Inflation, exchange rates and interest rates in Ghana: An autoregressive distributed lag model

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ABSTRACT

This paper analyses the implication of exchange rate depreciation and nominal interest rates on inflation in Ghana. It makes use of an autoregressive distributed lag model and an unrestricted error correction model. The results from the study show that in the short run a percentage point increase in the level of depreciation of the Ghana cedi leads to an increase in the rate of inflation by 0.20%. A percentage point increase in the level of nominal interest rates however results in a decrease in inflation by 0.98%. Inflation increases by 1.67% for every percentage point increase in the nominal interest rate in the long run. The study could not prove a significant long run relationship between exchange rate depreciation and inflation.

Key words: inflation, exchange rate depreciation, nominal interest rates, autoregressive distributed lag model, error correction model.

1. INTRODUCTION

Ghana formally adopted inflation targeting in 2007 making it one of the first group of emerging market economies and as at the time one of the first low income countries to do so. A 5 percent inflation rate was set as the medium target by the Bank of Ghana. This objective was however affected by negative shocks which made it difficult to achieve the target. Problems of this nature are common in the inflation reduction phase of inflation targeting countries and do not necessarily imply policy failure. It however means that there is the need for flexibility in the implementation of inflation targeting. Challenges in the implementation of inflation targeting policies are expected in the economy since it is vulnerable to shocks and has a history of high and variable inflation. Inflation rates dropped significantly to as low as 10.7% in 2010, 8.7% in 2011 and 9.2% in 2012. It has however returned to double digits, 13.5% as at the end of 2013.

In several instances, monetary policy authorities have reacted vigorously to short-run deviations from targets, in an attempt to maintain credibility. This had a destabilizing impact on the economy. Attempting to hit inflation targets for every year is not desirable and might not be feasible. The challenge should rather be to maintain the credibility of the ultimate target, in the face of variations in the path of inflation. This can be done by not just focusing on annual inflation targets but also being mindful of short-run trade-offs against output and employment. Ekholm K. (2010).

The study thus seeks to estimate the relationship between inflation, exchange rate deprecation and the level of nominal interest rates in Ghana. Inflation is one macroeconomic variable that remains elusive to the policy makers in the country. Though the much desired single digit level was attained in 2010, 2011 and 2012, it could not be sustained and has as expected returned to double digits and currently stands at about 13.5% at the end of the 2013 fiscal year. This trend is predicted to prevail for a while as policy makers struggle to discover the mix of policies that will control both inflation and its causal factors.

Literature on the relationship between inflation and the level of exchange rate is sub divided into two groups. The first group considers the responsiveness of the prices of tradable goods to changes in the exchange rate. In other words, it considers the validity of the Purchasing Power Parity. Dunn (1970) and Magee (1973, 1974) supported this assertion in their study. More recent contributions have attempted to use modern techniques and different aspects to establish PPP conditions, particularly since the work by Granger (1981), and Engle and Granger (1987) on co-integration relationships. MacDonald (1995) in his study, supported the idea of a long run Purchasing Power Parity. The PPP theory was however not supported by Krugman (1978) and Frenkel (1981). Studies based on the macroeconomics of the Ghanaian economy have employed co-integration based models e.g. Bawumia and Abradu-Otoo, (2003).

Bawumia et al (2003) examined the relationship between monetary growth, exchange rate and inflation in Ghana from 1983 to 1999. An error correction model (ECM) was applied in their analysis and their study showed the existence of a long run equilibrium relationship between inflation, money supply, the exchange rate, and real income.

This study adopts a similar approach however due to the fact that the variables are integrated of different orders, an autoregressive distributed lag model (ARDL) is applied for the analysis.

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2. MATERIALS AND METHODS

Time series data from 1991to 2013 was used and the data was obtained from the World Bank country indicators. The main variables for the study include: inflation ($INFL_t$), exchange rate depreciation (EXR_t) and the nominal interest rates ($INTR_t$). The average yearly inflation is used as a proxy for inflation in the study. Exchange rate depreciation was measured as the changes in the value of the Ghana cedi per the United States dollar. Nominal interest rate was measured as the central bank's monetary policy rate. In other words, the rate at which the central bank lends to commercial banks. The autoregressive distributed lag model approach is chosen due to the fact that the variables had a mixture of I(0) and I(1) properties. This method also makes it possible to assign different variables with different lag-lengths as they enter the model. The generation of the models and all diagnostic tests were done in GRETL software. The least squares regression method was used to estimate the model due to the fact that it minimizes the sum of squares of the prediction errors. The variables were first tested for non-stationarity properties using the Augmented Dickey Fuller method. First order differences were applied when necessary to remove non-stationarity properties. The basic autoregressive distributed lag model is given in Eq. 1.

Equation 1

$$\mathrm{INFL}_t = \beta_0 + \beta_1 \mathrm{INFL}_{t-1} + \ldots + \beta_f \mathrm{INFL}_{t-p} + \gamma_0 \mathrm{EXR}_t + \gamma_1 \mathrm{EXR}_{t-1} + \ldots + \gamma_j \mathrm{EXR}_{t-q} + \delta_0 \mathrm{INTR}_t + \delta_1 \mathrm{INTR}_{t-1} + \ldots + \delta_k \mathrm{INTR}_{t-m} + \varepsilon_t$$

Where $\varepsilon_t$is a random disturbance term which is serially independent. The ARDL model for the variables will be estimated as in Eq. 2.

Equation 2

$$\Delta INFL_t = \beta_0 + \Sigma\beta_i \Delta INFL_{t-1} + \Sigma\gamma_j \Delta EXR_{t-j} + \Sigma\delta_k \Delta INTR_{t-k} + \theta_0 INFL_{t-1} + \theta_1 EXR_{t-1} + \theta_2 INTR_{t-1} + \mu_t$$

Where β_0 is an intercept, β_i , γ_j , δ_k are short run coefficients , θ_0 , θ_1 and θ_2 are long run coefficients and Δ represents first order difference. Eq. 2 can further be expressed as in Eq. 3:

Equation 3

$$\Delta INFL_t = \beta_0 + \sum_{i=1}^{p} \beta_i \Delta INFL_{t-i} + \sum_{j=1}^{q} \gamma_j \Delta EXR_{t-j} + \sum_{k=1}^{m} \delta_k \Delta INTR_{t-k} + \theta_0 INFL_{t-1} + \theta_1 EXR_{t-1} + \theta_2 INTR_{t-1} + \mu_t$$

From estimating the model in Eq. 3, an F test on the null hypothesis $H_0 : \theta_0 = \theta_1 = \theta_2 = 0$ is performed to determine if the variables $INFL_{t-1}$, EXR_{t-1} and $INTR_{t-1}$ which have long run coefficients are statistically significant. If the independent variables are statistically significant and co-integrated then an unrestricted error correction model (ECM) is used to estimate the given long run relationships among them. This is given in Eq. 4.

Equation 4

$$\Delta INFL_t = \beta_0 + \Sigma\beta_1 \Delta INFL_{t-1} + \Sigma\beta_1 \Delta INFL_{t-2} + \Sigma\gamma_1 \Delta EXR_{t-1} + \Sigma\delta_1 \Delta INTR_{t-1} + \varphi z_{t-1} + \mu_t$$

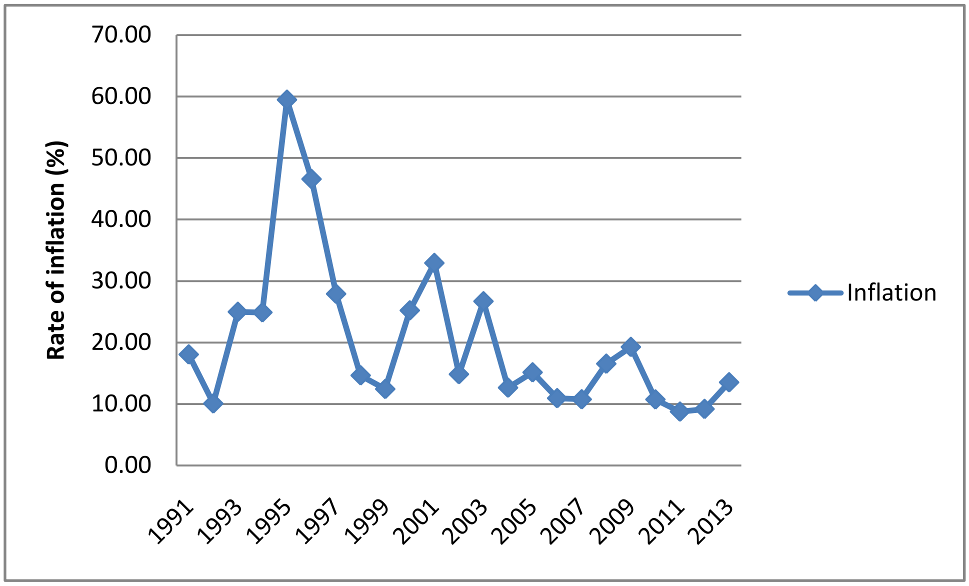
z_{t-1} isthe error-correction term and it is the OLS (Ordinary Least Squares) residual from estimating the model with the level variables. The short-run effects can therefore to be extracted from the unrestricted ECM as in Eq. 4.

Eq. 3 shows that, in the long-run equilibrium $\Delta INFL_t = 0, \Delta EXR_t = \Delta INTR_t = 0$. Therefore exchange rate depreciation and nominal interest rate elasticity of inflation are given by $-\left(\frac{\theta_0}{\theta_1}\right)$ and $-\left(\frac{\theta_0}{\theta_2}\right)$respectively. These represent the impact of both exchange rate depreciation and nominal interest rate on inflation in the long run.

2.1 General trend in inflation

Generally, inflation in Ghana has been declining since its historic high levels in the last two decades. It reached as high as 122% in 1983 and 59% in 1995. Currently the rate stands at about 13.5%. Single digit levels were recorded in the years 2010, 2011 and 2012. The rate has however returned to double digits and also assuming an upward trend since 2013. Fig. 1 illustrates the general trend in inflation in Ghana.

Figure 1. Trend in inflation



Source: Bank of Ghana

2.2 Inflation, exchange rate depreciation and interest rates

The level of interest rates in an economy plays a significant role in influencing the level of inflation. Rising nominal interest rates lead to rising inflation rates and vice versa all things being equal. The relationship is however opposite in the case of real interest rates. Rising real interest rates lead to declining inflation rates ceteris paribus. The relationship is explained in the simple Fisher equation where,

$$r = R - \pi$$

R=Nominal interest rates, r = real interest rates and π = expected inflation

The nominal exchange rate is basically an asset price that affects the real exchange rate in the short run. Exchange rates that are determined freely by the market are volatile and that is not different in the case of Ghana. The major trading partners of Ghana such as UK, USA and other European countries have monetary policies that differ from Ghana hence the inflation differential is very high. Thus, fluctuations in real exchange rate in the short run are caused by both the inflation differential and the nominal exchange rate. Depreciation of the real exchange rate has a huge impact on the rate of inflation. Declining rate of depreciation is accompanied by declining rate of inflation and vice versa ceteris paribus. An increase in the rate of depreciation means higher cost of imports (imported inflation) which is generally transmitted into domestic prices. Fig. 2 shows the relationship among the three modeled variables: inflation, exchange rate depreciation and interest rates.

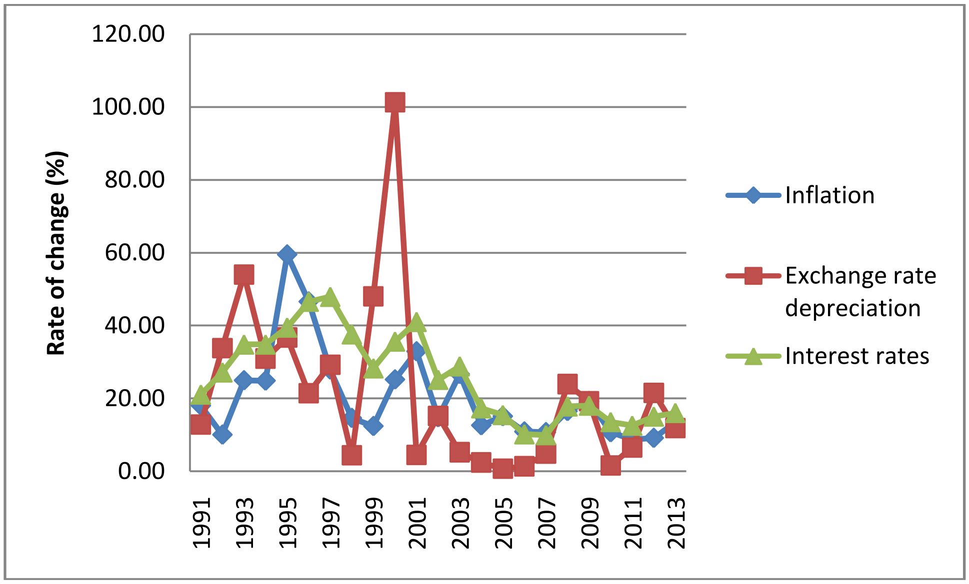


Figure 2. Inflation, interest rates and exchange rate depreciation

Source: Bank of Ghana

3. RESULTS

2.1 Unit root test for level variables

Since the study employed time series data which are often non stationary and lead to spurious regression estimates, (see e.g Granger and Newbold (1974)), the Augmented Dickey Fuller (ADF) method was employed to test the data for unit roots. Based on the test results an appropriate econometric technique is used in estimating the model. The results (see Appendices, Tab. A.1) show that, inflation and nominal interest rates were non-stationary at level but stationary after first difference i.e. I(1). Exchange rate depreciation was however stationary at level i.e. I(0), (see Appendices, Tab. A.1). Giving the fact that the variables were integrated of different orders, the study employed the autoregressive distributed lag model which was appropriate in this case. An error correction model was then used to estimate the short run relationship between the variables when it was established that the variables were co-integrated.

2.2 Constructing the autoregressive distributed lag model (ARDL)

Since the unit root test shows different orders of integration for all three variables. It became necessary to employ the ARDL model. The study first estimated an Ordinary Least Squares (OLS) model using the level variables. The residual term from this model was saved and used in the estimation of the long run relationship among the variables in the error correction model. Tab. 1 shows the level model results. Inflation ($INFL_t$) was the dependent variable while exchange rate depreciation (EXR_t) and the nominal interest rates ($INTR_t$) served as the independent variables.

Table 1. OLS Level model: dependent variable - $INFL_t$

	Coefficient	Std. Error	t-ratio	P-value
Constant	0.12	3.15	0.06	0.97
EXR_t	−0.03	0.04	-0.79	0.74
$INTR_t$	0.80	0.19	4.20	0.00***

R^2=0.55 n= 23 F(2,20)= 9.92, P(F) =0.00010

The asteriks * indicate the significance at 10% level, ** at 5% level and *** at 1% level.

The study then proceeds to estimate the ARDL model. Tab. 2 shows the results of the estimated model. The first order differenced inflation was regressed on the first order differenced independent variables including a maximum of two lags. Two lags of the first order differenced dependent variable are included in the system. The lagged level exchange rate depreciation is not statistically significant hence it was removed from the model. The results in Tab. 2 represent the restricted model without all insignificant variables. The study then proceeded to test for the stability of parameters in this ARDL model using the CUSUM test (see Appendices, Tab. A.2). The results show that the model parameters were stable and the model fulfills all diagnostic test requirements (see Appendices, Tab. A.2).

Table 2. ARDL. Dependent variable - $\Delta INFL_t$

Variable	Coefficient	Std. Error	t-ratio	P-value	
Constant	6.49	1.96	3.32	0.00	***
$INFL_{t-1}$	−1.35	0.39	-3.46	0.00	***
$INTR_{t-1}$	0.81	0.35	2.34	0.04	**
ΔEXR_{t-1}	0.16	0.05	3.30	0.00	***
$\Delta INTR_{t-1}$	−0.83	0.26	-3.15	0.00	***
$\Delta INFL_{t-1}$	0.83	0.32	2.63	0.02	**
$\Delta INFL_{t-2}$	0.67	0.26	2.58	0.02	**

R^2=0.61, F(6,13)=33.30 and P-value(F) =3.67e-07, n=20

The subscript t-q where q=1,2,3 shows the various lagged terms of the variables and the symbol, Δ before the variables denotes first order difference. The asteriks * indicate the significance at 10% level, ** at 5% level and *** at 1% level.

The estimated ARDL equation is given in Eq. 5.

Equation 5

$$\Delta INFL_t = 6.49 + 0.83\Delta INFL_{t-1} + 0.67\Delta INFL_{t-2} + 0.16\Delta EXR_{t-1} - 0.83\Delta INTR_{t-1} - 1.35 INFL_{t-1} + 0.81 INTR_{t-1} + \mu_t$$

To establish whether the model variables had a long run relationship or not, the study tested for the statistical significance of the coefficients of $INFL_{t-1}$ and $INTR_{t-1}$. Using the Wald test, the results (see Appendices, Tab. A.2) show that inflation and interest rate had a long run relationship.

3.3. Constructing the error correction model (ECM)

The long run relationships can therefore be estimated using an unrestricted error correction model if the variables are co-integrated using the ADF test on the lagged residual term from the level model, z_t. If the coefficient of z_{t-1} is negative and significant in the ECM then it validates the long run relationship.

In both cases of testing the unit roots in z_t (see Appendices, Tab. A.3),the p-values were less than 5% indicating that the variables were co-integrated. An unrestricted error correction model could therefore be used to estimate their short run relationships. It is given by the expression:

$$\Delta INFL_t = \beta_0 + \Sigma\beta_1\Delta INFL_{t-1} + \Sigma\beta_1\Delta INFL_{t-2} + \Sigma\gamma_1\Delta EXR_{t-1} + \Sigma\delta_1\Delta INTR_{t-1} + \varphi z_{t-1} + \mu_t$$

Where φ is the speed of adjustment parameter and z_t is the residual term from the estimated level model.

The Error Correction model results are displayed in Tab. 3. The first order differenced inflation is regressed on the lagged terms of the first order differenced inflation, nominal interest rates and exchange rate depreciation. The model also includes the lagged term of the residual term z_t from the level model. Tab. 3 shows the results of the restricted ECM without all insignificant variables.

Table 3. ECM model: dependent variable- $\Delta INFL_t$

	Coefficient	Std. Error	t-ratio	P-value	
Constant	−0.11	1.89	-0.06	0.95	
ΔEXR_{t-1}	0.20	0.04	4.56	0.00	***
$\Delta INTR_{t-1}$	−0.98	0.26	-3.73	0.00	***
$\Delta INFL_{t-1}$	0.87	0.36	2.40	0.03	**
$\Delta INFL_{t-2}$	0.67	0.28	2.43	0.03	**
z_{t-1}	−1.33	0.51	-2.61	0.02	**

R^2 = 0.57, F(5, 14) = 10.53 and P(F) = 0.0002, n=20. The asterisk * indicate the significance at 10% level, ** at 5% level and *** at 1% level.

3.3.1. *Statistical significance of the short-run coefficients*

After estimating the error correction model, it is necessary to test whether exchange rate depreciation and nominal interest rates affect inflation in the short run. This was done by restricting the coefficients of the short run variables, ΔEXR_{t-1} and $\Delta INTR_{t-1}$ to zero. The p-value obtained (see Appendices, Tab. A.4) from the test was less than the 5% significance level used indicating that the short run coefficients were statistically significant.

The coefficient of z_{t-1} was significant and negative thus validating the long run relationship between inflation and the nominal interest rate. The negative sign of the z_{t-1} indicates that previous year's deviation from equilibrium is restored by 133% in the current year. This indicates an overshooting adjustment. Model parameters of the ECM were also stable (see Appendices, Tab. A.4). The long run relationship between the nominal interest rates and inflation is then calculated using the coefficients from the ARDL model. The results are displayed in Tab. 4.

Table 4. Long run impacts

Variable	Long run coefficient	Symbols	Formula	Long run impact (elasticity)
INTR	0.81	θ_2	$-\left(\frac{\theta_0}{\theta_2}\right)$	1.67
INFL	−1.35	θ_0		

θ_0, θ_2 are the estimated coefficients from ARDL.

3.3.2. *Interpretation*

In the short run, a percentage point increase in the rate of depreciation of the Ghana cedi leads to an increase in inflation by 0.20% ceteris paribus. Inflation rate however decreases by 0.98% for every percentage point increase in the level of nominal interest rates. In the long run, exchange rate depreciation has no impact on inflation. The nominal interest rate elasticity in the long run is 1.67% (nominal interest rate elasticity). Implying that a percentage point increase in the nominal interest rate will lead to inflation of about 1.67% in the long run.

4. DISCUSSION

Exchange rate and nominal interest rate play vital roles in determining the level of inflation in Ghana. The results from the study show that inflation is affected by both factors in the short run and in the long run. The short run relationships were estimated using an unrestricted error correction model. The results show that a depreciation in the Ghana cedi by a percentage point leads to an increase in the rate of inflation by 0.20%. It however decreases by 0.98% for every percentage point increase in the nominal interest rate. The results from this study confirm the study by Bawumia et al (2003) which also proved a long run relationship between inflation and interest rate using co-integration and error correction analysis. Their study also concluded that the level of exchange rate depreciation affects inflation positively. The impact is however transmitted with a one-month delay.

This study however found a positive relationship between nominal interest rates and inflation in the long run which explains the overwhelming negative effect on the economy of raising interest rates for longer periods.

As mentioned earlier, stable single digit inflation has not been possible due to the fact that the economy is vulnerable to shocks. With exchange rate volatility and an inflation targeting mechanism, the Bank of Ghana is tempted to focus its efforts unduly on the exchange rate fluctuations. This case implies that the Bank of Ghana will be reacting to almost every or several of the fluctuations in

the exchange rate. Monetary policy will therefore also be volatile. This is obviously undesirable as it means that the central bank itself becomes a source of unnecessary disruptions in the economy. Volatile exchange rate such as seen in Ghana for the past few years will be problematic if the Bank of Ghana allows the exchange rate to take a very prominent position in its analysis. Higher interest rates need to only be temporary. Once the exchange rate is stabilized, interest rate should be allowed to decline given the cost of persistently high interest rates.
Temporary tight policies may signal the determination of the monetary authority to pursue exchange rate stability and low inflation. Even when the tight policies are withdrawn, the exchange rate would stabilize at a higher level.
Drazen and Masson (1994). When there are important structural issues aside the reputation of the monetary authorities, raising interest rates may not necessarily solve exchange rate crises. Even if interest rates as a monetary policy tool can stabilize exchange rates, the costs of raising interest rates may be too high.

5. SUMMARY

The study employed an autoregressive distributed lag model and an unrestricted error correction model to estimate the long run and short run relationships among inflation, exchange rate depreciation and the nominal interest rates. The error correction model was applied due to the fact that the variables were co-integrated. The long run relationships were estimated using the coefficients from the autoregressive distributed lag model. The ARDL model was also applied because variables were found to be integrated of different orders.
The results from the study show significant effects of interest rate and exchange rate on inflation in both the short run and the long run. However in carrying out monetary policy which aims at price stability, there is the need to reconcile the traditional interest rate-exchange rate trade-off, Goldfajn and Gupta (1998). This should be done being mindful of the inflation-output trade-off and the inflation-unemployment trade-off. The cost incurred in raising interest rates to stabilize the currency could be overwhelming if the banking sector is fragile such as the case in Ghana. This policy is only appropriate if the corporate sector is heavily exposed to foreign debt.
The Bank of Ghana needs to outline a credible view of the transmission mechanism, from policy instruments to objectives. This can be done using a model which will inform the decision making process so as to provide clear and consistent explanations for policy actions. Inflation expectation should be incorporated in this model of disinflation. The Bank of Ghana builds its credibility as it makes progress in the bid to achieve low inflation.
It is however worth admitting that modeling inflation in the Ghanaian economy will be challenging given the fact that, the economy is highly vulnerable to shocks and inflation expectations are unstable.

Appendices

Table A.1

Variable		Test Statistic	1% critical	5% critical	10% critical	MacKinnon approx. p-value for Z(t)	Decision
$INFL_t$	Z(t)	-2.45	-3.75	-3	-2.63	0.13	Unit roots
$\Delta INFL_t$	Z(t)	-5.70	-3.75	-3	-2.63	0.00	No unit roots
$INTR_t$	Z(t)	-1.21	-3.75	-3	-2.63	0.67	Unit roots
$\Delta INTR_t$	Z(t)	-4.51	-3.75	-3	-2.63	0.01	No unit roots
EXR_t	Z(t)	-3.48	-3.75	-3	-2.63	0.01	No unit roots

The absolute value of the Z(t) is compared with the absolute critical values at 5% level of significance. Z(t) > 5% critical value indicates a rejection of the null hypothesis of unit roots.

Table A.2.

Diagnostic test	Test	P values (5%)
Linearity test	Lagrange multiplier test	0.15
Model specification	RESET test	0.66
Heteroskedasticity	White test	0.19
Normality of residuals	Chi-square	0.07
Autocorrelation	Breusch-Godfrey test	0.76
Parameter stability test (CUSUM test)	Harvey-Collier	0.39
Test for long run relationship ($INFL_{t-1}$ and $INTR_{t-1}$.)	Wald test	0.00

Table A.3

	With constant	With constant and trend
Test statistic: tau_c(1)	-3.72	-3.59
Asymptotic p-value	0.00	0.03
Sample size (n)	21	21

P-values less than 5% indicate a rejection of the null hypothesis of non-stationarity.

Table A.4

Diagnostic test	Test statistic	P-values (5%)
Linearity test	Lagrange multiplier test	0.10
Model specification	RESET test	0.60
Heteroskedasticity	White test	0.24
Normality of residuals	Chi-square	0.11
Autocorrelation	Breusch-Godfrey test	0.92
Parameter stability test (CUSUM test)	Harvey-Collier	0.46
Test for short run relationships (ΔEXR_{t-1} and $\Delta INTR_{t-1}$)	Wald test	0.00

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