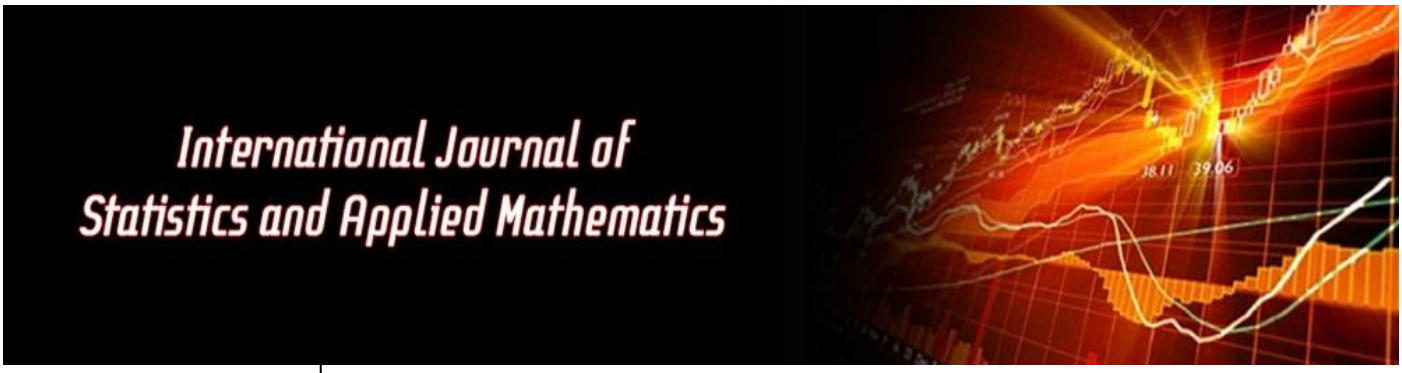

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Cointegration analysis of public debt in Kenya

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Abstract
In this paper, we consider cointegration analysis in a VECM framework. More precisely, we analyse the macroeconomic indicators so as to identify the determinants of Kenya's public debt for the period 2001 to 2021 by applying the Johansen cointegration test coupled with VECM analysis. Quarterly time series data sourced from CBK are used. Public debt is the dependent variable while independent variables are USD exchange rate, capital and reserves, trade balance, budget deficit, net foreign assets, interest payments on debts and credit to the private sector. Firstly, the variables are tested for stationary using unit root test. Trade balance, budget deficit, and interest payments on debts are stationary in the levels while public debt, USD exchange rate, capital and reserve, net foreign asset, and the credit to the private sector are non-stationary, however, stationary at first difference making them integrating time series of order one at a 5\% level of significance. Secondly, the VAR model is estimated using OLS. The results of the ECM indicate cointegration relationship with error term of 0.0454. The ECM identifies net foreign asset, USD exchange rate, and capital and reserves as the main determinants of increasing public debt following a long-run relationship. Net foreign assets and credit to the private sector reduces public debt while USD exchange rate and capital and reserves increases public debt in a long-run relationship. Thirdly, the VECM model is statistically significant at a 5\% level. Finally, under the prevailing financial mechanism, public debt is projected to hit Ksh 9.453 trillion mark with a margin of error of 0.556 trillion by June 2023.

Keywords: Macroeconomic indicators, public debt, VECM, cointegration, VAR, OLS, forecasting

1. Introduction
Public debt is the total amount of liabilities of a country's government which includes bonds and other securities. Debts play an important role in bridging the budget deficit gap. A budget deficit occurs when the government spends more than the revenue collected. By definition, government expenditure is the amount of money that is spent on development projects and recurrent expenditure which are met by public revenues. A budget deficit occurs when the amount of revenue collected does not meet the projected budget which is attributed to heavy investment in financing development projects, natural calamities and disasters, economic crises and increasing recurrent government expenditure. In order to bridge deficit gap, governments opt for public borrowing. Kenya's public debt has been increasing over the last decade with current debt standing at approximately Ksh 8 trillion as of December 2021. As of December 2010, public debt was at 51.0% of GDP compared to December 2021 where it's approximately 67.9% of the GDP. The increase is mainly attributed to the infrastructural development over the same period. In order to understand the dynamics of the public debt one has to investigate the underlying macroeconomic factors that influence its growth. Thus, there's need to identify macroeconomic factors that have led to the growth of public debt over the last twenty years. Technically, the problem entails investigating the long-term equilibrium and short-term dynamic relation between public debt and the independent macroeconomic variables, namely; USD exchange rate, capital and reserves, trade balance, budget deficit, net foreign assets, interest payments on debts, and credit to the private sector. The aim is to determine the factors that influence the growth of public debt in Kenya by determining a long-run equilibrium relation and short-run dynamic effect between public debt and other macroeconomic variables.
There are several existing literature on public debt. Barro (1979) [3] constructed a public debt theory that holds the Ricardian invariance theorem as a first-order proposition except in

scenarios where the timing of taxation and the excess burden may lead to the debt issue. Rahman *et al*. (2019) [10] and Aybar (2019) [2] articles highlights the effect of public debt on economic growth.

A positive effect is felt when both the economy and levels of debt grow simultaneously while a negative effect is felt when the economic growth decrease with an increasing debt. Public debt cause inflation, affect income distribution, sacrifice private sector production and inflict debt servicing burden. Ryan *et al*. (2014) [11] assessed Kenya's Public Debt Dynamics and Sustainability where he indicated that the public debt was sustainable. The VAR model indicated sustainable debt and the depreciation in the exchange rate having no significant effect on the average interest rates on external debt. Swamy (2015) [12] empirical investigation on government debt and its macroeconomic determinants where economic groupings, political groupings, income groupings, and governance groupings of countries in addition to macroeconomic variables were analyzed. Foreign direct investments, government expenditure, real GDP growth, inflation and population were observed to have a negative effect on debt growth while gross fixed capital formation, final consumption expenditure and trade openness influenced positively. Kirui (2017) [7] KIPPRA Discussion Paper attempted to evaluate and establish macroeconomic elements that accelerate debt accumulation in Kenya. The predictor variables, namely; gross fixed capital formation, interest payments on debts, real growth rate of GDP, saving gap, exchange rate of the USD, trade openness and foreign direct investment were significant except the real interest rate. Omrane *et al*. (2017) [9] carried out a case study in Tunisia on macroeconomic determinants of public debt growth. The study provided evidence that inflation and investment have a negative effect on debt while real interest rate, budget deficit and trade openness have a positive effect on debt. A study by Attapattu *et al*. (2018) [1] on the long-run association between public debt and economic growth in Sri Lanka showed a long-run relationship. The error correction term was significant, evidence of a long-run relationship. Any disequilibrium is corrected at a speed of 58% over the years. Liyambo *et al*. (2020) assessed the relationship between the public debt, government expenditure and revenue in Namibia. The ECM that showed a positive relationship between government expenditure and revenue with a 46.6% annual correction speed for any shift from equilibrium. IDA (2020) published an article on Debt Sustainability Analysis in Kenya which provided evidence of Kenya's debt being sustainable with the debt distress risk having changed from moderate to high due to the global impact of Covid-19 crisis.

2. Methodology

2.1 Data

This empirical study used the quarterly time series data for the period 2001 to 2021 with 2001 as the baseline year. The data was sourced from the Central Bank of Kenya. Kenya's public debt is the dependent variable with the predictor variables being USD exchange rate, capital and reserves, trade balance, budget deficit, net foreign assets, interest payments on debts, and credit to the private sector. The unit of measurement for all variables except USD exchange rate is Kenya Shillings in billions.

Table 1: Variable description

Variable	Identifier
Public debt	PD
Capital and reserves	CR
Trade balance	TB
Budget deficit	BD
Net foreign assets	NFA
Interest payments on debts	IPD
Credit to private sector	CPS
USD exchange rate	USDR

These variables are analysed via the functional form;

$$\mathrm{PD} = \mathcal{F}(\mathrm{CR}, \mathrm{TB}, \mathrm{BD}, \mathrm{NFA}, \mathrm{IPD}, \mathrm{CPS}, \mathrm{USDR}) \quad (1)$$

From the data, public debt has the highest standard deviation while USD exchange rate has the least. Two variables are noted to contain negative values. Budget deficit has positive and negative values, when negative it's a deficit while a positive it's a surplus. Trade balance has all values being negative implying that Kenya experiences more imports than export. All the variables were translated by a constant value of 2173 to eliminate the negative values and then a log transformation is performed so as to remove outlier effects and dampen the variance of the time series data. All the variables were considered for translation to avoid affecting the underlying relationship among the variables.

2.2 Model

2.2.1 Unit root test

Unit root test is used to check whether variable where a variable is stationary in levels or after differencing. The unit root test is used with the following model:

$$\Delta \mathrm{X}_t = \delta_0 + \delta_1 t + \delta_2 \mathrm{X}_{t-1} + \sum_{i=1}^{k} \alpha_i \, \mathrm{X}_{t-1} + \gamma_t \quad (2)$$

Where $\Delta \mathbf{X}_t$ is the first variable difference that captures serial correlation; $\delta_0 + \delta_1 t$ is the linear trend component, and γ_t is the error term. Generally, unit root tests involve testing the null hypothesis that $\delta_2 = 0$, that is, the existence of unit root of $\mathbf{X}_t$ versus an alternative hypothesis that $\delta_2 < 0$. The study uses the Phillips-Perron unit root test.

Table 2: Unit root test results

P-P test					
Variable	**Statistic (in level)**	**p value**	**Statistic ($1^{st}\Delta$)**	**p value**	**Order**
PD	-0.67653	0.99	-78.806	<0.01	I(1)
USDR	-8.0189	0.6464	-61.817	<0.01	I(1)
CR	-3.2996	0.9193	-101.68	<0.01	I(1)
TB	-30.12	<0.01			I(0)
BD	-80.202	<0.01			I(0)
NFA	-18.629	0.07818	-94.246	<0.01	I(1)
IPD	-68.246	<0.01			I(0)
CPS	-5.3078	0.8067	-38.869	<0.01	I(1)

From the table above, trade balance, budget deficit and interest payments on debts are stationary at a 5% level of significance. USD exchange rate, public debt, capital and reserve, net foreign asset and credit to the private sector are non-stationary at a 5% level of significance. Non-stationary time series have a trend or seasonality component and thus mean and variance are not constant. They are however stationary at first difference attaining the integrating time series of order 1 property at a 5% level of significance. A shock in Kenya's economy has permanent effect on USD exchange rate, public debt, capital and reserve, net foreign asset and credit to the private sector and transitory effect on trade balance, budget deficit and interest payments on debts. Public debt as the dependent variable and the independent variables of integrating order one are considered for the cointegration test.

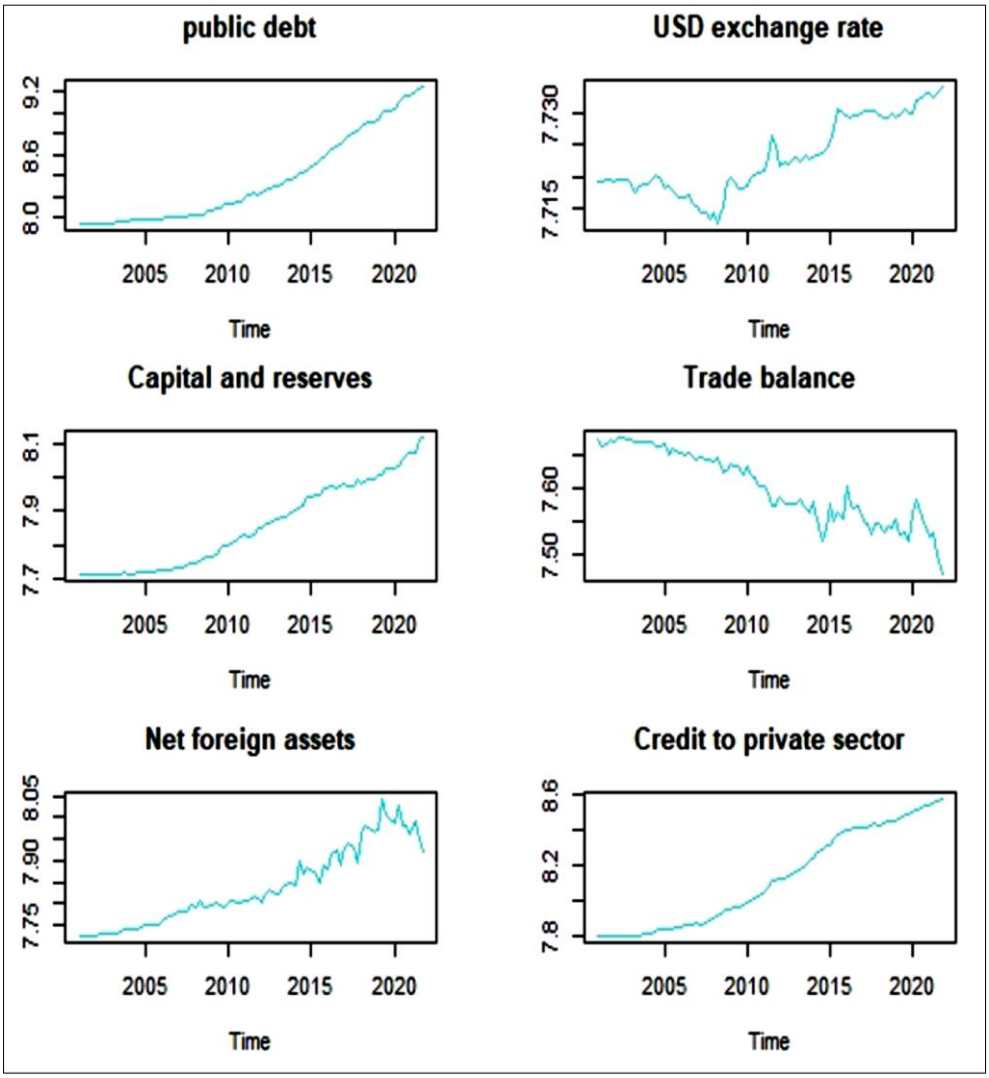

Fig 1: Time plots of integrating variables of order 1

2.2.2 Cointegration and Johansen test

Suppose $\overrightarrow{X_t} = (X_{1t}, X_{2t}, \dots, X_{nt})'$ denote an *n by 1* vector of I(1) time series. X_t is cointegrated if there exist an *n by 1* vector $\vec{\beta} = (\beta_1, \beta_2, \dots, \beta_n)'$ such that

$$\beta' X_t = \beta_1 X_{1t} + \beta_2 X_{2t} + \cdots + \beta_n X_{nt} \sim I(0) \quad (3)$$

Equation (3) means that non-stationary time series in X_t cointegrate if there exists a stationary linear combination of the time series. A long-run equilibrium relationship is the linear combination of time series of the same integrating order.
The cointegration vector is normalized following normalization assumptions to obtain $\vec{\beta} = (1, -\beta_2, -\beta_2, \ldots, -\beta_n)'$ such that

$$\beta' X_t = X_{1t} - \beta_2 X_{2t} - \beta_3 X_{3t} - \cdots - \beta_n X_{nt} \sim I(0) \quad (4)$$

By making X_{1t} the subject, equation (4) reduces to

$$X_{1t} = \beta_2 X_{2t} + \beta_3 X_{3t} + \cdots + \beta_n X_{nt} + \mu_t \quad (5)$$

where $\mu_t \sim I(0)$ is the cointegrating residual which is equal to zero in the long-run equilibrium.

Thus cointegration relationships is given as

$$X_{1t} = \beta_2 X_{2t} + \beta_3 X_{3t} + \cdots + \beta_n X_{nt} \quad (6)$$

For the *n by 1* cointegrating vector, there may exist *0 < r< n* linearly independent cointegrating vectors that is multiple cointegration relations.
This implies that β' becomes an *r by n* cointegrating matrix with cointegrating rank r for r < n given as

$$\beta' = \begin{pmatrix} \beta_1' \\ \beta_2' \\ \vdots \\ \beta_r' \end{pmatrix} = \begin{pmatrix} \beta_{11} & \beta_{12} & \cdots & \beta_{1n} \\ \beta_{21} & \beta_{22} & \cdots & \beta_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ \beta_{r1} & \beta_{r2} & \cdots & \beta_{rn} \end{pmatrix} \quad (7)$$

For possibly *0< r < n* cointegrating vector, Johansen *et al*. (1990) [6] procedure is used. The first difference form model is given by

$$\Delta X_t = \upsilon + \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-1} + \Pi X_{t-k} + \varepsilon_t \quad (8)$$

where ΔX_t is a *k by 1* variable vector; υ is a *k by 1* constant term vector; Γ_i for i=1,2,…,k-1 is *k by k* coefficient matrix; Π is *k by k* coefficient matrix; ε_t is a *k by 1* disturbance term coefficients.
The test statistic is based on two likelihood ratio tests of at most r cointegrating relationships among variables: λ_{trace} and λ_{max} based on trace statistic and eigenvalues respectively.
Table 3 shows the cointegration test results. For the null hypothesis using eigenvalues, r = 0, the calculated eigenvalue value (70.85) is greater than the critical eigenvalue (34.40) at a 5% level of significance, implying a co-integration relationship. For the null hypothesis, r=1, the test statistic value 41.94 is greater than the critical value (28.14) at a 5% level of significance, implying a co-integration relationship.
However, for the null hypothesis, r= 2, the test statistic (19.85) is less than the critical value (22.00) at a 5% level of significance, implying the cointegration relation is not significant.
The above results illustrate the existence of two cointegration relationships. The trace statistic test supports the result of the maximal eigenvalue test of r=2. There exist two long-run equilibrium relationship among public debt, capital and reserve, net foreign asset, USD exchange rate and credit to the private sector.
The characteristic function gives the eigenvalues:

$$\hat{\lambda}_1 = 0.5830;\ \hat{\lambda}_2 = 0.4042;\ \hat{\lambda}_3 = 0.2173;\ \hat{\lambda}_4 = 0.1156;\ \hat{\lambda}_5 = 0.0354;\ \hat{\lambda}_6 = 2.7943 * 10^{-15}$$

Table 3: Johansen cointegration test results

Eigen Values			**critical value**		
Null	**Alternative**	**Test statistic**	**90%**	**95%**	**99%**
r=0	r=1	70.85	31.66	34.40	39.79
r=1	r=2	41.94	25.56	28.14	33.24
r=2	r=3	19.85	19.77	22.00	26.81
r=3	r=4	9.95	13.75	15.67	20.20
r=4	r=5	2.92	7.52	9.24	12.97
Trace statistic			**critical value**		
Null	**Alternative**	**Test statistic**	**90%**	**95%**	**99%**
r=0	r=1	145.51	71.86	76.07	84.45
r=1	r=2	74.66	49.65	53.12	60.16
r=2	r=3	32.72	32.00	34.91	41.07
r=3	r=4	12.87	17.85	19.96	24.60
r=4	r=5	2.92	7.52	9.24	12.97

The corresponding significant normalized vectors are given as vector $\vec{\beta}_1'$ and $\vec{\beta}_2'$ respectively. The vector includes a constant as the cointegration model had a constant.

$$\vec{\beta}_1' = (1, 1.9192, -3.8755, 0.02180, -0.7741, 12.0495)' \quad (9)$$

$$\vec{\beta}_2' = (1, 19.9597, -12.0152, -2.6284, 4.4453, -83.712)'$$

The resulting cointegration equations are:

$$\text{PB} = -1.9192\ \text{USDR} + 3.8755\ \text{CR} - 0.0218\ \text{NFA} + 0.7741\ \text{CPS} - 12.0495 \quad (10)$$

$$\text{PB} = -19.9597\ \text{USDR} + 12.0152\ \text{CR} + 2.6284\ \text{NFA} - 4.4453\ \text{CPS} + 83.7120$$

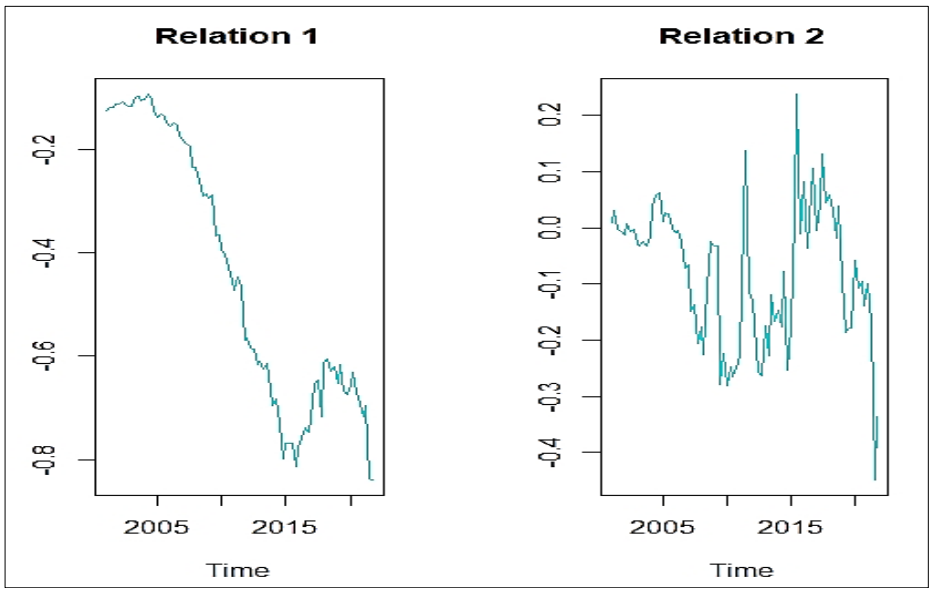

Fig 2: Cointegration relationships

2.2.3 Error correction model (ECM)

For non-stationary and cointegration series of the first order, the variable relationship is assessed through an ECM model. Engle *et al*. (1987) [4] stated that long-run equilibrium established by cointegration implies that deviations from equilibrium are stationary with finite variance as represented by a ECM model.
The above long-run cointegration produces a ECM of the form

$$\Delta PD_t = \beta_1 \Delta\, PD_{t-1} + \beta_2 \Delta\, USDR_{t-1} + \beta_3 \Delta\, CR_{t-1} + \beta_4 \Delta\, NFA_{t-1} + \beta_5 \Delta\, CPS_{t-1} + \lambda\, \mu_{t-1} + \nu_t \quad (11)$$

where: μ_{t-1} are estimated residuals of the cointegration regression which represents the deviation from the equilibrium state during a time t; λ is the short run parameter which represents the dependent variable reaction from the equilibrium at the start of each time t. It must be negative but if not, reject the existence of the error correction model ECM; and ν_t is a white noise disturbance.

The ECM results based on ordinary least squares(OLS) as are shown below.

Table 4: ECM results

Coefficient	Estimate	Std. Error	p value
β_1	-0.1307	0.1228	0.2908
β_2	1.0408	1.2215	0.3970
β_3	0.5842	0.2264	0.0119
β_4	-0.1169	0.0747	0.1221
β_5	-0.3759	0.1726	0.0327
λ	-0.0454	0.0063	<0.001

Model diagnostics: $\text{SE(residual)} = 0.01046$ on $\text{df} = 72; R^2 = 0.8096; R_A^2 = 0.7858;\ F(9,72) = 34.02;\ p - \text{value} = 0.0001$

The model is statistically significant at a 5% level. The results of the ECM equation (11) provide evidence of a short-term dynamic relationship between public debt in Kenya and USD exchange rate, capital and reserve, net foreign asset and credit to the private sector at a 5% level.
The error correction term $\lambda = -0.0454$ is negative as expected, confirming a long-term equilibrium confirming cointegration results. In the short-run, an increase in net foreign asset and credit to the private sector by 1% then induce a reduction in debt by 0.11% and 0.38% respectively. Inversely, increasing USD exchange rate and capital and reserve by 1% will induce an increase in debt by 1.04% and 0.58% respectively.

2.2.4 Forecast

If there exist a cointegration relation, then Vector ECM (VECM) model is applied to estimate the effect of the predictors. VECM model consist of a Vector autoregression (VAR) with stationary growth variables (ΔX_t) that describe a short-run dynamic and error correcting equation with non stationary level variables (X_t) that describe the long-run equilibrium.

$$\Delta X_t = \Pi X_{t-1} + \sum_{i=1}^{q} \Gamma_i \Delta X_{t-i} + CD_t + \varepsilon_t \quad (12)$$

where ΔX_t is the first difference of X_t; Π is a coefficient matrix of cointegrating relationships; Γ is a coefficient matrix of ΔX_{t-i} ; C is a coefficient matrix of a vector of deterministic terms d_t; and ε_t is an error term with mean zero and variance-covariance matrix Σ.

ΠX_{t-1} is the first lag of linear combinations of non-stationary level variables or error correction terms (ECT) which represent long-term relationships among non-stationary level variables.

To forecast public debt in Kenya, the VECM model in difference was transformed to a VAR model in levels thus including the short-run and the the long-run relationship of the variables. Thus, VECM (q) model equation (12) becomes a VAR (p) model as shown below. For p =q+1

$$X_t = \sum_{i=1}^{p} \Phi_i X_{t-i} + \Omega_t + \varepsilon_t \quad (13)$$

where Φ_i is the *n by n* coefficient matrix of X_{t-i} and Ω_t is the linear time component.

For model validation, the data set was divided into two sets: the large set covering the period first quarter in 2001 to the second quarter in 2020 and a small set of six observations for comparison with forecasts. The VAR is subjected to likelihood ratio test to test its statistical significance and a number of diagnostic test on the residual of the model performed, namely; normality test, and ARCH Lagrange multiplier test. The forecast horizon for the study was twelve with six for validation and six for predicting future values for the years 2022 and 2023. The VECM model has one lag, implying the resulting VAR has 2 lag and equation (13) reduces to

$$X_t = \Phi_1 X_{t-1} + \Phi_2 X_{t-2} + \Omega_t + \varepsilon_t \quad (14)$$

The estimates for equation (14) are

$$X_t = \begin{bmatrix} 0.978 & -2.471 & 1.405 & -0.822 & -0.187 \\ 0.013 & 0.863 & -0.011 & -0.024 & 0.022 \\ -0.058 & 0.108 & 0.507 & 0.126 & 0.218 \\ 0.097 & -2.541 & 0.903 & 0.172 & 0.093 \\ -0.041 & -1.363 & -0.216 & 0.081 & 1.306 \end{bmatrix} X_{t-1} +$$

$$\begin{bmatrix} 0.135 & -4.981 & -1.112 & -0.302 & 0.340 \\ -0.012 & -0.104 & 0.035 & 0.004 & -0.026 \\ 0.035 & 1.223 & 0.523 & 0.084 & -0.244 \\ 0.001 & -4.105 & -0.758 & -0.115 & -0.004 \\ 0.023 & -0.113 & 0.739 & -0.001 & -0.435 \end{bmatrix} X_{t-2} +$$

$$\begin{bmatrix} 580.219 & 3.353 & 61.046 & 23.412 \\ 19.344 & -0.366 & 0.165 & 1.350 \\ -105.656 & -10.115 & -10.751 & -8.050 \\ 525.147 & 3.619 & 44.931 & 10.749 \\ 120.050 & -10.180 & -0.192 & 0.627 \end{bmatrix} \quad (15)$$

Table 5 shows the diagnostic test results for the VAR model

Table 5: VAR model diagonstics

Test	statistic	Df	p value
Loglikelihood ratio test	-1533.909	70	< 0.001
Normality test	10.888	10	0.3663
ARCH LM test	1065	1125	0.8987

Table 6 presents the observed and forecast values of public debt for the validation period.

Table 6: Public debt comparison of observed and forecast results

Year	Quarter	observed value	predicted value	95% confidence lower limit	95% confidence upper limit
2020	q3	9.1371	9.1125	9.0957	9.1294
2020	q4	9.1543	9.1233	9.1001	9.1466
2021	q1	9.1604	9.1497	9.1233	9.1761
2021	q2	9.1988	9.1807	9.1514	9.2101
2021	q3	9.2271	9.2	9.1682	9.2319
2021	q4	9.2476	9.2179	9.1839	9.2519

Out of six observed values, only two values corresponding to the third and fourth quarters of 2020 falls outside the 95% confidence interval. This period corresponds to the period when Kenya's government introduced pandemic mitigation measures and economic incentives. However, the values are within the neighborhood of the upper bound for each estimated value.
The diagnostic test and validation results provides enough evidence of the model's ability to make satisfactory inferences for the post-sample period. Equation (15) results in the following predicted values for public debt for the period 2022 to 2023 as shown in table 7.

Table 7: Public debt forecast results

Year	Quarter	predicted value	PD in billions (Ksh.)	95% confidence lower limit	95% confidence upper limit
2022	q1	9.2662	8401.492	7764.791	8506.701
2022	q2	9.2711	8453.435	8059.252	8862.802
2022	q3	9.2902	8658.35	8235.728	9097.004
2022	q4	9.3077	8849.567	8396.206	9321.225
2023	q1	9.323	9019.509	8606.484	9612.203
2023	q2	9.361	9453.009	8910.358	10022.23

The public debt is expected to increase hitting a value of Ksh 9.453 trillion mark with a margin of error of 0.556 trillion by June 2023.

3. Discussion and conclusion

The study sort to establish existence of a significant short-short dynamic relationship and long-term equilibrium between public debt and the independent variables that are: USD exchange rate, capital and reserves, trade balance, budget deficit, net foreign assets, interest payments on debts, and credit to the private sector. The study provides sufficient evidence to conclude that trade balance, budget deficit and interest payments on debts are stationary while USD exchange rate, public debt, capital and reserve, net foreign assets and credit to the private sector are of integrating order 1.
The study provides evidence of the existence of long-run dynamic relationships among public debt and capital and reserves, net foreign assets and USD exchange rate. Both the maximal eigenvalue and trace statistic cointegration test resulted in two cointegrating relationships. Vector error correction model (VECM) supports the results of the cointegration relationship with the error term of -0.0454. The ECM identifies net foreign asset, USD exchange rate and capital and reserves as the main determinants of increasing public debt following a long-run equilibrium. Net foreign assets and credit to the private sector have a negative effect on public debt while USD exchange rate and capital and reserves have a positive effect in a long-run relationship. The VECM model is statistically significant at a 5% level. Under the prevailing financial mechanism, public debt is projected to hit Ksh 9.453 trillion mark with a margin of error of 0.556 trillion by June 2023.
The government is implementing a policy framework of acquisition of external concessional loans and lengthening debt maturity profile, it's recommended that the maturity of loans be lagged/translated with respect to time avoiding the second quarter (April to June) period. Trade balance is identified as a stationary variable over the study period. Kenya's economy is mostly agricultural-based, and policy guidance on the protection of Kenya's farming activities from the internal market needs to be developed. This will help reduce the fraction of agricultural product/input imports, reducing the trade balance gap. Net foreign assets and credit to the private sector hurt public debt, its recommended that the government develop necessary regulatory policies to harness the benefits of net foreign assets and also create more room for borrowing in the private sector. Fiscal policies are required to stabilize the USD exchange rate so as to mitigate the positive effect it has on debt. An assessment needs to be carried out on capital and reserves to avert the positive effect on debt.

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