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Money Demand Estimation using SAS®

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Abstract

The paper attempts to empirically investigate the stability and model Cagan money demand using SAS/ETS procedures PROC ARIMA and PROC VARMAX for the case of the West African country Cote D'Ivoire. The behavior and stability of money demand in the long run has been documented in recent years for mostly developed countries but rarely the literature has focused on the same issue in the poor and underdevepped economies. Therefore in filling the gap we try to see whether each definition of money M1 or M2 is stable for the Ivorian economy and their long run movement. Our finding is that there is an evidence of long-run equilibrium relationship between either money M_1 or M_2 and its determinants real income and the expected inflation. However there is a large difference in the magnitude of the elasticity of income with the greater being the elasticity of income with respect to M2.M2 money demand is highly elastic (1.40) compared to an inelastic M1 money demand (0.939).

1. Introduction

Even if the subject of money demand in Economics is not a new idea and was at heart of some of the great works of brilliant economists of the three decades following the Second world War ,its modeling and very much understanding represents today one of the cornerstone of any monetary policy conducted by a Central bank .However Its importance is not to be limited to the labor of the central bank but can also find useful meaning in the hands of businesses in their attempt to forecast aggregate demand either in a short term or in a long run. Also the other importance is that money demand could be a source of a inflation majorly in the short term. Friedman (1959) was the first to theoretically and empirically produced the analysis on the money demand function .Since then Mankiw (1986) and Faig (1988) and many more have incorporate the transaction costs when keeping the Friedman framework .Thus the demand function of money is believed to be some positive function of real income (with a higher income people carry more transactions ceteris paribus) whereas the opposite behavior encountered if one is to expect an increase in future prices. So in the case of a future decline in the value of the money the individuals behavior is to buy a IPhone now when it cost $400 rather than waiting for the next month when it will cost $500.This interpretation translates into the times series analysis of real money balance, real income and the interest rate having the same time trend. And one should be careful running a linear regression when dealing with times series data because of the biasness of the estimators that generally results from such exercise. Luckily there exists some time series techniques to properly estimate the money demand time series and allows us to avoid the bias which arises from a simple OLS regression. Both PROC ARIMA and PROC VARMAX provide a great range of flexibility and solutions to many of Autoregressive Integrated Moving Average (ARIMA) models from identification and cointegration to forecasting .The ARIMA procedure as the name indicate is useful for univariate time series analysis. It is the complete package to study Box-Jenkins model. ARIMA model predicts a value in a response time series as a linear combination of its own past values, past errors (also called shocks or innovations), and current and past values of other time series. Finally, PROC VARMAX is useful in grouping times series that normally have a relationship to study the extent of their relationship.

Definition of the money

Economists have a very broad definition of money different from the piece of bill that we actually carry for our daily transaction. So money means for economists everything that can achieve these 3 functions at the same time:

i. Means of payment for example a check
ii. Store of value for example a saving account
iii. Unit of account

Therefore with the goal of knowing how much the economy has they measure two important quantities M1 (money that is can be easily converted to cash such as currency and demand deposit), M2 (M1 money +saving account basically anything less convertible to cash).

2. Money demand model

2.1 Model

It follows from the introduction that money demand model can be summarized in the following long run equilibrium relationship:

$$m_t - p_t = \alpha + \alpha_y y_t + \alpha_i E_t(\pi_{t+1}) + u_t \qquad 1.1.$$

Most in the literature used the interest rate instead of the expected inflation .In our study of Cote D'Ivoire money demand we will subsidy the rate of interest by the expected inflation $m_t - p_t$ is the log real money balance, y_t is the log real income, $E(\pi_t)$ the expected inflation and u_t a stationary process. In order to study the long-run equilibrium relationship of $m_t - p_t$, y_t and $E(\pi_t)$ we will need to show that all the variables have the same order of integration using the two most used unit root test Augmented Dickey-Fuller (ADF) and Phillips and Perron (PP) test.

For the real money balance $m_t - p_t$ and the real income and the Expected inflation to be in equilibrium as stated in equation 1.1 the times series analysis require the different processes to have the same stochastic and deterministic trend .In another words it is required that money balance, income and Expected inflation are cointegrated. This co-movement or economic relationship that the economics theory requires among$m_t - p_t , y_t$ and $E(\pi_t)$ is only making sense if any deviation in the demand for money is necessarily temporary in nature. This last statement has for meaning that the sequence of error terms u_t is stationary. Thus in order to correctly model our money demands our set of variables need to have the same order of integration. Couple of SAS/ETS procedures PROC ARIMA and PROC VARMAX allows us to work effectively with these time series properties.

2. 2 Graphical analysis and data step

The data is provided by the IFS (international Financial Statistics) .And the collected sample is from 1960 to the latest data available (2009): One difference in our modeling with previous studies on the issue of money demand is the decision to not consider the interest rate as the opportunity cost of holding money. The main reasons of the omission of the interest rate in the money demand determinants find support in the poor level of financial development and the low amount of the less liquid of the money data. The data shows a very poor level of interest bearing money such as saving supporting our choice of not including the interest rate as part of explaining the long run equilibrium of money demand. Our alternative is then the expected inflation which we argue it provides a better indication than the interest rate of the amount of money the individuals are willing to hold in order to carry future transactions. We generate the expected inflation as a proportion of lag1 inflation after rejection of the further lags values appear to be not significant.

Using the SAS/ACCESS interface to PC files and the Libname statement (the Excel Engine statement) to read and write the data on SAS.

```
/*reading and writing the excel file into sas
by using the libname excel engine*/
libname money'C:\Users\Gerard Tano\Documents\Dissertation\Dataset\
CI_paperdata.xls';
/*The imported data has variables in real terms
ie realincome =log(GDP)
M1Balance =log (M1 Money stock /P)
M2Balance =log (M2 Money stock /P)
M1velocity=log (GDP*P/M1 Money stock)
M2velocity=log (GDP*P/M2 Money stock)
E_inflation comes from a one lag modelling of the inflation series*/
proc print data=money.'CI$'n ;
var Country year realincome M1Balance M2Balance M1velocity
M2Velocity E_inflation;
run;
data sasuser.Money_demand(keep=Country year realincome M1Balance M2Balance
M1velocity M2Velocity E_inflation);
set money.'CI$'n;
run;
```

Below is the first 10 observations of the sas table Money_demand generated by the proc print .Notice the first two observations are missing data.

Table1 Print output

Obs	Country	Year	RealIncome	M1Balance	M2Balance	M1Velocity	M2Velocity	E_Inflation
1	Cote d'Ivoire	1960	7.73735	.	.	.	.	.
2	Cote d'Ivoire	1961	7.74977	.	.	.	.	.
3	Cote d'Ivoire	1962	7.76836	7.04056	7.07157	1.68721	1.65620	8.69315
4	Cote d'Ivoire	1963	7.84002	7.10204	7.12956	1.68450	1.65698	2.67670
5	Cote d'Ivoire	1964	7.88511	7.13981	7.22612	1.67937	1.59306	3.60230
6	Cote d'Ivoire	1965	7.88133	7.15727	7.22050	1.64813	1.58491	3.60230
7	Cote d'Ivoire	1966	7.92909	7.19706	7.26244	1.65482	1.58944	4.52791
8	Cote d'Ivoire	1967	7.95391	7.21580	7.29503	1.65504	1.57581	4.99072
9	Cote d'Ivoire	1968	7.99495	7.26395	7.35294	1.62071	1.53172	4.06511
10	Cote d'Ivoire	1969	8.02045	7.31482	7.43456	1.58820	1.46846	5.45352

```
/* Graphing the times series variables Realincome ,Money Balance to visualize
their long run movement*/
%macro scatterplot(M=M1Balance,GDP=realincome);
PROC GPLOT DATA = sasuser.Money_demand
;
PLOT &GDP *&M /VAXIS=AXIS1
 HAXIS=AXIS2
FRAME LEGEND=LEGEND1
;
RUN;QUIT;
%mend scatterplot;

%Macro lineplot(Balance=M1Balance ,E_inflation=E_inflation);
SYMBOL1
      INTERPOL=JOIN
      HEIGHT=10pt
      VALUE=NONE
      LINE=1
```

```
        WIDTH=2

        CV = _STYLE_
;
SYMBOL2
        INTERPOL=JOIN
        HEIGHT=10pt
        VALUE=NONE
        LINE=1
        WIDTH=2

        CV = _STYLE_
;
Legend1
        FRAME
        ;
Axis1
        STYLE=1
        WIDTH=1
        MINOR=NONE
;
Axis2
        STYLE=1
        WIDTH=1
        MINOR=NONE
;
TITLE;
TITLE1 "Line Plot";
PROC GPLOT DATA = sasuser.Money_demand
;
PLOT &E_inflation * year /
        VAXIS=AXIS1 HAXIS=AXIS2
FRAME;
PROC GPLOT DATA = sasuser.Money_demand
;
PLOT &Balance * year RealIncome *year /
 OVERLAY
        VAXIS=AXIS1 HAXIS=AXIS2
FRAME LEGEND=LEGEND1
;
RUN; QUIT;
TITLE; FOOTNOTE;
GOPTIONS RESET = SYMBOL;
%Mend lineplot;
```

Calling the above two Macro definitions to generate the graph of the different variables:

```
%lineplot(Balance=M1Balance,E_inflation=Realincome)
```

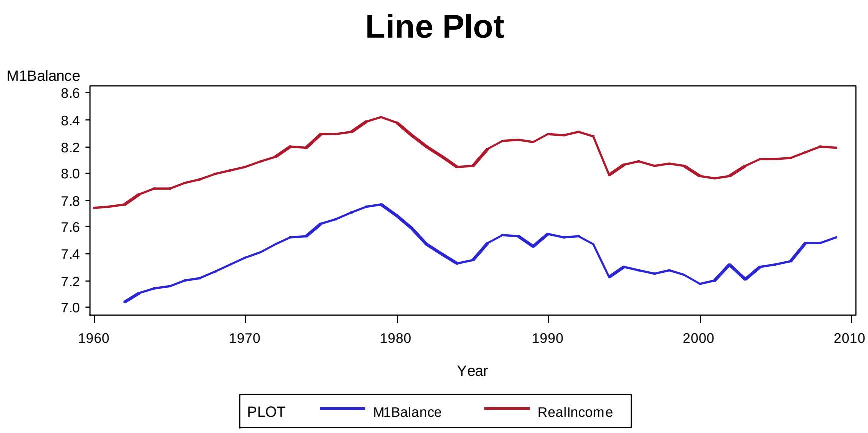

Figure 1 : Times series plot of M1 money demand and national income

```
%lineplot(Balance=M2Balance ,E_inflation=E_inflation)
```

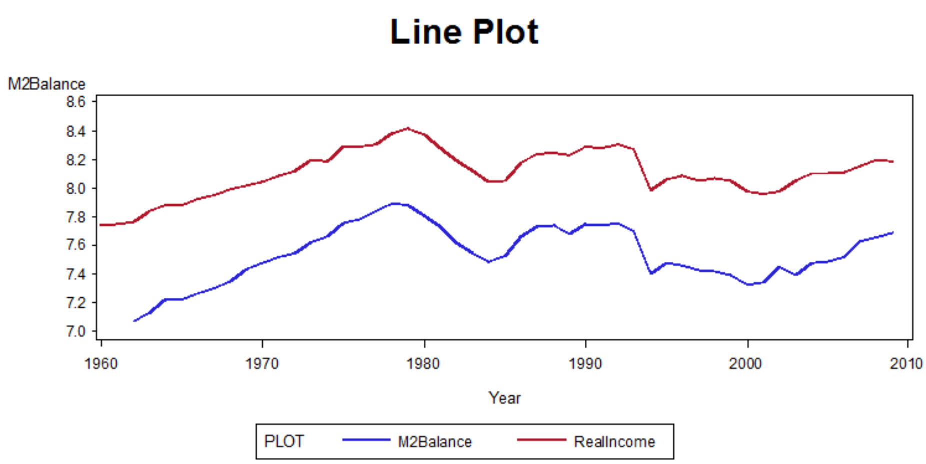

Figure 2 : Times series plot of M2 money demand and national income

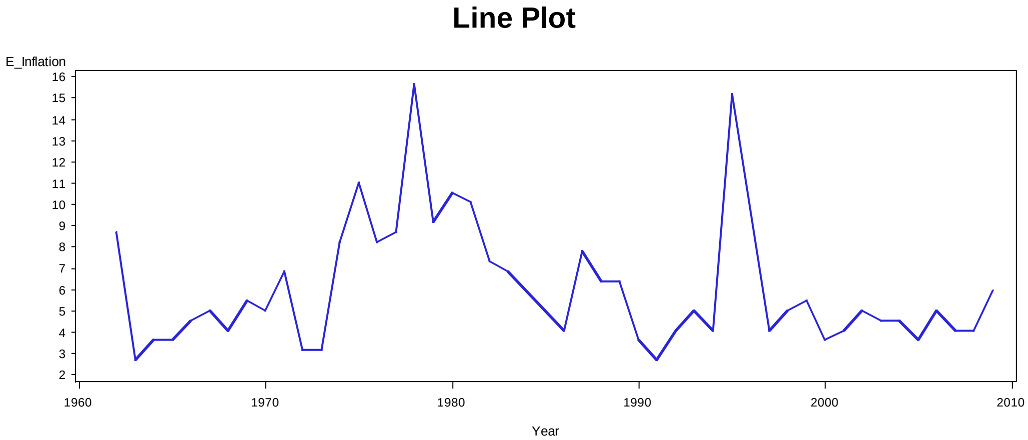

Figure 3: Times series of Expected inflation

Figure 1 to 3 shows the different times series movement starting from 1960 to 2009.Real money balance for M $_2$ and M $_1$ graphically look to share the same time trend with the real income series. Also we can notice two noises appearance in the expected inflation series in late 1970 and in 1994.The first noise in the expected inflation is food price inflation created by the oil price shock in the late 1970 whereas the second noise is attributed to the devaluation of the CFA franc in 1994 which created a skyrocketing in domestic prices.

2.3 Order of integration of the variables

At this point we would like to extract the pattern in the different variables and to understand the order of integration of our variables. The ARIMA Box and Jenkins (1976) model for x_t to test for the null hypothesis of unit root (nonstationarity) is the following dynamic regression (Equation 1.2). x_t is for the variable of interest money demand $m_t - p_t$ (M1 or M2), realincome y_t , and the expected inflation $E(\pi_t)$.

$$(1-L)x_t = x_0 + \delta_1 x_{t-1} + \sum_{i=0}^{p} \delta_{2+i} x_{t-2-i} + \varepsilon_t \qquad 1.2$$

$Lx_t = x_{t-1}$ L is the lag operator. x_t is a univariate series representing money demand, real income and expected inflation. p is for the autoregressive order. And as most aggregate economic times series processes the order should generally be less than 2 or 3 ($p \leq 3$).One rule of thumb (probably more than just a rule of thumb it could be a theorem)very helpful in the choice of the order of the autoregression is that the time length t and the autoregressive order p move in opposite direction. Thus we will expect a process to have a larger memory for a daily or monthly times series than if the data was collected for yearly .In attempting to model our money demand the useful indication coming from the graphs orders that the constant x_0 should be set to 0 .This is just because the different times series do not exhibit a perpetual deterministic trend(linear trend over the period 1960 to 2009).The ARIMA procedure in SAS/ETS provides a very valuable toolset to analyze and forecasts equally spaced univariate times series data, transfer function data, and intervention data by using the autoregressive integrated moving average(ARIMA) model. The ARIMA procedure provides comprehensive tools for single variable time series identification of the order of integration, estimation of the moving average parameters and many more such as forecasting and diagnostic checking.

```
/***************************************
Beginning of the Analytical part*/
/*M1Balance appears to be a AR(1) processes*/

/***************************************
Beginning of the Analytical part*/
/*M1Balance appears to be a AR(1) processes*/

proc arima data=sasuser.Money_demand;
*identify var=M1Balance stationarity=(ADF=(0,0));
identify var=M1Balance(1)stationarity=(PP=(1,0))clear;
identify var=M1Balance(1) stationarity=(ADF=(1,0));
run;
estimate p=1 plot;
*estimate p=1 q=1;
quit;

/*M2Balance appears to be a AR(1) processes*/
proc arima data=sasuser.Money_demand;
*identify var=M2Balance stationarity=(ADF=(0,0));
identify var=M2Balance(1)stationarity=(PP=(1,0))clear;
identify var=M2Balance(1)stationarity=(ADF=(1,0));
quit;

/*Realincome also follows the same process order AR(1)*/
proc arima data=sasuser.Money_demand;
*identify var=Realincome stationarity=(ADF=(0,0));
identify var=Realincome(1)stationarity=(PP=(1,0))clear;
identify var=Realincome(1)stationarity=(ADF=(1,0));
quit;

/*The results are contradictory when comparing the ADF to the white-noise
test the first
suggesting to reject the null hypothesis and the second to reject the white -
noise hypothesis however
the Zero mean in the ADF reconciles both tests by failing to reject the unit
root*/

proc arima data=sasuser.Money_demand;
*identify var=E_inflation stationarity=(ADF=(0,0));
identify var=E_inflation(1)stationarity=(ADF=(1,0));
quit;
```

Below are some sample of the main outputs on the identification from the above PROC ARIMA statements, omitting the descriptive statistics, autocorrelations (ACF) ,inverse and partial autocorrelations portions .And we also report the ADF test omitting the PP test for unit root for the simple reason of saving space . However the PP test in our output has the same conclusion on the hypothesis as the ADF test.

Table 2: White noise Test for M1 model residuals as a AR(0)

Autocorrelation Check for White Noise									
To Lag	Chi-Square	DF	Pr > ChiSq	Autocorrelations					
6	97.61	6	<.0001	0.868	0.729	0.573	0.404	0.271	0.128
12	108.73	12	<.0001	0.003	-0.103	-0.141	-0.188	-0.217	-0.244

Table 3: ADF test for M1 as AR(0)

Dickey-Fuller Unit Root Tests							
Type	Lags	Rho	Pr < Rho	Tau	Pr < Tau	F	Pr > F
Zero Mean	0	0.0611	0.6921	0.90	0.8992		
Single Mean	0	-5.7739	0.3458	-2.11	0.2427	2.71	0.4006
Trend	0	-5.7707	0.7440	-2.10	0.5327	2.57	0.6741

Table 4: white-noise test for M1 as a AR(1)

Autocorrelation Check for White Noise									
To Lag	Chi-Square	DF	Pr > ChiSq	Autocorrelations					
6	5.06	6	0.5365	0.129	0.144	0.166	-0.156	0.089	0.005

Table 5: ADF test for M1 as AR(1)

Augmented Dickey-Fuller Unit Root Tests							
Type	**Lags**	**Rho**	**Pr < Rho**	**Tau**	**Pr < Tau**	**F**	**Pr > F**
Zero Mean	0	-39.4260	<.0001	-5.84	<.0001		
	1	-29.3843	<.0001	-3.78	0.0003		
Single Mean	0	-40.0556	0.0004	-5.85	0.0001	17.09	0.0010
	1	-30.3503	0.0004	-3.79	0.0056	7.17	0.0010
Trend	0	-40.5887	<.0001	-5.82	0.0001	16.96	0.0010
	1	-31.0753	0.0013	-3.76	0.0286	7.09	0.0416

Table 6 : White test for M2 residuals as a AR(1)

Autocorrelation Check for White Noise									
To Lag	**Chi-Square**	**DF**	**Pr > ChiSq**	**Autocorrelations**					
6	5.97	6	0.4270	0.230	0.153	0.146	-0.079	0.110	-0.003

Table 7: ADF test for M2 as a AR(1)

Augmented Dickey-Fuller Unit Root Tests							
Type	**Lags**	**Rho**	**Pr < Rho**	**Tau**	**Pr < Tau**	**F**	**Pr > F**
Zero Mean	0	-34.4136	<.0001	-5.20	<.0001		
	1	-27.1584	<.0001	-3.71	0.0004		
Single Mean	0	-35.3816	0.0004	-5.26	0.0001	13.83	0.0010
	1	-28.3873	0.0004	-3.72	0.0066	6.95	0.0032
Trend	0	-36.2862	0.0002	-5.27	0.0005	13.93	0.0010
	1	-29.3043	0.0024	-3.67	0.0347	6.86	0.0469

Table 8: White test on the residuals for Real-income as AR(1)

Autocorrelation Check for White Noise									
To Lag	**Chi-Square**	**DF**	**Pr > ChiSq**	**Autocorrelations**					
6	3.00	6	0.8088	0.184	0.010	0.084	-0.117	-0.038	0.012
12	7.65	12	0.8119	-0.091	-0.157	-0.043	-0.000	0.106	0.164

Table 9: ADF test on Realincome as AR(1)

Augmented Dickey-Fuller Unit Root Tests							
Type	**Lags**	**Rho**	**Pr < Rho**	**Tau**	**Pr < Tau**	**F**	**Pr > F**
Zero Mean	0	-38.3333	<.0001	-5.59	<.0001		
	1	-38.5693	<.0001	-4.30	<.0001		
Single Mean	0	-39.1336	0.0004	-5.62	0.0001	15.81	0.0010
	1	-40.3303	0.0004	-4.34	0.0011	9.43	0.0010
Trend	0	-40.1978	<.0001	-5.70	0.0001	16.23	0.0010
	1	-43.4049	<.0001	-4.45	0.0047	9.89	0.0010

2.4 Cointegration test and long run equilibrium

The idea of this stable relationship in Equation (1.1) suggests these 3 times series share the common trend (also called cointegrated).We will avoid entering in the literature of times series on the cointegration. Interested readers should refer to popular textbook or papers in the section below.. PROC VARMAX is a very powerful procedure able to compile Error Correction Model, dynamic regression and determine whether a set of time series are cointegrated.
Finding the vector parameters in Equation 1.1 would require using the cointegration analysis on the equation 1.2 with this time the x_t is the set of our variables of interest. You can rearrange this equation 1.2 as the following matrix expression :

$$(1-L)x_t = \alpha\beta' x_{t-1} + \sum_{i=0}^{p-1}\phi_i(1-L)x_{t-i} + \varepsilon_t \qquad 1.3$$

$\beta^t = \begin{bmatrix} 1 \\ \alpha \\ \alpha_y \\ \alpha_i \end{bmatrix}^t$ β^t is the the long term equilibrium parameters. ε is a white noise process.

The Johansen and Julius λ_{trace} cointegration statistic test for testing the null hypothesis that there are at most r cointegrated vectors is used versus the alternative Hypothesis of more than r cointegrated vectors or Eigenvalues or Characteristic roots are chosen over the mere test of another Augmented Dickey Fuller(ADF) test on the residuals .The VARMAX procedure tells that Rank=2 (there is two cointegration vectors) M1 (M2)Money demand are cointegrated with the real income and the expected inflation because the trace value is smaller than the critical value at 5% level.

$$\lambda_{trace} = -T \sum_{i=r+1}^{k} \log(1-\lambda_i) \qquad 1.4$$

```
proc varmax data=sasuser.Money_demand;
model M2Balance Realincome
E_inflation/cointtest=(johansen=(normalize=M2Balance));
run;

proc varmax data=sasuser.Money_demand;
model M1Balance Realincome
E_inflation/cointtest=(johansen=(normalize=M1Balance));
run;
```

Table 10: Johansen Cointegration test : Money demand(M2)

Cointegration Rank Test Using Trace Under Restriction						
H0: Rank=r	**H1: Rank>r**	**Eigenvalue**	**Trace**	**5% Critical Value**	**Drift in ECM**	**Drift in Process**
0	**0**	0.4456	58.1030	34.80	Constant	Constant
1	**1**	0.3838	30.3772	19.99		
2	**2**	0.1496	7.6189	9.13		

Table 11 : Johansen cointegration test :Money demand (M1)

Cointegration Rank Test Using Trace Under Restriction						
H0: Rank=r	H1: Rank>r	Eigenvalue	Trace	5% Critical Value	Drift in ECM	Drift in Process
0	0	0.4091	48.9176	34.80	Constant	Constant
1	1	0.3388	24.1910	19.99		
2	2	0.0961	4.7468	9.13		

Table 12 :Long run parameters values

Long-Run Coefficient Beta Based on the Restricted Trend			
Variable	1	2	3
M2Balance	1.00000	1.00000	1.00000
RealIncome	-1.40845	-0.38676	-0.82893
E_Inflation	0.00018	-0.10183	0.00277
1	3.90310	-3.79068	-0.86539

Long-Run Coefficient Beta Based on the Restricted Trend			
Variable	1	2	3
M1Balance	1.00000	1.00000	1.00000
RealIncome	-0.93924	-1.47408	-0.62912
E_Inflation	-0.03087	0.01060	0.00474
1	0.42242	4.52991	-2.34112

3. Conclusion

The use of PROC ARIMA to study the stationary properties of money demand(M1 and M2),Real income and Expected inflation along with PROC VARMAX to investigate the cointegration relationship(common trend) of these variables for the case of Cote D'Ivoire suggests the stability of both M1 and M2 in the long run .All the variables appear to have the same order of integration of order 1(AR(1) processes with drift) .Finally It should be noted that the cointegration regression helps understand the long -run relationship of the money demand and its components but provides little answer when it comes to examine the short-run dynamics of the money demand. A method such as the Error Correction Model (ECM) method developed by Engle and Granger eloquently allows us to analyze the short-run deviation of the real money demand from its expected long-run path.

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