Estimating and evaluating measures of core inflation in Lesotho

By Realeboha Khamali[1]

Abstract

THIS PAPER estimates and evaluates the measures of core inflation in Lesotho for the sample period March 2009 to December 2017 using the CPI data. Using five exclusion-based measures and one limited influence estimator, the results reveal that the 30%-trimmed mean tracks trend inflation very well relative to other measures and using the one-month ahead forecasts only 30%-trimmed mean core inflation indicator has significant predictive power for the future headline inflation. Nonetheless, as the forecasting horizon increases some measures have significant predictive content for the future headline inflation but the 30%-trimmed mean surpasses all of the calculated core inflation indicators. It is therefore adopted as the ideal measure of core inflation for Lesotho.

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1 INTRODUCTION

ONE OF THE most important economic variables is the inflation rate, which is the rate at which general prices in the economy change. The inflation rate affects the overall economy through several channels (du Plessis, du Rant and Kotze, 2015). For example, high and unstable inflation rates create uncertainty about the course of future inflation, clouding consumers' saving and businesses' investment decisions. The second, but not the last, channel through which inflation affects the economy is the redistribution of wealth such as capital gains/losses between creditors and borrowers (Pedersen and Wagener, 2000). Therefore, in order to curb the negative impact of inflation rate, most governments around the globe have mandated their central banks to achieve and maintain price stability.

Given the costs of inflation on the economy, the need for the proper measure of inflationary pressures in the economy is key for policymakers in order for them to achieve price stability. In this endeavour, most central banks monitor and analyse developments in the Consumer Price Index (CPI), even though there are other measures such as the GDP deflator and Personal Consumer Expenditure (PCE), which is mostly used in the United States (US). This is because CPI is easily understandable by the public and mostly produced on a higher frequency relative to other measures of general prices.

Nonetheless, while there are advantages in using the CPI as a measure upon which monetary policy can be based, it contains information that is too noisy for policy and forecasting purposes, thus making it a doubtful policy target, especially for monetary policy. This is because CPI contains information on transient developments in prices such as a shock of bad weather conditions, which may raise prices of items like maize meal. The price of maize meal may be short-lived and if monetary policy is used to react to such developments, it can be distortionary on the overall economy (du Plessis *et.al,* 2015).

For CPI to be used as policy target that captures the medium to long term changes in prices, economists and policymakers have tried to separate the transitory movements from CPI, to get the underlying trends and this has led to the concept of core inflation. According to Nessen and Soderstrom (2001), core inflation captures the price changes mostly relevant for monetary policy. This is because changes to policy have long lasting effects and policy effects come out but with a lag. In this regard, several measures of core inflation are developed that are used to gauge the underlying trend in inflation.

This note outlines the concept of core inflation as widely used in the inflation dynamics literature. It provides literature review on the measures of core inflation. The third section presents the CPI data set for Lesotho's measure of inflation and some descriptive statistics, while estimation results for core inflation measures are presented in the fourth section. The fifth section evaluates the measures of core inflation using the criteria often applied in literature and the last section is the conclusion and recommendations.

2 LITERATURE REVIEW

Despite the prevalent uses of core inflation measures for monetary policy and inflation forecasting purposes, the concept of core inflation in itself is not clearly defined according to Bryan and Cecchetti (1994). Roger (1998) argues that this is because core inflation is better explained or defined by the method used to derive it but he contends that the general concept revolves around measuring the persistent or underlying trends in inflation. Figueiredo (2001) points out that these trends are generally related to the demand pressures in the economy and some long lasting shocks over the economy's productive capacity, which leave out the transient shocks that may self-correct without policy intervention in the short-run and some supply-side shocks.

According to Bryan and Cecchetti (1994) some earlier attempts to define core inflation dates as far back as the early 1970s and 1980s, when oil prices rose substantially. Gordon (1975) excluded food and energy in his estimation of the core price equation while assessing the importance of the demand and supply factors of the US inflation. At the beginning of the decade that followed Gordon's work, Otto Eckstein (1981) defined core inflation in terms of the "trend rate of increases of the prices of the aggregate supply" in his seminal work on the development of core inflation. The concept further received other definitions such as "that inflation rate which has no medium to long term effect on real output" by Quah and Vahey (1995). Other authors such as and Lafleche and Armour (2006) defined core inflation as the "underlying trend or movement" in the general price level, using CPI as the measure of the price level. In all of these definitions, the concept of core inflation is that which captures the underlying trends of the general prices in the economy.

Like the concept itself, the measures for calculating core inflation also vary depending on the purposes for which they are constructed and the distribution of the price level on which they are based. All measures of deriving core inflation broadly revolve around the statistical and model-based approaches (Mallick and Sethi, 2014). While the statistical or reduced-form techniques exploit the statistical properties of prices such as using means, median, standard deviations, among others and the disaggregated price data, the model-based method is grounded in economic theory (Gupta and Saxegaard, 2009). In the case of the model-based approach, an econometric model is formulated in which core inflation is linked to its fundamental economic determinants such as the current level of output. The most popularly known technique under the model-based approach is the Vector Autoregressive (VAR) technique popularised by Bryan and Cecchetti (1994).

The statistical approach to measuring core inflation consists of techniques that are broadly defined into three main groups, namely, the exclusion-based methods, the limited influence estimators (LIE) as well as weighted variance and persistence-weighted methods (Chamberlin, 2009). The approach strips the overall headline inflation of those items deemed most volatile and mostly driven by supply-side disturbances such as some food and energy items, which normally exhibit large price changes. The second set of items that are usually excluded from the headline inflation to obtain core are those price series[1], which are not shaped by market mechanism but are controlled by some regulatory authority such as water and electricity in

[1] These price series are referred to as the administered prices.

the case of Lesotho. According Alvarez and Matea (1999) the following formula is used in calculating core inflation indicator:

$$CCIP = \frac{\sum_{i=1} w_i * p_i - \sum_{j \neq i} w_j^{excl} * p_j^{excl}}{\sum_{i=1}^{n} w_i - \sum_{j \neq i}^{m} w_j^{excl}} \quad (1)$$

The first part in the numerator is the sum of the weighted price indices of items in the overall CPI basket, while the second one in the numerator is that of the excluded items. In the denominator, the sum of the weights of the excluded items is subtracted from the sum of the weights of all items in the overall CPI. ***i*** and ***j*** are the goods and services included and excluded from the overall CPI basket, where ***n*** and ***m*** are the number of goods and services included and excluded from the overall CPI basket, respectively.

Some drawbacks of the exclusion-based methods include: 1) excluding a set of pre-determined price series whose volatility may change over time thus leading to erroneous calculation of core inflation, 2); removing food or energy items, for example, whose weights take a lion's share in the representative consumption basket of a particular country. For example, food items take over a third of the total CPI basket in Lesotho while in other countries it takes over 50.0 per cent. Removing such items that have bigger weights may lead to a useless indicator.

To overcome the weaknesses of the exclusion-based methods as explained above, some authors introduced the LIE. This approach strips the headline inflation of the outlying portions of the price change distribution of the measure of inflation (Gupta and Saxegaard, 2009). That is, it trims the lowest and highest price changes in the distribution on basis that they convey little information on the underlying trend of inflation relative to the centre of the distribution (Bryan and Cecchetti, 1993). Every time when the measures are calculated, the new set of items are removed which may have not been removed in the past. This feature overcomes the fixed criteria used for exclusion-based methods. The LIE includes the weighted median CPI and trimmed means.

According to Mankikar and Paisley (2004) and Silver (2007), the trimmed mean is derived by cutting off a specified upper and lower tails of the price distribution. This is based on a determined percentage cut off when prices are ordered in either ascending or descending order as well as the cumulative weights. For example, a 30.0 per cent trimmed mean estimate excludes the 15.0 per cent of weight at the top of the distribution and another at the bottom, if the price distribution is normal. However, in the case of non-normal distribution the percentage cut-offs both at the upper and lower ends are not similar. This may be caused by high skewness or kurtosis. In this case, the asymmetric trimmed mean is calculated, where say, 25.0 per cent of the cumulative weight is cut at the top and 10.0 per cent at the bottom. Then rest of the remaining weights are then normalized so that they add up to 1.

According to Vega and Wynne (2001), the trimmed mean is calculated by sorting the data on price change in a descending or ascending order with their respective weights. Then, the cumulative weight is defined from 1 to i as W_i. Formally, it is defined as shown below (Berkmen, 2002):

$$W_i = \sum_{j=1}^{i} W_j$$

The set of observations to be averaged to calculate the trimmed mean is determined as

$\frac{\alpha}{100} < W_i < \frac{1-\alpha}{100}$ and called as I_α.

The trimmed mean is calculated as below according to Bryan, Cecchetti and Wiggins (1997),

$$\bar{X}_\alpha = \frac{1}{1-2\frac{\alpha}{100}} \sum_{i=1}^{I_\alpha} w_i x_i \qquad (2)$$

Where $\bar{X}\alpha$ is the sample mean (The trimmed mean estimator), w_i and x_i are vector of weights and price changes, respectively. The percentage to be trimmed in the case of symmetric trimmed mean approach is α at both the lower and upped ends. For asymmetric trimmed mean, $\alpha = [\alpha_1, \alpha_2]$.

Nonetheless, the most pressing issue with this method is to decide the level of cut-off since statistical and economic theory does not provide any guidance on the optimal level of the percentage to be trimmed. If the distribution of prices is not normal, or they are skewed, then the mean may not be the best indicator and sometimes, the weighted median approach is used in such cases (Aghajanyan, 2005).

The weighted median is an extreme case of the trimmed mean. It represents the growth rate of the price of the component that is situated in the middle of the increasingly ordered distribution. For the weighted median, half of the weighted monthly increases are above the weighted median and half are below. Then, the median is calculated according to the previous procedure, except that it is the first price change whose cumulative weight is greater or equal to 50 per cent. Alternatively, Taillon (1999) and ALEEM (2004) suggests using the following formula to calculate the weighted mean estimator;

Let WMI represent the weighted median inflation, then

$$WMI = \frac{\pi_1(50\% - cw_1) + \pi_2(cw_2 - 50\%)}{cw_2 - cw_1}, \tag{3}$$

where cw_1 is the cumulative weight of the first value in the median and cw_2 is for the second value. Likewise, π_1 is the percentage change in the price of the first item in the median value whereas π_2 is for the second one.

All of the above methods of calculating core inflation exclude items that are selected according to a certain criterion, mostly the large price changes or those with high volatility. Chamberlin (2009) argues that this feature can be refined by including all of the price changes but down-weighting those items that are highly volatile[2] or less persistent. In the case of most volatile items, the weight of an item is calculated as the ratio of the inverse of the respective volatility over the sum of the inverses of all the items. The weight of item i is formally defined as below.

Let w_1 be defined as the weight of item i, then according to Dow (1994)

[2] Volatility an item is measured by the standard deviation of that item over the entire period or in the past 5 years.

$$w_i^{DW} = \frac{1/\sigma_i}{\sum_{i=1}^{n} 1/\sigma_i}$$

where n is the number of items under consideration, σ_i represents the standard deviation (volatility) of item i. Thus the measure of core inflation, π_1^{core}, is then calculated according to the following estimator:

$$\pi_t^{core} = \sum_{i=1}^{n} w_{i,t}^{DW} x_{i,t} \tag{4}$$

where $x_{i,t}$ is a vector of price changes (inflation rates) of the components of the overall CPI.

Another method, which downplays the importance of each item in the calculation of the core inflation, is the persistence-weighting approach (Chamberlin, 2009). This method derives its existence from Blinder's definition of what core inflation is. Blinder (1997) defines core inflation as that part of actual inflation, which only includes the permanent or persistent price movements that are likely to carry information for future inflation, when the transitory price changes have been removed or reversed (Cutler, 2001). The persistence-weighted approach as suggested by Cutler (2001) re-weights the price movements in monthly inflation rate by using the coefficients from the following first order autoregressive, AR (1) model:

$$\pi_{it} = \alpha_i + \beta_i \pi_{i,t-1} + \varepsilon_{it} \tag{5}$$

where π_{it} is the price change for item i at a particular time t, and β_i is the coefficient of the measure of persistence in item i's past annual inflation rate. The estimate of persistence is then used as a weight of the respective item in the aggregate inflation rate to calculate the underlying trend. The weight of an item in the aggregate inflation is derived formally as follows:

Let w_i represent the weight of component i in the aggregate inflation, that is defined as:

$$w_i = \frac{\beta_i}{\sum_{i=1}^{n} \beta_i}$$

Where $i \in [1, n]$ for n items that make up the aggregate inflation when the less persistent items are removed. If β_i is negative, it means that the respective component's past price changes are quickly reversed, hence not persistent and it is therefore assigned a zero weight. In the case of positive persistence coefficient, the weight of an item is equal to the size of the coefficient estimated, with the sum of all positive coefficients normalized to 1.

Finally, yet not least and last, is the measure of core inflation that uses structural modelling techniques. As mentioned earlier, the model-based approaches to measuring core inflation are based on economic theory. In this case, core inflation is defined as that part of aggregate inflation that does not have an impact on medium-to long-run real output (Quay and Vahey, 1995). The core inflation under this approach is derived using its fundamental economic determinants, for example, output by the use of the structural vector autoregressive (SVAR) model. Where monthly output measures such as GDP are not available, output proxies such as industrial production or manufacturing output are used.

In order to estimate the SVAR model, core inflation is assumed to be influenced by two types of shocks (Goyal and Pujari, 2005), namely the demand (core) and supply (non-core) shocks that are uncorrelated. They argue that one type has only transitory impact on real output while the other one has unrestricted impact on headline inflation and output but does not affect the underlying inflation. Then the underlying inflation that corresponds to the second type of disturbance is calculated.

However, Quah and Vahey (1995) point out that there may be more than two types of disturbances that may affect inflation and output. Nonetheless, the concept of core inflation that is being considered makes an assumption of only two types of uncorrelated disturbances as part of restriction in the SVAR approach.

3 DATA

In this paper, price indices that are used to construct core inflation measures are expressed in terms of the Consumer Price Index (CPI). The primary source of the CPI data is Bureau of Statistics, Lesotho. The CPI data is used at the most disaggregated level of 182 items over a period from March 2010 to December 2017 (105 months) and the inflation rate is calculated as the year-on-year change in CPI, consequently termed 12-month inflation rate or (annual inflation rate). The year-on-year change in CPI is used because it smooths seasonal fluctuations in data relative to month-on-month changes in prices' indices. The annual inflation rate for a given month is calculated as follows:

$$\pi_t = 100 * \frac{CPI_t}{CPI_{t-k}} - 100 \quad (6)$$

Where CPI is the measure of consumer price index and t is the current time period while k stands for the time interval between the current period and the previous one. For example, the month-on-month change in CPI (monthly inflation rate) corresponds to $k = 1$ while for the 12-month inflation rate, k becomes 12. While most measures of the underlying inflation rate are calculated using the most disaggregated CPI data, some measures such as the persistence-weighted core inflation can also be constructed much more easily if the series is aggregated at a lesser level. This is because estimating the AR (1) model may involve many equations, which may be tedious to work with. All the exclusion-based measures and the LIEs are constructed based on disaggregated CPI.

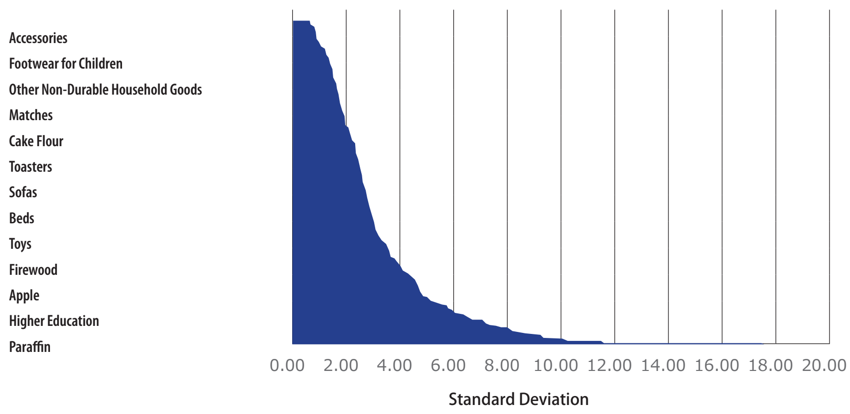
4 ESTIMATION RESULTS

This section presents the estimation results of the core measures of inflation as discussed in the literature above, except for the volatility-weighting, persistence-weighting, median CPI inflation and SVAR model. For SVAR, the analysis is limited because it requires a measure of output on a much higher frequency (monthly) and currently there is no such measure.

4.1 The Exclusion-based Approach

As discussed above, the first measure of core inflation that is estimated is the exclusion of the most volatile components from the overall CPI. The volatility of an item is measured by its historical standard deviation over the whole sample period. The cut-off value of the standard deviation is set at four, in which case any item whose corresponding standard deviation exceeds the cut-off point is eliminated in deriving the core estimate of inflation. The cut-off point of four has been chosen after examining the nature of the distribution of the CPI items' standard deviations as show in figure 1 below.

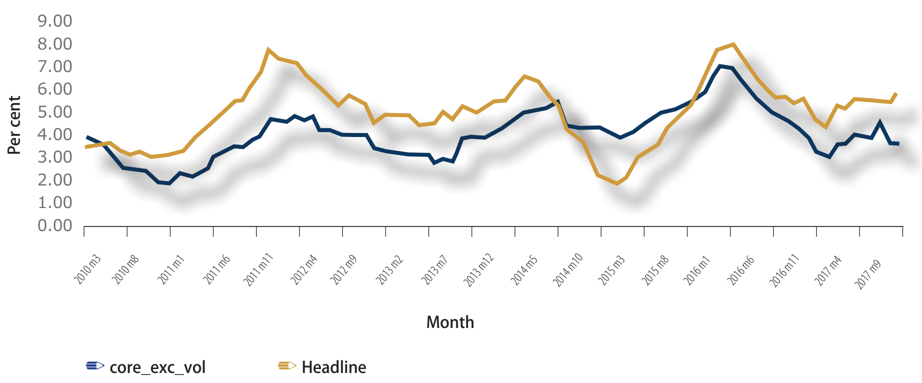
Figure 1 Distribution of CPI items by their volatility



Source: Authors calculations and BOS

Figure1 above exhibits the standard deviations of the 182 CPI items from March 2010 to December 2017. Any item for which standard deviation is above four is taken as highly volatile and it is a candidate for exclusion in calculating core inflation. The results show that about 24.0 per cent of the respective items have standard deviation values of greater than four each, and hence they are candidates for exclusion. Each of these items is at least three times as volatile as the overall inflation rate. The standard deviation value of the headline inflation rate is 1.4 per cent. Most food and energy items have high standard deviations and are thus excluded to derive the core inflation indicator as shown in figure 2 below.

Figure 2 Time path of headline inflation versus core-excluding volatile items

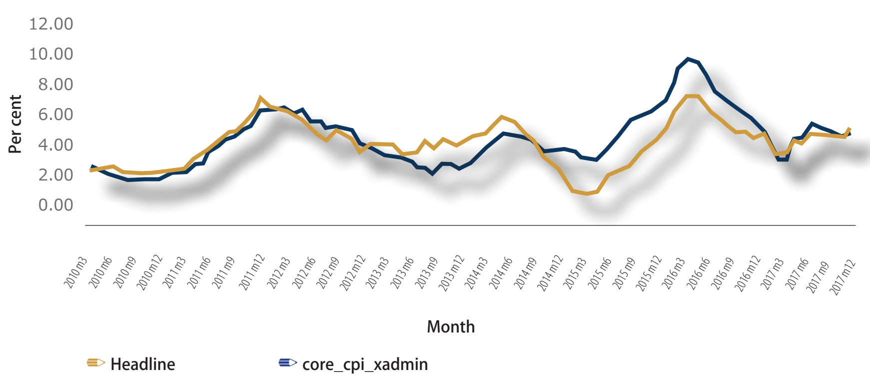


Source: Authors calculations and BOS

Core inflation excluding the most volatile items was calculated and the results are shown in figure 2 above. While the average headline inflation rate was 5.0 per cent during the review period, the core estimate was 4.0 per cent, but the volatility of the former was almost twice the latter. The standard deviation of the headline inflation during the sample period was 1.4 per cent while that of the core inflation rate was 0.74 per cent. The core inflation rate has been below the headline for a large part of the sample period except for the period between October 2014 and January 2016. The five quarters from October 2015, marked the period of declining food and fuel prices, especially oil prices at the international, and hence Lesotho's domestic front.

Figure 3 below shows the estimated core inflation, which excludes the administered prices plotted against the headline inflation rate. The administered group of prices are not determined by markets forces but are controlled by the government or designated authority, and they vary from country to country. In Lesotho, the items in this category include energy and water prices, education and health, public and personal transport, telecommunications and social protection, among others. Some regulatory organs in the country include Lesotho Energy and Water Authority for water and electricity, and Lesotho Communications Authority for the telecommunications sector.

Figure 3 Headline inflation versus Core-excluding administered prices

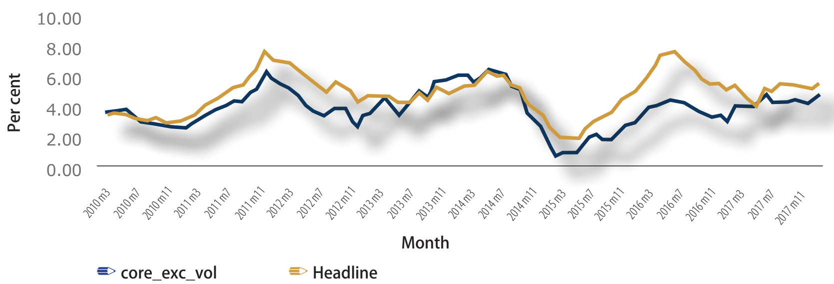


Source: Authors calculations and BOS

The figure above shows that from March 2010 until the second half of 2013, the core inflation rate excluding the administered component moved very closely with the headline inflation rate. Nonetheless, the subsequent months until the end of the sample period saw the gap between the two rates widening though at a smaller pace. Just like the exclusion of the most volatile items, the core excluding the administered prices is less volatile than the headline inflation with the standard deviations of 1.07 per cent for the former and 1.40 per cent for the latter. While the headline inflation rate was at a trough of 2.0 per cent in March 2015, the corresponding core inflation rate was twice as much. In March 2016, the latter peaked at 10.0 per cent, 2.0 percentage points higher than the headline inflation rate.

Figure 4 displays the time paths of the headline inflation rate against the core measure estimated by excluding food component only. Clark (2001) argues that food prices are excluded when estimating the core indicator because they are commonly regarded as being prone to changes that often fail to persist. Food prices are also subject to supply disruptions such as drought. In the overall CPI basket, food component takes 36.1 per cent. According to figure 4 below the two series display similar trends with the core inflation rate below the headline series over the entire sample period, but the gap widens between June 2016 and March 2017. During the sample period, the headline inflation rate averaged 5.0 per cent while the corresponding core measure averaged 4.0 per cent. The standard deviation of the headline inflation rate was 1.4 per cent while the respective core indicator was 1.1 per cent, indicating that the former is more volatile than the latter.

Figure 4 Headline versus core-excluding food

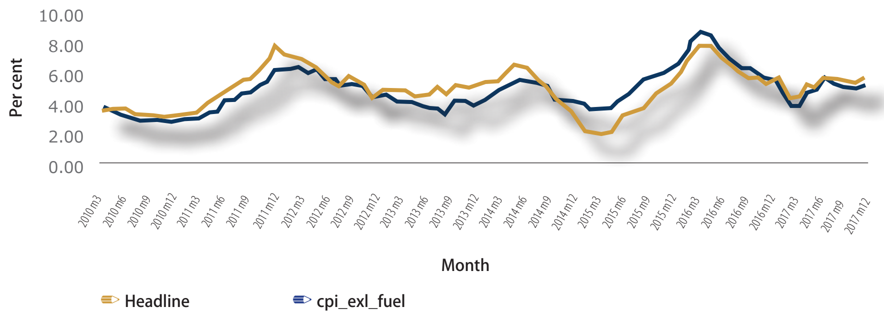


Source: Authors calculations and BOS

The food component commands a larger share of the CPI basket in Lesotho like in many other countries such Bangladesh and Swaziland, among others. Therefore, excluding the whole of this category has some drawbacks. One of the disadvantages of excluding the whole of the food component is that this may lead to ignoring the price signal that may be very important for the underlying measure of inflation in the economy.

Figure 5 below plots the historical path of the headline inflation against that of the core inflation, which excludes energy prices. Energy prices in Lesotho include electricity, gas, water, fuels (solid and liquid), among others and constitute a share of 7.9 per cent in the overall CPI. The chart shows the close movement of headline and core inflation. On average, the headline and core inflation rates recorded averages of 5.0 per cent and 4.9 per cent during the entire sample period while their respective volatilities are 1.40 per cent and 1.35 per cent.

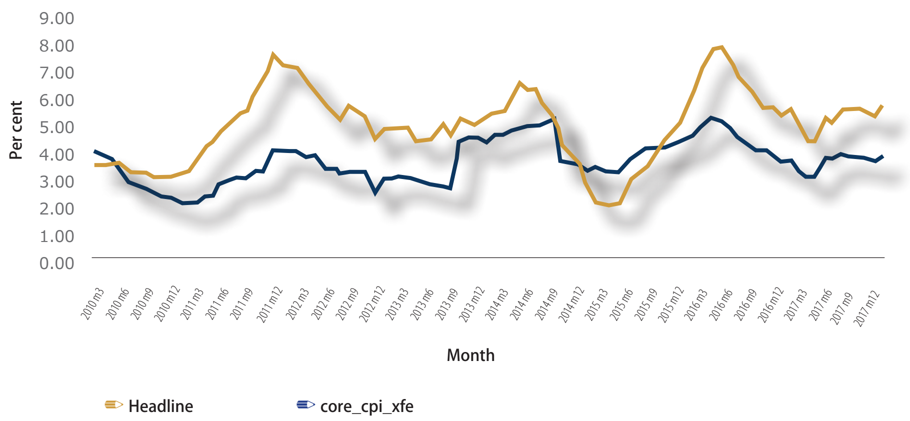
Figure 5 Headline inflation versus Core-excluding administered prices



Source: Authors calculations and BOS

Graph 6 below presents the historical path of the headline inflation rate against the measure of core inflation, which excludes the energy and food components in its calculation. The total weight for excluded food and energy items constitutes 42.8 per cent. During the sample period, the headline inflation rate was higher than the core indicator by 1.35 percentage points, and its volatility was almost twice that of the core indicator. The core measure has trended below the headline inflation rate during the sample period but they exhibited almost similar trends.

Figure 6 The headline inflation rate and CPI-excluding energy and food prices

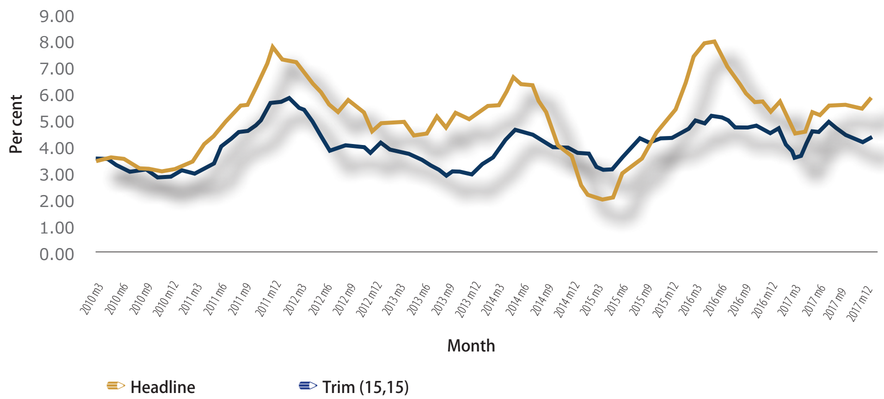


Source: Authors calculations and BOS

4.2 Limited Influence Estimator

The results for the estimated symmetric trimmed mean as a measure of core inflation are shown in figure 7 below. The trimmed mean measure as calculated in this paper constitutes removing 30 per cent of the distribution of price changes symmetrically. This means that 15.0 per cent is cut from the bottom of price changes distribution and the other 15.0 per cent at the top of the distribution.

Figure 7 Headline versus symmetric trimmed mean inflation



Source: Author's calculation using data from BOS

In figure 7 above, the core inflation rate (the 30 % -trimmed mean) is plotted against the headline rate. As with other measures of core inflation, the trimmed mean has been below the headline over the entire sample period with the latter averaging 5.0 per cent relative to 4.0 per cent for the former, except for the period starting from December 2014 to September 2015. The trimmed mean indicator has been less volatile than the headline inflation rate during the sample period but they showed similar trends.

5 EVALUATION OF MEASURES OF CORE INFLATION

This section evaluates the relative performance of various measures of core inflation calculated in the preceding section against a given set of criteria. Clark (2001) points out that there are many criteria used in evaluating measures of core inflation. Among others, Lafleche & Armour (2006) and Silver (2007) use timelines and credibility, ability to track trend inflation and ability of core inflation to predict future headline inflation. Nonetheless, Bicchal, Sharma & Kamauah (2010) argue that just like the definition of core inflation and frameworks in calculating core inflation, there is no consensus regarding the best evaluation criterion. Clark (2001) argues that the commonly used criteria are the ability to track trend inflation and the ability of a given core indicator to predict future overall inflation.

5.1 Ability to Track Trend[4] Inflation

According to this criterion, a good core inflation indicator should neither overstate nor understate the long run growth of the overall CPI (Rich & Steindel, 2007). This means that in the long run, the means of the two series should be equal. Another way of assessing whether core inflation tracks the trend inflation is by examining the volatility of the deviation between the two series or by minimising it. If the former tracks the latter accurately, either the standard deviation of their respective deviation will be relatively smaller or root mean squared error (RMSE) will be (Clark, 2001) and Rich & Steindel (2007). This means that any change (rise or fall) in trend inflation should be matched by a commensurate change in core inflation indicators.

Table 1 Summary statistics for Headline inflation rate and core measures

Inflation measure	Average rate	Volatility	Volatility around trend	Coefficient of Variation
Overall CPI	5.01	1.40	1.18	0.28
CPI excluding food	4.02	1.31	1.26	0.33
CPI excluding energy	4.86	1.35	1.16	0.28
CPI excluding food & energy	3.66	0.80	0.85	0.22
CPI excluding administered prices	5.29	1.70	1.48	0.31
CPI excluding most volatile	4.06	1.08	1.02	0.26
CPI excluding administered prices	5.29	1.70	1.48	0.31

Notes: The coefficient of variation is the standard deviation divided by the mean.
All figures in table 1 are expressed in percentages.

Source Author's calculations and BOS

[3] Trend inflation in this case is measured by the use of Hodrick-Prescott filter using the lambda value of 14,440 for monthly data.

Table 1 above depicts the averages and volatilities of the headline inflation rate and a series of core inflation indicators for the entire sample period. According to the table, the following core inflation indicators have long run means lower than the headline inflation and the difference between the respective indicators and headline inflation means are all statistically significant[4] at all levels (1%, 5% and 10%); CPI excluding the most volatile items, food and energy, food only and the 30%-Trimmed mean. This means that there is a downward bias for all the four core inflation indicators. The CPI excluding only energy also has a downward bias in its mean relative to the overall inflation and but the difference between the two series is not statistically significant at any level less than 8.9 per cent.

Finally, yet importantly, the difference between means of the CPI excluding the administered prices only and the headline inflation is statistically significant at 5% and 10% levels only but not at 1% level. For this core inflation indicator there is, however, an upward bias. Under this criterion of equal means, no core inflation indicators exactly match the headline inflation rate's mean. This means that all candidates are biased estimators of the overall CPI inflation. Nonetheless, CPI excluding fuel tracks the underlying inflation with no bias but only at 1% and 5% significance levels, while CPI excluding administered prices becomes an unbiased estimate only at 1% significance level.

According to (Clark, 2001), the accuracy with which core inflation tracks trend inflation is measured by the volatility around the trend (standard deviation of the difference between the respective series) or the RMSE of the difference between core indicator and trend inflation (Rich and Steindel, 2007:25). The respective RMSE is calculated as follows:

$$RMSE(\pi^{trend} - \pi^{core}) = \sqrt{\frac{1}{T}\sum_{t=1}^{T}(\pi^{trend} - \pi^{core})^2} \quad for\ t = 1 \dots T \tag{7}$$

Where π^{trend} is the trend inflation at time t and π^{core} is core indicator of inflation at time t.

[4] This is done by using t-tests of equal means, with the Null Hypothesis $\mu^{headline} = \mu^{core}$, assuming equal variance.

By this criterion, trimmed mean performs better than the rest of the five measures. Its volatility around the trend and the respective RMSE (Table 2 below) are the smallest among the rest of the core inflation measures. The CPI excluding food and energy follows in the second top most of the list and the CPI excluding the most volatile items is the third top most performer. This means that they efficiently capture the persistent movements in the headline inflation relative to alternative measures.

Table 2 The Root Mean Squared Errors (per cent)

Core	Root Mean Squared Error (RMSE)
CPI excluding most volatile	1.390
CPI excluding energy	1.163
CPI excluding food and energy	1.592
CPI excluding food	1.597
CPI excluding administered prices	1.504
30%-Trimmed mean	1.157
Source: Author's calculations and BOS	

5.2 Predictive Ability

The good performance of the core inflation indicator can also be assessed by its ability to predict future headline inflation. In evaluating the predictive ability of core indicator, the following benchmark model has been used in the literature by Johnson (1999) and Clark (2001), among others.

$$\pi_{t+k} - \pi_t = \alpha + \beta(\pi_t^{core} - \pi_t) + \varepsilon_t \tag{8}$$

Where π_t represents the headline CPI inflation and π_t^{core} is the measure of the core inflation at time. The parameter k measures the number of periods in the future for the overall CPI inflation, for example, k = 1, 3, 6 and 12 months ahead. The equation generally measures how much of the current gap between core and headline inflation is able to predict the change of inflation over the next period, for example, over the next month or three months.

The benchmark model should satisfy the following restrictions, $\alpha = 0$ and $\beta = 1$ if core inflation is to an unbiased predicator of future headline inflation. If the first restriction fails to hold, then there is a systematic bias in the core inflation indicator. The latter restriction captures the extent to which the core indicator understates or overstates the transitory movement in headline inflation. If $\beta < 1$, then core inflation understates the future headline inflation and the specific shock that might have hit the headline inflation will be reversed in the future. In this case, headline inflation should therefore be expected to fall.

According to Lafleche and Armour (2006), the ability of the deviation of headline inflation from core inflation to predict the future headline inflation is measured by the relative size of the R^2. After estimating equation (8) above for all core indicators, the estimated R^2 for every measure of core inflation is compared to those of others and the regression that portrays relatively high R^2 means that the relevant core indicator performs better than its counterparts and has relatively good predictive content. The size of β in the above equation is positively related to the measure of predictive ability such that the more positive and closer to one the β is, the higher the R^2.

Table 3	The gap[5] model for the ability of core inflation to predict future inflation			
Core	R^2	β (s.e)	*P - value* $H0: \beta = 1$	*t - statistic*
1-month ahead (k=1)				
core_exc_vol	0.009	0.056(0.059)	0.348	0.94
cpi_exl_fuel	0.010	0.078(0.079)	0.329	0.98
core_cpi_xfe	0.014	0.067(0.059)	0.255	1.15
core_cpi_xfood	0.000	0.002(0.068)	0.979	0.03
core_cpi_xadmin	0.008	0.049(0.060)	0.413	0.82
Trim(15,15)	0.060	0.185(0.077)	0.018	2.40**
3-months ahead (k=3)				
core_exc_vol	0.141	0.644(0.170)	0.000	3.79***
cpi_exl_fuel	0.052	0.460(0.209)	0.031	2.20**
core_cpi_xfe	0.188	0.711(0.158)	0.000	4.51***
core_cpi_xfood	0.026	0.314(0.207)	0.133	1.52
core_cpi_xadmin	0.018	0.214(0.170)	0.212	1.26
Trim(15,15)	0.213	0.752(0.154)	0.000	4.88***

Notes: *Standard errors (s.e) are corrected for first-order serial correlation. * $p<0.05$, ** $p<0.01$, *** $p<0.001$.*

Source: Author's calculations and BOS

Table 3 above presents results from the gap model above for both the 1-month and 3-months forecasting horizons. The results for 6-months and 12-months horizons are in Appendix 1. The first panel of table 3 shows the results of the gap equation for 1-month ahead horizon. Among the six measures considered in this case, only the coefficient related to the 30%-trimmed is statistically significant at both 5% and 10% levels but not at 1% level. This means that for the shortest horizon possible, 30% trimmed mean indicator is the only candidate, which provides the significant predictive power as shown by its relatively highest $R^2 = 0.062$, among the respective candidates.

[5] This model actually tests whether the current gap between the headline and core inflation is statistically significantly in relation to the gap between the current and future headline inflation. It actually enables assessment of the convergence of headline inflation towards measure of core inflation, after a temporary shock.

Nonetheless, as the horizon increases to 3 months, the number of indicators which show a significant explanatory power for predicting future headline inflation increases to four. The coefficients for the models related to 30%-trimmed mean, CPI-excluding food and energy and the CPI-excluding the most volatile items are all statistically significant at 1%, 5% and 10%. The coefficient for CPI-excluding only energy is significant at any level above 3.1%. In this case, the indicator that has the relatively highest R^2 is the 30%-trimmed mean followed by the CPI-excluding food and energy, then CPI-excluding the most volatile items and finally the CPI excluding energy.

It is worth noting that as the forecasting horizon increases to six and twelve months, the predictive power of most core inflation indicators increase too. For example, the number of candidates which have a significant predictive power for the future headline inflation increase from four to five as the forecasting horizons increase to six and twelve months. In all these four horizons used in this paper, the CPI-excluding food does not have any predictive content for the future headline inflation, which is evidenced by its relatively lowest R^2 among the core inflation candidates.

6 CONCLUSION AND POLICY RECOMMENDATIONS

In conclusion, the foregoing attempt to measure core inflation and their evaluation helped in identifying what best measures can be used in the case of Lesotho. Using CPI data for the sample period from March 2009 to December 2017, the paper estimated six measures of core inflation, which generally involved measures that are based on exclusion of some items in the aggregate inflation rate. The evaluation of these measures against the set of criteria mentioned above has revealed important points about the behaviour of underlying inflation rate in Lesotho.

All of the calculated measures of core inflation have the desirable features of being easily calculated, timely and understandable by the public. This means that they can be produced almost at the same time as the overall CPI inflation. They can also be verifiable by the parties external to the CBL and this means they are credible. Nonetheless, some measures are superior in performance relative to others when evaluated against certain criteria. All of the calculated core inflation indicators exhibited the mean and the volatility (measured by standard deviation) lower than the headline inflation except for the CPI-excluding administered prices. The measures with lowest volatility include the 30%-Trimmed mean, CPI-excluding food and energy and the CPI-excluding the most volatile items with volatility of 0.74 per cent, 0.79 per cent and 1.04 per cent, respectively.

In terms of tracking trend inflation, the 30%-Trimmed mean, CPI-excluding food and energy outperformed other measures with the lowest volatility around the trend. The root mean squared errors (RMSE) were also calculated for the measures, from which 30%-trimmed mean, CPI-excluding fuel and CPI-excluding the most volatile items outperformed others with lowest RMSEs. This means that these measures are able to track the trend inflation relatively well.

The last criterion used is the predictive ability of core measures in relation to the future headline inflation. In this case, assessment was made to determine which measures are able to predict future inflation using the p-values of the coefficients of the deviation of headline inflation from the core indicators as shown in the gap model in the preceding section over the horizons of one, three, six and twelve months ahead. According to the results, the 30%-trimmed mean outperformed all other core indicators in all the forecasting horizons. In the one-month ahead forecast, it is the only candidate that passes the test of predictive power. As the forecasting horizon increases to three and six months ahead, the 30%-trimmed mean and CPI-excluding food and energy outperforms other candidates. However, for the twelve-month ahead forecasts, the 30%-trimmed mean followed by the CPI-excluding the most volatile items and then the CPI-excluding food and energy outperform others in terms predictive ability.

As the above analysis shows, it is apparent that the 30%-Trimmed mean outperforms all of the five measures calculated. The fact that other measures do not consistently follow the 30%-trimmed mean in terms of their performance ranking in predicting future headline inflation, makes it the only candidate that is recommended for Lesotho's case relative to the other five. It is in this regard that Central Bank of Lesotho has adopted the use of the 30%-trimmed mean as its core inflation measure. Others measures that are discussed above are complex in calculation such as the SVAR and persistence weighting, for example and they may not be easily understood by the public but they will be calculated in future in order to use them for internal consistency and robustness checks with the 30%-trimmed mean.

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APPENDIX

Appendix 1	The gap model for the ability of core inflation to predict future inflation			
Core	R^2	β (s.e)	*P - value* $H^0 : \beta = 1$	*t - statistic*
K=6				
core_exc_vol	0.233	0.956(0.188)	0.000	5.08***
cpi_exl_fuel	0.124	0.835(0.241)	0.001	3.46***
core_cpi_xfe	0.240	0.918(0.177)	0.000	5.18***
core_cpi_xfood	0.007	0.206(0.265)	0.439	0.78
core_cpi_xadmin	0.056	0.463(0.207)	0.027	2.24***
Trim(15,15)	0.295	1.008(0.169)	0.000	5.96***
K=12				
core_exc_vol	0.282	1.329(0.239)	0.000	5.56***
cpi_exl_fuel	0.165	1.249(0.316)	0.000	3.94***
core_cpi_xfe	0.260	1.196(0.227)	0.000	5.27***
core_cpi_xfood	0.002	0.147(0.383)	0.702	0.38
core_cpi_xadmin	0.089	0.774(0.280)	0.007	2.77***
Trim(15,15)	0.542	1.719(0.178)	0.000	9.67***
Source	Author's calculations and BOS			