İktisat Politikası Araştırmaları Dergisi -
Journal of Economic Policy Researches
Cilt/Volume: 10, Sayı/Issue: 1, 2023
E-ISSN: 2148-3876

İSTANBUL UNIVERSITY PRESS

RESEARCH ARTICLE / ARAŞTIRMA MAKALESİ

The Econometrics of Factor Loadings and Implications for Monetary Policy in a Small Open Economy (2005-2020) – Sierra Leone

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ABSTRACT

In this paper, the authors explored the interaction of macroeconomic variables with some form of vague interrelationships. The relevance of factor analysis has demonstrated an existing association between manifest and latent variables in helping the researchers come out with informed and justified suggestions that are relevant to inform effective policy decisions for the central bank action in Sierra Leone. We examine the relationships among some significant manifest and latent variables in a small open economy (Sierra Leone) using time series data spanning from 2005 to 2020. Both international crude oil prices and the local currency in circulation were found to be loadable under two factors (domestic and external), while the exchange rate was observed to be loaded under the external factor. The outcome also proved that the effects of domestic and international economic shocks (sudden but temporarily disrupted) converged (dissipated) after six to eight months. The paper concludes that innovation and energy diversification are important for domestic and external stability in a small open economy.

Keywords: Bayesian Analysis, Economic Shocks, Exchange Rate, Factor Loadings, Manifest and Latent Variables
Jel Code: C22, E42, E51

DOI: 10.26650/JEPR1082693

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Submitted/Başvuru: 05.03.2022
Revision Requested/Revizyon Talebi: 07.05.2022
Last Revision Received/Son Revizyon: 23.05.2022
Accepted/Kabul: 24.06.2022

Citation/Atıf: Warburton, C.E.S., Jackson, E.A. (2023). The econometrics of factor loadings and implications for monetary policy in a small open economy (2005-2020) – Sierra Leone. *İktisat Politikası Araştırmaları Dergisi - Journal of Economic Policy Researches, 10*(1), 19-35. https://doi.org/10.26650/JEPR1082693

1. Introduction

This paper examined the interaction of macroeconomic variables with imprecise interrelationships. Unlike some relatively older econometric models, factor analysis compiles manifest variables with a strong association for confirmatory or exploratory econometric analysis that leads to informed policy decisions. Using monthly time series data from 2005 to 2020, we examined the relationships among some significant manifest and latent variables in a small open economy (Sierra Leone). We find that international crude oil prices and the local currency in circulation are loadable under two factors (domestic and external)—with a strong exchange rate loading under what is considered an external factor. We find that the effects of domestic and international economic shocks (sudden but temporary disruptions) on the small economy have prospects of converging (dissipating) after about six to eight months.

The paper was consistent with the fundamental objectives of the Bank of Sierra Leone (BSL)—as authorized by the BSL Act of 2019—to facilitate the macroeconomic stability via the channels of the general price level and financial stability.[1] Notably, efforts to stabilise the economy were driven by short- and long-term monetary policies (Tamuke, Jackson, & Sillah, 2018; Jackson, Tamuke, & Sillah, 2018; Jackson & Tamuke, 2019; Jackson, Tamuke, Jabbie, & Ngombu, 2020). Invariably, successful monetary policies were also contingent on the fiscal policies that facilitate internal and external stability (full employment and current account balances). However, fiscal (political) policies are beyond the scope of this paper.

The impetus of this paper was to utilise econometric methodology tools (Principal Component Analysis and Bayesian Vector Autoregression) to examine the influences of shocks (both internal and external). Sierra Leone is a small open economy with a plethora of natural resources, but the influence of the resource-curse syndrome (see Jackson, 2016) and specifically, poor management of resources to capacitate productive real sector operations resulted in the country's exposure to both internal and external shocks. The vulnerability of the country's primary material exports to price fluctuations in the global market, low proceeds from domestic revenue collection and the slow efforts towards domestic diversification exercises made it difficult for the country to realise surpluses in its balance of payment accounts. The situation explained so far gave rise to an elevated level of borrowing (domestic as well as external) by successive governments – all the more reason for the Bank of Sierra Leone (BSL) to be given the scope for supporting fiscal deficit financing, which added pressure on its ability to address its core mandates of price and financial stability. The BSL currently operates on monetary targeting, which exposes the institution to intense

[1] The provisions of the BSL Act of 2019 can be found in http://www.bsl.gov.sl/BSL_Act_2011.pdf

difficulty in managing its core mandates, while at the same time sustaining pressure in having to meet high demands for imports to support domestic consumption needs.

The primary objective of this study was not restricted to policy matter, but an associational inquiry, implying that the primary objective was to discern which variables could agglomerate under the broadly defined latent categories of domestic and external indicators. In short, it was a kind of inquiry that could not be conducted by a conventional VAR, but the influence of agglomeration was used to insinuate policy implications as a residual matter. Theoretical propositions made a priori assumptions that may not be significantly supported by research design (in fact, falsely so because of assumptions and restrictions inter alia). The proposed econometric methodology used for this study (Principal Component Analysis – see Zaidi, Hussain, & Uz Zaman, 2021) was a novelty as evidence that shows it has never been used for a study in Sierra Leone and it was hoped that findings from the study would add value to the literature for future empirical investigations.

The paper was structured into multiple sections that pursued predetermined objectives. Section two provides a very brief overview of the literature or conversations in the literature. In Section Three, the methodology is discussed, which includes the models utilized to accomplish the research objectives of the paper – this section provides a discussion of the manifest variables that were targeted based on data availability. Section four discusses the empirical findings, while Section five concludes with pointers for policy discussion.

2. Literature overview

The literature provided an eclectic array of macroeconomic disturbances, monetary policy responses, and the utility of policy rates. The responsibilities of central banks have traditionally increased because of shocks and financial instabilities. This was historically the case after the Great Depression of the 1930s, the Savings, loans, and debt Crises of the 1980s, the East Asian Crisis of the 1990s, and the mortgage-backed security (MBS) and COVID crises of the twenty-first century. Policy responses were noticeably variegated; some banks indulged in expansionary policies without pushing real rates into negative territory. Others adopted policies that pushed real rates into negative territory even in the presence of long-term structural rigidities. Controversially, the European Central Bank (ECB) adopted a contractionary policy as part of austerity measures in the wake of the MBS crisis.

The literature reflected challenges that confronted researchers who tried to model the interactive effects of interdependent macroeconomic variables on the performance of national economies, occasionally with a reasonable amount of success. The multiplicity of economic variables made assorted categories of VARs into the methodological workhorse of

diverse banking institutions. Variations in the performance of VARs led to the evolution of VARs. A comprehensive analysis of the early evolution was found in the work of Stock and Watson (2001). It was fashionable to lecture that VARs provided great promise for a "coherent and credible approach to data description, forecasting, structural inference, and policy analysis."

The VAR methodology made its debut in the 1980s through the work of Christopher Sims; after which it evolved from an atheoretic variety to structural forms with restrictions. Structural forms further evolved from the frequentist genre in search of parameter estimates to the probabilistic forms of the Bayesian variety in quest of data validity and probabilistic outcomes or likelihood.

VARs were traditionally been presented in three forms: (i) reduced, (ii) recursive, and (iii) structural. Reduced forms express each variable as a linear form of its past values and the past values of other variables, assuming that the errors were uncorrelated. Recursive VARs specified each error expression in the VARs to be uncorrelated with the previous by including contemporaneous values as regressors. Structural VARs used economic theories to impose restrictions that allowed correlations to be interpreted causally (Bernanke, 1986; Blanchard & Watson, 1986; Bangura, Caulker, & Pessima, 2012). Using VARs to derive monetary policy rules, for example, the Taylor Rule, and studying the behavior of business cycles was attractive in empirical undertakings (Kapetanios, Mumtaz, Stevens, & Theodoridis, 2012).

De Gregorio (2012) pursued an empirical discussion to assess the importance of commodity price shocks (CPS) in monetary policy that were given recent experiences of global perturbed conditions. The study utilized regression analysis and one of its methodological tools to prove that food and energy had important effects on headline inflation, with only food showing a second-round effect on inflation. The author emphasized the importance of energy inflation, which could not be ignored since in most cases monetary policy reactions did not pay premium attention to its overall impact on inflationary pressures. In general, the author concluded that commitment to inflation targeting often reduced responses to maintaining price stability amid Commodity Price Shocks (CPS), which eventually also reduced the overall cost of achieving price stability in an economy.

On an equal note, Nazlioglu and Soytas (2019) utilized VAR to evaluate the causality between oil prices and monetary policy for the emerging markets using data spanning 200M1 to 2015M12 – for example, Brazil, India, Indonesia, South Africa, and Turkey. The authors explored the importance of exchange rates, inflation, and interest rates. The empirical study commenced by utilising the "*Toda–Yamamoto causality framework*", which later

augmented the model to account for structural adjustments, specifically factoring in gradual and smooth shifts. The study outcome proved that factoring for gradual structural shifts was necessary to show causal relationships between oil prices and monetary policy variables. The outcome also showed that utilizing bivariate or multivariate frameworks (with some exceptions) was not so important as a control for structural breaks that manifested in the causal linkages between variables.

In the Bayesian tradition, Kapetanios et al. (2012) examined the macroeconomic impact of the first round of quantitative easing (QE) on the aggregate economy by using Bayesian VAR. They quantified the effects of QE by focusing on the impact of lower long-term interest rates on the wider economy and found that QE had effects on the level of real GDP and consumer inflation. Using time-series data from 2007 to 2018, Warburton and Jackson (2020) incorporated the frequentist and Bayesian probabilistic evaluations into their study of monetary policy response in Sierra Leone to exogenous shocks. The interaction of the financial, real, and external sectors was targeted for analysis. Empirical findings indicated that a central bank in a small open economy could be exposed to peculiar challenges in its efforts to stabilize prices and liquidity or attain full employment, given time constraints. It was discovered then that external shocks to crude oil prices could have persistent effects on low-frequency data.

The factor augmented VAR (FAVAR) proposed by Bernanke, Boivin, and Eliasz (2005), popularised factor analysis as a methodology for analyzing monetary policy. Factor analysis was conceived in a variety of ways (Roll & Ross, 1980; Connor & Korajczyk, 1986, 1988 & 1993). In the tradition of principal component analysis (PCA), Hawkesby, Marsh, and Stevens (2007) applied the technique to large complex financial institutions and equity returns. The paper of Bernanke et al. (2005) emanated from dissatisfaction with the limitations of SVARs and the less apparent interactions of variables or restrictions that could arise from discarding diverse but essential variables in VAR specifications; thereby extending the usefulness of the literature for monetary policy in a variety of ways. This paper exploited the empirical technique in an exploratory manner to better understand the interaction of economic variables and their monetary policy orientation.

Unlike Sierra Leone, large open economies that followed hundreds of data series lost a lot of essential information by focusing on small amounts of variables to satisfy the structural requirements of VARs that would otherwise require a substantial amount of important macroeconomic variables. However, like in Sierra Leone, knowledge of the appropriate associations and loadings of variables under specific latent factors were unknown but taken for granted. The incompleteness of knowledge made factor analysis a robust econometric undertaking for central banks and targeted policy decisions even when unemployment and

output data were inadequate. Large sample sizes were preferred because they presupposed uncorrelated errors and the suitability of principal component analysis (PCA).

In this paper, factor analysis was utilized as an econometric procedure for modelling multivariate data as a function of limited underlying latent factors. The manifest (observable) variables procedurally outnumbered the latent variables. The procedure was traditionally consistent with all factor analyses in which an attempt was made to establish multiple correlations between manifest variables that were contingent on the probable behaviors of the latent variables (factors). Of course, factor analysis could be exploratory or confirmatory.

The interactive nature of macroeconomic variables created uncertainties about causal relationships or varying correlative relationships of significance. Therefore, we preferred the exploratory decisions of scientific procedures after multiple Monte Carlo simulations. Though we were theoretically interested in the interactions of the manifest variables—inflation, the exchange rate, fuel prices, and the local currency in circulation, we were equally mindful of the fact that latent variables, notably internal and external conditions underpin the performance of manifest variables. The explanatory power of latent variables was equally contingent on their interdependence, especially through the exogenous shocks of crude oil prices, exchange rate, and supply of local currency, which also affected the exchange rate (see also Jackson, Tamuke, & Sillah, 2018; Warburton & Jackson, 2020). Accordingly, the value of this paper was intrinsically related to the use of latent factors for aggregating macroeconomic variables, deriving the explanatory power provided by the latent factors, and utilizing derived information for studying the propagation of shocks to essential macroeconomic variables for internal and external stability.

3. Methodology: Model Specification and Data Description

3.1. The generative Bayesian and factor models

For a variety of reasons, the Bayesian factor model (BFM) is preferred. The variables are numerically quantified, and the model accommodates interactions with disparate error variations (heteroskedasticity). Its results are probabilistic and less susceptible to computational controversies. The simulated data closely approximated actual data and made provision for the estimation of multiple parameters in the multivariate framework. Expert opinions and reasonable intuitions of the data could be incorporated into the generative model as prior information.

The parts of the Bayesian model are comprehensively probabilistic. The posterior distribution, the product, or the generative model, contains information derived from the data. The probability of estimated parameter combinations from the data ($p(\theta|\zeta)$ is

proportional to the likelihood of the data, weighted by probable parameter combinations, ($p(\zeta|\theta)p(\theta)$, denominated by the marginal data density (the predictive density) ($p(\zeta)$). The generative model is therefore granted equivalence to a scientific likelihood:

$$p(\theta \mid \zeta) = \frac{p(\zeta \mid \theta)p(\theta)}{p(\zeta)} \tag{1}$$

Equation 2 provides a simplified probabilistic rendition (equality) of Equation 1:

$$p(\theta \mid \zeta)p(\zeta) = p(\zeta \mid \theta)p(\theta) \tag{2}$$

The literature held contending perspectives about priors and prior distributions, ranging from non-informative to informative. Since policy decisions are hardly made from ignorance and are usually influenced by precedents, the theory of *a priori* information is more appealing when considering posterior outcomes. A common choice of prior in Bayesian analyses is the normal distribution with a mean of zero and a standard deviation of 1. The IG prior (distribution) has a density of:

$$f(x) = \frac{\beta^{\alpha}}{\Gamma(\alpha)} x^{-\alpha-1} \exp(-\beta / x), \; for \; x > 0. \tag{3}$$

The shape parameter (α), which determines the height of the distribution, becomes taller as the parameter increases, and the scale parameter (β) becomes flattered as the parameter increases. The IG prior is one of the multiple alternatives to the diffuse prior, which presumes ignorance or no a priori information.[2] It is useful for Gaussian likelihoods with unknown variance.

The discrete form of the posterior outcome is integrated to obtain a continuous probability (marginal data) density function:

$$p(\zeta) = \sum_{i=1}^{n} p(\zeta \mid \theta_i)p(\theta_i) = \int p(y \mid \theta)p(\theta)d\theta. \tag{4}$$

The expected performance of the economy (Y), which is normally distributed with a mean and variance, is defined by the collection of manifest variables (X)

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[2] The inverse Wishart distribution can also be utilized for the variance-covariance matrix in multivariate computation of the posterior results. The Wishart prior has been determined to be an extension of univariate gamma distribution (Lynch:70); where the inverse Wishart is denoted as:

$$f(X) \propto |X|^{\frac{-\nu+d+1}{2}} \exp\left\{-\frac{1}{2} tr(SX^{-1})\right\};$$

$^{\nu}$ is for degrees of freedom and S is for a scale matrix of dimension d; X and S are both positive definite (the scalar of a transpose (T) is positive for every non-zero column vector z of n real numbers); that is, $z^{T}Xz > 0$ and $z^{T}Sz > 0$ for any non-zero vector z of length d (Lynch:70). The Wishart prior is notably a conjugate—the posterior distribution is in the family of the Wishart prior (continuous probability distribution)—derived from real-valued positive-definite matrices; there is also the Jeffreys' prior which, like the diffuse prior, is Noninformative.

$$E(Y \mid X_1 = x_1 .....X_p = x_p); \tag{5}$$

But the manifest variables are notably distributed as a logit:

$$\pi_i(y) = P(X_i = 1 \mid Y = y) = \frac{e^{\alpha_i + \beta_{iy}}}{1 + e^{\alpha_i + \beta_{iy}}} \rightarrow \log it\{\pi i(y)\} = \alpha_i + \beta_{iy}; \tag{6}$$

The logit can be transformed into a normal model by an increase in dimensionality.[3] The *p* manifest variables, $X^T = X_1 \ldots X_p$ is assumed to be linearly related to the *q* latent variables,

$Y^T = (Y_1 \ldots Y_q)$ in the form proposed by Bernanke (1986):

$$X = \mu + \Lambda Y + U; \tag{7}$$

Where *Y* and *U* are independent and multivariate normally distributed with a ψ variance-covariance matrix for the error distribution.

$$Y \sim N_q(0,1) \text{ and } U \sim N_p(0, \Psi). \tag{8}$$

The latent variables Y_j are the factors (domestic and external) and the lambda (Λ) matrix is a matrix of factor loadings, expected to be absolutely and significantly greater than 0.32 to explain more than 10 percent of the variance in loadings.

Given some unobserved explanatory variables and observed dependent variables, the normal theory factor analysis model estimates the latent factors. The model is implemented using a Markov Chain Monte Carlo algorithm (Gibbs sampling with data augmentation) (see Conti, Fröhwirth-Schnatter, & Heckman, 2014).

Factors = number of the factors to be fitted (defaults to 2)

3.2. The manifest variables

Data utilized for this study were restricted to the period (2005-2020) due to difficulty in obtaining more recent data, particularly because of the COVID-19 pandemic. To start with, the urban National Consumer Price Index (*CPI*, Composite Index) was obtained from Statistics Sierra Leone. It measured the change in prices, on average, from month to month, of the goods and services bought by households, in Sierra Leone including all expenditure groups including both families and single people. The index included sampled outlets from urban towns representing significant geographic regions of the country; for example, Kenema and Koidu (in the Eastern province), Bo (in the Southern Province), Makeni (in the Northern Province), and Freetown (in the Western Area). Compilation efforts concentrated

[3] If Y and β_i take the same dimension *q*, then $Y \sim N_q(0, I) \approx \log it\{\pi_i(Y)\} = \alpha i + \beta_i^T y$.

on core inflation (items that are consumed every month with less price volatility); these items constitute about 80 percent of all urban household consumption.

Accordingly, the weighted index consisted of about 400 goods and services that were popularly consumed (note that CPI data for this study were retrieved before rebasing in December 2021). The items of the CPI were purposefully classified by the functions of individual consumption and then weighted. The composition changed in 2007 to include housing, gas, water, electricity, and other fuels.[4]

Fuel (*FL*) was an abbreviated subcomponent that was extracted from the CPI. It included changes in monthly prices that were affiliated with housing, water, gas, electricity, and other fuels. It constituted a unique category of essential household consumption or absorption that generated demand-pull inflation. Fuel cost in Sierra Leone was determined to be influenced by three components: external costs, taxes, and duties, and the subsidy amount (fiscal policies) (see World Bank Poverty Reduction & Economic Management, 2014). To make fuel relatively less costly for households, the government waived some revenue in taxes and duties on retail fuels—as it did in 2012.

The local currency in circulation (*M2*) was an important monetary variable obtained from the Bank of Sierra Leone (BSL). Values for December 2004 were utilized as reference points to prevent a loss of data points in the monthly transformation. The monetary variable interacts with other manifest variables to characterize sensitivities (or the lack thereof) to inflation and local currency valuation. Currency in circulation captured the functions of money as a medium of exchange and store of value for a small open economy. It was also an indicator or critical component of the velocity of money (the speed at which money circulates in the economy, the nominal value of output denominated in terms of money). This variable was expected to have a significant presence at home and abroad.

The exchange rate (*ExR*) was operationalized as the average monthly Leone-US dollar exchange rate from January 2005 to December 2020. Time series data for the average monthly series were obtained from FXTOP. The exchange rate was theoretically expected to have a dominant domestic and foreign presence, and the latent factors were expected to capture significant variations in the factor loadings. However, this was not necessarily be the case for a small open economy without a regularized convertible currency.

Changes in the price of crude oil (*Crd*) are fundamentally disruptive to the cost of production and consumption in small open economies. The monthly changes in the prices of

[4] Fuel was granted a weight of 6.5 till 2007, after which housing, gas, electricity and other fuels were added in 2007 with a weight of 9.82. The weight dropped marginally to 9.63 in September and back to 9.82 in August 2009. The weight was increased to 13.7 in 2010. It incrementally dropped to 13.6 in October 2018 before moving back to 13.7 in 2019; the weight was decreased to 13.6 in February 2019 but increased to 13.7 in July of 2019.

crude oil are also expected to affect the values of currencies that are denominated in convertible currencies. We used changes in the monthly imported crude oil prices into the US, denominated in US dollars as a proxy for the international cost of fuel that could have feedback back effects on non-convertible currencies. Imported prices were adjusted for inflation ($/barrel) and the data was sourced from the US Energy Information Administration (EIA). Figure 1 typifies the stationarity of the time series data and Figure 2 depicts an *a priori* relationship between the manifest and latent variables. With a modicum of knowledge, we can therefore presume that a diffuse prior (ignorance) is less appealing.

Though the variables are known with some amount of macroeconomic familiarity, the data does not presuppose the number of factors that they represent in any apparent or meaningful way. Accordingly, exploratory factor analysis can enable us to determine the factors, and the nature of the loadings can help us to classify or categorize the variables under the latent factors. The classification becomes important for assessing the interactions of the variables, the significance that they represent under each factor, and the appropriate policy analysis that can be derived from the factor loadings. Mathematical procedures for deriving factors are multiple but the principal components analysis (PCA) is attractive and supported by SPSS (the statistical package that is utilized for part of this work). The PCA extracts factors from all the individuals rather than shared differences.

High-frequency data are preferred because of sample requirements, retention of seasonal information, or variations in the data, and the transformations that are essential for standardization and interpretation of the empirical results. Percentage changes have been computed for each variable and the results of sample adequacy are reported in Table 1.

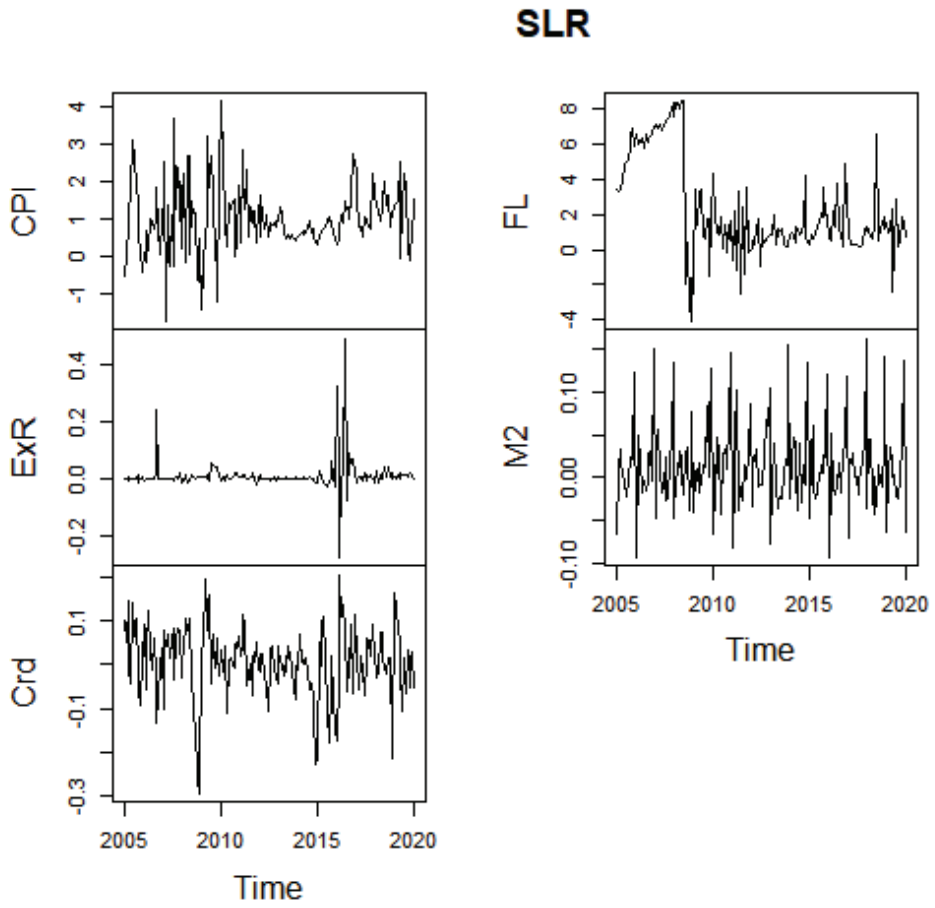
Table 1: The KMO and Bartlett's Test of sampling adequacy

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.	0.56
Bartlett's Test of Sphericity: Approx. Chi-Square	23.928
Df	10
Sig	0.008**
Sample size	192

Notes: Sphericity is an ANOVA test for homoscedasticity, which is intended to prevent the effect of a Type I error; the sphericity result =0.008

The null the sample which is not adequate is rejected. The data sources, the BSL, Statistics Sierra Leone, and FXTOP did a decent job in terms of collecting data for a small open and developing economy. Larger sample sizes are preferable for higher scores; scores that are closer to 1. The sample size makes it possible for variations in the manifest variables to be explained by the latent variables that could be extracted from the data. Figure 1 depicts the transformational data

Figure 1: The manifest variables (Jan.2005-Dec. 2020)



We posit a primitive (*a priori*) relationship of the relationship among the manifest and latent variables in Figure 2. The exposition is usually consistent with elusive economic expectations.

Figure 2: The primitive hypothesis connecting manifest and latent variables

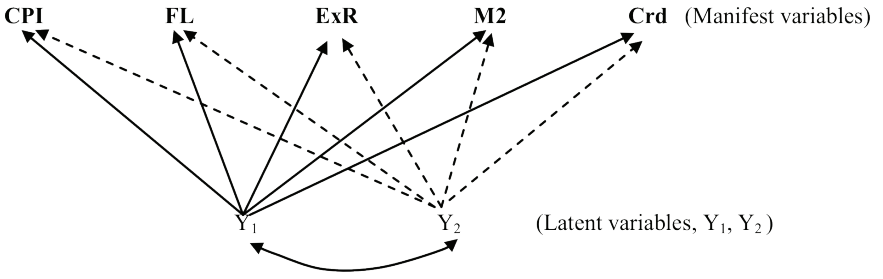
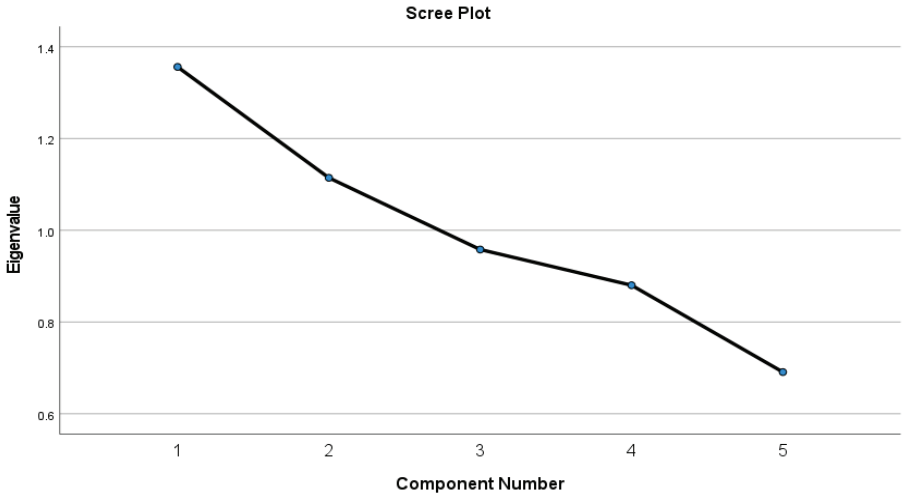


Figure 3: Factor determination and the Scree Plot



4. Empirical findings - How do the variables load and what are the implications of the loadings?

As previously mentioned, the preliminary research objective was to determine how the manifest variables could be positioned under latent factors that may not show interaction. The secondary objective was to then analyze the results of loadings and determine the susceptibility of the variables to relevant shocks and the period of dissipation. With the two components above an eigenvalue of 1, the Scree Plot (Figure 3) indicates that only two factors can be extracted from the data; components that are below the eigenvalue of 1 are not worthy of consideration; since components with higher eigenvalue (>1) are most probably going to represent a latent factor.[5] Table 2 reports the proportion of variance for each variable that can be explained by the factors and Table 3 reports the factor loadings.

Table 2: Proportion of variance for each variable that can be explained by the factors

Variables (monthly changes)	Initial value	Extraction Value
Consumer inflation (*CPI*)	1	0.352
Exchange rate Le/US$ (*ExR*)	1	0.616
External price of crude oil (*Crd*)	1	0.552
Domestic cost of energy (*FL*)	1	0.580
Local currency in circulation (*M2*)	1	0.370

Notes: Extraction method for communalities= Principal Component Analysis (PCA)

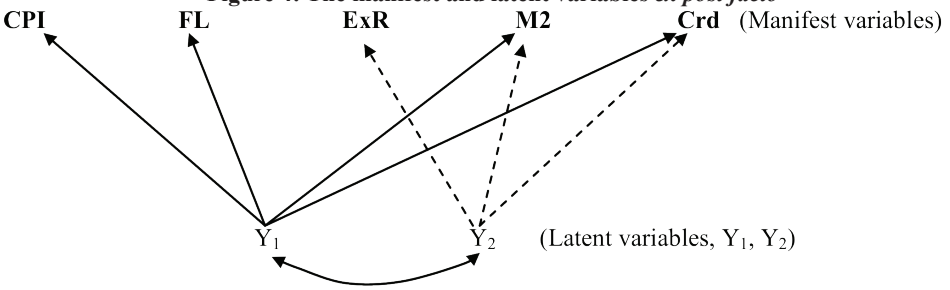
[5] Eigenvalues (λ_i) are the scalar solutions of square matrices; $\lambda c=Ac$ or $c(A-\lambda I)c=0$; where c is for an unknown $k*1$ vector (an eigenvector of A) and A is for a $k*k$ matrix of known values.

Table 3: The Component matrix of factor loadings*

Variables	Y_1	Y_2
Consumer inflation (*CPI*)	0.556	X
Exchange rate Le/US$ (*ExR*)	X	(0.781)
External price of crude oil (*Crd*)	0.558	0.454
Domestic cost of energy (*FL*)	0.754	X
Local currency in circulation (*M2*)	(0.357)	0.492

* Absolute value of loadings is significant; (extraction method = PCA)

Figure 4: The manifest and latent variables *ex post facto*



The empirical results of Table 3 permit us to modify a *priori* macroeconomic perceptions of Figure 2; Figure 4 is revealing of the post-optimality analysis (update). Only the significant explained variations were reported. The exchange rate fails to load under the latent factor Y_1, which is presumed to be domestic; that is, the domestic factor does not seem to explain the variations in changes in the exchange rate. Of course, while this might be a matter of omitted variable bias, more significantly, a small open economy has little clout in international or global market transactions; especially when its currency is not convertible. The factors (domestic and external) commonly explain changes in the variations in local currency in circulations and changes in international crude oil prices; most likely through the currency and absorption (demand) channels. These findings provide clinical opportunities for deriving Bayesian confidence intervals and the dynamics of shocks (perturbations) to specific variables that are associated with domestic and foreign factors. Based on model selection—with an inverse gamma prior—and the estimates of Bayesian factors, the data on crude oil provide the most scientific evidence in support of our hypothesis (13.4).[6] The scientific affirmation also makes a compelling case for meaningful energy diversification. The posterior mean and 95% credible interval are reported in Table 4.

[6] The Bayesian factor is an estimate of a ratio of probability of odds in favor of the scientific validity of data: $BF = \frac{pr(\zeta \mid H_1)}{pr(\zeta \mid H_2)}$, the posterior odds of H_1 to that of H_2.; where odds=p/(1-p) and H_1 is the likelihood that the data provides scientific evidence in support of the model (see Jeffreys (1961) and Kass & Raftery (1995) for further discussions).

Table 4: The mean and credible interval of the posterior distribution*

Variables	Mean	Lower Bound	Upper Bound
Consumer inflation (*CPI*)	0.99	0.87	1.12
Exchange rate Le/US$ (*ExR*)	0.01	(0.01)	0.03
External price of crude oil (*Crd*)	0.01	(0.01)	0.03
Domestic cost of energy (*FL*)	2.12	1.73	2.51
Local currency in circulation (*M2*)	0.01	(0.001)	(0.03)

Note: * Prior is based on variance (inverse gamma), with Monte Carlo samples of 10,000 and a credible volatility interval of 95%.

The credible intervals present the scientific intervals within which the variables are expected to vacillate every month after augmenting the data with Monte Carlo simulations. A variant of the simulation is the Markov Chain Monte Carlo (MCMC) simulation.[7] The Leone (relative to the US$ can be expected to appreciate by 1% and depreciate by 3 % every month. The volatility of the domestic cost of energy can change from 1.73% to 2.51% every month. Monthly changes in the exchange rate, the local currency in circulation, and external prices of crude oil exhibit little volatility.

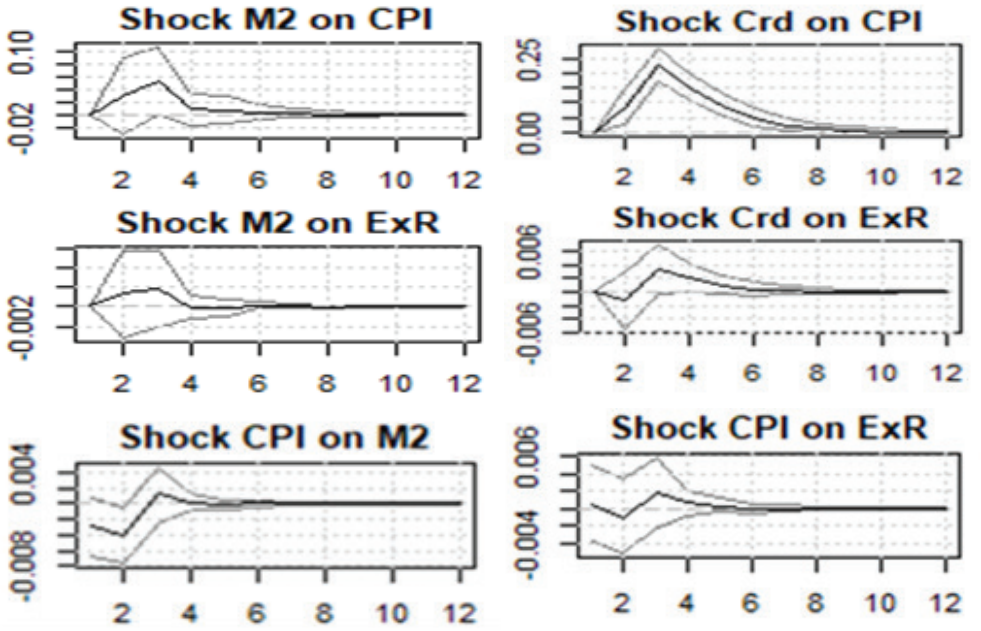
The assortment of the variables into stipulated factors and the corresponding values of their loadings provide unique opportunities for analysis of disturbances in the economy. The Akaike information criteria (AIC) are utilized to determine the structure of the lags for the impulse response functions. The effects of targeted shocks are presented in Figure 5.

[7] The MCMC was developed in the 1950s. A comprehensive discussion of the MCMC can be found in the work of Geyer (2011); summarized here for convenience. A sequence $X_1, X_2 \ldots$ of random elements of some set is considered to be a *Markov chain* if the conditional distribution of X_{n+1} given $X_1, \ldots, X_n$ depends on X_n only. However, the MCMC theory holds that a *Markov chain* has stationary transition probabilities if the conditional distribution $X_{n+1}|X_n$ does not depend on *n*. The set in which the X_{is} take values, which can be finite or infinite, is known as the state space of the *Markov chain*. When the state space becomes infinite, the initial distribution or transitional probability distribution ceases to be a vector or matrix to become conditional or unconditional probability distribution. The Ordinary Monte Carlo (OMO) like the MCMC is considered to be "independent and identically distributed"—each random variable has the same probability distribution like others although the sample items are independent events—and therefore stationary and reversible; the expected mean of X in a state space (*g*) is just:
$\mu = E\{g(X)\} = \hat{\mu}_n = \frac{1}{n}\sum_{i=1}^{n} g(X_i)$, with variance σ2=var {g(X)}.
For $Y_i = g(X_i)$ the sample mean and Central limit theorem become:

$$\hat{\mu}_n \approx N\left(\mu, \frac{\sigma^2}{n}\right).$$

Unlike the estimating procedure of the variance in the CLT: $\hat{\sigma}_n^2 = \frac{1}{n}\sum_{i=1}^{n} g(X_i - \hat{\mu}_n)^2$, the variance of the Markov chain, $\sigma^2 = \text{var}\{g(X_i)\} + 2\sum_{k=1}^{\infty} \text{cov}\{g(X_i), g(X_{i+k})\}$, cannot be estimated in a straightforward way. Monte Carlo uses a batch (*b*) (subsequence of consecutive iterates) to estimate a mean and variance; where the batch mean becomes: $\frac{1}{b}\sum_{j=1}^{b} g(X_{k+j})$ with an approximate distribution of $N(\mu, \sigma^2/b)$; where *b* is for the batch length (entire run of length *n*) with an asymptotic variance σ^2/b (for infinite sample sizes) rather than σ^2/n (finite sample sizes) (Geyer, 2011, p. 1-14).

Figure 5: The effects of domestic and external perturbations



As expected, a positive money supply shock increases consumer inflation on impact. A similar reaction applies to the response of consumer inflation in the domestic economy to the external shock of crude oil prices. [8] Though the exchange rate does not significantly load under the local factor, shocks to the currency in circulation have an immediate depreciation impact on the value of the Leone relative to the dollar. The loadings help to unearth transmissions of shocks.[9] A shock to external crude oil prices has a comparable effect on the value of the exchange rate. Consumer inflation has a lagging effect on the local money supply and exchange rate. Notably, the sudden but temporary disruptions (shocks) are not generally persistent; they tend to dissipate after about 6 months.

5. Conclusion and policy implications

The study found two factors (clusters) for the variables that have been considered in this paper, with dual clusters for changes in local currency in circulation and changes in the price

[8] $AIC = \ln\left(\frac{e'e}{n}\right) + \left(\frac{2k}{n}\right)$; where k is for the number of independent variables, n is for the sample size, and e =y-Xb—with b minimizing the error/residual sum of squares (e'e). The Schwarz information criteria (SIC) provides identical diagnosis.

[9] For example, Hawkesby et al. (2007) were able to unearth probable channels of commonality through which cross-border and cross-market financial shocks were transmitted; this is a useful strategic approach for analyzing shocks and monetary policy objectives of the BSL.

of crude oil. Notably, the clusters of the exploratory experiment explain significant variations in the variables of interest.

Significantly, the variables—changes in local currency in circulation and changes in the price of crude oil—that are common to the domestic and external clusters have a dominant presence in consumer inflation when they are subjected to disturbances or shocks. Productivity and growth in national output can attenuate the effects of the shocks though they do not seem to have a long-lasting impact but are momentarily impactful. Monetary policy is insufficiently capable of dealing with inflationary pressures; that is, the real sector must react to such pressures. "Inflation is just too much money chasing too few goods in rudimentary or simplistic terms." Consumer inflation in turn impacts changes in the money supply and the volatility of the exchange rate, which is denominated in US dollars (a convertible currency).

Energy diversification remains a critical precondition for minimising the effects of disturbances associated with crude oil prices on the domestic economy and the exchange rate. As enshrined in the 2019 BSL Act, central bank autonomy is also necessary for maintaining the optimal circulation of local currency, including transactional increases in liquidity afforded by local depository institutions.

Peer-review: Externally peer-reviewed.
Author Contributions: Conception/Design of Study- C.E.S.W., E.A.J.; Data Acquisition- C.E.S.W., E.A.J.; Data Analysis/Interpretation- C.E.S.W.; Drafting Manuscript- C.E.S.W., E.A.J.; Critical Revision of Manuscript- C.E.S.W., E.A.J.; Final Approval and Accountability- C.E.S.W., E.A.J.
Conflict of Interest: The author has no conflict of interest to declare.
Grant Support: The author declared that this study has received no financial support.

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