Inflation Rate and Exchange Rate in the Sudan: Causality Analysis

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Abstract:
This paper empirically examines the causality relationships between inflation rate and exchange rate in the Sudan. Yearly readings of inflation rate and exchange rate during the period 1970 – 2015 were used in the analysis of this paper.

The Augmented Dickey Fuller of unit root test was applied to the data to check for stationarity, the empirical results of the ADF test revealed that both inflation rate as well as exchange rate series level was nonstationarity whereas the first difference of both series was found stationary.

A Pair wise Granger Causality tests was applied to data representing inflation rate and exchange rate, to investigate the causality relationship among both variables, the empirical results shown that; inflation rate cause exchange rate however, exchange rate doesn’t cause inflation rate.

VAR two dimensional models were also to the data in order to investigate the relationships among both variables under consideration, the empirical results concluded that according to AIC, SC and HQ of order selecting criteria, VAR(1) model was chosen as an appropriate model to represent inflation rate and exchange rate relationship, moreover the LM test results confirmed that there is no serial correlation at lag one, also both Jarque–Bera and portmanteau tests
conclude that the residuals of VAR(1) model distributed as a normal distribution i.e. the error term was random.

A VAR Granger Causality test was also applied to the data, the findings also concluded that inflation rate as well as its all lags granger cause exchange rate therefore there was a unidirectional relationship however, exchange rate and its all lag does not granger cause inflation rate.

**Key words:** Inflation rate, Exchange rate, ADF– test, Granger Causality, VAR Models.
المستخلص:

تهدف هذه الورقة لاختبار العلاقة السببية بين معامل التضخم و سعر الصرف في السودان. استخدم في تحليل هذه الدراسة بيانات سنوية لمعامل التضخم و اسعار الصرف للفترة من 1970 الى 2015. استخدم اختبار ديكي فولار المطور في التحقق من سكون بيانات السلسلة و قد أشيرت نتائج تحليل الامurities عدم سكون سلسلة البيانات الأصلية لمعامل التضخم و معدل سعر الصرف بينما أوضحت نتائج نفس الاختبار سكون سلسلة الفروق الأولى للبيانات. تم تطبيق اختبار بير وايس للسبيبية لدراسة العلاقة السببية بين معدل التضخم و معدل سعر الصرف و قد أشيرت نتائج تحليل الامurities حالياً هذه العلاقة. 

تم تطبيق اختبار بير وايس لمسببية لدراسة العلاقة السببية بين معدل التضخم و معدل سعر الصرف و قد أشيرت نتائج الاختبار إلى وجود علاقة سببية ذات اتجاه واحد بين معدل التضخم و معدل سعر الصرف بينما اشارت نتائج نفس الاختبار إلى عدم وجود علاقة سببية بين معدل سعر الصرف و معدل التضخم، و معدل سعر الصرف بينما أشارت نتائج نفس الاختبار إلى عدم وجود علاقة سببية بين معدل سعر الصرف و معدل التضخم.

كما استخدم نموذج فضاء المتجها لتقديم العلاقة بين متغيرات الدراسة، معدل التضخم و معدل سعر الصرف، و قد أشارت نتائج التقييم أنه بناءً على معايير اختيار رتبة المذائع تم اختيار نموذج فضاء المتجها من الرتبة الأولى (VAR(1)) لتمثيل العلاقة بين معدل التضخم و معدل سعر الصرف.

تم تقدير النموذج و قد أشيرت نتائج اختبار لاقرانج إلى عدم وجود ترابط ذاتي بين حدود الخطأ للنموذج المقدر، كما أشارت نتائج اختباري جارك بيرإ و بارتمانتيو للعشوائية أن سلسلة بوافي النموذج المقدر عشوائية و تتبع التوزيع الطبيعي. استخدم اختبار السببية لفضاء المتغيرات لدراسة العلاقة السببية بين معدل التضخم و معدل سعر الصرف و قد أشيرت النتائج أن هناك علاقة سببية بين معدل التضخم و جميع فترات إبطائه و سعر الصرف بينما لا توجد علاقة سببية بين سعر الصرف و جميع فترات إبطائه و معدل التضخم.
Introduction:

Inflation in general means an increasing of all prices in a given economy. It is present in the economy or any country when there is excess of money supply compared to the quantity of goods and services, if Inflation is high this would be considered as a serious illness of macroeconomics. Exchange rate refers to the number of units of one nation’s currency that equals one unit of another currency (Tucker, 2006: 427). Exchange rate is one of the most important policy variables in an open economy as it affects the macroeconomic variables like inflation. The causal relationship between inflation rate and exchange rate has been one of the most debated topics in finance during the last few decades. A number of studies have been conducted to investigate the causality relationships, Madesha et al (2013), Khodeir (2012), Ammanuel Pitia Zacharia Lado (2015), numerous empirical literatures have been done on the inflation rate and exchange rate relationships, the aim of this study is to find out the relation of these two economics indicator, exchange rate and inflation rate in the Sudan.

The problem:

The problem of this study is concentrating in the following questions:

What is the nature of the relationship between inflation rate and exchange rate in the Sudan?

If this relationship was exist, what is the direction of this relationship?
Is inflation rate granger cause exchange rate and vice versa?

**The Objective:**

The objective of this study is to:

Investigate the causality relationships among the e inflation rate and exchange rate in the Sudan. Perform an appropriate VAR Mode to represents the relationships and helps in forecasting future values.

**The hypothesis:**

This paper hypothesizes that;

Inflation rate and its lags granger cause exchange rate.

Exchange rate and its lags does not granger cause inflation rate.

Inflation rate and its lags granger cause exchange rate and exchange rate and its lags does not granger cause inflation rate.

There is a long run relationship among inflation rate and exchange rate.

**Methodology:**

The empirical analysis framework in this study shows the applications of ADF test to investigate the stationarity of time-series, A pair wise causality analysis determine the effect and cause between the variables, VAR models to construct an appropriate model to represent the variables, and VAR causality analysis to investigate the relationship that may exist among the variables to data representing
inflation rate and exchange rate in Sudan, this will be utilized through EViews software.

**Literature review:**

There are numerous studies dealing with the Inflation Rate and Exchange Rate Causality Analysis around the world. In this section empirical studies in developed and developing countries will be reviewed.

Ammanuel Pitia Zacharia Lado (2015) carried the relationship between exchange rate and consumer price index (as a measure of inflation) in South Sudan using Granger causality approach employing monthly data for the period August 2011 to November 2014. The results revealed that there has been a unidirectional link running from exchange rate to consumer price index in the country.

Khodeir (2012) studied the relationship between exchange rate and inflation rate, monthly data from January 1990 to April 2008 were used. The results revealed that there was causality between the nominal exchange rate and inflation in Egypt with feedback effects.

Madesha et al (2013) carried out an empirical test of the relationship between exchange rate and inflation in Zimbabwe. Using Granger–causality approach for the annual data 1980 to 2007, the study established the existence of bidirectional causality. This means that the two variables were feeding each other.
Makochekekwa (2007) employed annual time series data in Zimbabwe to test the relationship among inflation and black market exchange rate using 1975 to 2006 data. He found that granger causality is bidirectional for the statistical significance of the variables that relate inflation to black market foreign exchange.

Odedokun (1995) identifies in his studies causes of inflation in sub-Saharan Africa. By employing econometrics to analyze annual reports data for 35 countries from 1971 to 1990. The findings suggest that monetary growth, the rate of domestic currency depreciation, and the expectation of inflation have positive effects on inflation, while expansion of per capita food production as well as overall economic growth serve to reduce inflation rates.

**Augmented Dickey Fuller Test:**

Dickey and Fuller extended their test procedure by suggesting an augmented version of the test which includes extra lagged terms of the dependent variable in order to eliminate autocorrelation. The lag length on these extra term is either determined by AIC or BIC. The three possible forms of the ADF test are given by the following equations:

\[
\Delta INF_t = \alpha + \beta t + \rho INF_{t-1} + \sum_{i=1}^{p} \delta_i \Delta INF_{t-i} + \varepsilon_t
\]
\[ \Delta EXR_t = \alpha + \beta t + \rho EXR_{t-1} + \sum_{i=1}^{p} \delta_i \Delta EXR_{t-i} + \varepsilon_t \]

The test statistic is: \[ \tau = \frac{\hat{\rho} - 1}{SE(\hat{\rho})} \]. The null hypothesis of a unit root test is \( H_0: \rho = 1 \), while the alternative hypothesis is \( H_0: \rho \neq 1 \). Rejection of the null hypothesis indicates that the series has roots outside the unit circle which indicates that the series is stationary.

**VAR Models:**

In an econometrics analysis, determination of an effect variable and the determination of cause variable is a great problem. Such a problem was analyzed by Granger casualty theory which is based on VAR (p) models. Granger test finds in empirical way the relationship that may exist among the variables in short term periods. The simplest case, of VAR (p) model of two dimensional for variables inflation rate and exchange rate general form of expressed as follows:

\[ INF_t = \sum_{i=1}^{m} \alpha_{1i} EXR_{t-i} + \sum_{i=1}^{m} \alpha_{2i} INF_{t-i} + \varepsilon_{1t} \]

\[ EXR_t = \sum_{i=1}^{m} \beta_{1i} INF_{t-i} + \sum_{i=1}^{m} \beta_{2i} EXR_{t-i} + \varepsilon_{2t} \]

Where: \( \alpha_{1i}, \alpha_{2i}, \beta_{1i}, \beta_{2i} \) are parameters, \( \varepsilon_{1t}, \varepsilon_{2t} \) are white noise error terms. In the above VAR model in equation 1, inflation rate is the dependent variable and the independent variables are inflation rate in lags and exchange rate in lags. If all
coefficients $\alpha_{1i} = 0$, therefore exchange rate does not affect on inflation rate. Similarly, in equation 2, exchange rate is the dependent variable and the independent variables are exchange rate in lags and inflation rate in lags. If all coefficients $\beta_{1i} = 0$, therefore inflation rate does not affect on exchange rate.

**Granger Causality Test:**

Causal can be defined from the evaluation of equations 1&2 through the test of the following null and alternative hypothesis:

The null hypothesis: $\sum_{i=1}^{m} \alpha_{1i} = \sum_{i=1}^{m} \beta_{1i} = 0$ against the alternative hypothesis:

$\sum_{i=1}^{m} \alpha_{1i} \neq 0, \sum_{i=1}^{m} \beta_{1i} = 0, \sum_{i=1}^{m} \alpha_{1i} = 0, \sum_{i=1}^{m} \beta_{1i} \neq 0, \sum_{i=1}^{m} \alpha_{1i} = 0 \neq 0, \sum_{i=1}^{m} \beta_{1i} \neq 0$

**Empirical Results:**

This section involves the applications of ADF test, A pair wise granger causality test and VAR models representation to data representing inflation rate and exchange rate in the Sudan to investigate the relationships among them and to perform an econometric model to help in forecasting.

**Data:**

The data will be used in the analysis of this paper are yearly readings of inflation rate and Exchange Rate in the Sudan for the period 1970 – 2015. The data are obtained from Central Bureau of Statistics and Bank of Sudan.
The sequence charts of inflation rate as well as exchange rate the Sudan for the period 1970 – 2015 and their first difference are shown below.

Figure (1) sequence charts of the series level and first difference inflation rate and exchange rate in the Sudan for the period 1970 – 2015.

It can be seen that inflation rate fluctuate has an increased since 1970 till 1995, and decreased till begging of 2000, after that inflation rate fluctuate steadily till 2012 and shown increase till 2013 before it decrease in 2014. Moreover, the exchange rate sequence charts shows steadily fluctuation from 1970 till 1990 then increase sharply till 2015. Bellow also the sequence charts of the first difference of both inflation rate as well as exchange rate in the Sudan for the period 1970 – 2015.
ADF Stationarity test results:

This section involves the application of the ADF of unit root test in testing whether inflation rate as well as exchange rate series levels are stationary or not. The ADF test results were carried out in the table (1) below:

Table (1) ADF test results of inflation rate and exchange rate (1970 – 2015):

<table>
<thead>
<tr>
<th>Variables</th>
<th>Level Intercept</th>
<th>First Difference Intercept</th>
<th>Trend and Intercept</th>
<th>Trend and Intercept</th>
</tr>
</thead>
<tbody>
<tr>
<td>INF</td>
<td>-2.181</td>
<td>-6.794*</td>
<td>-6.756*</td>
<td></td>
</tr>
<tr>
<td>EXR</td>
<td>-0.973</td>
<td>-3.455*</td>
<td>-3.610*</td>
<td></td>
</tr>
</tbody>
</table>

* means rejection of the null hypothesis (the series has a unit root) at 5% significance level

The ADF test with trend and intercept results in table (1) shown that both inflation rate and exchange rate series level in the Sudan are nonstationary however, the first difference of both series are stationary. Therefore, Granger casualty test and the VAR model approach may be better to use since both variables are I (1).

Granger Causality Test:

This section provides the empirical results of granger causality test on inflation rate and Exchange Rate in the Sudan for the period 1970 – 2015.
The ADF test results of both variables conclude that both variables are I (1), therefore Pair wise Granger Causality Tests will be done under the following possible outcomes:

Inflation rate causes Exchange rate and exchange rate causes inflation rate.

Inflation rate causes exchange rate and exchange rate does not cause inflation rate.

Inflation rate does not cause exchange rate and exchange rate causes inflation rate.

Inflation rate does not cause exchange rate and exchange rate does not cause inflation rate.

The Pair wise Granger Causality Tests results on the inflation rate and exchange rate for the period 1970 to 2015 are given below:

Figure (2) Pairwise Granger Causality Tests of inflation rate and exchange rate (1970 – 2015):

<table>
<thead>
<tr>
<th>Null Hypothesis</th>
<th>Obs</th>
<th>Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXR does not Granger Cause INF</td>
<td>44</td>
<td>1.53740</td>
<td>0.2277</td>
</tr>
<tr>
<td>INF does not Granger Cause EXR</td>
<td>7.54808</td>
<td>0.0017</td>
<td></td>
</tr>
</tbody>
</table>
A Pair wise Granger Causality Tests findings concluded that the calculated F–Statistic value is 1.5374 with probability value 0.2277 > 0.05, this result confirmed that exchange rate does not granger cause inflation rate. Furthermore the calculated F–Statistic value is 7.548 with probability value 0.0017 < 0.05, this result confirmed inflation rate granger cause exchange rate.

**VAR model order determination:**

This part illustrate the construction of VAR models to data representing inflation rate and Exchange Rate in the Sudan for the period 1970 – 2015, through VAR lag order selection criteria, LM serial correlation test, residuals tests as well as VAR granger causality test.

Figure (3) VAR model lag order determination of inflation rate and exchange rate (1970 – 2015) :

<table>
<thead>
<tr>
<th>Lag</th>
<th>LogL</th>
<th>LR</th>
<th>FPE</th>
<th>AIC</th>
<th>SC</th>
<th>HQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-169.8209</td>
<td>21.34094*</td>
<td>18.19957*</td>
<td>8.576628*</td>
<td>8.827394*</td>
<td>8.667943*</td>
</tr>
<tr>
<td>3</td>
<td>-166.7347</td>
<td>0.451986</td>
<td>23.27380</td>
<td>8.816328</td>
<td>9.401451</td>
<td>9.029398</td>
</tr>
<tr>
<td>4</td>
<td>-164.2476</td>
<td>3.882314</td>
<td>25.25185</td>
<td>8.890128</td>
<td>9.642428</td>
<td>9.164074</td>
</tr>
</tbody>
</table>

* indicates lag order selected by the criterion
Figure (3) shows the lag order selection criteria, according to AIC, SC and HQ of lag order selection criteria, the VAR model of order one i.e. VAR(1) of an appropriate model to represent inflation rate and exchange rate relationship.

After a VAR(1) model has been chosen as a parsimonious model to represent inflation rate and exchange rate in the Sudan for the period 1970–2015.

The estimation results of VAR(1) model are given below:

Figure (4) VAR(1) model parameter estimation of inflation rate and exchange rate in the Sudan for the period 1970–2015.

<table>
<thead>
<tr>
<th></th>
<th>D(INF)</th>
<th>D(EXR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>D(INF(-1))</td>
<td>-0.090563</td>
<td>-0.002194</td>
</tr>
<tr>
<td></td>
<td>(0.15399)</td>
<td>(0.00086)</td>
</tr>
<tr>
<td></td>
<td>[-0.58812]</td>
<td>[-2.55488]</td>
</tr>
<tr>
<td>D(EXR(-1))</td>
<td>-35.14174</td>
<td>0.512115</td>
</tr>
<tr>
<td></td>
<td>(21.8281)</td>
<td>(0.12173)</td>
</tr>
<tr>
<td></td>
<td>[-1.60993]</td>
<td>[4.20691]</td>
</tr>
<tr>
<td>C</td>
<td>2.197238</td>
<td>0.026313</td>
</tr>
<tr>
<td></td>
<td>(4.04126)</td>
<td>(0.02254)</td>
</tr>
<tr>
<td></td>
<td>[0.54370]</td>
<td>[1.16753]</td>
</tr>
</tbody>
</table>
Figure (4) above demonstrate the estimated vector autoregressive model parameters, standard errors and t-statistics for inflation rate and exchange rate in the Sudan for the period 1970–2015, a VAR(1) model of inflation rate as well as exchange of order 1 is expressed as follows:

\[
\Delta INF_t = 2.197 - 0.091\Delta INF_t(-1) - 35.141EXR_t(-1) + \varepsilon_{1t}
\]

\[
\Delta EXR_t = 0.026 + 0.512\Delta EXR_t(-1) - 0.002\Delta INF_t(-1) + \varepsilon_{2t}
\]
To check whether the estimated VAR(1) model has a serial correlation, the LM test of order two was carried out, below is a LM test results:

Figure (5) VAR(1) model serial correlation test

<table>
<thead>
<tr>
<th>Lags</th>
<th>LM–Stat</th>
<th>Prob</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5.168884</td>
<td>0.2704</td>
</tr>
<tr>
<td>2</td>
<td>4.910637</td>
<td>0.2966</td>
</tr>
</tbody>
</table>

Probs from chi–square with 4 df.

Figure (5) above shows a LM test for serial correlation, the LM test values at lag 2 are 5.17 and 4.91 with probability values 0.270 and 0.296 respectively, this results confirmed the acceptance of the null hypothesis that there is no serial correlation at lag one.

The portmanteau test for randomness was also used check whether the error term of the estimated VAR(1) model is random, the empirical results are shown below:
Figure (6) VAR(1) Residual Portmanteau Tests for Autocorrelations

VAR Residual Portmanteau Tests for Autocorrelations

Null Hypothesis: no residual autocorrelations up to lag h

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.408615</td>
<td>NA*</td>
<td>0.418118</td>
<td>NA*</td>
<td>NA*</td>
</tr>
</tbody>
</table>
|      |          |       | 0.278      |       | 0.255 | df is degrees of freedom for (approximate) chi–square distribution
| 2    | 5.089365 | 3     | 5.321760   | 8     | 4   |

*The test is valid only for lags larger than the VAR lag order.

The VAR residual portmanteau test results in figure (6) shown that the Q– statistics at lag 2 is equal 5.089 with probability value of 0.255 greater than 5% significant level which indicates that VAR(1) error term is distributed as a normal distribution.
The Jarque–Bera was also applied to test for randomness, the results shown below:

Figure (7) VAR(1) Residual Jarque–Bera Tests results:

<table>
<thead>
<tr>
<th>Component</th>
<th>Jarque–Bera</th>
<th>df</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.248102</td>
<td>2</td>
<td>0.3250</td>
</tr>
<tr>
<td>2</td>
<td>41.34959</td>
<td>2</td>
<td>0.1300</td>
</tr>
<tr>
<td>Joint</td>
<td>43.59769</td>
<td>4</td>
<td>0.1120</td>
</tr>
</tbody>
</table>

The Jarque–Bera test results on the residuals of VAR(1) conclude that the residuals distributed as a normal distribution.

Heteroscedasticity test on the residuals of VAR(1) model was carried bellow:

Figure (8) VAR(1) Residual Heteroscedasticity Tests for Autocorrelations

<table>
<thead>
<tr>
<th>VAR Residual Heteroskedasticity Tests: Includes Cross Terms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Joint test:</td>
</tr>
<tr>
<td>Chi–sq</td>
</tr>
<tr>
<td>15.11829</td>
</tr>
</tbody>
</table>

Individual components:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>res1*res1</td>
<td>0.175384</td>
<td>1.616407</td>
<td>0.1792</td>
<td>7.716882</td>
<td>0.1725</td>
</tr>
<tr>
<td>res2*res2</td>
<td>0.056705</td>
<td>0.456864</td>
<td>0.8057</td>
<td>2.495015</td>
<td>0.7772</td>
</tr>
<tr>
<td>res2*res1</td>
<td>0.087029</td>
<td>0.724472</td>
<td>0.6093</td>
<td>3.829284</td>
<td>0.5742</td>
</tr>
</tbody>
</table>
The residual hetroscadastisity tests results findings concluded that chi–square test value is 15.1182 with probability value 0.442, which indicates that the residual has a constant variance.

VAR Granger Causality test was also carried out to investigate the relationship among inflation rate and exchange rate in the Sudan, the results demonstrated bellow:

Figure (9) VAR Granger Causality lag 1 test results:

<table>
<thead>
<tr>
<th>Dependent variable: D(INF)</th>
<th>Excluded</th>
<th>Chi–sq</th>
<th>df</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>D(EXR)</td>
<td>2.591883</td>
<td>1</td>
<td>0.1074</td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>2.591883</td>
<td>1</td>
<td>0.1074</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dependent variable: D(EXR)</th>
<th>Excluded</th>
<th>Chi–sq</th>
<th>df</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>D(INF)</td>
<td>6.527413</td>
<td>1</td>
<td>0.0106</td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>6.527413</td>
<td>1</td>
<td>0.0106</td>
<td></td>
</tr>
</tbody>
</table>

A VAR granger causality test results in figure (9) shown that; chi–square value is equal to 2.591 with probability value of 0.1074 > 0.05 which means accept the
null hypothesis that exchange rate and its all lags does not granger cause inflation rate in the Sudan. Moreover, the result also concludes that; chi–square value is equal to 6.527 with probability value of 0.010 < 0.05 which mean rejection of the null hypothesis that exchange rate does not granger cause exchange rate therefore inflation rate and its all lags granger cause exchange rate in the Sudan.

Conclusion:

This paper were examined the empirical relationships among the inflation rate and exchange in the Sudan, to test whether the inflation rate and exchange rate are stationarity or not, the Augmented Dickey Fuller of unit root test results conducted that the inflation rate as well as exchange rate series level was nonstationarity whereas the first differences of both series were found stationary. Also Pair wise Granger Causality test was applied to inflation rate and exchange rate data, the empirical findings revealed that inflation rate cause exchange rate however, exchange rate does not cause inflation rate.

VAR two dimensional models were applied to the data, to explain the relationships between both variables. According to AIC, SC and HQ of order selecting criteria, VAR(1) model was selected as an appropriate model to represent inflation rate and exchange rate relationship. The LM test results confirmed that there is no serial correlation at lag one. Furthermore both Jarque–Bera and portmanteau tests of randomness conclude that the residuals of VAR(1) model distributed as a normal
distribution i.e the error term was random. VAR Granger Causality test was also concluded that exchange rate does not granger cause inflation rate however, inflation rate granger cause exchange rate.

These findings indicate that there was a unidirectional relationship between inflation rate and exchange rate in the long run.
Reference:


