

Monetary Model of Exchange Rate Determination in Tanzania: A Cointegration Analysis

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Abstract

The purpose of this paper is to consider a monetary model of exchange rate determination for Tanzanian and test for its long run relationship. The paper confines follows the analysis of the Dornbusch's (1976) monetary model of exchange rate determination. The paper uses quarterly time series data for Tanzania and U.S to analyze the exchange rate determination model for Tanzanian economy for the period of 2009 to the first quarter of 2019 making a total of 41 observations. The paper specifies the Autoregressive Distributed Lag model for analysis of monetary model and test for long run relationship through Bound test. The results from Bounds test concluded that the model has no long-run equilibrating relationship, thereafter the fitting of the long-run equation was done to extract the error correction term and visualize fitting of the long-run equation. The results that this study has come up with suggest that that there is no evidence of long-run relationship between exchange rate and the monetary model of exchange rate determination. With this results the study can conclude, though with caution that the sticky-price monetary model of exchange rate determination is inappropriate for forecasting long-run exchange rate trends in Tanzania.

Keywords: Exchange Rate, Monetary Models, Autoregressive Distributed Lag, Tanzania.

JEL Classifications : E5; E52; E58

Introduction

This paper presents a monetary model of exchange rate determination for Tanzanian economy and test for its long run relationship. There has been a number of popular exchange rate determination models that have been developed, used and modified by various scholars. The models may include sticky-price monetary model by Dornbusch (1976), flexible price monetary models by Frenkel and Mussa (1976) and real interest rate differential model by Frankel (1979). There are also various approaches developed in exchange rate determination like portfolio balance model, purchasing power parity approach and equilibrium and liquidity models (see Taylor, 1995, Hallwood and MacDonald, 1986; Levich, 1983 as cited by Boyko, 2002). Prices are assumed to be flexible and the purchasing power parity holds in the Frenkel & Mussa (1976) model of flexible-price monetary model, whereas Dornbusch (1976) treats prices as sticky in the short run since they adjust slowly relative asset prices. The two models assume both domestic and foreign money demand are stable, perfect capital mobility with uncovered interest rate parity. The Frankel (1979) model of real interest rate differentials assumes that there is an efficient market where bonds of different countries are perfect substitutes and the expected rate of depreciation of exchange rate is determined by current spot rate and equilibrium rate, expected long-run inflation differential among two countries, domestic and foreign.

This paper confines itself to the analysis of the Dornbusch's (1976) monetary model of exchange rate determination. We seek to analyze the long-run relationship of the model and see if it fits the Tanzanian economy context. This paper is divided into five sections; introduction, the model, data, estimation results and conclusion. In the following section we will discuss the model based on Dornbusch (1976) framework, then on section three data type, justification and

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sources is discussed, then section for gives the estimation results of the model and discussion of the results and the last section the paper gives some conclusion and areas for further extensions.

Methodology

The Model

In the model building following the Dornbusch (1976) framework we assume a small country economy in the large facet of the world were a small economy is insignificant and has no influence on the foreign prices of goods and financial assets. The model further assumes perfect capital mobility such that it equates expected net yields; world rate will equal domestic interest rate less expected rate of depreciation, import goods prices are assumed to be given hence sticky. Domestic output is also assumed to be imperfect substitute for imports, and aggregate demand for domestic goods.

Perfect capital mobility

Assets or bonds in domestic and foreign currency denominations are assumed to be perfect substitutes. With expectations formation on domestic currency depreciation, interest rate on domestic assets will exceed those assets in abroad by a margin of expected rate of depreciation. Given r is the domestic interest rate and r^* is the foreign rate of interest and x is the expected rate of increase of domestic currency price of foreign exchange.

$$r = r^* + x \quad (1)$$

Consider a relationship between long-run exchange rate \bar{e} to which an economy will converge and the spot exchange rate e , which the difference between the two explains the expectation of the market players.

$$x = (\bar{e} - e) \quad (2)$$

Equilibrium money market

Demand for real money balances equals real money supply, and the demand for real money balances is determined by domestic interest rate and real income. The functional form of the money market model follows a log of nominal quantity of money m , price level p and real income y . Given;

$$-\lambda r + \phi y = m - p \quad (3)$$

Consider that the money market clears and net assets equals both in the domestic and foreign market, then we combine (a), (b) and (c) to get a relationship between spot rate, price level and long-run exchange rate as follows

$$p - m = -\phi y + \lambda r^* + \lambda(\bar{e} - e) \quad (4)$$

So, with equal interest rate and a fixed money supply in the long-run the exchange rate will be equal and the equality collapses to;

$$\bar{p} = m + (\lambda r^* - \phi y) \quad (5)$$

where, (e) is long-run equilibrium price level

The estimation of monetary model

The basic estimation model that the study follows is given as:

$$s_t = \beta_1(m_t - m_t^*) + \beta_2(y_t - y_t^*) + \beta_3(r_t - r_t^*) + u_t \quad (6)$$

where s is the natural log of nominal exchange rate, m and y denote natural logs of domestic money supply and real output, r is domestic short-term interest rate and u is the error term. All asterisk denotes foreign quantities of respective variables. The model used is adopted from Baillie & Selover (1987) with modification to exclude expectation formation to fit the Dornbusch (1976) sticky-prices model where prices are taken as given and do not adjust to affect nominal interest rate. The model expects parameters $\beta_1 = 1$, $\beta_2 < 0$, the sign for $\beta_3 = 0$ is expected if the economy follows the Dornbusch's sticky-price model or other wise $\beta_3 < 0$ may be unclear if the economy's exchange rate

follows the Keynesian assumption of increasing domestic interest rate effect on currency appreciation or $\beta_3 > 0$ if there is a rise in interest rate due to inflationary expectations. However, our analysis is confined to a sticky-price model then we make strong assumption to assume that Keynesian assumption does not hold and that the prices are sticky enough not to affect interest rate and make conclusions about it.

Data sources and sampling

The study uses quarterly time series data for Tanzania and U.S to make analysis of the exchange rate determination model for Tanzanian economy. The period of the data is from 2009 to the first quarter of 2019 making a total of 41 observations. The main sources of the data were OECD Data bank for all variables of money supply (M1) m^* , nominal short-term interest rate r^* , and industrial manufacturing output index y^* for U.S. Data for Tanzania on the all variables money supply aggregate (M1) m , weighted exchange rate s , industrial manufacturing output, and nominal interest rate r , were all collect and gathered from Bank of Tanzania (BOT) quarterly and annual monetary policy statements and other statistical publications. The variables and the time for analysis were purposely sampled based on literature and availability of data.

Results and Discussion

Unit root test: ADF test

Variables	s_t	$\frac{(m_t - m^*)}{t}$	$\frac{(y_t - y^*)}{t}$	$\frac{r_t - r^*}{t}$
Level	-1.02473	-3.4454**	0.8175	1.6692
1 st difference	-4.4433*	-	-3.47036**	-3.85318*
2 nd difference	-	-	-	-

Note: The 1% and 5% significance level were -3.61 and -2.93 respectively, the asterisk represents level of significance, (*) =1%, (**) =5% and (***) =10%

The unit root test shows that the dependent variable, nominal exchange rate and two independent variables, output and nominal interest rates are integrated of order 1 hence following a random walk process since we fail to reject null that series contain unit root at levels but after first difference, we were able to reject null. However, money supply is integrated of order zero and stationary at level. The results for unit root suggest that we cannot establish a long run relationship of the model (6) above since variables are of different order of integration.

Table 2: OLS estimation of eq. (6)

	<i>Constant</i>	$\frac{(m_t - m^*)}{t}$	$\frac{(y_t - y^*)}{t}$	$\frac{r_t - r^*}{t}$	R^2	DW-statistic
Coefficients	-2.348177	0.365680	0.919307	-0.006221	0.93	0.77
<i>t - statistic</i>	(-3.1417)	(2.69838)	(6.8861)	(-0.34896)		

* *t - statistics are in parantheses*

In table 2 above we represent estimation results of equation (6), though results suggest that money supply and output are statistically significant except nominal interest rate, but we cannot conclude directly that because the estimates are based on some series that are not stationary, however the R^2 is very high with a significant small Durbin Watson statistic this perhaps is a clear sign of non-stationary series (Nkoro & Uko, 2016). Thus, we can detect that our model is faced with a problem of spurious regression and hence standard errors are no longer useful and t-statistic are not appropriate since errors may be serially correlated. With the results of the ADF test that shows one of the variables is $I(0)$ and other variables are $I(1)$, and from theory it is evident that if two or more series are $I(0)$ and $I(1)$ then the two series must be $I(1)$. To show this a group ADF test was conducted:

Table 3: Intermediate ADF test results

Series	Prob.	Lag	Max Lag	Observations
D(S)	0.0010	0	9	39
D(MS1)	0.0013	2	9	37
D(OUTPUT_Y)	0.0148	3	9	36
D(INTEREST_R)	0.0054	1	9	38

From Table 3 it is evident that all the variables are $I(1)$ therefore one or more variable is either $I(0)$.

Therefore, to establish a long-run relationship we use this criterion to choose the Autoregressive Distributed Lag (ARDL) model for this study. Specifying the ARDL model for the cointegration test we use:

$$\Delta Y_t = \delta_0 + \sum_{i=1}^k \alpha_i \Delta Y_{t-i} + \sum_{i=1}^k \alpha_2 \Delta X_{t-i} + \delta_2 X_{t-1} + \delta_2 X_{t-1} + v_{1t}$$

Here, k represent a number of ARDL model maximum lag that can be selected.

Table 4: ARDL model estimation results

Dependent variable: S_{t-1} (Nominal exchange rate), Method: ARDL			
Variable	Coefficient	t-statistics	Prob.
C	-0.603112	-1.292981	0.2074
S (-1)	1.106906	6.705498	0.0000
S (-2)	-0.405995	-1.577530	0.1268
S (-3)	0.471703	1.670258	0.1069
S (-4)	-0.469716	-3.533986	0.0016
MS1	0.099643	0.822479	0.4183
MS1(-1)	-0.253111	-1.078916	0.2905
MS1(-2)	-0.280915	-2.157830	0.0404
MS1(-3)	0.363662	2.057433	0.0498
OUTPUT_Y	0.351685	3.098628	0.0046
INTEREST_R	-0.000330	-0.042254	0.9666

Source: ARDL estimation , 2024.

The initial estimation of the ARDL model show that the best model selected is the 4, 3, 0, 0 lags model for dependent variable s , money supply m , real output y , and nominal interest rate r , respectively. At all selected lags for the model all variables are significant except nominal interest which is not significant.

Diagnostic test

Serial correlation test

The Breusch-Godfrey test (Godfrey, 1978) for serial correlation is performed to check for correlation between different lags of the residuals. Serially correlated residuals can lead to biased results. The test follows the following **hypothesis**

$H_0: \rho = 0, \text{No serial correlation}$

$H_1: \rho \neq 0, \text{There is serial correlation}$

Here we want to fail to reject the null hypothesis for the residuals to serially uncorrelated to get efficient estimates.

Heteroskedasticity test

The test for constant variance i.e. tests for heteroskedasticity. It is assumed that residuals have a constant variance both in Ordinary Least Square estimation and ARDL model, since a model without homoscedastic residuals tend to produce inefficient estimation (Larsson, 2016). The test for heteroscedasticity is given as:

$H_0: \text{Constant variance of the residuals} - \text{homoscedasticity}$

$H_1: \text{Non} - \text{constant variance of the residuals} - \text{Heteroscedasticity}$

Here we want to fail to reject the null for the residuals to be Homoscedastic and conform with the theory.

Specification error test

The Ramsey (1969) RESET test was run to test for miss-pecification error test, the test checks for non-linear combinations of the fitted values that can describe independent variables (Larsson, 2016)

Table 5: Diagnostic test

Breusch-Godfrey Serial Correlation LM Test:			
F-statistic	0.118715	Prob. F(2,24)	0.8886
Obs*R-squared	0.362453	Prob. Chi-Square(2)	0.8342
Heteroskedasticity Test: Breusch-Pagan-Godfrey			
F-statistic	1.708305	Prob. F(10,26)	0.1321
Obs*R-squared	14.67103	Prob. Chi-Square(10)	0.1445
Scaled explained SS	7.949994	Prob. Chi-Square(10)	0.6337
Ramsey RESET Test			
	Value	df	Probability
t-statistic	0.251946	25	0.8031

F-statistic 0.063477 (1, 25) 0.8031

The Table 5 above presents three diagnostic tests for serial correlation, Heteroscedasticity and model misspecification test. The results indicate that there is no evidence of serial correlation since we fail to reject Breusch-Godfrey null hypothesis of no serial correlation. The Breusch-Godfrey Heteroskedasticity test shows no evidence of Heteroskedasticity, as well as the RESET test presents no evidence of misspecification error. Now that our model is good, we take a step further to check for cointegrating relationship and bound test.

ARDL Cointegrating and long run form: Model estimation

The cointegrating and long-run form model was estimated as shown in Table 6, and the error correction term represented as CointEq (-1) theoretically shows the speed of adjustment from the disequilibrium. The long run coefficients for money supply and interest rate are not significant except output which is significant however its sign is not what we expected. In the monetary exchange rate model output is expected to have a negative sign which means money growth would appreciate domestic currency. In accordance to the results it means a 1% growth of output leads to 1.18% increase in exchange rate hence depreciation of the domestic currency. However, it will be trivial to make conclusions about error correction term without performing a bound test to check for statistical significance of the long-run form model.

Table 6: Cointegrating and long-run form model

Variable	Coefficient	t-Statistics	Probability
D(S(-1))	0.404008	2.522252	0.0181
D(S(-2))	-0.001988	-0.010194	0.9919
D(S(-3))	0.469716	3.533986	0.0016
D(MS1)	0.099643	0.822479	0.4183
D(MS1(-1))	0.280915	2.157830	0.0404
D(MS1(-2))	-0.363662	-2.057433	0.0498
D(OUTPUT_Y)	0.351685	3.098628	0.0046
D(INTEREST_R)	-0.000330	-0.042254	0.9666
CointEq(-1)	-0.297102	-2.844372	0.0086

Long-run coefficients

Variable	Coefficient	t-Statistic	Prob.
MS1	-0.238035	-0.706395	0.4862
OUTPUT_Y	1.183721	5.878205	0.0000
INTEREST_R	-0.001110	-0.042180	0.9667

C	-2.029986	-1.629769	0.1152
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Source: Author's calculations, 2024

The ARDL Bounds test was performed to test for long run relationship between dependent variable nominal exchange rate and broad money supply (M1), real output y , and nominal interest rate, of which all variables were $I(1)$ except money supply that was $I(0)$. Since one of the variables is integrated at level and all others at first difference then it follows that all variables are stationary at first difference (see Table 3 above). The bounds test follows the testing of the hypothesis;

$$H_0: \text{No long-run relationships exist}$$

For the cointegration analysis to establish a long-run relationship we sought to reject the null to establish any long-run equilibrium between the variables. Table 7 below evidently shows that the Bounds test F-statistic of 1.0816 is below the critical values bounds at all significance levels 1%, 2.5%, 5% and 10% for both $I(0)$ and $I(1)$ bound, which is the evidence of no long-run equilibrium relationship since we fail to reject the null hypothesis.

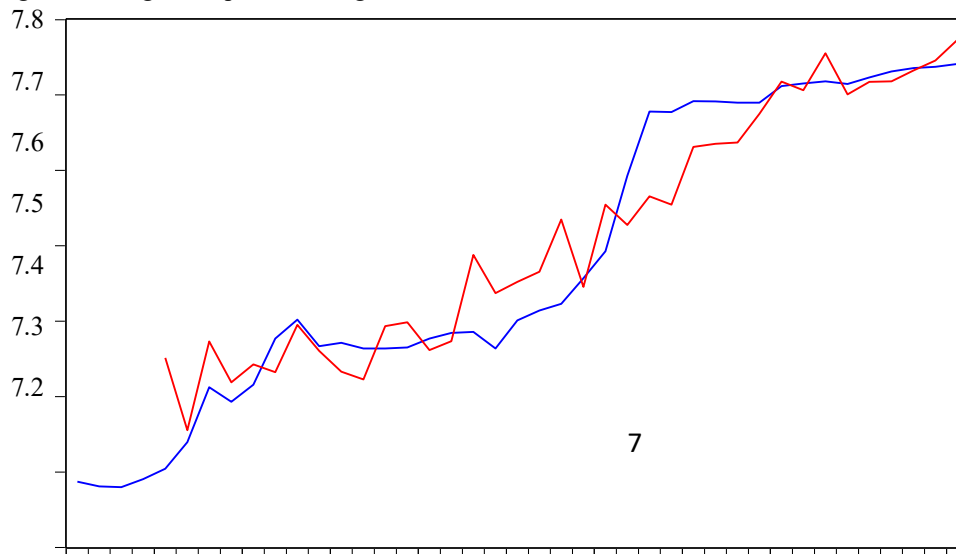
Table 7: ARDL Bounds test

Null hypothesis: No long-run relationships exist

Test Statistic	Value	k
F-statistic	1.081626	3
Critical Value Bounds		
Significance	I (0) Bound	I (1) Bound
10%	2.72	3.77
5%	3.23	4.35
2.5%	3.69	4.89
1%	4.29	5.61

Given the Bounds test results can conclude that the model has no long-run equilibrating relationship. However, we sought to visualize how the long-run equation fits with the dependent variable by extracting the error correction term (EC-term) and subtract it from the dependent variable, then we plotted the difference and the dependent variable to visualize fitting of the long-run equation. The figure 1 below shows the fitting of the long-run equation into the dependent variable s_t .

Figure 1: Long-run equation fitting



2009 2010 2011 2012 2013 2014 2015 2016 2017 2018

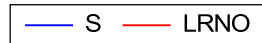


Figure 1: S represents dependent variable s (nominal interest rate) and LRNO is the difference between error correction term (EC) and dependent variable (s_t) [$s_t - EC$]

It is evidently that the model shows much of disequilibria trends and that the possibility of regression to study long-run adjustment is of no use for this purpose.

Conclusions

The results of his study in suggest that that there is no evidence of long-run relationship between exchange rate and the monetary model of exchange rate determination in Tanzania. With this results the study can conclude, though with caution that the sticky-price monetary model of exchange rate determination is inappropriate for forecasting long-run exchange rate trends in Tanzania. However, we cannot totally discard the monetary model of exchange rate since we could also allow for flexible prices and expectations to test the model. Since the scope of this study was confined to sticky-price model then we couldn't explore further to relax more assumptions for the model analysis.

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Appendix

Appendix 1: Data and variables definitions

Variable	Definition and measurement	Presentation	Source
s_t	Natural log of Weighted Average Exchange Rate (WAR)	S	Bank of Tanzania, Interbank Foreign Exchange Market (IFEM) Summaries
y_t	Natural log of Quarterly manufacturing output (GDP constant prices 2007, millions Tshs)	–	National Bureau of Statistics (NBS), Tanzania
y_t^*	Natural log of U.S industrial output index, 2015	–	OECD Database, U.S
m_t	Natural log of Tanzanian Narrow Money (M1), billions LCU	–	Bank of Tanzania, Annual Monetary Statements (2009-2019)
m_t^*	Natural log of U.S narrow money (M1) index	–	OECD Database, U.S
r_t	Short-term overall lending rate (Tanzania)	–	Bank of Tanzania (BOT)
r_t^*	Short-term interest rate (U.S)	–	OECD Database, U.S
$y_t - y_t^*$	Difference between domestic and foreign values of log of output	OUTPUT_Y	–
$m_t - m_t^*$	Difference between domestic and foreign values of log money supply M1	MS1	–
$r_t - r_t^*$	Difference between domestic and foreign short-term interest rates	INTEREST_R	–