Effect of Oil Prices and Inflation on the Cost of Electricity in Rwanda: A Multivariate Time Series Approach

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Abstract: **Electricity price has often been analyzed using univariate time series approach, where for example autoregressive and moving average models were used to model and forecast. But these univariate econometric models are not able to capture the evolution and the interdependencies between multiple time series; to measure the effect of each independent variable on dependent variable. This research project was aimed to measure the effects of Consumer Price Index CPI; fuel price FP and gasoil price GP on electricity price EP in Rwanda. This study used a vector autoregressive model to evaluate the effects of the oil price and consumer price index on electricity price in Rwanda. The model used observed secondary data from 2006 to 2015 on oil price, and consumer price index. Unit root test was conducted in order to know if the data are stationary. The co-integration approach was employed to investigate the long-run relationship between electricity price and variables mentioned above. Ordinary least square was adopted as estimation technique of the parameters to test their adequacy, also Granger causality tests were used to analyze the dynamic relationship between electricity price and its independent variables. The impulse response functions and variance decomposition were used to show how the fluctuations in oil prices and consumer price index affect the electricity price in Rwanda. In this study, Eviews software was used for data analysis and the results revealed that the considered variables are not co integrated, means that there is no long run relationship among the variables.**

Keywords: **Vector autoregressive, VAR model, Consumer price index, inflation, and Oil price.**

I. INTRODUCTION

The electricity sector has long been an integral part of the engine of economic growth and a central component of sustainable development. Before 1999s, electricity had been considered a natural monopoly, and electricity price in most countries was owned or strictly regulated by public company. Particularly in developing countries, public company leadership in the development and use of electricity was a part of a broader 'social compact'. Then, with astonishing speed, a revolution in thinking swept the sector.

Several countries undertook major reforms, ranging from opening their electricity markets to independent power generators to broad-based reforms remaking the entire sector around the objective of promoting competition (Mtunya, May, 2010). Due in part to these changes, $187 billion was invested in energy and electricity projects in developing countries and the economies in transition in Central and Eastern Europe between 1990 and 1999.

A 1998 survey of 115 developing countries found that nearly two thirds had taken at least minimal steps toward market-oriented reforms in the electricity sector (Bacon, 1999). Electricity price has often been analyzed using univariate time series approach, where for example autoregressive and moving average models were used to model and forecast. But these univariate econometric models are not able to capture the evolution and the interdependencies between multiple time series; to measure the effect of each independent variable on dependent variable.

Petroleum is one of the components of Rwanda's energy. Petroleum products are essential for industrial use, lighting, and transport. Over the economic development,maintaining a stable supply of low-cost petroleum products will become more and more important.

This is particularly important in aviation. Rwanda is planning to position itself as a regional airtransport hub, as such, supply of low cost reliable aviation fuels is essential if this ambition is to be realised (Mininfra, 2013).

To establish the effect of oil price and inflation on electricity price in Rwanda will help the Rwanda Energy Group (REG) to regulate the price through those factors. The study is important in understanding if the Consumer Price Index CPI; and oil prices (fuel and Gasoil) have effect on electricity price in Rwanda, through this, the government will be assisted to know to extent the electricity generation needs to be opened up.

The study is also important in addressing the financial situation of Rwanda Energy Group (REG) which has affected the electricity price (i.e how the fluctuations in oil price and consumer price index are affecting electricity in Rwanda). In addition, the study provides the relationship between the independent variables (oil price; cost price index) and the dependent variable (Rwanda household electricity price). From the associated multivariate model, we can check whether the corresponding coefficients are statistically significant or not. Once the coefficients are statistically significant, this means that the particular independent variable is significant to the dependent variable (household electricity price). Through this, Rwanda energy group will have the opportunity to identify if there is significant effect of the stated independent variables on electricity price or not, and to link variability of household electricity price with variability of oil price, and consumer price index in Rwanda.

Rwanda Energy Group REG is only one public owned company which is in charge of electricity business and electricity accounts for only about 5% of primary energy use in Rwanda. Biomass is the primary source of energy accounting for some 84% of primary energy use, and petroleum products account for the rest (ie. 11% of primary energy). Rwanda has one of the lowest electricity consumption per capita compared to other countries in the region.

Rwanda has some of the highest electricity tariff in the region. The current electricity tariff is FRW 112/kWh (+vAT) for small Lv (low voltage) consumers and FRW 105/kWh (+vAT) for large commercial and industrial MV (Medium Voltage) consumers. A consultant study estimates that the tariff for residential customers is below the marginal cost of supply to residential customers, whereas the current industrial tariff is above the marginal cost of supply (Rwanda, 2011).

Objective of the study:

Specifically the study aimed at achieving the following objectives:

1. To estimate the corresponding multivariate time series model.
2. To examine whether the coefficients of identified model are significant or not
3. To test the causality of the determinants of electricity price.
4. To measure the effect of oil price and consumer price index on electricity price in Rwanda

II. LITERATURE REVIEW

Electricity is among the most volatile of commodities. Daily average change of the spot electricity price can be up to 50%, while at the same time for other commodities is up to 5%. There are many market players depending on electricity price trends, such as generators, traders, suppliers and end customers (particularly large industrial customers) (Tina Jakaša #1, 2011). Electricity is homogeneous good that cannot be stored at reasonable economic costs. However, the demand is highly seasonal and needs to be satisfied at all times. Hence, it is most efficient to generate electricity with a mixture of various technologies with different properties regarding capital cost and marginal costs. These technologies also differ in terms of input fuels and carbon emissions. Therefore, how input price variations affect the electricity price critically depends on the marginal technology used; and the marginal technology used depends on the level of the residual demand. The present paper tries to investigate exactly this effect. If the residual demand is low (e.g. because electricity demand is low in the night; or because there is a lot of wind feed-in), the marginal power plant will be a coal fired power plant, and we expect that changes in the gas price will not affect the electricity price. This will be the case only if demand is high.

The approach in the present paper allows identifying how the fuel price effects vary with the size of the residual demand (thoenes, 2011).

The energy sector in Rwanda consists of three components; Electricity, Biomass and petroleum, with each playing a key role in Rwanda's transition to a middle income country by the end of the decade. Energy is a service and a key input into economic development and household activity. Different sources of energy have different uses and there is need to ensure that the most appropriate form of energy is available in a cost effective, reliable and sustainable manner. As an axample, it would be impossible to charge a mobile phone using biogas and its as well not cost effective to use electricity for cooking. Electricity is an essential driver of modern technology and socio-economic development. Use of electricity is required for both low consumption devices such as lights and mobile phone and large users such as industry which will enable industrial processing activities, value addition, driving exports and job creation.

Electricity access can be through on-grid connections to households and business and off-grid solutions such as mini hydros as well as small solar generation.

Network connections require significant capital costs but are able to provide the reliable, high voltage electricity required for commential and large residential users.

To keep pace with the increased demand for electricity, Rwanda will ensure increased electricity generation capacity above the current capacity of around 110 MW. Approximately 45% of the existing generation will enable the government maintain a regionally competitive tariff whilst eradicating subsisdies to the energy tariff.

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A Vector auto regression (VAR) was introduced by Sims (1980) as a technique that could be used by macroeconomists to characterize the joint dynamic behavior of a collection of variables without requiring strong restrictions of the kind needed to identify underlying structural parameters. It has become a prevalent method of time-series modeling and forecasting.

Fritzer et al. (2002), Lutkepol (2003) and many other authors suggest that for the calculation of forecasts of economic indicators VAR models should be applied because all variables in these models are endogenous, and, therefore, not a single variable may be removed when explanations for the behavior of other variables are offered. Applications of VAR models to financial data are given in Hamilton (1994), Campbell, Lo and MacKinlay (1997), Cuthbertson (1996), Mills (1999) and Tsay (2001). These models will be used to provide forecasts of a large number of economic variables, including electricity price time series (Brooks, Introductory Econometrics foro finance, 2008).

Oil price declines have been followed by temporary falls in global inflation. Although the decline in inflation has been quite pronounced in high- income countries, the impact across countries has varied significantly, reflecting in particular the importance of oil in consumer baskets, exchange rate developments, and the stance of monetary policy, the extent of fuel subsidies and other price regulations (John Baffes, 2015).

In general, the pass-through from oil prices to inflation appears to have declined over time owing in part to the reduced oil dependence of production and consumption and a better anchoring of inflation expectations. This has significantly reduced the second round effects of oil price fluctuations on core-inflation. The dynamics of the propagation of commodity price shocks across a sample of 46 countries studied in Pedersen (2011) also confirm a limited impact of oil price changes on core-inflation, contrasting with the more lasting effect of food price shocks, particularly in emerging and developing economies. Historically, oil price drops have been followed by temporary declines in inflation, especially in high-income countries. The pass-through from oil prices to core inflation is generally muted. The projected 45 percent decline in oil prices in 2015 is likely to temporarily lower inflation by up to 1.2 percentage point, but the impact will dissipate in 2016. The oil price decline can be expected to affect natural gas prices, especially in Asia and, to a lesser extent, in Europe. (John Baffes, 2015). Inflation is defined as an annual increase in the price of a basket of goods and services that are purchased by consumers in an economy. Inflation rate therefore measures the changes over time of consumer price or the GDP deflator which takes into account prices of goods and services produced in the country. The inflation rate is calculated as a relative change of consumer price index (CPI) or retail price index (RPI) (Charline, 2015).

III. METHODS OF DATA ANALYSIS

The analysis of this study is divided into four parts. First, the unit Root Test of each variable was verified, this will help us to make the variables under study stationary. Secondly, cointegration test was applied to measure whether the variables under study moved together in the long-run. Third, Granger causality test was examined and fourth, we analyzed the empirical effect oil price and consumer price index on electricity price using impulse response function and variance decomposition.

Once the co integration is revealed, error correction model will be applied; otherwise the VAR model will be applied.

Co integration means that each of the variables is no stationary by itself, but a linear combination of these integrated variables is stationary. The vector error correction model (VECM) is employed to analyze the effects between the oil prices and the household electricity price; inflation and the household electricity price; the consumer price index CPI and the household electricity price. The VECM can be derived from the vector auto regressive model (VAR), which is a multivariate dynamic regression model. The specification in this study follows Johansen and Juselius (1990).

Consider the p-dimensional VAR model of the order k

$$X_t = \prod_1 X_{t-1} + \cdots + \prod_k X_{t-k} + \epsilon_t \qquad \textbf{(1)}$$

Where $\boldsymbol{\epsilon_t}$ is a vector of independent identical normally innovations with E (ϵ_t) = 0,

E (ϵ_t, ϵ_t^T) = Σ (positive definite covariance matrix), and $\Pi_i$are (K x K)coefficient matrices. After taking first differences with $\Delta = 1 - L$, the model can be expressed as

$$\Delta X_t = r_1 \Delta X_{t-1} + \cdots + r_{k-1} \Delta X_{t-k+1} + \prod X_{t-k} + \epsilon_t \qquad \textbf{(2)}$$

With

$$\Gamma_i = -(I - \Pi_1 - \cdots - \Pi_i), i = 1, \ldots, k-1$$

and

$$\prod = -(\boldsymbol{I} - \prod_{\mathbf{1}} - \cdots - \prod_{\boldsymbol{k}})$$

The rank of the matrix ∏ determines the long-run relationship. The Johansen test, which is used to test for rank of the matrix, is employed in chapter four of this study.

If the matrix ∏ has the full rank p, the vector process X_t is stationary and normal VAR for the level of the variable can be used. If the rank of the matrix is 0, there is no long-run relationship and the model above is equal to a VAR in differences. If the rank is greater than 0 and smaller than p, there is a co integration relationship of rank r. In this case, there are pxr matrices α and β such that equation $\prod = \alpha\beta'$ holds. Multiplying the r co integration vectors β by the vector process X_t gives the stationary term$\beta' X_t$. The vectors α are called adjustment vectors. In a VECM, there are two ways of price interdependency.

Short-term effects of the variables are captured similar to the vector autoregressive model of differences. The long-term effects enter the model with the term $\prod X_{t-k}$.

Vector Error Correction Model (VECM):

If co integration has been detected between series we know that there exists a long-term equilibrium relationship between them so we apply VECM in order to evaluate the short run properties of the co integrated series. In case of no co integration VECM is no longer required and we directly precede to granger causality tests to establish causal links between variables. The regression equation forms for VECM is as follows:

$$\Delta Y_t = \alpha_1 + p_1 e_1 + \sum_{i=0}^{n} \beta_i \Delta Y_{t-i} + \sum_{i=0}^{n} \delta_i \Delta X_{t-i} + \sum_{i=0}^{n} \gamma_i Z_{t-i} \qquad \textbf{(3)}$$

$$\Delta X_t = \alpha_2 + p_2 e_{i-1} \sum_{i=0}^{n} \beta_i Y_{t-i} + \sum_{i=0}^{n} \delta_i \Delta X_{t-i} + \sum_{i=0}^{n} \gamma_i Z_{t-i} \qquad \textbf{(4)}$$

In VECM the cointegration rank shows the number of cointegrating vectors. For instance a rank of two indicates that two linearly independent combinations of the non-stationary variables will be stationary.

A negative and significant coefficient of the ECM indicates that any short-term flictuations between the independent variables and the dependent variable will give rise to a stable long run relationship between the variables.

Stationary Test of time series:

Sim, et al (1990) suggest that non-stationary time series are still feasible in VAR modeling. But in practice, using the non-stationary time series in VAR modeling is problematic with regards to statistical inference since the standard tests used for inference are based on the condition that all of the series used must be stationary. If we have a non-stationary time series it is not a good idea to regress one on the other. Even if they are independent, the vast majority of the points will be significantly correlated to one another. If we fit an OLS, the parameter beta will look statistically significant even though they are independent (spurious regression).

Stationary of a series is an important phenomenon because it can influence its behavior. Time series stationarity is the statistical characteristics of a series such as its mean and variance over time. If both are constant over time, then the series is said to be a stationary process (i.e. is not a random walk/has no unit root).

Differencing a series using differencing operations produces other sets of observations such as the first differenced value, the second differenced value and so on (1Fadli Fizari Abu Hassan Asari, 2011).

Johansen Test for Co integration:

Testing for cointegration is necessary step to check if you are modeling empirically meaningful relationships. If variables have different trends processes, they cannot stay in fixed long-run relation to each other, implying that you cannot model the long-run, and there is usually no valid base for inference based on standard distributions. If you do not find cointegration it is necessary to continue to work with variables in differences instead. In a nutshell, cointegration assumes a common stochastic non-stationary process underlying two or more processes X and Y (Gathingi, 2014).

Granger-Causality:

A general specification of the Granger causality test in a bivariate (X, Y) context can be expressed as:

$$Y_t = \alpha_0 + \alpha_1 Y_{t-1} + \cdots + \alpha_i X_{t-i} + \beta_1 X_{t-1} + \cdots + \beta_i X_{t-i} + \mu \quad \textbf{(5)}$$

$$X_t = \alpha_0 + \alpha_1 X_{t-1} + \cdots + \alpha_i X_{t-i} + \beta_1 Y_{t-1} + \cdots + \beta_i Y_{t-i} + \mu \quad \textbf{(6)}$$

In the model, the subscripts denote time periods and μ is a white noise error.The constant parameter "α_0 represents the constant growth rate of Y and X in the above equations and thus the trend in these variables can be interpreted as general movements of cointegration between X and Y that follows the unit root process.

We can obtain two tests from this analysis: The first examines the null hypothesis that the X does not Granger-cause y and the second test examines the null hypothesis that the Y does not Granger-cause X. If we fail to reject the former null hypothesis and reject the latter, then we conclude that X changes are Granger-caused by a change in Y. Unidirectional causality will occur between two variables if either null hypothesis of one the above equations is rejected. Bidirectional causality exist if both null hypotheses are rejected and no causality exists if neither null hypothesis of equation (3.6) nor (3.7) is rejected (Brooks, Econometrics for finance, 2008)

IV. DATA ANALYSIS RESULTS, INTERPRETATION AND DISCUSSION

At 5% the critical values are more than the P-value after the first differencing for all variables, this means that the variables under study are stationary after the first differencing and the order of integration for them is one I(1). Trace and max eigen value tests indicates that there is no cointegration (the null hypothesis H_0 is accepted at 5% level) at 0.05 level,this means that there is no long-run association between the variables under study. The estimated VAR model is the following:

DEP = -0.013*DFP(-1) + 0.010*DFP(-2) - 0.046*DFP(-3) - 0.018*DGP(-1) + 0.051*DGP(-2) + 0.054*DGP(-3) - 0.029*DEP(-1) + 0.148*DEP(-2) + 0.083*DEP(-3) + 0.024*DCPI(-1) - 0.069*DCPI(-2) - 0.040*DCPI(-3) + 0.551

For the residuals diagnostic, we check serial correlation; the test statistics and probabilities from Breush-Godfrey serial Correlation LM test and white heteroskedasticity test indicate respectively that there is no problem of serial correlation and heteroscedasticity. The Jarque-Bera test revealed that the residuals of this model are not normally distributed.

Pairewise Granger causality tests revealed that there is causality from the gasoil and fuel prices to the electricity price that is almost significant at the 5% level, but no causality in the opposite direction. There is causality from gasoil price to the fuel price, but no causality in the opposite direction. No causality between the consumer price index and electricity price in either direction.

Impulse response functions:

Response of DEP to DCPI means that, if one standard deviation shock is given to consumer price index how the electricity price shall be reacting. Initially (for the first months) when consumer price index has positive or negative shock, the electricity price becomes positive. After first month the function shows that one standard deviation shock given to consumer price index does not affect electricity price i.e reaction of electricity price is approximatively zero. Response of DEP to DFP means that, if one standard deviation shock is given to fuel price how the electricity price shall be reacting. Initially the reaction is negative, after two months the reaction becomes positives until the seventh month, from the eighth to the tenth month the reaction becomes zero.

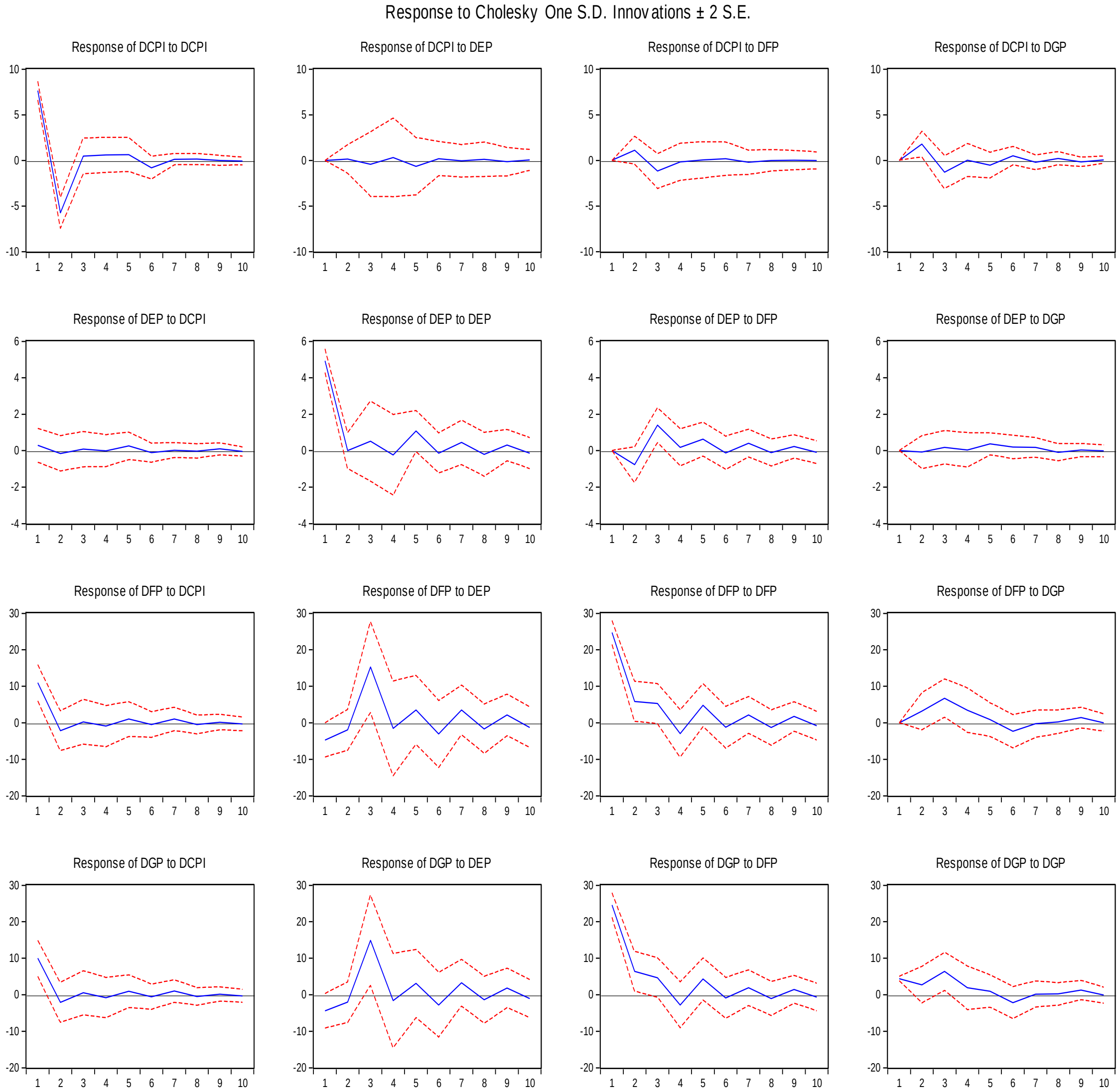

Figure 1: Impulse response functions

Variance decomposition:

The variance decomposition shows the variance forecast error. In the short run, for instance three months, the impulse or shock to electricity price account for 9.25% variation of the fluctuation in fuel price FP; the impulse or shock to electricity price EP account for 0.49% variation of the fluctuation in gasoil price; the impulse or shock to electricity price account for 89.28% variation of the fluctuation in electricity price (own shock); and the impulse or shock to electricity price account for 0.97% variation of the fluctuation in consumer price index CPI.

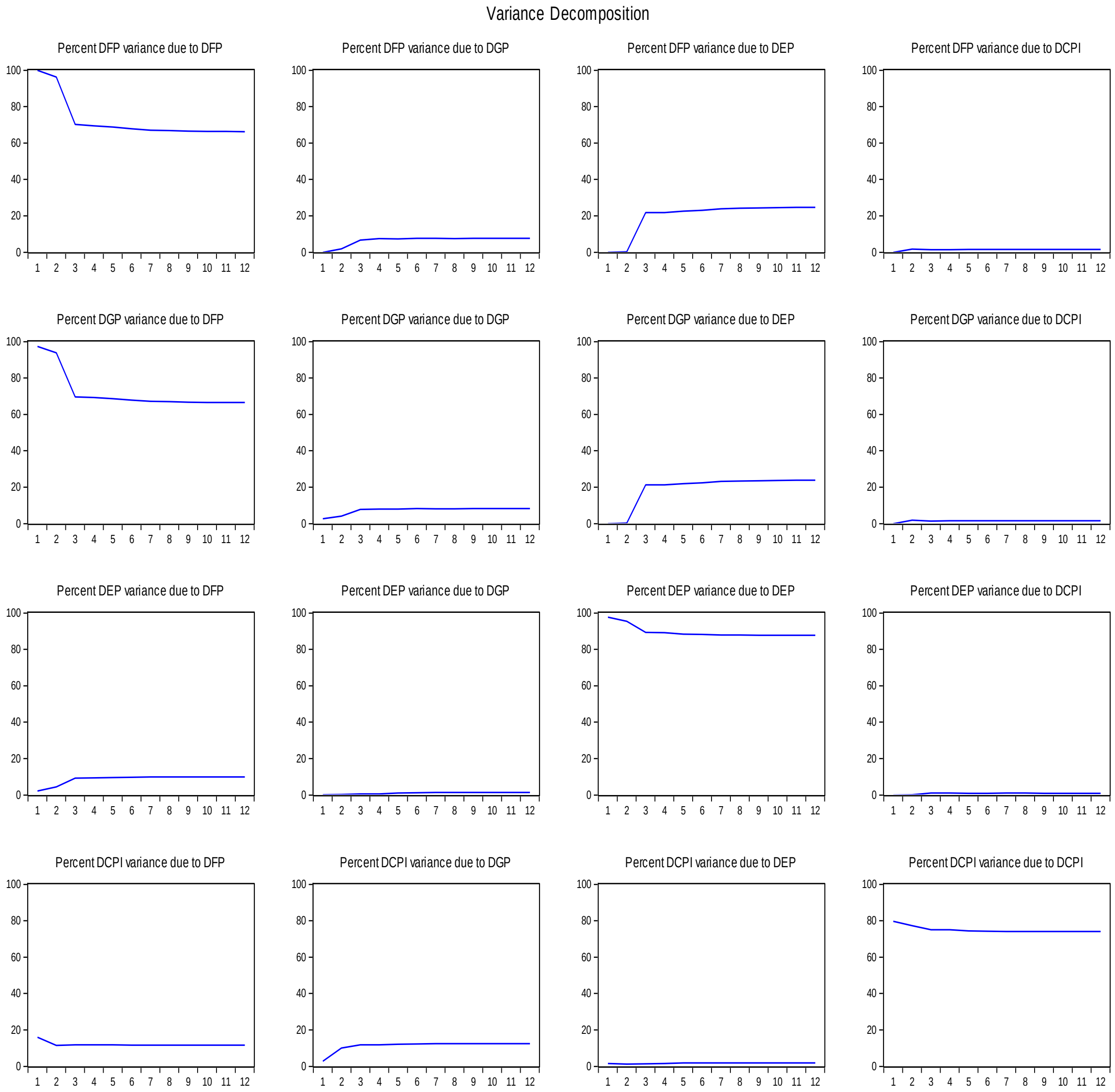

Figure 2: Variance decomposition

As shown in the following table, shocks to fuel price in eight months are 9.83%, gasoil price is 1.36%, and cost price index is 0.96%. Shock on electricity price cause 87.83% fluctuation to electricity price variance and decreases in the long run. Shocks applied on fuel and gasoil price increase in the long run while shocks applied on cost price index decreases in the long run.

Table 1:Results ;Variance decomposition

T	S.E.	DFP	DGP	DEP	DCPI
1	4.947	2.168	0.115	97.715	0.000
2	5.010	4.370	0.167	95.353	0.107
3	5.230	9.251	0.495	89.282	0.970
4	5.239	9.364	0.500	89.155	0.978
5	5.404	9.625	1.064	88.390	0.920
6	5.412	9.656	1.187	88.238	0.917
7	5.449	9.838	1.336	87.859	0.966
8	5.455	9.834	1.366	87.834	0.965

V. CONCLUSION AND RECOMMENDATION

Conclusion:

The result from vector autoregressive analysis revealed that fuel price, gasoil price and consumer price index each has no statistically significant impact on the cost of electricity in Rwanda. Change in fuel price, in gasoil price and consumer price index have no statistically significant effect on the cost of electricity price, this was revealed from the probability of the coefficients of the VAR model (all the probabilities of model coefficients are greater than 5%). In the short run, for instance three months, the impulse or shock to electricity price account for 9.25% variation of the fluctuation in fuel price; the impulse or shock to electricity price account for 0.49% variation of the fluctuation in gasoil price, and 0.97% variation of the fluctuation in cost price index CPI.The impulse or shock to electricity price account for 89.28% variation of the fluctuation in electricity price (own shock); and the impulse or shock to electricity price account for 0.97% variation of the fluctuation in cost price index. Shocks to fuel price in eight months are 9.83%, gasoil price is 1.36%, and consumer price index is 0.96%. Shock on electricity price cause 87.83% fluctuation to electricity price variance and decreases in the long run. Shocks applied on fuel and gasoil price increase in the long run while shocks applied on cost price index decreases in the long run.

Recommendation:

REG: The research conducted has proved that there no statistically significant impact of inflation on electricity prices and of oils prices (fuel and gasoil price) on electricity prices, from that we recommend Rwanda Energy Group (REG) to announce to the customers and the public the factors they consider when increasing the electricity price, this would reduce the complains and tensions of community towards the institution as till now it seems not clear for the public how the electricity prices change over time.

RURA, MINICOM, and MINECOFIN: It is almost known by everybody that the oil prices influence the prices of many goods in different countries, and in developed countries inflation and oil prices influence also the electricity prices, in Rwanda it is not the case unless further studies are done and prove that. These institutions should play a key role in stabilizing the electricity prices, as many changes may affect population's economy. These institutions should be in regular contact with REG and make sure the prices set are affordable by households and in case of changing the prices; there should be awareness on what has influenced the cost.

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