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CHARACTERISTICS OF INFLATION IN BOTSWANA - HIGH OR LOW PERSISTENCE

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Abstract: *Inflation persistence has been defined in various, but somewhat equivalent ways. This is an important topic in the literature since inflation persistence has serious monetary policy implications in terms of its impact on the output costs of reducing inflation to a desired level and on the ability of the central bank to achieve its inflation objective. Although the topic has been extensively researched for developed countries, the same is not true for developing countries; hence, this paper is the first to focus on investigating the persistence property of inflation for Botswana. The paper uses the reduced-form approach and estimates persistence in terms of the augmented Dickey-Fuller test, the sum of the autoregressive term coefficients and half-life. These tests point to a high level of persistence in Botswana's inflation aggregates (headline and trimmed-mean core inflation, as well as core inflation excluding administered prices). A notable finding is that the adjustment of administered prices seems to help reduce inflation persistence in Botswana. The empirical results can be used to improve monetary policy effectiveness, and also the forecasting performance of macroeconomic models in Botswana.*

1. INTRODIUCTION

Inflationpersistence has been defined differently in economics literature. Some view it as the phenomenon where inflation exhibits inertia i.e., an inflationary trajectory that tends to continue after its cause has ceased to exist (cf. Hertel and Lezczynska, 2013). In this context, inflation would be viewed as having a tendency to remain constant. This implies that inflation would tend to be perpetuated around the recent level, in the absence of any economic shock that could move it elsewhere (see Fuhrer, 2009 for details). Others consider the persistence of inflation as the degree to which past shocks have effect on current inflation. Yet other researchers, more precisely, regard inflation persistence as referring to the speed with which inflation returns/converges to the baseline (or equilibrium, or mean) value after a shock (Willis, 2003; Marques, 2004). As clarified by Margues (2004), the issue is about the speed with which inflation responds to a shock.Specifically, if the speed is low we say that inflation is (highly) persistent while if the speed is high we say that inflation is not (very) persistent" (Margues, 2004, p.8).

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High persistence means that the impact on inflation of changes in the macroeconomic variables that determine inflation lasts very long since inflation does not quickly respond to shocks. Thus, high inflation persistence has serious monetary policy implications, given that it can undermine the public's confidence in the central bank's policy. As Jain (2013) puts it, it could cause divergence between inflation expectations and the central bank's inflation objective if expectations become sensitive to the economic shocks. Consequently, in response to a temporary shock (such as a rise in the price of fuel), inflation that was supposed to only rise temporarily and then fall back, would instead rise for a long time, despite the central bank's policy to control it. This is what would happen if the public did not believe that the central bank's mandate to maintain price stability is credible.

A consensus in modern macroeconomic analysis is that monetary policy can reduce inflation by causing a slack in economic activity[1]. Meanwhile, the extent of economic slack to achieve the needed reduction in inflation depends on the degree of persistence in inflation; the higher the persistence, the greater the amount of output that must be lost to achieve the inflation reduction (cf. Moreno and Villar, 2009).In this context, the output costs of disinflation associated, even with moderate inflation levels, need not be small; they can be accentuated by the high persistence of inflation.

The foregoing arguments imply that it is important for monetary policymakers to have a good understanding of the underlying patterns and determinants of inflation inertia. Such understanding would enable the central bank to more accurately forecast inflation and make appropriate monetary policy decisions in response to inflation shocks.

In this context, the objective of this paper is to estimate the degree of persistence for Botswana's inflation. The degree of persistence in inflation provides an important test concerning the effectiveness of monetary policy in controlling inflation. In relation to this, Phiri (2016) explains that the persistence of inflation provides an indicator of whether or not the monetary authorities have appropriate control over the inflation process. In this regard, "… high levels of inflation persistence signal the inability of Central Banks to control inflation such that any deviations of inflation from its steady-state will ensure that inflation does not easily adjust back [to] its long-run equilibrium" (Phiri, 2016, p.3).

In terms of approach, the paper adopts the reduced-form approach and uses a univariate model of inflation to estimate its persistence. This approach is commonly used to study persistence, as opposed to the structural approach. The latter entails structural econometric models in which the perceived causal

1 This phenomenon is referred to as the sacrifice ratio.

economic relationship between inflation and its determinants is modelled in the context of a multivariate approach (cf. Margues, 2004).

This paper is organised as follows. This introductory section is followed by a brief review of relevant literature in Section 2. Section 3 presents the data and methodology of the study, while section 4 presents estimation results and discussion. Then section 5 offers concluding remarks.

2 BRIEF LITERATURE REVEIW

Formally, the definition of inflation persistence can be said to have been established by the Inflation Persistence Network (IPN) research programme for the euro area countries which considered inflation persistence as "the tendency of inflation to converge slowly (or sluggishly) towards its long-run value following a shock which has led inflation away from its long-run value" (Altissimo, Ehrmann and Smets, 2006, p. 9). This definition of persistence has two practical implications: one implication relates to the relatively low speed of adjustment of inflation in response to a macroeconomic disturbance; and the other relates to the assumption about the equilibrium level of inflation (or the mean of inflation) which inflation converges to after a macroeconomic shock (Vladova and Pachedjiev, 2008).

In terms of the sources of inflation persistence, the IPN discussed them in the context of the prevailing theoretical framework for empirical analysis of inflation, viz., the New Keynesian Phillips Curve (NKPC) (Vladova and Pachedjiev, 2008). Several papers produced under the IPN recognise three major sources. The first is the intrinsic persistence, which is viewed as originating in past inflation, particularly in the mechanisms of price- and wage-setting processes that use a backward-looking indexation rule. The second is the extrinsic persistence. This emanates from inertia in the factors determining inflation, which is then inherited by inflation. The third relates to the inflation expectations formation. In this case persistence arises because inflation characteristics have impact on the behaviour of private agents and that private agents only have imperfect information, such that their behaviour involves learning and not based on rational expectations. These factors have the effect of slowing private agents' responses to macroeconomic disturbances (see Vladova and Pachedjiev, 2008; Kota, 2011 for details).

2.1 Modelling Inflation Persistence

Researchers have used two main approaches to measure inflation persistence, the reduced form and structural approaches. In the reduced-form modelling approach, inflation persistence is merely an empirical property of an observed inflation measure, without an identifiable economic source of the persistence (see Fuhrer, 2009). On the other hand, in the structural modelling approach,

persistence can be identified with one of three types of economic sources, as discussed below.[2]

In terms of measuring inflation persistence, the reduced-form approach's analytical representation entails, mostly[3], modelling inflation using a univariate autoregressive equation. Then various measures of persistence are derived from the autocorrelation function for inflation. Examples of such measures include the sum of the autoregressive coefficients of the equation, half-life, the spectrum at zero frequency, etc.

Meanwhile, structural methods emphasise that a measure of inflation persistence can only be useful to policymakers if it can be associated with a structural economic source. Structural methods are commonly based on analysis of structural model parameters of the NKPC (and its hybrid version)in order to parse underlying sources of inflation persistence into extrinsic persistence, intrinsic persistence and persistence induced by the actions or communication strategy of the central bank (for details, see Fuhrer, 2009; Hertel and Lezczynska, 2013). These are multivariate structural models[4], in which oneof the central equations is the NKPC equation used by policy institutions and academia to perform forecasts and policy analysis. A typical NKPC equation is expressed as follows:

$$\pi_t = \delta_1 \pi_{t-1} + (1 - \delta_1)E_t(\pi_{t+1}) + \delta_2 mc_t \quad (1)$$

where π_t is actual inflation (annual) in the current period, π_{t-1} is the previous period's annual inflation, $E_t(\pi_{t+1})$ is expected annual inflation one period ahead (whereby expectations of future inflation are formulated using information available in the current period)[5], mc_t is real marginal costs in the current period.

It is apparent that structural models have advantages over the reduced-form models, particularly as regards policy analysis. The main advantage being the ability to identify the sources of inflation persistence, which is essential to the policymakers. Nevertheless, univariate (reduce-form) models have tended to be

2 Fuhrer (2009) calls the former reduced-form persistence, and labels the latter structural persistence.

3 Some studies used multivariate models, such as vector autoregressive models, to obtain measures of persistence that use information not only in inflation, but also in other variables, to make inference about the persistence of inflation.

4 Some of the authors distinguish between reduced-form analysis (which they associate with the univariate model) and structural analysis (which they regard as synonymous to multivariate models). But it is important to recognise that not all multivariate models can be regarded as structural. For example, vector autoregressive models entail multivariate analysis, but are not necessarily structural.

5 The E_t is the mathematical expectations operator.

the preferred workhorse in the persistence literature (see Vladova and Pachedjiev, 2008; Ellul and Micallef, 2013).

It is noted that each of the three sources of inflation persistence can be identified in equation (1). The first explanatory variable shows the role of past inflation in contributing to inflation persistence. The degree to which persistence is determined by past inflation (intrinsic persistence) is given by the parameter δ_1. The second explanatory variable indicates the contribution of inflation expectations to inflation persistence (known as expectations-based persistence). The weight of expectations in the inflation process is given by the parameter $(1 - \delta_1)$.[6] The last explanatory variable represents the impact of cost conditions on price changes. Given the usual assumption that cost conditions vary according to the cyclical position of the economy, this explanatory variable is often proxied by different macroeconomic variables that correspond to the business cycle (e.g., output gap, the deviation of unemployment from the non-accelerating inflation rate of unemployment, etc). The parameter, δ_2, indicates the degree of contribution of extrinsic persistence to inflation.

In calculating inflation persistence, two crucial issues need to be considered. One issue is that any estimate of inflation persistence depends on the assumed steady state (or equilibrium level) inflation path (see Margues, 2004). This is because in order to tell whether inflation is moving slowly or quickly in response to a shock, there is need for information concerning the path inflation could have followed in the absence of the shock, and on the level inflation is expected to be after the effect of the shock has dissipated. The information on this is provided by the central bank's target level, or average level of inflation (where the central bank defines its inflation objective in terms of a range).[7] Many empirical studies, particularly those that used the univariate autoregressive model of inflation in the reduced-form approach, have calculated persistence assumingthat the long-run equilibrium value of inflation remains constant throughout the period of analysis (ibid). As Kota (2011) observes, the assumption of constant equilibrium inflation level was commonly used in empirical studies prior to 2011.A constant steady state inflation level tends to result in a large value of inflation persistence. However, some studies have used a time-varying level of steady state inflation (see, for example, Margues, 2004; Kota, 2011; and Darvas and Varga, 2013). The time-varying estimation approach can help in capturing changes in inflation

6 The parameters δ_1 and $(1 - \delta_1)$ are assumed to add to unity, in accordance with modern macroeconomic theory that maintains that there is no long run trade-off between inflation and economic growth (cf. Ellul and Micallef, 2013).

7 The underlying assumption is that in the medium- to long-run, inflation is determined by monetary policy. In this context, we can consider the long run level of inflation as corresponding to the central bank's inflation target (Margues, 2004).

persistence overtime, depending on the various economic events that occurred and impacted on inflation developments. For example, according to the empirical country-specific results of Darvas and Varga (2013), the US experienced low inflation persistence in the 1950s and 1960s. However, persistence increased in the 1970s due to the oil crisis; it then decreased since the 1980s, initially due to aggressive monetary policy, and subsequently, due to the global economic and financial crises.

The other important issue to consider when computing a measure of inflation is whether the steady state inflation level should be treated as exogenous or endogenous to the hypothesized shock to inflation. When considered exogenous, the long-run inflation path cannot be affected by shocks; but if endogenous, it can be influenced by some shocks. In the univariate modelling context, when measuring inflation persistence the long-run inflation level will inevitably be considered exogenous and independent of macroeconomic shocks (see Margues, 2004).

Yet another important issue to keep in mind is that analysis of inflation persistence differs from analysis of factors driving inflation. Analysis of the factors that drive inflation focuses on determining the factors that underlie/cause inflation movements/trends. Such analysis has been undertaken in various countries, particularly by central banks. Indeed, such analysis is needed by the monetary policy committee of the central bank in order to appropriately adjust monetary policy.

However, analysis of inflation persistence relates to the examination of the behaviour of the inflation process itself (see Vladova and Pachedjiev, 2008). To the knowledge of the author, this kind of analysis has never been undertaken in respect of inflation for Botswana. Thus, this study contributes to the literature by analysing the characteristics of Botswana inflation.

2.2 Empirical Studies on Inflation Persistence

A number of studies have estimated inflation persistence for different countries. Extensive empirical analysis of inflation inertia was undertaken for the euro area, particularly under the IPN, and also for individual European Union member states. The IPN was a collaborative effort of all the national central banks to undertake a large-scale research project of the Eurosystem entitled *Inflation Persistence Network*[8] whose purpose was to empirically study the persistence of inflation in the euro area. Most of the studies examined inflation persistence in the context of the reduced-form approach, using the univariate autoregressive model (Ellul and Micallef, 2013).In summarising the main findings of the IPN studies, Altissimo

8 This IPN project was implemented during the period 2003-2005.

et al. (2006, p.7) observed that "under the current monetary policy regime, the estimated degree of inflation persistence in the euro area is moderate".

In the case of the Central and Eastern Euro countries, empirical evidence relating to Estonia, Latvia and Lithuania suggests that inflation persistence tends to be higher when inflation is also higher (Darvas and Varga, 2013).

For Albania, Kota (2011) found that the persistence of headline inflation was higher over inflationary periods. However, inflation persistence declined after 1997, when monetary policy became effective in stabilising inflation expectations.

Similarly, Gamber, Liebner and Smith (2013) find that inflation persistence in the US tended to be high over high inflation periods and lower during lower inflation periods. On the other hand, using Bayesian methods, Pivetta and Reis (2004) obtained different results for the US economy. Their finding is that, despite use of different estimation methods, inflation persistence in the US had been high and the persistence remained high for over three decades since around the mid-1960s.

For Bulgaria, Vladova and Pachedjiev's (2008) univariate model indicate overall low level of inflation persistence for inflation. This result is not unique to Bulgaria.Ellul and Micallef (2013) also using a univariate model, observed a low level of inflation persistence for Malta.

Coming closer to home, Mourelle and Cuestas (2009) investigated inflation persistence for a group of African countries -Burkina Faso, Cameroon, Egypt, Ethiopia, Gambia, Ghana,Ivory Coast, Kenya, Madagascar, Mauritius, Morocco, Niger, Nigeria, Senegal, Seychelles,South Africa, Sudan and Swaziland. Using a smooth transition autoregressive (STAR) model, the authors find lack of persistence patterns in most of the countries. This implies that macroeconomic shocks to inflation tend to have temporary effects.

Another study using inflation data for some African countries is Phiri (2016). Using a panel data modelling approach for 46 countries[9] that include Botswana, Phiri estimate a first-order autoregressive model for inflation for inflation-targeting countries, non-inflation targeters and for the full-sample. Phiri's results lead him to make three inferences, which can be summarised as follows. Firstly, as in the case of Mourelle and Cuestas (2009), Phiri (2016) states that overall inflation in African

9 The panel data are for the period 1994-2014 for the following countries:Algeria, Angola, Benin, Botswana, Burkino Faso, Burundi, Cameroon, Cape Verde, Central African Republic (CAR), Chad, Democratic Republic of Congo (DRC), Cote d□ Ivore, Egypt, Equatorial Guinea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea Bissau, Kenya, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, South Africa, Sudan, Swaziland, Tanzania, Togo, Tunisia, Uganda, Zambia and Zimbabwe.

countries has not been very persistent. Secondly, although inflation rates were lower for non-inflation targeting countries than for inflation targeters (Ghana and South Africa) in the pre-inflation targeting periods, in the post-inflation targeting period, inflation persistence is higher (by 290 percent) for non-inflation targeters, while it has fallen(by 40 percent) for inflation-targeters.

However, in a country-specific study, Phiri (2012) investigated the existence of threshold effect in the aggregate inflation for South Africa.He finds that inflation varies between two regimes. Notably, when inflation is below the threshold value, inflation is highly persistent (characterised by the presence of a unit root); while when inflation rates are outside the threshold value, it exhibits low persistence.

For Botswana, Mokoti (2011) attempted to estimate the sacrifice ratio (a measure of lost output growth that is required to reduce inflation by a percentage point). When coupled with inflation persistence, the sacrifice ratio has implications for the output cost of monetary policy. High levels of inflation persistence should, in general, imply agreater the sacrifice ratio, and more costly disinflationary monetary policy. Mokoti's (2011) results are difficult to interpret in the context of the two-variable model that the study used. As pointed out by the author, such a model cannot identify monetary shocks from other demand shocks. However, from the dominance of supply shocks, in influencing aggregate domestic output, Mokoti concludes that the sacrifice ratio in Botswana should be small. It is observed here that this conclusion is not consistent with Mokoti's (2011) finding that, for the period studied,Botswana's inflation was characterised by existence of unit root. The presence of unit root points to a highly persistent inflation process, which implies a costly disinflation policy and hence, a large sacrifice ratio.

This brief literature review on persistence shows that investigating the persistence of inflation remains an important topic. However, although research (both theoretical and empirical) is abundant for developed countries, such research is sparse for developing countries, particularly for African countries. Consequently, given the absence of such research for Botswana, it is imperative to estimate inflation persistence for Botswana, using country-specific inflation data in order to provide an idea of the cost of disinflationary policy, and the effectiveness of monetary policy in Botswana.

3. DATA AND METHODOLOGY

This study investigates inflation persistence in the aggregate headline[10] inflation and core inflation measures used by the Bank of Botswana (BoB). The core inflation measures are the trimmedmean and inflation excluding administered prices.

10 Headline inflation refers to inflation calculated from the consumer price index (CPI) that encompass all the individual commodity prices.

In addition to headline inflation, BoB also looks at the core inflation measures for the following reasons. The trimmed-mean core inflation excludes volatile price movements in headline. In this regard, the trimmed-mean core inflation should better capture the trend in underlying domestic inflation, as compared to headline inflation. As for core inflation excluding administered prices, the measure excludes prices that are not market-determined and hence, not subject to monetary policy effect. These are prices that are determined by government policies, such as fuel prices, electricity tariffs, etc. Thus, core inflation excluding administered prices should give a betterindication of policy stance (compared to headline inflation).

As explained above, the literature presents two main approaches that have been used to model the backward-looking tendency for inflation.Despite the advantage presented by the structural modelling of inflation persistence, no consensus has yet emerged on the most appropriate way to model inflation (see for example Kota, 2011).

As stated above, univariate models have been more prevalent than structural models in the persistence literature. The most commonly used measure of persistence is the sum of the coefficients of lagged inflation terms, which represents a measure of intrinsic persistence – reflecting backward-looking inflation expectations. The reasons for the dominance of the univariate models include (i) ability to produce concise results that can be directly comparable across countries, and (ii) univariate models can be implemented on sub-indices, which helps to shed light on the persistence properties of headline inflation.

Given the paper's modest objective of aiming to provide just a measure of a general extent of inflation persistence in Botswana, the paper uses univariate models to measure persistence of inflation in Botswana. It is considered that this approach should provide a starting point of analysis of inflation persistence in Botswana.

3.1 Autoregressive Modelling of Inflation and Persistence

This study specifies the standard autoregressive (AR) model in the conventional form as:

$$y_t = \gamma + \sum_{i=1}^{p} \alpha_i y_{t-i} + \varepsilon_t \tag{2}$$

where y_t represents year-on-year inflation in the current period (i.e., the current month, given the monthly data used in the study), ε is a classical error term, while γ and α_i are unknown coefficients to be estimated.

In order to have a single indicator of inflation persistence, equation (1) is transformed and estimated in its equivalent form in (2).

$$\Delta y_t = \gamma + \sum_{i=1}^{p-1} \theta_i \Delta y_{t-i} + (\rho - 1) y_{t-1} + \varepsilon_t \tag{3}$$

where, in this reparameterised equation, (p – 1) is the optimal lag length for the empirical model (established by using one of the information criteria), and the parameter of interest is given by

$$\rho = \sum_{i=1}^{p} \alpha_i \tag{4}$$

In particular, ρ measures persistence in terms of the sum of the autoregressive (SAR) terms' coefficients in (1). Notably, the SAR terms' coefficients, which essentially capture serial correlation among the autoregressive terms, provides information on the degree of persistence of shocks to inflation. Hence, SAR coefficients measure inflation persistence in terms of the speed or sluggishness at which inflation responds to shocks (see Vladova and Pachedjiev, 2008).

Unit Root Tests

An important point to note is that when equation (2) is estimated with the lagged first differences as regressors, the equation gives us the augmented Dickey-Fuller (ADF) testing equation for the presence of a unit root in the time series.[11] In this regard, it is often perceived that the first test of persistence should be a unit root test (Fuhrer, 2009; Roache, 2014). Assessing the stationarity property of inflation is important because it helps policymakers determine whether shocks to the inflation series are permanent; implying that the persistence of the series is infinite.

Half-Life

In simple terms, a stationary process is described as a mean-reverting process; following from its tendency to frequently cross its mean value. In equation (2), the term ($\rho - 1$) gives a measure of the speed of mean reversion. As noted in Ellul and Micallef (2013), one common way to measure the speed of mean-reversion is to calculate the half-life of a shock – the concept of half-life of inflation refers to the estimated time taken for half of a unit shock to inflation dissipate. It is noted that the larger the autoregressive coefficient (i.e., the persistence parameter), the greater the number for half-life of a shock to inflation, and in turn, the longer it takes for inflation to return to its mean value (or long-run value) after a shock.

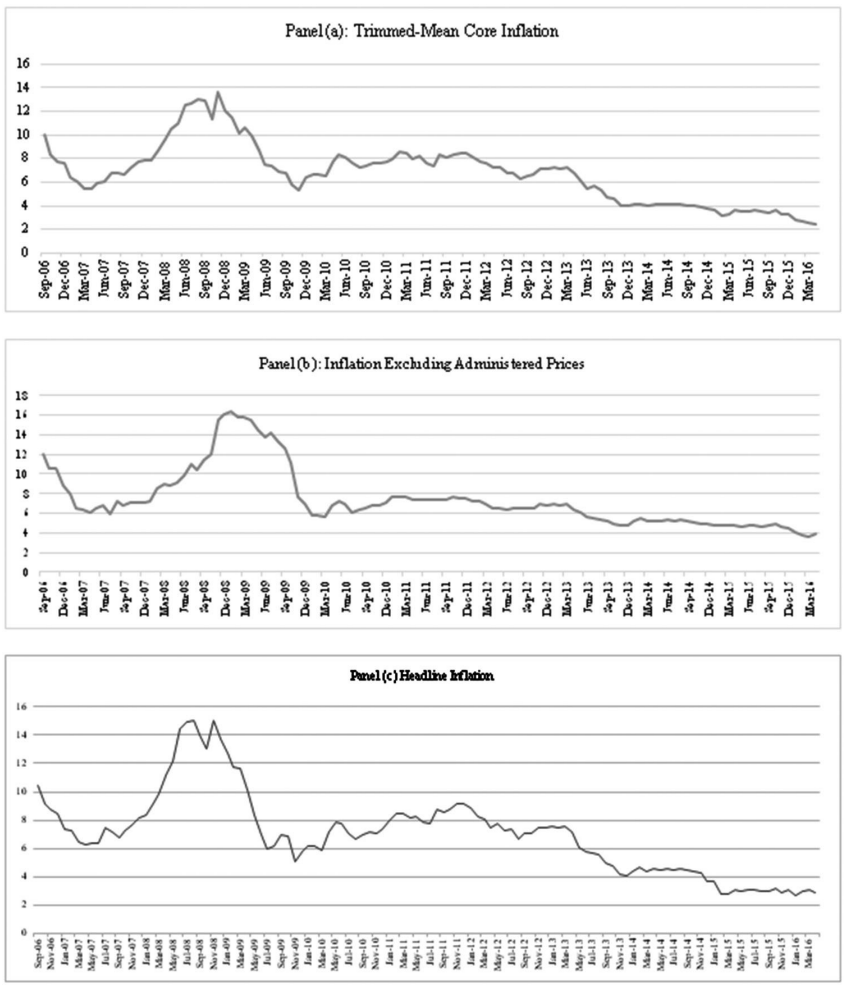
The exact calculation of the half-life for an AR(p) process is rather difficult. Consequently, in empirical work the AR(1) process is used an approximation.

11 If equation (2) is estimated without lagged first-difference terms, then the model reduces to the Phillips-Perron unit root testing equation, which does not use lagged terms of the dependent variable to whiten residuals.

Thus, although the empirical models in this paper range from AR(2) to AR(5) – see Table 1 – the half-life associated with the estimated values of persistence from these models is calculated using a first-order autoregressive model. For an AR(1) model, half-life (HL) measured in years, is calculated as:

$$HL = \frac{\ln(0.5))}{ln|\rho|} \tag{5}$$

Prior to presenting estimation results, the graphical depiction of Botswana's inflation series is presented in Figure 1.



Source: Statistics Botswana data

Figure 1. Inflation Aggregates for Botswana

As Figure 1 shows, apart from the spike in inflation series that occurred in the 2008-09 period, Botswana core inflation (whether measured by the trimmed-mean

inflation (see panel (a)) or by excluding administered prices (see panel (b))) has very broadly fluctuated around the mean value of about 7 percent.(It is noted, however, that the trimmed-mean core inflation seems to have a more noticeable trend than core inflation excluding administered prices.) Similarly, headline inflation seems to have very broadly fluctuated around 7 percent, although it appears to have an evenmore pronounced downward slope, particularly in the post-2011 period. Hence, the estimation of a fixed-mean model for inflation that is undertaken in this study seems justifiable.

4. ESTIMATION RESULTS

As already stated, unit root tests seem to be the logical first step in the empirical investigation of inflation persistence. Unit root test results help make a broad statement about the time series properties of inflation. Notably, the tests indicate whether inflation is stationary (or non-stationary); implying that shocks to inflation die off over time (or permanent).

4.1 Unit Root Test Results

Given that the transformed univariate model of inflation (equation (2)) is the same as the ADF unit root testing equation, this paper uses the ADF approach to examine time series properties of Botswana inflation series. That is, the decision as to whether the three Botswana inflation series (headline and trimmed-mean core inflation, as well as core inflation excluding administered prices) have unit root will be based on the ADF test results. It is noted, however, that a rigorous unit root testing exercise may require the use of several unit root testing approaches, given that each has its strengths and weaknesses – this may be considered in future work.

The results for performing unit root tests on the levels of the inflation series are presented in Table 1. As can be seen, all the inflation aggregates are stationary in levels, except inflation excluding administered prices (for which the empirical t-value is greater, instead of being less, than the tabulated t-value at the 5% level)[12]. What this shows is that the presence of administered prices in two inflation aggregates (headline and trimmed-mean core inflation) causes them not to be infinitely persistent; while the absence of administered prices in inflation excluding administered prices causes it to be infinitely persistent. This hypothesis seems to be supported by the finding in Vladova and Pachedjiev (2008) to the effect that, for Bulgaria, administered prices inflation displays a very low level of persistence.

The unit root test outcome seems to suggest that administered prices play a significant role in the time series properties of Botswana inflation. The results

12 Core inflation excluding administered prices is stationary in first differences.

seem to imply that in the absence of prices that can be institutionally controlled by Government policy, shocks to inflation are permanent. This seems to imply that administered prices in Botswana behave in a manner that is supportive to the objective of monetary policy.

Table 1.
ADF Test Results for Botswana Inflation

Inflation Type	*T-Statistic*	*SIC-Lag Length*
Headline inflation	–3.78*	4
Trimmed-mean core inflation	–4.92*	5
Core inflation excluding administered prices	–2.34	2

Notes:

1. *Dickey-Fuller 5% critical values = -2.89 with intercept but no trend; -3.45 with intercept and trend.*
2. ** denotes significance at the 5% level.*
3. **Source:** *Author's model estimations.*

On the other hand, the results also seem to imply that some of the commodity-group prices in the CPI may not be amenable to monetary policy effect. These commodity-group prices could be associated with international commodity prices (e.g., global oil prices). This argument would particularly hold if it can be argued that the BoB has been focusing on the price stability over the period spanning September 2006 to present, as seems to be suggested by the literature.

Sum of the Autoregressive (SAR) Coefficients

The unit root test results imply that headline and trimmed-mean core inflation aggregates may be modelled as stationary autoregressive processes with a measure of persistence (approximated by the estimate of) 'significantly' less than unity, in order to reflect stationarity. However, the measure of persistence associated with inflation excluding administered prices may be expected to be unity or, close to unity (since the series is non-stationary). It should be recalled that the ADF unit root test has low power against a stationary process characterised by an autoregressive coefficient that is less than, but close to unity.

Table 2 presents the estimates of (based on equation (2)), which represent the degree of persistence in each inflation aggregate.

Table 2.
Inflation Persistence Estimates

Inflation Type	*Inflation Persistence Measure*
Headline inflation	0.89
Trimmed-mean core inflation	0.85
Core inflation excluding administered prices	0.92

Source: Author's model estimations.

The estimated value of persistence ranges from 0.85 to 0.92. The smallest estimated persistence value is for trimmed-mean core inflation, while the largest value is for core inflation excluding administered prices.

The estimated values of inflation persistence are consistent with the unit root testing results. According to unit root testing results, headline and trimmed-mean inflation aggregates have no unit root, while inflation excluding administered prices has a unit root. The correspondence to the SAR results is that stationary inflation series have smaller persistence values, whereas the series which has a unit root has a large estimated persistence value (close to unity).

In the overall, the estimated values of persistence are high for all the three measures of Botswana inflation. This implies that Botswana inflation, whether considered as headline or core inflation, has a high level persistent. This, in turn, implies that shocks to Botswana inflation tend to have permanent effects, rather than transitory effects on inflation aggregates. In these circumstances, controlling inflation using monetary policy becomes very challenging. In other words, once inflation is subjected to a shock that takes it away from the equilibrium value (say, the value of inflation within the Bank of Botswana's objective range), then it would become very difficult for BoB to bring inflation back inside the objective range.

Half-Life

This sub-section presents the estimated time taken by Botswana inflation measures to return to the equilibrium/mean value following a unit shock. The estimated half-lives, based on the model of Botswana inflation measures, are presented in Table 3.

Table 3.
Half-Lives for Shocks to Botswana Inflation

Inflation Type	*Estimated Half-Life (Months)*
Headline inflation	30.3
Trimmed-mean core inflation	33.3
Core inflation excluding administered prices	22.5

Source: Author's calculations.

The results of half-lives suggest the trimmed-mean core inflation is the most persistent aggregate, followed by headline inflation; while core inflation excluding administered prices is the least persistent. Specifically, the results suggest that the impact of a shock to trimmed-mean core inflation is halved over a period of about 33 months, while the impact of a shock to core inflation excluding administered prices is halved over a period of about 23 months.

It is noted that the information from the half-life measures is not consistent with that provided by the ADF unit root tests and the sum of the autoregressive coefficients. This inconsistency is not necessarily a puzzle. Notably, the inconsistency can perhaps be explained in terms of the following points that have often been noted in the literature on persistence. Firstly, as has already been explained, the half-life for models has to be approximated using the half-life for the model. However, it is possible that the half-life for a more general model, with more lags included, may differ from that obtained from the model. Secondly, the half-life measure may significantly underestimate the level of persistence if any of the coefficients of the model of inflation is negative (see Hertel and Lezczynska, 2013).

Nevertheless, inconsistency aside, when taken together, all the results (the SAR and half-life indicators, as well as the unit root outcome) point to a high level of persistence for Botswana inflation. Thus, macroeconomic or price shocks to inflation would tend to have a long-lasting impact on inflation.

However, the foregoing empirical results should be taken with caution. The estimated model did not account for possible structural breaks in the inflation series. Existence of structural breaks tends to reduce the power of unit root tests against the null hypothesis. Thus, it is possible that after accounting for structural change(s), the ADF test may not fail to reject the null hypothesis in respect of core inflation excluding administered prices. Similarly, the modelling approach adopted in the paper assumed a constant equilibrium value for inflation. This has the effect of accentuating the degree of persistence. It has been established in the literature that models that allow time-varying equilibrium value generate somewhat less persistence.

5. CONCLUSION

This study breaks new ground in the analysis of inflation persistence for Botswana. It contributes to the empirical literature of persistence, particularly for developing countries in Africa.

The study's estimated indicators of persistence all point to a high level of inflation persistence in Botswana inflation. This suggests that the control of domestic inflation by the Bank of Botswana is not an easy task since shocks to inflation would tend to have permanent effects on the trajectory of inflation. It is noted, however, that the level of persistence may be somewhat less than estimated in the context of a model allowing structural breaks in the trend of inflation and a time-varying equilibrium value of inflation (provided that the behaviour of "BoB's inflation target" justifies such an approach).

In terms of policy implications, the results on the persistence of Botswana inflation are useful as they should help improve understanding of the underlying

process of domestic inflation. This should help policymakers and researchers to improve on the macroeconomic models used for forecasting, inter alia, and policy analysis. Moreover, although the specific source of persistence cannot be identified, in order to reduce the degree of inflation persistence, BoB may consider enhancing efforts to conduct policy with a view to anchoring inflation expectations of economic agents. Notably, by reducing overall inflation persistence such that it does not cause divergence between inflation expectations and the inflation objective, BoB could ensure that actual inflation does not deviate for too long from what was announced as the medium-term objective for inflation.

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