The Science and Art of Communicating Fan Chart Uncertainty: The case of Inflation Outcome in Sierra Leone

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Abstract

The use of macro-econometric modelling technique has become a norm for policy decisions in central banks and in particular, the Bank of Sierra Leone. This study has leveraged on the technicalities of scientific and artistic approaches of assessing risks around point / baseline forecast; this in general makes it more convincing for probability confidence bands to be used in explaining uncertainty that surround point forecast in particular. In the case of this study, the use of the Box-Jenkins ARIMAX model has made it possible to highlight the relevance of Composite Leading Indicator (CLI) like Exchange Rate in alerting signals about early turning point of inflation outcome, both in terms of the uncertainty and risks surrounding its projections. With the derived (scientific) probability distribution of risks (30%, 60% and 90%), it was possible for the study outcome to unearth vast amount of information from the Inflation Fan Chart, particularly with respect to the art of providing balanced assessment of policy framework needed to communicate the BSL's price stability objective. While the use of Fan Chart is hailed as a very relevant tool, the paper also recommend the use of other model approaches like Scenario and Sensitivity analysis, also considered relevant in providing leading evidence of balancing risks surrounding macroeconomic outlook.

Keywords: *Fan Chart; Normal Distribution; Forecast uncertainty; Balanced Risks*

Jel Classification: *C15, C53, C81, E37, E59*

1. Introduction

Future deliberation, particularly one that is connected with policy decision in central banks is highly hinged on the assessment of uncertainty around point-forecast. This normally provide an idea of likely risks, which can either turnout to be symmetrical or asymmetrical, depending on various factors like the nature of the historical data used and in addition, the influence of Composite Leading Indicators (CLI) on the variable of interest. The

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use of uncertainty chart, as in the case with Fan Chart made its way in 1996, when Bank of England first introduce it as a way of improving communication of risks surrounding point forecast estimation (Razi and Loke, 2017). The technique is aimed at providing constructive assessment of uncertainty and risks that surround short-term inflation outlook, with models like ARIMA, ARIMAX and VAR (Jackson et al, 2019).

Given the heavy-weighted nature of statistical contents in the derivation of Fan Chart methodology (reference to Appendix 1), it is but appropriate to incorporate subjective judgments in ensuring consistency is maintained when addressing risks to forecast in general. On this note, it is therefore necessary that in the process of constructing a Fan Chart (particularly one that addresses the influence of a leading indicator like exchange rate) for thorough assessment of common risks affecting the variable of interest are rooted on theoretical foundation (Razi and Loke, 2017). The probability distribution surrounding forecast would normally provide enormous information pertaining to risks affecting forecast estimation and the extent of their uncertainty. The use of Fan Chart in particularly, makes it worthwhile for technocrats to provide thorough assessment of upside and downside risks, which are then forwarded to policy makers, based on their scientific outcome of likely risks that could emanate outside of point or baseline forecast. The use of this approach is now becoming a strong-hold for central banks around the world, particularly in relation to decisions that bothers around stipulating monetary policy rates, which is aimed at securing sustainable level of growth, while at the same time, addressing core mandate on price stability.

In a country like Sierra Leone, where the influence of external perturbations seem to be dominating volatile movement in economic indicators (Warburton and Jackson, 2020), it is almost certain for Exchange Rate in this case, to be utilised as a Composite Leading Indicator (CLI) in determining the direction of inflation dynamics in the country. Given the mandate of the central bank to monitor price stability, it has become a normal practice for forecasting outcomes to provide an assessment of risks that surround the outlook of inflation in the short term, particularly with the use of econometric models like ARIMA[X] and VAR. It is now a common practice for all monetary policy committee meetings at the Bank of Sierra Leone (BSL) to anchor decisions around Monetary Policy Rates (MPR) through assessment of risks, which would have been deliberated upon at technical level, in view of intense empirical research carried out by staff, mostly in the research and other policy oriented departments.

Unlike in institutions like the Bank of England, where the degree of uncertainty and asymmetry of Fan Chart interpretation is determined by a "*top-down*" approach of MPC members (Blix and Sellin (1997), the BSL seem to have utilised a "*bottom-up*" approach, in which the degree of uncertainty and asymmetry around Fan Chart is the resultant outcome from uncertainty and inclination of risks factors proposed at technical deliberation level.

In view of the above introduction, the motivation for this study is to facilitate critical discourse in view of the scientific process entailed in the construction of a Fan Chart, which is now a norm for policy deliberation at the BSL, particularly in affirming confidence on rates announced and the future outlook of growth and well-being for citizens in the country. On this note, the use of Box-Jenkins ARIMAX model is the recommended methodology for this study. This is done as a way of illustrating the relevance of statistical confidence levels in Fan Chart attributable to uncertainty emanating from point forecast and their interpretation when communicating outcomes about MPR to the public. The progress of this paper is therefore, based on the following research question: "*How relevant is probability confidence chart in ascertaining uncertainty and risks around inflation forecast for policy formulation at the BSL?*"

In order to answer the above research question pertaining to uncertainty and risks surrounding the use of Fan Chart, the researchers have identified key achievable objectives to affirm their empirical endeavours in the study:

- *Provide short-term inflation forecast using ARIMAX methodology;*
- *Examine the level of uncertainty and risks surrounding the forecast using Fan Chart probability confidence bands;*
- *Provide an assessment of risks based on (artistic) intuition in support of effective policy decision making in the short term.*

The rest of the paper is detailed as follows. Section 2 provides a summarised literature review pertaining to Fan Chart uncertainty and methodologies from earlier research endeapvours in communicating outcomes to the public. Section 3 provide details on the Science behind the construction of a Fan Chart; this is also further sub-sectioned to capture the methodological procedures entailed in the forecast process and the construction of a Fan Chart by utilising data from Sierra Leone. Section 4 provides a summary pertaining to the art of assessing Fan Chart uncertainty and risks, while Section 5 conclude, with pointers for sound policy deliberation and future endeavours.

2. Literature Review

The procedure for communicating uncertainty and risks in constructing a Fan Chart can prove very daunting, and even difficult, when the focus is to instill confidence surrounding point or baseline forecast to the public. Forward looking policies in central banks require accurate and precise projection of forecast outcomes, considered very important in affirming public confidence on the direction of an economy, particularly in relation to citizen's welfare, also linked with price stability mandate (Aikman et al, 2010).

According to Razi and Loke (2017), uncertainty around forecasts are normally presented using all or any of the three parameter approaches highlighted here: *(1) The use of quantitative assessment provide a probability density distribution using fan charts, with different possible outcomes; (2) The use of Scenario analysis provide forecasts of different scenarios, with different assumptions to enable possible outcomes in guiding successful policy decisions and (3) Sensitive analysis provide forecast based on estimation, with possibility of one key assumptions or series of shocks about a system*.

Depending on the sophistication level of institutional capability, many central banks are normally seen to be actively utilising all three approaches (reference to Razi and Loke, 2017) in order to improve the effectiveness of communicating uncertainty and risks to the public. This is also common in central banks, where inflation targeting is the dominant regime; this makes it more reinforcing and mandatory for those at policy level to assert their confidence when communicating outcomes to the public about future the direction of an economy (Franta et al, 2014; Elder, 2005).

Notably, study carried out by Ehrmann and Fratzscher (2005) investigated the impact of central bank communication on interest rate. The study outcome proved that monetary policy communication has a significant effect on the level of short and medium-term possibility of the yield curve. Reaction on the part of the MPC, particularly in view of speeches and testimonies portrayed relatively weak results, suggesting their infrequent and unresponsiveness to an increase in volatility as a result of communication.

As time progresses, research undertakings on the use of Fan Chart seem to have taken a more diverse approach, incorporating techniques like VAR and Bayesian Vector Autoregression (BVAR) as utilised by Franta et al (2014). This, like any other approach, provide scope in building understanding around the asymmetries of uncertainty and risks surrounding baseline forecast, but with illustration of the different possibilities emanating from the confidence band levels.

With reference to the use of Fan Chart in assessment of risks in the West African region, Mordi et al (2012) utilized STIF approach to forecast inflation. The outcome of their study revealed that disaggregated forecast approach can provide a more accurate means for policy decisions, particularly where risks are identified using specified confidence bands. Given the stochastic nature of data utilised, particularly inflation, outcomes from the empirical study, and its association with risks can help researchers explore different outcomes on how data can respond to *a priori* expectations, with the underlying focus in serving its purpose of addressing core policy decision of maintaining price stability.

Moving closer to home, Jackson et al (2019) developed a short term inflation forecasting (STIF) modelled on a parallel line with that of Mordi et al (2012); Box-Jenkins time series approach (ARIMA) was utilised to analyse inflation uncertainty and associated risks to Sierra Leone's short-term inflation outlook. The model was aided by thirteen Fan Charts as represented in the CPI disaggregated basket for Sierra Leone. This was done in a bid to enable policy makers' utilise expert judgments for all components in a bid to explore in detail, areas posing serious concern to price stabillity in the economy. The uniqueness of this paper is its interpretation of risks to each of the disaggregated components, while also improving credibility of decisions taken by policy makers at the Bank of Sierra Leone [BSL]. Empirically, Food and Non-Alcoholic Beverages proved to be the most threatening item to price volatility in the basket, indicating that shocks arising from within or outside of Sierra Leone can significantly impact headline CPI, with immediate pass-through effect to consumers' increased spending habit formation, at least in the short to medium term. The outcome of this empirical research shows uniqueness of the disaggregated model in tailoring policy makers' attention towards targeting sector-specific policy interventions on risk mitigation.

3. Scientific Methodology in Constructing the Fan Chart

The theoretical framework of this study is based on the "*Two-Piece Normal (TPN)*" distribution. As emphasised by Johnson et al (1994), TPN is claimed to be an original work of Gibbons and Mylroie (1973) and John (1982). The technique of TPN distribution is a widely used method in the construction of Fan Chart on account of its asymmetric shape and the ease of the computation of cumulative density function. The TPN and its probability density function (PDF) is a combination of two halves of two normal distributions (Wallis, 2014), where the modes (μ) are the same, while also possessing different standard deviations (see Appendix 2).

In furtherance of the construction of a Fan Chart, which is aimed at unearthing uncertainty and risks around point / baseline inflation forecast, the incorporation of Exchange Rate utilised as an exogenous variable is to ensure that discussions at policy level takes into consideration balance of uncertainty and risks surrounding the asymmetry of the Fan Chart(s) produced in the given period under investigation. In constructing Fan Chart using the TPN approach, it must be noted that both the upper and lower standard deviations, notably σ_1 and σ_2, should be derived, with emphasis given to three core parametric steps of the forecast distribution: (1) a central projection, which is the mode of the variable; (2) the degree of uncertainty surrounding the central projection, a reflection around the width of a Fan Chart; and (3) the distributional Skewness around the forecast, which also provide balance of risks emanating from the forecast.

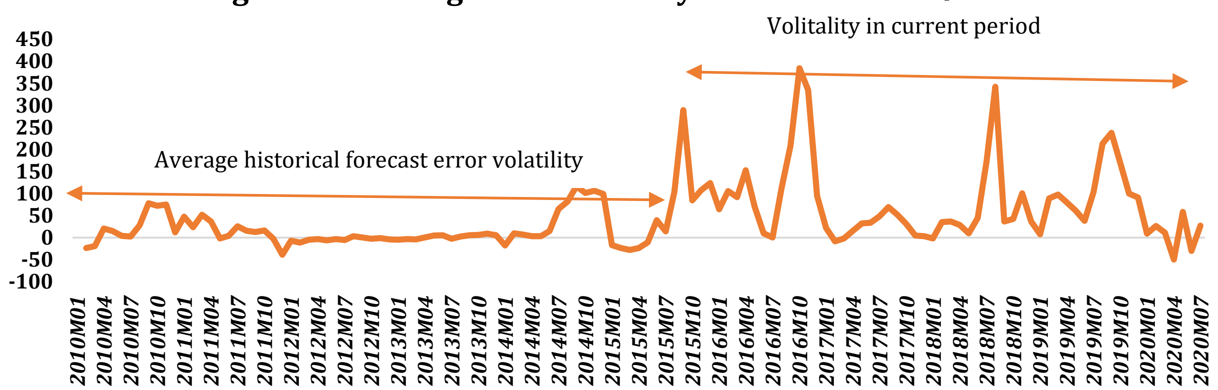
In general, the central projection, also referred to as the baseline forecast can be obtained from a specified methodology, notably in this case, the ARIMAX model. As specified in Appendix 2, the mode of the distribution, also akin to the baseline forecast, is indicative of probable outcomes from utilised models. Therefore, the degree of uncertainty emanating from the Fan Chart produced will unearth varying level of possible risks surrounding baseline forecast, and the degree of uncertainty is normally manifested around the spread of the Fan-out distribution of the specified Fan chart using confidence band limits. Such degree of uncertainty is expressed as the degree of error surrounding the baseline forecast, which literally is derived through computational adjustment of the historical forecast error. Hence, as expressed by Razi and Locke (2017), the degree of uncertainty of the baseline forecast, σ_y^2 is expressed as the variance of historical forecast errors of the distribution, σ_e^2, which adjust for uncertainty surrounding the impending risk factors as expressed in Equation 1.

$$\sigma_y^2 = \sigma_e^2 \frac{\Sigma w_i x_i}{\Sigma w_i \bar{x}_i} \quad \text{Eq. 1}$$

Where: w_i is the elasticity of the key assumptions factored in the computation, while x_i and $\bar{x}_i$ are representation of current and historical degree of uncertainty of the risk factors surrounding the baseline forecast,

With reference to the second objective of the paper, which is intended to construct a Fan Chart in measuring uncertainty and risks by utilising confidence bands, it is the intention here to provide a thorough assessment of uncertainty by comparing historical outlook using multiplicative indicators like variance factor. In furtherance, given the volatility of price level and the external influence of Exchange Rate dynamics, we have taken into consideration the uncertainty of these factors (reference to Figure 1), which tend to tilt risks surrounding the Fan Chart asymmetrically (Razi and Loke, 2017: 5).

Figure 1: Exchange Rate Volatility Indicator Assumption

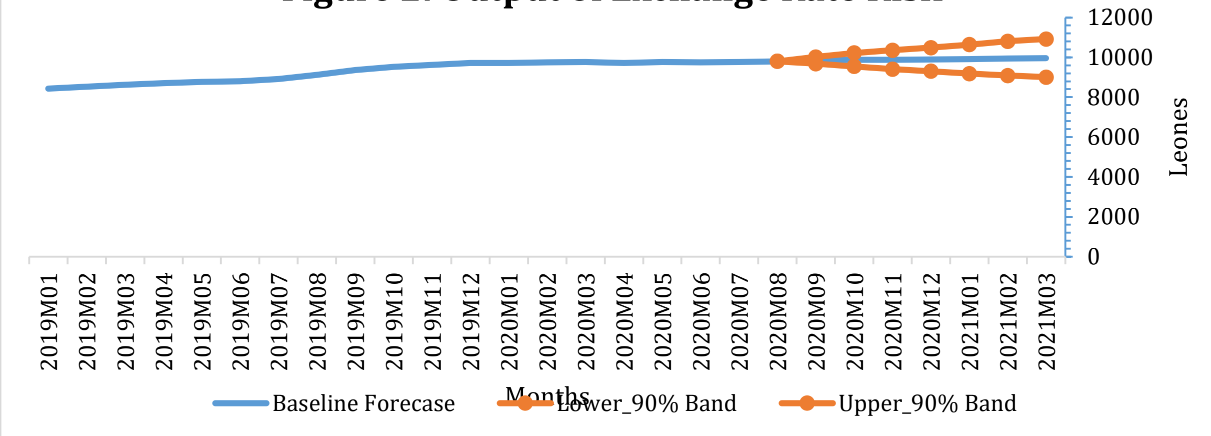


The parameter of Skewness or asymmetry of the distribution around the baseline projection as expressed by γ_y can be derived through linear combination of the skew coefficients of risk factors expressed here as γ_i as shown in equation 2.

$$\gamma_y = \Sigma w_i \gamma_i \qquad \text{Eq. 2.}$$

With technical competencies of forecasters and also knowledge about the economy of Sierra Leone in particular, discourses surrounding risk factors can be addressed using volatile indicator like exchange rate, a proxy for the assumption built in this study. Events in the domestic economy pertaining to the influence of exchange rate and also expectations about inflation could account for the highs and lows experienced in the width of an uncertainty Fan Chart. The relevance of the computed standard deviation values would in general, be utilised in the confidence bands to give a clear picture of uncertainty surrounding the assumption, as shown in Figure 2 below.

Figure 2: Output of Exchange Rate Risk

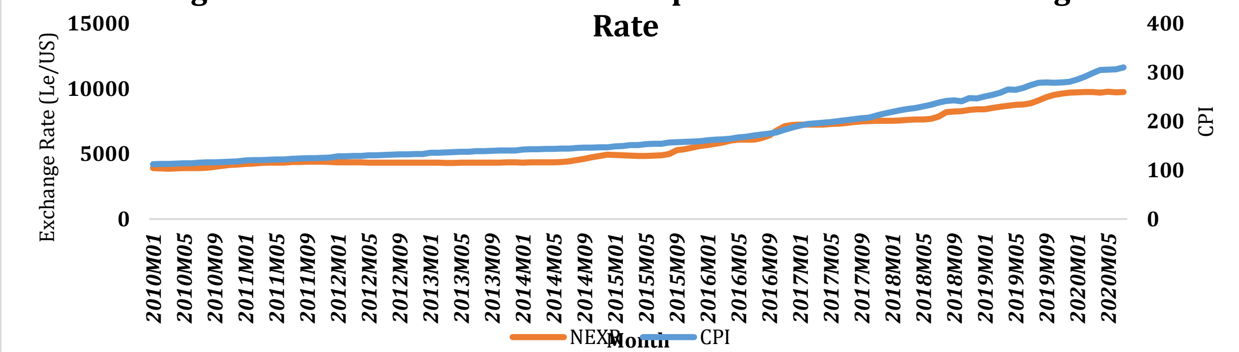


Source: ***EVIEWS Output***

3.2. Series Co-Movement and Causal Relationship and Unit Root Test

Figure 3 below provide an illustration of variables utilized, with indication of co-movement pattern that reflect high degree of correlation (Appendix 3) between Exchange Rate and Consumer Price Index (inflation proxy), with data spanning from 2010M1 – 2020M7.

Figure 3: Co-movement relationship between CPI and Exchange Rate



Appendix 3 provide an indication of strong correlation between the two variables, but the reality of causality as presented in Table I manifest uni-directional outcome, strongly influenced by Exchange Rate variable. In reference to theoretical underpinnings and research outputs from studies conducted in recent past (Jackson et al, 2020; Jackson and Tamuke, 2018), there is indication pointing to the fact that Exchange Rate is a strong influence of inflation dynamics in Sierra Leone, owing to weak real sector activities in the country. In other words, the high level of trade imbalance and imports of essential inelastic goods for domestic consumption (Jackson and Jabbie, 2020) is making it possible for the country's currency to be devalued, with persistent level of lagged pass-through effect of imported prices to economic agents in the country.

Table 1: Pairwise Granger Causality Tests

Null Hypothesis:	Obs	F-Statistic	Prob.
NEXR does not Granger Cause CPI	125	5.64375	0.0045
CPI does not Granger Cause NEXR		1.55637	0.2151

Table 2: ADF and PP Unit Root Test Outcomes

	ADF			PP		
Variable	**I(0)**	**I(1)**	**I(2)**	**I(0)**	**I(1)**	**I(2)**
CPI	0.835861	-1.366220	-3.345558	2.951293	-6.885539***	N/A
NER	-1.038473	-5.358172***	N/A	-0.795232	-5.293923***	N/A

Note: *** = 1% significance

The empirical contribution of this paper is constructed on inflation forecast (as detailed in the initial diagnostic Unit Root test outcome), with its exogenous influence of Exchange Rate, while ensuring level of uncertainty and Skewness of risks are discussed as part of the Fan Chart interpretation (Jackson and Tamuke, 2018; Kongcharoen and Kruangpradit, 2013). In the case of this study, we suggest the use of time-variant coefficients to reflect the dynamic effects of the two variables at play, but with greater emphasis on the forecast outlook of Inflation variable. Time-variant coefficients in this study was computed using the Autoregressive Integrated Moving Average and its exogenous component (ARIMAX). Notable reflection of the application of macroeconomic forecast can be linked to Stock and Watson (2003), whose exploration proved that the incorporation of a principal indicator has the capability of improving the overall performance of forecast.

Ideally, Exchange Rate can be a good predictor in building understanding of the turning point of an economy, particularly as utilised in the case with Hamilton and Perez-Quiros (1996) in their prediction of GDP growth. In the case of this study, the influence of exchange rate is a major threat to the stability of price dynamics in the Sierra Leone economy as revealed in several contemporary studies (Jackson et al, 2020). Therefore, we are convinced that the inclusion of Exchange Rate will help project the reality of inflation dynamics and direction of uncertainty and risks (reference to Figure 2). Hence, the representation of the model is hereby expressed as $ARIMAX_{(p,d,q)}$, with p, d, q representing the Autoregressive (AR), integrated differencing (d) and the Moving Average (MA) components respectively. This can be expressed mathematically as a stationary series (Yt) shown in Equations 1 and 2, where outcome of the estimation process is indicated the coded steps provided in Appendix 1:

$$Y_t - \theta_1 Y_{t-1} - \ldots - \theta_p Y_{t-p} = \varepsilon_t + \theta_1 \varepsilon_t + \ldots + \theta_q \varepsilon_t - q \qquad \text{Eq. 1}$$

$\theta(L)(1-L)^d Y_t = \theta(L)X_t + \theta(L)\varepsilon_t$ Eq.2

- Where: 'p,d,q' represent the non-seasonal form of the ARIMAX process [automated format factors incorporating Autoregressive component (AR), differenced operator (d) and finally, the Moving average (MA) component. Where seasonality adjustment is factored in the series, p, d and q will automatically be capitalised or represented as upper cases].
- $\theta(L)$), (L) and $(1-L)$ are the moving average polynomial of the autoregressive process of Y_t.
- ^{d} is the differenced operator and ε_t is white noise.
- X_t is an explanatory variable, which is Exchange Rate.

It is worthwhile to note that as represented in Appendix 1, the emphasis of risk is on the headline inflation (CPI_13) as opposed to the disaggregated components (see Figure 3). Details in the methodological procedure for producing point forecast / headline forecast is detailed in the automated coding steps as shown in Appendix 1.

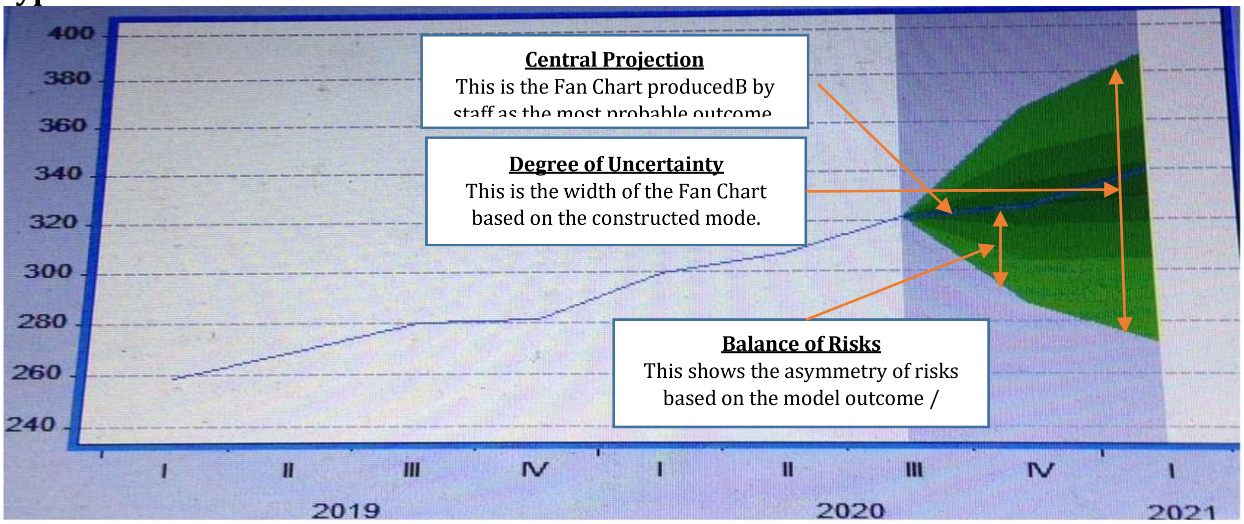
With the TPN distribution as utilised by Razi and Loke (2017: 6-7), it is possible to derive the three key parameters of the Fan Chart; t*he lower and upper standard deviation,* σ_1 *and* σ_2*, and the lower and upper value confidence intervals (*z_1 *and* z_2*)* as detailed below and also represented in Appendix 1 of this research paper.

$$z_1 = \mu - \frac{\sigma_1}{\sigma_2}(z_2 - \mu) \quad \text{Eq. 3}$$

$$z_2 = \mu + \mu_2\theta^{-1}\left(\frac{1+q}{2}\right) \quad \text{Eq. 4}$$

Where: θ^{-1} is represented by the inverse of the standard normal distribution curve, while q is the level of confidence. Figure 4 below provide an illustration of the three parameters of a typical TPN Fan Chart, where different shades are represented by confidence bands or intervals. Notable in this case, 90%, 60% and 30% probability confidence bands that captures the true value of inflation.

Figure 4: Fan Chart from ARIMA Model Forecast incorporating 3-Parameter of a typical TPN



Source: *EVIEWS Output*

Figure 4 provide a clear illustration of the science behind the Fan Chart, with uncertainty of risks balanced heavily on the downward, thereby indicating a higher chances for inflation to subdue in the short-run with effective policy measures. The robustness of risks interpretation require expert judgment from technocrats, particularly in effectively prioritizing policies geared towards subduing inflation in the short to medium-term. While the symmetry of risks is more favourable towards the downside, effort must be fully explored, with knowledge of the domestic economy to mitigate the actuality of inflation moving well over the targeted period.

4. The Art of Assessing Fan Chart Uncertainty and Risks

The use of Fan Chart to portray uncertainty and risks is considered as both a Science and an Artistic process. The abundance of information contained within the constructed Fan Chart as shown in Figure 4 above, makes it possible for decision pertaining to economic stabilisation to be realised through deliberation of expert judgments at technical and as well as at policy level. Discourses pertaining to the artistic process of Fan Chart analysis can be dealt with through critical assessment of the fan-out look of the Fan Chart. The Fan Chart has been technically designed in cognisance of the three parameters detailed in Appendix 1; where the Mean, Variance and Skewness are serious indicators of the direction of uncertainty and risks. As noted by Razi and Loke (2017), there are two levels of uncertainty that is said to have emanated from the Fan Chart; these include (1) uncertainty of the forecasting model (consisting of inflation forecast result, with its exogenous component and (2), assumptions built into the construction of the Fan Chart.

In interpreting the Fan Chart as detailed in Figure 4, the '*Degree of Uncertainty*' manifest the totality of the fan-out figure, with the embedded '*Central Projection*' accounting for the baseline or point forecast produced from the automated Fan Chart. On a last note, the 'B*alance of Risk*' illustrate the Skewness of the Fan Chart, which in this case is asymmetrical on the downside. In order words, it indicate a 90% likelihood of inflation falling below the central projection. The actuality of such a downside risk would in general, be supported by effective policy actions as deliberated at MPC level based expert judgments, which would have been explored through research endeavours at the technical level. It is worthwhile to note that, under a normal probability distribution curve, with 90% upper and lower probability confidence limit, the remaining non-accounted 10% of the Fan Chart represent a *tail-end* risk events. In order words, such risks are considered to be outliers, with risks perceived as infinitesimal to the overall inflation outlook.

Therefore, Fan Chart construction for an economy like Sierra Leone can be seen as a scientific endeavour as portrayed in the probability confidence bands. The artistic process of ensuring uncertainty of assumptions embedded within the forecast process are thoroughly assessed, through expert judgments in a bid to ensure price stability target is achieved. Such approach is seen as the basis of communicating good or worrying news in the public fora. Where possible, the use of suite of models incorporating cases of scenarios (notably from VAR and FPAS), also one of the three types of approach utilised in constructing uncertainty around forecast construction, can be made possible, in conjunction with Fan Chart. This is considered helpful in assessing the state of possible actions the central bank can utilise in ensuring stability and growth are realised in the domestic economy.

5. Conclusion

The study has provided an illustration of the relevance of Fan Chart in addressing uncertainty and risks in an economy. Policy makers in central banks and in particular, the Bank of Sierra Leone are highly reliant on Fan Chart as a way of eliciting precise judgments about the way forward in addressing price stability pressures. The use of ARIMAX as the model for constructing Fan Chart in this case has been helpful in portraying the complexity of risks associated, with two volatile variables like Exchange Rate and CPI utilised in the assessment of future welfare condition for citizens in the Sierra Leone economy.

With reference to the highlighted objectives, the use of Fan Chart makes it possible for robust deliberation amongst technical experts to be dealt with in view of uncertainty and risks that normally surround baseline forecast as presented in Figure 4. The asymmetrical diagram indicate a higher scope of risks to inflation, which is tilted towards the downside, while the possibility of some level of upside risks makes it onerous on technical experts and policy makers to deliberate critically in preparation for both worse and best case situation of risks that can occur. Given the possibility of continued perturbations as witnessed in the current state of COVID19 and in particular, the historical state of fragility in the Sierra Leone economy to external shocks, which normally feeds in the form of an easy pass-through effect of higher prices, there is a need to make sure policy deliberation is well prepared in addressing the continued state of volatile shocks to the economy.

In summary, technical experts in their use of models, will need to make themselves adaptive to varying methodologies and approaches that are relevant in ensuring uncertainty and risks are monitored throughout their endeavour to support policy decisions around price stability. Consideration at some point in time would need to be given to alternative approaches like Scenario and Sensitivity Analysis in a bid to affirm policy decisions connected with price stability mandate. There is a need for policy makers to continue their strides in supporting the effort of technical users of Fan Chart technology, possibly through knowledge update or customize-training, so as to make it worthwhile for Fan Chart to be utilised in the best possible way of supporting effective policy decision, and also as an effective means of communicating information to the public.

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Appendix 1: EVIEWS Model Code for ARIMAX

```
'Code for selecting optimal lag lengths for ARMA models

smpl @all 'Set sample period
scalar n1=@obs(cpi) 'Number of observations of CPI data
scalar components = 13 'Number of CPI components, including aggregate index
scalar maxar = 11
scalar maxma = 11


'Rename series
series cpi_1 = fnab
series cpi_2 = alctob
series cpi_3 = cf
series cpi_4 = housing
series cpi_5 = furn
series cpi_6 = health
series cpi_7 = trans
series cpi_8 = comm
series cpi_9 = reccult
series cpi_10 = educ
series cpi_11 = rest
series cpi_12 = misc
series cpi_13 = cpi


'Seasonally adjust data
for !i = 1 to components
cpi_!i.x12(mode=m) cpi_!i
nexr.x12(mode=m) nexr

next

'For each component produce ARMA(a,m) with varying orders
for !i = 1 to components
   for !a = 1 to maxar '12
       for !m = 1 to maxma '12


       smpl 2007m1 2007m1+n1-1
       equation arma_!i_!a_!m.ls d(cpi_!i_sa) c ar(1 to !a) ma(1 to !m) log(nexr)-log(nexr(-
12))

       next
```

```
    next

next

'Identify the ARMA for each component with the optimal AR and MA orders according to the Akaike Information Criterion.  Change to @schwarz or @hq for Schwarz and Hannan-Quinn criteria.
for !i = 1 to components
!mininfocrit = 9999

    for !a = 1 to  maxar '12
        for !m = 1 to maxma '12

        if arma_!i_!a_!m.@aic<!mininfocrit then
        !besta = !a
        !bestm = !m
        !mininfocrit = arma_!i_!a_!m.@aic

        endif

        next

    next

'Save the equation with the best order structure
smpl 2007m1 2007m1+n1-1
equation arma_best_!i.ls d(cpi_!i) c ar(1 to !besta) ma(1 to !bestm) log(nexr)-log(nexr(-12))


smpl 2007m1+n1 2022
arma_best_!i.forecast cpi_forecast_!i

next

'Show best ARMA models for selected components
for !i = 13 to 13
show arma_best_!i

next

'show exp(cpi_forecast_13)/exp(cpi_forecast_13(-12))*100-100
'*
```

Appendix 2: Two-Piece Normal Distribution

TPN probability density function is hereby presented as illustrated below (also, reference to Razi and Loke, 2017):

$$f(x) = Aexp\{\left\{-\frac{(x-\mu)^2}{2\sigma_1^2}\right\} \; for\; x \le \mu$$

$$f(x) = Aexp\{\left\{-\frac{(x-\mu)^2}{2\sigma_2^2}\right\} \; for\; x < \mu$$

Where A = $\sqrt{\frac{2}{\pi}}\,(\sigma_1+\sigma_2)^{-1}$ is a constant of proportionality to ensure the distribution is continuous and is integrated to One.

As emphasised by John (182), the properties of the distribution are outlined below:

Mean: $E(x) = \mu - k(\sigma_2 - \sigma_1)$ (a)

Variance: $V(x) = \sigma_1\sigma_2 + (1-k^2)(\sigma_2 - \sigma_1)^2$ (b)

Skew: $\gamma^{(x)} = k(\sigma_2-\sigma_1)[(2k^2-1)(\sigma_2-\sigma_1)^2 + \sigma_1\sigma_2]$ (c)

Where A = $\sqrt{\frac{2}{\pi}}$

Two-Piece Normal Distrubution Curve

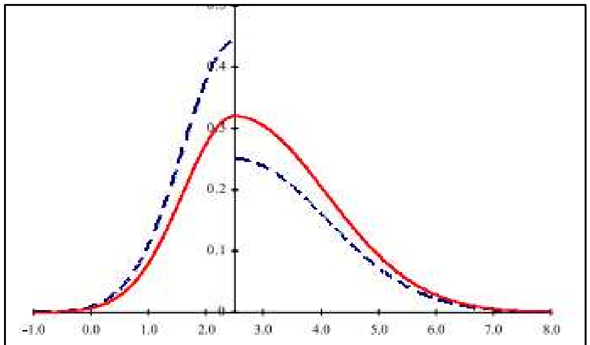

FIG. 1. *The probability density function of the two-piece normal distribution. Dashed line: left half of $N(\mu,\sigma_1)$ and right half of $N(\mu,\sigma_2)$ distributions with $\mu = 2.5$ and $\sigma_1 < \sigma_2$. Solid line: the two-piece normal distribution.*

Source: Wallis (2014)

In the case of the above, the mode, variance and skew as illustrated in equations (2) and (3) can be solved for σ_1 and σ_2.

With reference to the above probability density function, it can be noted that the probability of being between any two points, L_1 and L_2, which is described as the area under the curve can be computed as:

$$P(L_1 < L_2) = \int_{L_1}^{L_2} f(x)\,.\,dx = 2((\sigma_2-\sigma_1)^{-1}[\sigma_2\varphi\left(\frac{L_2-\mu}{\sigma_2}\right) - \sigma_1\varphi\left(\frac{L_1-\mu}{\sigma}\right) + \left(\frac{\sigma_1-\sigma_2}{2}\right)]$$

Where φ (.) is the cumulative distribution function of the standard normal curve.

Appendix 3: Correlation Table of Exchange Rate and Consumer Price Index (CPI)

	CPI	**NEXR**
CPI	1	0.99
NEXR	0.99	1