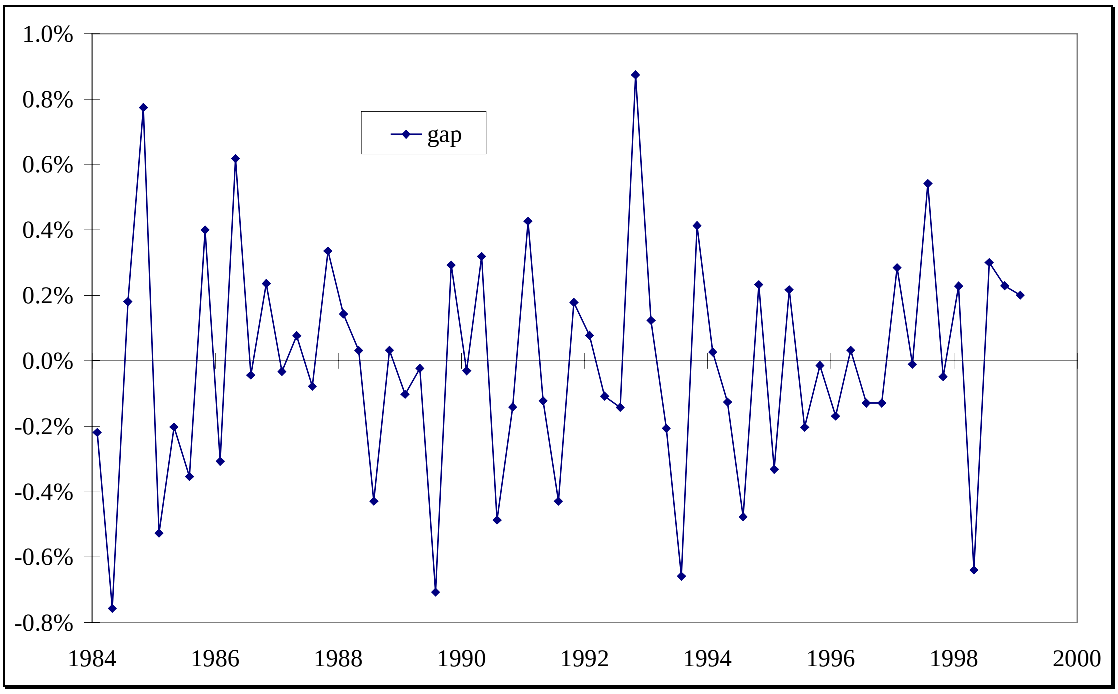


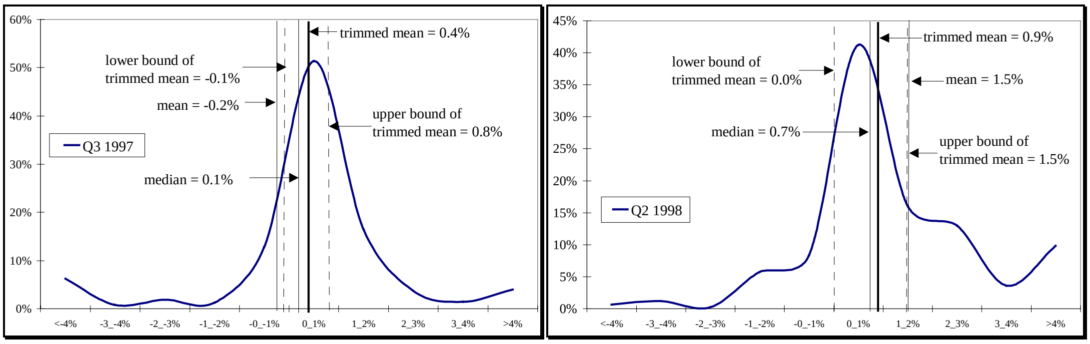
Figure 7 plots the gap between the optimal trimmed mean measure of core inflation and the actual inflation rate. The gap ranges from -0.76 per cent to 0.87 per cent. The mean of the series is not significantly different from zero at 0.01 per cent, with a standard deviation of 0.34 per cent. The series was also tested for non-stationarity which was rejected at the one per cent level. Thus the gap between actual and core inflation does appear to be a zero mean stationary series as specified in Equation 5.

Fig. 7 - Gap Between Measured and Core HICP inflation, 1984-1999



To understand further the impact of variations in the distribution of price changes and to illustrate graphically how trimmed means operate, Figure 8 plots the distribution of price changes for two specific quarters. The weighted mean, median, trimmed mean are illustrated, along with the upper and lower bounds used to calculate the trimmed mean.[18] The first chart shows the distribution of price changes in Q3 1997. It is clear that the distribution is left skewed. The median (0.1 per cent) lies above the mean (-0.2 per cent). The trimmed mean measure of core inflation truncates the distribution at -0.1 per cent and 0.8 per cent, discarding observations outside that range. The core rate of inflation is calculated as 0.4 per cent, significantly above the measured rate of inflation of -0.2 per cent. Thus, while measured inflation was negative in Q3 1997, estimated core inflation was positive. Furthermore, in this instance the mean rate of inflation actually lies outside the range used to calculate the trimmed mean. The second chart shows the distribution of price changes in Q2 1998. This distribution is right skewed. The median (0.7 per cent) lies significantly below the mean (1.5 per cent) of the distribution. The trimmed mean measure of core inflation truncates the distribution at 0.0 per cent and 1.5 per cent, and calculates the rate of core inflation at 0.9 per cent.

Fig. 8 - Price Distributions, Q3 1997 and Q2 1998



4. FORECASTING USING CORE INFLATION

One test of the usefulness of the concept core inflation is to compare the forecasting performance of core inflation to the forecasting performance using noisy measured inflation data. Tables 4-6 present forecast statistics, using out-of-sample data, for measured HICP inflation, core inflation and forecasts of core inflation against measured HICP

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[18] The upper and lower bins of the distribution include all observations greater than or less than four per cent. Graphically this distorts the distribution as some observations can be greater than plus or minus forty per cent.

inflation.[19] The RMSE for forecasts of measured inflation, 0.40 per cent, is considerably higher than that for core inflation, 0.24 per cent. This would imply tighter confidence intervals for forecasts of core inflation. The 90 per cent confidence interval for one-step ahead forecasts of core inflation would be approximately 0.8 per cent compared to approximately 1.4 per cent for measured inflation. Another test of the core inflation series would be to compare out-of-sample forecasts of core inflation against actual 'noisy' inflation.[20] These results are shown in Table 6. They are marginally worse than using ARIMA models of measured inflation to forecast measured inflation. The fact that the core inflation predicted measured inflation marginally worse than measured inflation did, does not mean that the core inflation measure is flawed, as the measured inflation data contains noise, which we do not necessarily want core inflation to forecast.

TABLE 4 - FORECAST STATISTICS FOR ARIMA MODEL OF MEASURED HICP INFLATION (1993Q2 - 1999Q1)

Step	Mean Error	Mean Abs. Error	RMS Error	Theil U	N.Obs
1	0.02	0.31	0.43	0.64	24
2	-0.00	0.30	0.41	0.66	23
3	-0.04	0.27	0.38	0.60	22
4	-0.04	0.28	0.38	0.78	21
Avg. 1-4	-0.01	0.29	0.40	0.67	

[19] The forecasts are constructed using the best performing ARIMA models chosen using the procedure outlined in Meyler *et al* (1998).

[20] The forecast performance of the HICP excluding seasonal food and energy was also evaluated. It performed less well (with an average RMSE of 0.47 per cent) than the statistically-based core inflation measure.

TABLE 5 - FORECAST STATISTICS FOR ARIMA MODEL OF CORE HICP INFLATION (1993Q2 - 1999Q1)

Step	Mean Error	Mean Abs. Error	RMS Error	Theil U	N.Obs
1	0.02	0.21	0.25	0.72	24
2	-0.00	0.20	0.23	0.65	23
3	-0.02	0.19	0.23	0.71	22
4	-0.02	0.20	0.23	0.72	21
Avg. 1-4	-0.00	0.20	0.24	0.70	

TABLE 6 - FORECAST STATISTICS AGAINST ACTUAL INFLATION FOR ARIMA MODEL OF CORE HICP INFLATION (1993Q2 - 1999Q1)

Step	Mean Error	Mean Abs. Error	RMS Error	Theil U	N.Obs
1	-0.02	0.37	0.46	0.69	24
2	-0.02	0.38	0.46	0.74	23
3	0.00	0.35	0.45	0.72	22
4	0.03	0.31	0.40	0.80	21
Avg. 1-4	-0.00	0.35	0.44	0.74	

5. MONTHLY VERSUS QUARTERLY DATA

Since January 1997, price data are available at a monthly frequency. It is most likely that the distribution of monthly price changes differs significantly from the distribution of quarterly price changes. Table 7 shows the sample moments of both monthly and quarterly data. Inferring too much from the sample moments is not advisable as there are only eight quarterly observations and 24 monthly observations available. The monthly moments have been converted to the same dimension as the quarterly data to facilitate comparison. The standard deviation and skew of monthly price changes appear to be higher than for the quarterly price changes. The kurtosis of monthly prices changes is broadly similar to that of the quarterly price changes. Consistent with the higher degree of skew is the fact that the median lies further below the mean for monthly data, and the percentile which contains the mean is higher for monthly data.

Table 7 - Summary of Price Change Moments, Q2 1997 (Mar. 1997) - Q1 1999 (Feb. 1999)

Period	Mean	Std. Dev.	Skew	Kurtosis	Median	Percentile
Quarterly	0.421%	3.6%	0.3	87.9	0.323%	50.7%
Monthly	0.422%	6.4%	1.8	89.1	0.160%	58.2%

Assessing alternative measures of core inflation at a monthly frequency is fraught with danger given the low number of observations. Nonetheless, alternative trimmed mean estimators were constructed, using a seven-month centred moving average as the benchmark measure for core inflation. The RMSE of alternative trimmed mean estimators are shown in Figure 9. The measure with the lowest RMSE is a 45 per cent trimmed mean with a skew of 58 per cent. The RMSE for this measure is 0.109 per cent compared to 0.321 per cent for the actual HICP series, a decrease of 66 per cent.

Fig. 9 - RMSE of Alternative Monthly Core Inflation Measures, 97-99

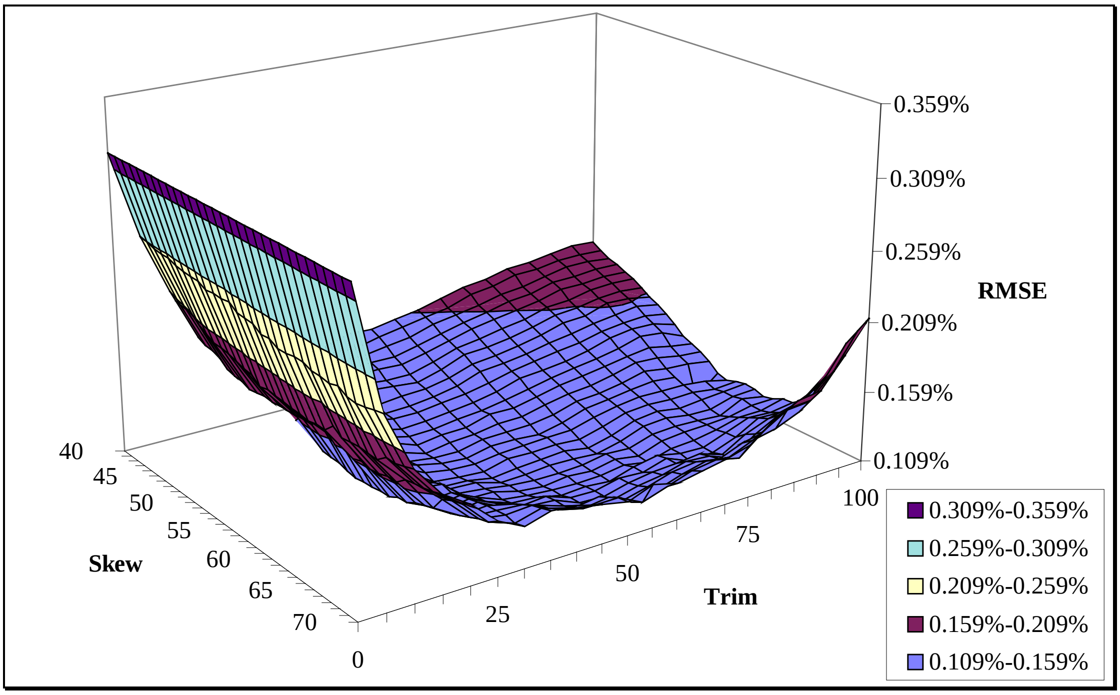


Figure 10 plots the minimum RMSE at each degree of trim and shows the associated degree of skew. In common with the results for the quarterly data, only a small amount of trim is required to bring about a significant reduction in the RMSE. A trim of 20 per cent reduces the RMSE by 59 per cent from 0.321 per cent to 0.132 per cent, or by 89 per cent of the maximum reduction in the RMSE.[21] The degree of skew is relatively volatile but this is probably due to the small sample size (18 observations).

[21] Using the overall HICP excluding unprocessed food and energy increases the RMSE compared to the zero trim mean measure from 0.321 per cent to 0.398 per cent.

Fig. 10 - Min. RMSE (& associated skew) by Degree of Trim, 1997-99

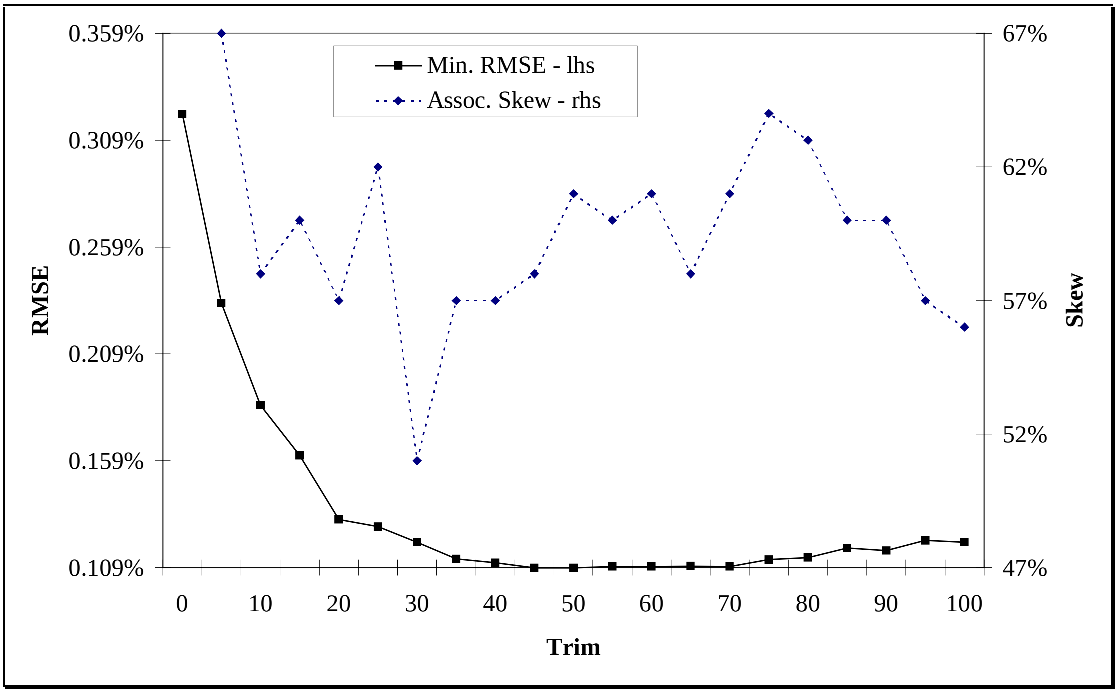
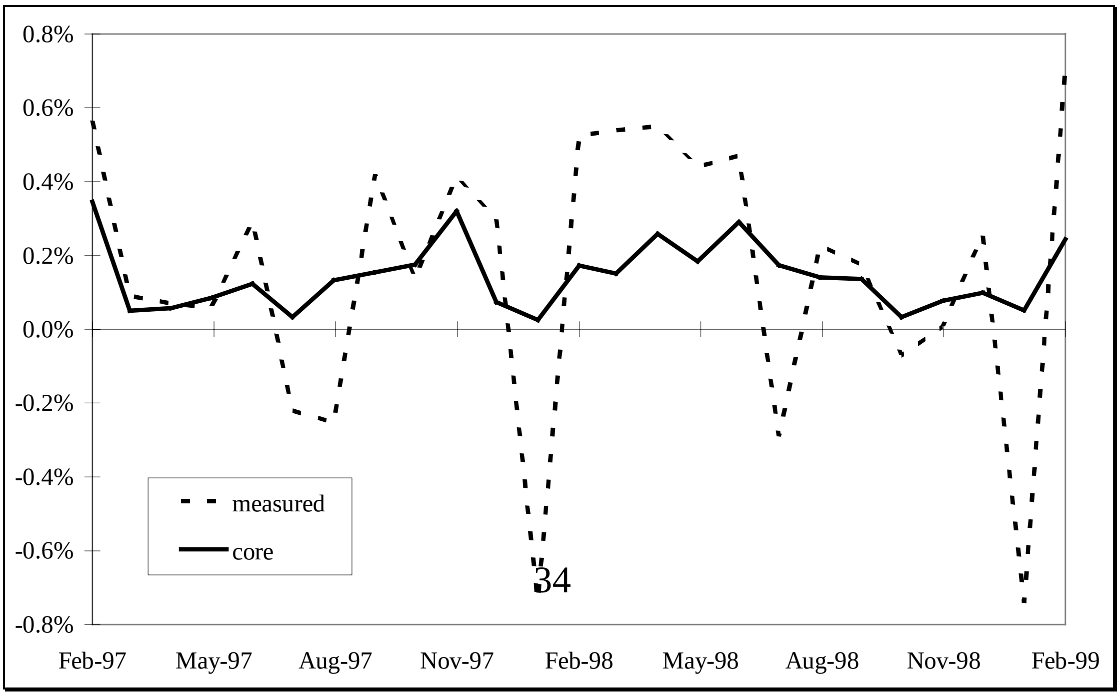


Figure 11 plots measured and core monthly inflation. The core inflation measure has a much less pronounced seasonal effect than the measured inflation series. This can especially be seen in the January and July observations which reflect sales activity.

Fig. 11 - Measured and Core Inflation, 1997 - 1999



6. EVALUATING STATISTICAL MEASURES OF CORE INFLATION

What are the relative advantages of statistical measures of core inflation relative to alternative techniques, such as Quah and Vahey (1995) SVAR estimation?

Relative Advantages of Statistical Measures of Core Inflation

- They can be produced simultaneously with headline rates of inflation. No additional variables are needed, such as output which is required to calculate Quah and Vahey type estimates, that might only be available with a long lag. This is a major advantage of the statistical approach, and makes it preferable for policy purposes.
- They are easy to construct and readily reproducible.
- There are clear statistical grounds for using 'limited influence' measures of central tendency.

Relative Disadvantages of Statistical Measures of Core Inflation

- It might be difficult to gain public acceptance of the concept as it is not easily conceptualised.
- The process by which the optimal trim and skew is determined is relatively *ad hoc* and is subject to the usual small-sample error.
- Some authors (e.g., Wynne 1997) criticise the monetary inflation concept preferring the microeconomic based cost of living approach to inflation measurement.
- Perhaps the most challenging criticism of statistically-based measures of core inflation is that the distribution of price changes may not be

independent of the mean of the price changes. Thus, if there is a change in the inflation environment, it might require a change in the measure of core inflation used.

Thus, while statistically-based measures of core inflation may be criticised for being relatively *ad hoc*, they are timely to produce and as such are more practical measures than alternatives such as SVAR estimates.

7. CONCLUSIONS

It was shown that the distribution of quarterly price changes in the HICP differs significantly from the normal distribution. In particular, the high degree of kurtosis in the distribution means that the mean might not be the most efficient estimator of central tendency. Using trimmed mean estimators and correcting for skewness in the distribution, alternative estimators of core inflation were constructed. Only a small amount of trim was required to reduce the RMSE of the core inflation measure relative to the mean. This was especially true for monthly data. Cecchetti (1997, pg. 154) concludes that "monthly percentage changes in virtually any inflation measure contain so much noise that they are virtually useless". However, the optimal trimmed mean measure of core inflation found in this paper removes a considerable proportion of this noise. Traditional measures of core inflation (i.e., excluding unprocessed food and energy from the overall index) were shown to add additional noise relative to the mean, which is exactly the opposite of the intended effect.

Removing the noise present in quarterly and monthly data should enable policy makers to follow more accurately price change developments and to respond in a more effective manner to actual deviations from desired long-run levels, rather than responding incorrectly to short-term noise in inflation data. Analysis of the distribution of price changes yields considerable insight beyond that available from the headline rate of inflation alone. This suggests that publication of key summary statistics of the distribution of price changes underlying the headline rate of inflation would be justified for policy and analytical purposes.

A possible extension to the work here would be to apply Cecchetti's (1997) DFI approach to the dataset to reduce the bias in the inflation measure which arises from using incorrect weighting. The DFI reweights individual price series based on the strength of its common inflation signal. The statistical approach to measuring core inflation, outlined in this paper, could then be applied using the weights generated by the DFI. However, given the complexity of the DFI approach, considerable aggregation of the data would be needed. For example, Cecchetti uses 36 components compared to the 529 categories considered in this paper. Work is also currently underway examining structural VAR estimates of core inflation in Ireland.

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