**Health and Economic Growth in Sudan: Cointegration and Granger Causality Analysis (1969-2015)**

**TABLE 1.** Descriptive statistics

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | GDP | THE | TIV | UMR | CO2 | IMZ |
| Mean | 2,130 | 4.542 | 5342.096 | 118.550 | 0.244 | 43.24 |
| Median | 1,230 | 4.030 | 1815.908 | 122.980 | 0.216 | 52.84 |
| Maximum | 97,100 | 8.620 | 26667.35 | 155.880 | 0.382 | 95.16 |
| Minimum | 1,850 | 2.830 | 237.1590 | 68.1600 | 0.113 | 0.77 |
| Std. Dev. | 2,230 | 1.823 | 6878.856 | 26.421 | 0.083 | 35.56 |
| Skewness | 1.485 | 1.372 | 1.574 | -0.388 | 0.369 | -0.034 |
| Kurtosis | 3.819 | 3.407 | 4.368 | 1.872 | 1.624 | 1.455 |
| Jarque-Bera | 18.576 | 15.061 | 23.067 | 3.672 | 4.776 | 4.686 |
| Probability | 0.00009 | 0.0005 | 0.00001 | 0.1594 | 0.0912 | 0.096 |
| Observations | 47 | 47 | 47 | 47 | 47 | 47 |

**TABLE 2.** Correlation matrix

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | GDP | THE | TIV | UMR | CO2P | IMZ |
| GDP | 1 |  |  |  |  |  |
| THE | 0.90 | 1 |  |  |  |  |
| TIV | 0.98 | 0.88 | 1 |  |  |  |
| UMR | -0.87 | -0.77 | -0.87 | 1 |  |  |
| CO2P | 0.55 | 0.53 | 0.60 | -0.31 | 1 |  |
| IMZ | 0.77 | 0.67 | 0.78 | -0.95 | 0.22 | 1 |

**TABLE 3.** ADF unit root test: at level I(0) and first difference I(1)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Variable | ADF Test Statistic Value I(0) | 5% Mackinnon  Critical  Value I(0) | ADF Test Statistic Value I(1) | 5% Mackinnon Critical Value I(1) | Order of Integration |
| L(GDP) | -0.836 | -2.927 | -5.7180\* | -2.928 | I(1) |
| L(THE) | -1.014 | -2.927 | -7.080\* | -2.928 | I(1) |
| L(TIV) | -0.761 | -2.927 | -5.910\* | -2.928 | I(1) |
| L(UMR) | 2.689 | -2.928 | -9.451\* | -2.928 | I(1) |
| L(CO2) | -1.043 | -2.928 | -8.394\* | -2.928 | I(1) |
| L(IMZ) | -1.550 | -2.928 | -3.248\* | -2.928 | I(1) |

**TABLE 4.** Unrestricted cointegration rank test: Trace and Max-Eigen statistics

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Null Hypotheses | Eigen  Value | Trace  Statistic | 0.05 Critical  Value | Prob.\*\* | Max-Eigen Statistic | 0.05 Critical Value | Prob.\*\* |
| r = 0 | 0.794 | 139.638 | 95.754 | 0.0000\* | 69.558 | 40.078 | 0.0000\* |
| r ≤ 1 | 0.491 | 70.080 | 69.819 | 0.0477\* | 29.703 | 33.877 | 0.1454 |
| r ≤ 2 | 0.332 | 40.377 | 47.856 | 0.2093 | 17.751 | 27.584 | 0.5159 |
| r ≤ 3 | 0.257 | 22.626 | 29.797 | 0.2650 | 13.056 | 21.131 | 0.4471 |
| r ≤ 4 | 0.169 | 9.570 | 15.495 | 0.3153 | 8.124 | 14.265 | 0.3663 |
| r ≤ 5 | 0.032 | 1.446 | 3.841 | 0.2291 | 1.446 | 3.841 | 0.2291 |
| **Notes:** Trace test indicates 2 cointegrating equation while Max-Eigen value test indicates 1 cointegrating equation at the 0.05 level; \* denotes rejection of the hypothesis at the 0.05 level; \*\*MacKinnon-Haug-Michelis (1999) p-values | | | | | | | |

**TABLE 5.** Summary results of unrestricted VAR

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variable | Coefficient | Std. Errors | t. stat. | P. Values |
| L(GDP)t-1 | 0.87 | 0.2034 | 4.2698 | 0.0000\*\*\* |
| L(GDP)t-2 | 0.19 | 0.2318 | 0.8122 | 0.4177 |
| L(THE)t-1 | -0.54 | 0.2188 | -2.4503 | 0.0152\*\* |
| L(THE)t-2 | 0.03 | 0.2047 | 0.1540 | 0.8778 |
| L(TIV)t-1 | -0.17 | 0.0948 | -1.7419 | 0.0831\* |
| L(TIV)t-2 | 0.0001 | 0.1001 | 0.0013 | 0.9990 |
| L(UMR)t-1 | -0.84 | 1.0233 | -0.8203 | 0.4131 |
| L(UMR)t-2 | -0.86 | 1.0144 | -0.8510 | 0.3958 |
| L(CO2)t-1 | -0.07 | 0.1951 | -0.3638 | 0.7164 |
| L(CO2)t-2 | 0.10 | 0.1917 | 0.5005 | 0.6173 |
| L(IMZ)t-1 | -0.24 | 0.2018 | -1.2112 | 0.2273 |
| L(IMZ)t-2 | 0.17 | 0.1939 | 0.8647 | 0.3883 |
| C | 9.16 | 4.1641 | 2.2008 | 0.0289\*\* |
| **Notes:** R-squared = 0.98; Adj. R-squared = 0.97; SSR = 0.88836; SER = 0.1666; F. Stat. = 109.4648; LL. 24.4611; AIC = -0.5094; SC = 0.0125 | | | | |

\*\*\*, \*\*, \* indicates significance at 1%, 5% and 10% level respectively

**TABLE 6.** VAR lag order selection criteria

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Lag | Log L | LR | FPE | AIC | SC | HQ |
| 0 | -83.80970 | NA | 2.39e-06 | 4.082259 | 4.325558 | 4.172486 |
| 1 | 202.4565 | 481.4476 | 2.78e-11 | -7.293475 | -5.590385\* | -6.661887\* |
| 2 | 246.5069 | 62.07105\* | 2.12e-11 | -7.659403 | -4.496522 | -6.486454 |
| 3 | 290.2341 | 49.69001 | 1.92e-11\* | -8.010640\* | -3.387967 | -6.296330 |
| **Note:** \* indicates lag order selected by the criterion | | | | | | |
| LR: sequential modified LR test statistic (each test at 5% level) | | | | | | |
| FPE: Final prediction error | | | | | | |
| AIC: Akaike information criterion | | | | | | |
| SC: Schwarz information criterion | | | | | | |
| HQ: Hannan-Quinn information criterion | | | | | | |

**TABLE 7.** Summary results of estimated VECM

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| VECM Short Run Dynamic Coefficients | | | | | VECM Long Run Coefficients | | | |
| Variable | Coefficient | St. Error | t. Stat. | P. value | Variable | Coefficient | St. Error | t. Stat. |
| ECTt-1 | -0.32 | 0.04104 | -7.7834 | 0.0000\*\*\* | *L(GDP)t-1* | 1.000 |  |  |
| *d(L(GDP)t-1* | -0.09 | 0.11733 | -0.7788 | 0.4371 | *L(TIV)t-1* | -0.05 | 0.1116 | -0.4912 |
| *d(L(GDP)t-2* | 0.12 | 0.11497 | 1.0190 | 0.3096 | *L(THE)t-1* | 1.58 | 0.2753 | 5.7320\*\*\* |
| *d(L(TIV)t-1* | -0.008 | 0.05704 | -0.1382 | 0.8902 | *L(UMR)t-1* | 6.95 | 1.0724 | 6.4850\*\*\* |
| *d(L(TIV)t-2* | -0.19 | 0.05996 | -3.1746 | 0.0018\*\*\* | *L(CO2)t-1* | -0.18 | 0.2024 | -0.8870 |
| *d(L(THE)t-1* | 0.07 | 0.13675 | 0.4891 | 0.6254 | *L(IMZ)t-1* | 0.17 | 0.0621 | 2.6706\*\* |
| *d(L(THE)t-2* | 0.48 | 0.13282 | 3.5904 | 0.0004\*\*\* | *C* | -58.96 |  |  |
| *d(L(UMR)t-1* | 0.16 | 0.78321 | 0.2097 | 0.8341 |  |  |  |  |
| *d(L(UMR)t-2* | 0.51 | 0.69117 | 0.7450 | 0.4572 |  |  |  |  |
| *d(L(CO2)t-1* | -0.30 | 0.13976 | -2.1461 | 0.0332\*\* |  |  |  |  |
| *d(L(CO2)t-2* | -0.82 | 0.13610 | -6.0354 | 0.0000\*\*\* |  |  |  |  |
| *d(L(IMZ)t-1* | 0.18 | 0.11394 | 1.5580 | 0.1210 |  |  |  |  |
| *d(L(IMZ)t-2* | 0.22 | 0.10461 | 2.1085 | 0.0364\*\* |  |  |  |  |
| *C* | 0.06 | 0.03041 | 1.9111 | 0.0576\* |  |  |  |  |
| Notes: R-squared = 0.78; Adj. R-squared = 0.68; SSR = 0.327; SER = 0.1044; F. stat. = 8.0296; LL. 45.415; AIC = -1.427937; SC = -0.86024; DW = 2.02  VECM Diagnostic Tests  Autocorrelation: χ2 = 65.750, P(0.4855)  Residual Heteroskedasticity: χ2 = 543.19, P( 0.5259)  Normality: JB. = 36.42, P(0.0003)  Functional Form: Stability: Specification imposes 5 roots, none is out the unit circle | | | | | | | | |

\*\*\*, \*\*, \* indicate significance at 1%, 5% and 10% level respectively.

**TABLE 8.** Response of GDP

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Period | L(GDP) | L(TIV) | L(THE) | L(UMR) | L(CO2P) | L(IMZ) |
| 1 | 0.10439 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 2 | 0.10555 | 0.00970 | -0.04684 | -0.04044 | -0.02490 | 0.01585 |
| 3 | 0.10154 | -0.06709 | -0.05369 | -0.01419 | -0.07480 | 0.02978 |
| 4 | 0.09186 | -0.07822 | -0.09285 | -0.05142 | -0.03850 | 0.00533 |
| 5 | 0.07652 | -0.00020 | -0.10540 | -0.05108 | -0.00724 | 0.00260 |
| 6 | 0.03744 | 0.03289 | -0.09516 | -0.07874 | 0.00209 | -0.01986 |
| 7 | 0.01782 | 0.03184 | -0.08484 | -0.07014 | 0.02793 | -0.03382 |
| 8 | 0.00576 | 0.05751 | -0.07988 | -0.07674 | 0.04334 | -0.05079 |
| 9 | -0.00940 | 0.07042 | -0.06782 | -0.07473 | 0.04145 | -0.05791 |
| 10 | -0.02060 | 0.06943 | -0.06046 | -0.07608 | 0.044866 | -0.07004 |
| **Notes:** Cholesky Ordering: L(GDP) L(TIV) L(THE) L(UMR) L(CO2P) L(IMZ) | | | | | | |

**TABLE 9.** Variance decomposition of GDP

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Period | S.E. | L(GDP) | L(TIV) | L(THE) | L(UMR) | L(CO2P) | L(IMZ) |
| 1 | 0.10439 | 100.0000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 2 | 0.16381 | 82.13189 | 0.35057 | 8.17675 | 6.09479 | 2.31010 | 0.93589 |
| 3 | 0.22630 | 63.16726 | 8.97372 | 9.91394 | 3.58693 | 12.1365 | 2.22167 |
| 4 | 0.28026 | 51.92902 | 13.6405 | 17.4405 | 5.70536 | 9.79989 | 1.48472 |
| 5 | 0.31333 | 47.50821 | 10.9129 | 25.2687 | 7.22198 | 7.89355 | 1.19471 |
| 6 | 0.34105 | 41.30509 | 10.1410 | 29.1144 | 11.4257 | 6.66645 | 1.34734 |
| 7 | 0.36288 | 36.72436 | 9.72684 | 31.1816 | 13.8281 | 6.48076 | 2.05836 |
| 8 | 0.38955 | 31.89002 | 10.6197 | 31.2628 | 15.8798 | 6.86181 | 3.48583 |
| 9 | 0.41480 | 28.17812 | 12.2490 | 30.2473 | 17.2518 | 7.05041 | 5.02351 |
| 10 | 0.44007 | 25.25354 | 13.3712 | 28.7603 | 18.3158 | 7.30323 | 6.99596 |
| Notes: Cholesky Ordering: L(GDP) L(TIV) L(THE) L(UMR) L(CO2P) L(IMZ) | | | | | | | |

**TABLE 10.** Summary of pair wise Granger causality results

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Null Hypothesis: | Obs. | F-Statistic | Prob. | Decision | Direction of Causality |
| H0: L(TIV) does not Granger Cause L(GDP) | 45 | 0.982 | 0.3834 | Accept | None |
| H0: L(GDP) does not Granger Cause L(TIV) | | 2.002 | 0.1483 | Accept | None |
| H0: L(THE) does not Granger Cause L(GDP) | 45 | 0.909 | 0.4111 | Accept | None |
| H0: L(GDP) does not Granger Cause L(THE) | | 3.867 | 0.0292 | Reject | GDP to THE |
| H0: L(UMR) does not Granger Cause L(GDP) | 45 | 2.872 | 0.0683 | Reject | UMR to GDP |
| H0: L(GDP) does not Granger Cause L(UMR) | | 0.015 | 0.9847 | Accept | None |
| H0: L(CO2P) does not Granger Cause L(GDP) | 45 | 1.044 | 0.3613 | Accept | None |
| H0: L(GDP) does not Granger Cause L(CO2P) | | 3.978 | 0.0266 | Reject | GDP to Co2P |
| H0: L(IMZ) does not Granger Cause L(GDP) | 45 | 0.426 | 0.6563 | Accept | None |
| H0: L(GDP) does not Granger Cause L(IMZ) | | 0.713 | 0.4962 | Accept | None |
| H0: L(TIV) does not Granger Cause L(THE) | | 2.836 | 0.0705 | Reject | TIV to THE |
| H0: L(UMR) does not Granger Cause L(TIV) | 45 | 5.221 | 0.0097 | Reject | UMR to TIV |
| H0: L(TIV) does not Granger Cause L(CO2P) | | 7.129 | 0.0022 | Reject | TIV to CO2P |
| H0: L(UMR) does not Granger Cause L(THE) | 45 | 2.629 | 0.0846 | Reject | UMR to THE |
| H0: L(UMR) does not Granger Cause L(CO2P) | | 2.545 | 0.0911 | Reject | UMR to CO2P |



**Figure 1.** VECM stability test