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ALTERNATIVE APPROACHES TO FORECASTING CURRENCY DEMAND IN THE JAMAICAN ECONOMY

by

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Abstract

Alternative Approaches to Forecasting the Demand for Currency in the Jamaican Economy

Base money or 'high-powered' money represents the primary instrument that the Central Bank uses in the conduct of monetary policy. As defined, it operates as the fundamental means of payment in the Jamaican economy and therefore can be managed to affect the availability of credit in the banking system. Fluctuations in base money which propagate money supply changes will feed into the Bank's ultimate objective of controlling excessive movement in inflation. In this regard, since the Bank's primary focus is containing inflation, it is essential that attendant base money shocks emanating from any component be adequately assessed, to avert adverse effects on the monetary aggregates.

Currency issue, one of the components of the monetary base, has displayed significant shifts, and hence does not facilitate easy and reliable forecasts for the Bank's management of base money growth. The paper attempts to formalize the forecasting techniques currently being used, in addition to investigating the existence of short-run and long-run relationships between currency demand and macroeconomic variables, which will give further insight on the likely impact of monetary policies on economic parameters, and hence on the public's demand for notes and coins. The paper examines the forecasting powers of two alternative methodologies: one based on time series analysis, and the other on the specification of a structural relationship between currency demand and macroeconomic variables.

It is shown that the forecasting powers of the structural Error Correction Model is superior in its forecasting ability, and yields more insights into the underlying relationships between the public's currency demand and various macroeconomic variables. However, the usefulness of the pure time series model is not negated, as it is observed that the specification closely tracks the monthly demand for currency by the public. There is scope for use of both ARMA and ECM specifications to generating forecasts and monitoring for the Bank's monthly base money management targets.

1. *INTRODUCTION*

Base money[i] or 'high-powered' money represents the primary instrument that the Central Bank uses in the conduct of monetary policy. As defined, it operates as the fundamental means of payment in the Jamaican economy and therefore can be managed to affect the availability of credit in the banking system. Over the past two to three years, monthly base money fluctuations have been caused by significant monthly shifts in the level of currency issued by the Bank of Jamaica. The resulting impacts of such shifts have made the management of high-powered money very difficult. Given that base money management represents the central operating target through which the monetary aggregate is influenced, these shifts have presented challenges to threaten the Bank's fulfillment of fiscal year inflation and exchange rate targets. It is therefore imperative that the Central Bank develops better understanding of the behavioral fluctuations in the components of this operating target - one of which is the currency issue.

The links between the Bank's base money management strategies and the money creation process is not direct. However, the process is assumed to occur through the multiplier, which has a direct proportional relationship with the base. Hence fluctuations in base money, which propagate money supply changes will feed into the Bank's ultimate objective of controlling excessive movement in inflation. In this regard, since the Bank's primary focus is containing inflation, it is essential that attendant base money shocks emanating from any component be adequately assessed, to avert adverse effects on the monetary aggregates.

Currency issue, defined as the sum of notes and coins demanded by the public through commercial banks, has displayed significant shifts, and hence does not facilitate easy and reliable forecasts for the Bank's management of base money growth. Previously, forecasting of the currency issue primarily employed trend analysis backed by assumptions relating to seasonality factors and economic developments, to estimate month end stocks. However, in recent periods this technique has demonstrated certain deficiencies in accurately predicting monthly movements in the demand for domestic currency. This is in light of significant macroeconomic developments in the Jamaican economy which, since 1990, has been characterized by an increased openness associated with liberalization policies pursued. Given the degree of openness capital movements, whether cash or other non-liquid assets across international borders are unrestricted. Hence there exists the potential for significant influences on the spectrum of micro and macro economic aggregates from various external sources.

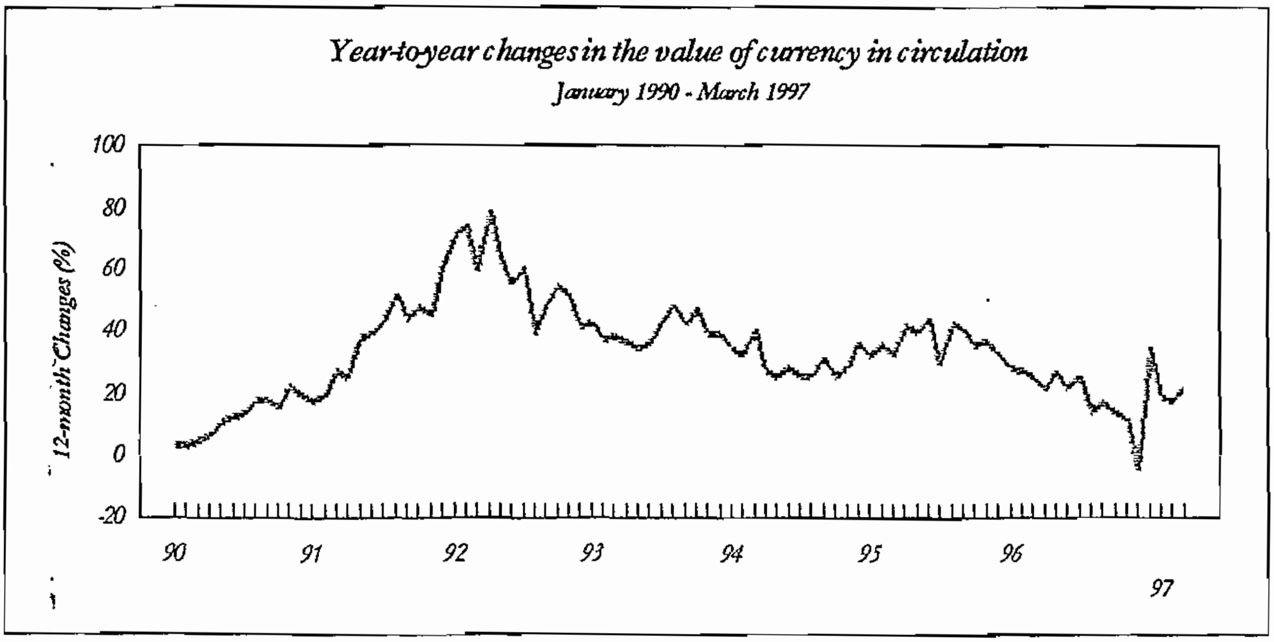
This paper attempts to address the shortfalls in forecasting the monthly currency issue, presenting a more scientific approach, to formalize the forecasting techniques currently being used. Additionally, one of the techniques employed here, allows an investigation of the existence of short-run and long-run relationships between currency demand and macroeconomic variables, which will give further insight on the likely impact of monetary policies on economic parameters, and hence on the public's demand for notes and coins. The paper examines the forecasting powers of two alternative methodologies: one based on time series analysis, and the other on the specification of a structural relationship between currency demand and macroeconomic variables. It is shown that the forecasting powers of the structural Error Correction Model is superior and yields more insights into the underlying relationships between the public's currency demand and various macroeconomic variables. However, the usefulness of the pure time series model is not negated, as it is observed that the specification tracks the monthly demand for currency by the public. Hence, while the ECM specification demonstrates superior forecasting powers, there is scope for use of both ARMA and ECM specifications to generate forecasts for the Bank's monthly base money management targets.

The organization of the paper is as follows. Section 2 synoptically examines the evolution of the value of notes and coins in the Jamaican economy since 1990 and provides the background to the development of the forecasting exercise. Section 3 examines the details of the modeling techniques included in the exercise and the data employed for carrying out the analyses. In Section 4, a summary of the results from the estimated models is presented. Forecasts and respective evaluations are examined to provide the evidence for the selection of an appropriate model. This will facilitate the generation of forecasts for the Central Bank's base money operating targets, in addition to providing the basis for analysis on the structural relationships. Relevant conclusions are presented in the final section. The appendix summarizes the main results from statistical tests for the finally selected models.

2. *HISTORICAL BACKGROUND*

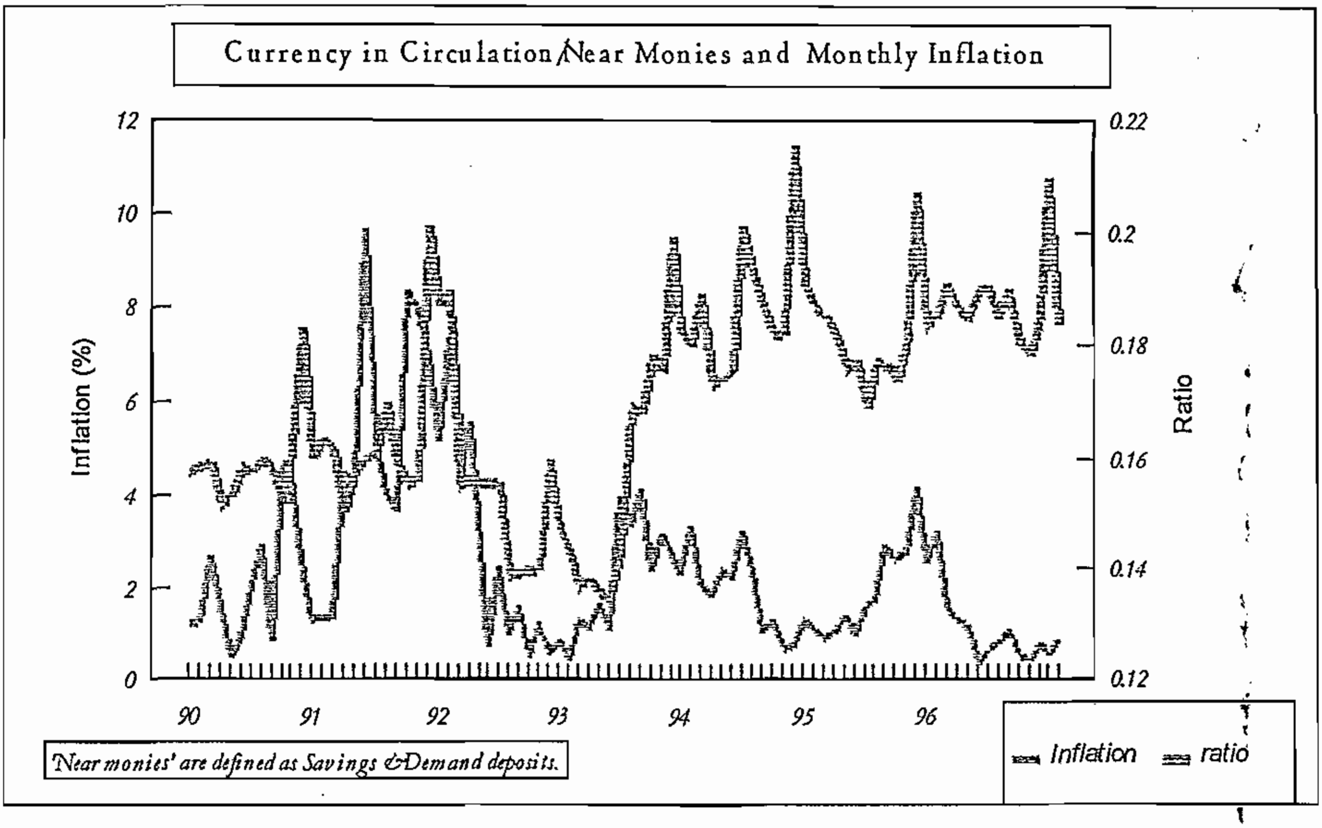
The Jamaican economy during its post-liberalization period has been characterized by volatile periods of high inflation, and since 1996, relatively low inflation. Following the introduction of liberalization policies in 1990, the impact of the high inflation environment is the increased growth in the currency in circulation, which continued up to mid-1992 (as shown in figure 2.1). With the relative fluctuations during the subsequent years, the 12-month growth in the public's currency demand subsided, and has since declined progressively, as the inflation volatility abated. The noted impact during the latter years, is the diminished year-to-year movement in the total value notes and coins held by the public. Figure 2.1 while illustrating these observed trends in currency demand by the public, it attests the hypothesized relationship that monthly movements in inflation is closely correlated with the monthly demand for currency; which by extension, the relationship should persist over the long-term.

Figure 2.1: ***Evolution of the Value of Currency with the Public: Year-to-year 1990-1996***



currency use during 1991 and 1992 coincide with economic periods of high inflation, spurred by excessive exchange rate volatility. However, the marked increase in the ratio since 1994 has an observed constant trend, which may be attributed to other structural economic factors. Conjectural analysis of this observed trend, points to two possible reasons: a) the bouts of financial sector instability could have encouraged this surge in currency holdings, and b) the increased activity in the informal sector during the latter years of the sample period. Nonetheless, the data substantiates that the demand for notes and coins has a direct link to various quantifiable and non-quantifiable economic variables.

Figure 2.2: Measuring the relative use of Currency to other groups of 'near money'



conducting cash transactions has been reduced. On the other hand, as more Jamaicans transact payments in the formal economy using credit cards and point of sale systems, currency demand may fall[ii], leaving an ambiguous total effect.

3. *MODELING TECHNIQUES and DATA ANALYSIS*

Existing empirical analysis on the demand for money in the Jamaican economy has concentrated on the wider monetary aggregates. In a recent study, Craigwell(1991) uses cointegration[iii] modeling to examine the structural relationship between the aggregate of currency plus commercial bank demand deposits and major economic variables to investigate the possibility of estimating a stable money demand function.. This paper focuses on the narrowest monetary aggregate, that of notes and coins, which forms the base of any monetary economy. While the primary objective rests with deriving an adequate time series model which best forecasts the monthly movements in the notes and coins in circulation, special attention is given to a time series model that incorporates the theoretical and economic relationships between currency demand and major economic variables. Thus, the forecasting of monthly changes in the demand for Jamaican notes and coins is carried out using two different methodological processes. The first technique utilizes pure time series analysis to model the monthly changes in currency demand. In the subsequent technique, a structural economic relationship is explored to provide an alternative forecasting methodology.

3.1 MODEL TECHNIQUES

3.1.1. ARMA Model

The univariate Autoregressive Moving Average (ARMA) model is a time series methodology that uses past and current values of the dependent variable to produce forecasts of the variable. The technique generates forecasts by modeling the correlation between the series and its past values, and assumes that this identified correlation will continue into the future. In this way, it becomes possible to obtain good approximation of the behavior of a variable by a purely statistical approach. Based on the Box-Jenkins (1976)[iv] modeling technique, ARMA methodology seeks to establish a parsimonious relationship, using as few parameters as possible. For example, to forecast future values of a series y, using the ARMA technique, the general model specification for the series is expressed as:

$$y_t = \underbrace{\left(a_1 L + a_2 L^2 + \ldots + a_p L^p\right) y_t}_{AR(p)} + \underbrace{\left(1 + b_1 L + \ldots + b_q L^q\right) e_t}_{MA(q)}, \qquad (3.1)$$

which can be expressed as

$$y_t = \sum_{i=1}^{p}\left(a_i L^p\right) y_t + e_t + \sum_{i=1}^{q}\left(b_i L^q\right) e_t$$

where p and q = the number lags for autoregressive (AR) and moving average (MA) processes respectively;

e_t = an error process, with $e_t \sim N(0,1)$.

L= the lag operator on the processes; defined as $L^n x_t = x_{t-n}$.

The specification is further extended to include explicit modeling of seasonal factors observed in the data. Apart from specifying seasonal dummy variables, the pure time series ARMA specification is extended to the Seasonal Autoregressive Moving Average (SARMA). The specification of this model variation, using the series y_t, is as follows:

$$\left(1 - a_1 L\right)^p y_t = \left(1 + b_1 L\right)^q * \left(1 + b_2 L^s\right)^e \varepsilon_t$$
$$y_t - a_1 y_{t-1} = \varepsilon_t + \varepsilon_{t-12}$$
$$\therefore\ y_t = a_1 y_{t-1} + \varepsilon_t + \varepsilon_{t-12}$$

where p and q are the lags as defined above, and e and s represent the lag lengths for the seasonal component.

To determine the appropriate lag lengths of the processes, examination of the autocorrelation (acf) and partial autocorrelation (pacf) functions is necessary, as these functions give the relationship between data points, and indicates the memory of the data generation process. Perusal of these functions will facilitate an assessment of the additional information obtained from past values, resulting in testing and elimination of unnecessary or uninformative lags, to derive the final parsimonious SARMA model.

The main premise on which ARMA models is generated is the property of 'stationarity' in the series, which is defined as reversion of the series to its mean regardless of short-term fluctuations in the variable. The significance of this property is that the series displays constant mean and time in-variant variance, which, with its absence, estimation would be impossible since the variance would be inestimable. One attractive feature of this technique is that it does not rely on any a priori specification of economic hypotheses, and the use of the technique itself circumvents the possible problems which may arise in estimating structural models, for example omitted variables, variable definition problems, multicollinearity, and other model specification issues.

3.1.2. The Currency Demand Model

A standard money demand function is estimated to perform a two-fold role:

1. to generate future period forecasts of the demand for local denominations of notes and coins; and
2. to assess the policy implications by establishing and defining the short-run and long-run economic relationship(s) which exist between major economic variables and the demand for currency.

The model represents an eclectic combination of the transactions demand and the portfolio balance demand theoretical specifications. The transactions demand for currency describes the need to hold cash balances to facilitate planned and less significantly, unexpected expenditure such as unplanned bills. The portfolio balance model emanates from the model reformulated (Tobin, 1958) from the speculative motive of Keynes' theory of money demand. In the two-asset approach, the individual allocates his portfolio between money, assumed to be interest free, and alternative assets with uncertain rates of return. Portfolio adjustments require relative adjustments in balances to attain maximal returns on existing resources. The motive for adjustments in the balances of currency relative to 'near liquid' interest earning assets is assessed to determine the relative elasticities of adjustments.

Based on these 'traditional' theories of money demand, the defined model with adaptations reflective of characteristics of developing economies like Jamaica is as follows:

$$M_t = f(P_t, R_t, X_t, \tau_t)$$

where M_t = amount of notes and coins demanded, and is in circulation with the public at time t

P_t = consumer price index at time t

R_t= a weighted average deposit rate for financial institutions' deposit instruments

X_t= the exchange rate defined as \$Jx=US\$1

τ_t = consumer imports selectively comprising of food and non-durable items.

Assuming a semi-log demand function, with linear mathematical specification, the estimated model is:

$$m_t = \underset{}{\alpha_0} + \underset{(-)}{\alpha_1 R_t} + \underset{(+/-)}{\alpha_2 x_t} + \underset{(+)}{\alpha_3 p_t} + \underset{(+)}{\alpha_4 \tau_t}$$; *where lower case letters are in logs.*

The paper analyzes monthly data, and conjectures that as monthly ad hoc expenditures fluctuate across periods, so will the holdings of currency holdings. Currency demand, although operating in a lagged-structure with the measure of the level of transactions in the economy, moves proportionally upward (downward) as the level of transactions of the previous month are high (low). It is further hypothesized that the portfolio of assets is adjusted between currency holdings, relative to the asset return on short-term deposits and expected fluctuations in the foreign exchange rate. Where these relative returns fluctuate, the hypothesized effect is the reversed adjustments in the demand for notes and coins.

The demand function includes variables and proxies to capture various economic effects identified from the theories and the experiences of the Jamaican economy. Theoretical specifications of the transactions demand for money incorporates prices, and a scale variable to capture the level of monthly economic transactions. In the model, it is represented by the level of food and non-durable consumer imports. From studies done by Astley and Haldane (1997) it was demonstrated that correlation between currency and non-durable consumption is significant, as is the relationship between currency and GDP [v]. However, the studies showed that the significance of the correlation between investments and currency breaks down, which provide support for using a model with disaggregated transactions data, rather than GDP. In addition, by not including GDP, which is not available monthly, the model overcomes the sample size and variable definition problems by using non-durable consumer imports as a reasonable proxy to represent the value of monthly transactions.

The representative asset group for the portfolio balance model includes a range of financial sector deposits, specifically, short-term savings, and demand deposits. Also, it has been observed that for various reasons (including speculative depreciation of the domestic currency), Jamaicans hold foreign currency as an asset. The individual is assumed to hold domestic currency when the opportunity cost associated with interest rates on deposits is minimal. In this light, the model includes, in addition to the inflation variable, other measures of opportunity costs such as the average weighted deposit rate and the exchange rate, reflecting the prices of alternative uses of currency.

As previously mentioned, with the advent of electronic technology in providing basic retail banking services, the implications for the demand for currency are numerous. Having established a "**Multi-Link**" network, there is easier access to currency (specifically notes), at lower transaction costs. Plausible explanations of the effect are inconclusive as it depends on the extent to which agents manage cash holdings at intervals between withdrawals. However, with the increasing use of electronic Point of Sale (POS) systems in the future, the potential for the reversal of the initial expansion in the aggregate might occur. Additionally, credit card usage which shows increases during the years, have undergone an evolution, now including the latest product of transacting in domestic currency (J$) or US dollars. These innovations will have implications for any specification of a money demand function for developing economies. However, given the newness of these features data availability imposes constraints on their inclusion in this exposition. Obtaining and using data that captures these innovations provides a basis for future analysis of money demand in the Jamaican economy, which needs to reflect the evolutionary changes and developments in the means of payments.

For its usefulness to informing policy decisions, there is additional interest in determining short-run and long-run relationships. In this regard, a cointegration approach using an Error Correction Model (ECM) is adopted to estimate the currency demand function. To illustrate the usefulness of the technique, consider two series x and y, both of which are nonstationary $\{I(1)\}$. Then a cointegrated series z_t may exist as a linear combination of x_t and y_t such that z_t is stationary

- i.e. $z_t = y_t - bx_t$, with a single unique factor b, in the bivariate case and possibly more than 1, in the multivariate equation containing more than two I(1) variables. The series z_t measures the short-run deviations from the equilibrium relationship, and is stationary {I(0)} as the long-run (low frequency) components of bx_t and y_t cancels. The z_t is known as the error correction term, and having identified the cointegrating relationship, the ECM is estimated as specified in equation 3.2:

$$\Delta y_t = \alpha + \beta_1 \Delta x_{t-1} + \beta_2 z_{t-1} + e_t \tag{3.2}$$

where the z_t is represented by the white noise error process from the previously estimated cointegrating regression.

Using equation 3.2, both short-run and long-run dynamics are incorporated in a statistically acceptable mechanism (Miller 1991). While differencing eliminates the low frequency (long-run) information, the cointegration and EC methodology reintroduces the long-run dynamics through its inclusion of the error correction term z_{t-1} in equation 3.2; and the short-run fluctuations by changes in x_t and y_t.

Summarizing the sequential steps in utilizing this methodology comprises four distinct phases: a) testing variables for stationarity and determining their level of integration, b) estimating the cointegration equation/(s) using variables of similar order of integration, c) testing for stationarity in the residuals of the cointegrating equations, since these will be used further as the error correction term, and d) construction of the ECM which is specified as a function of lagged values of the dependent variables. The summary of these estimation stages with the relevant data to the paper are reported in the subsequent section on data analysis.

3.2 *DATA ANALYSIS*

The paper analyzes monthly data for the period December 1990 - December 1996. Graphical analysis of the currency in circulation points to significant increases in the total value of notes and coins in circulation during 1990-1996. The monthly year-to-year growth for currency in circulation reflects the periods of combined high inflation and exchange rate instability during the initial periods of economic liberalization. The growth rate however declines during the latter years of the analysis (specifically 1996) during which monetary policies restrained the volatility in the exchange rate market, resulting in lower inflation periods. Generally, the data exhibits clear seasonal patterns of demand for notes and coins. December is usually characterized by increased spending activity and currency data indicates the peaks in December for any year. The reversal of this over-excessive demand during this period occurs mainly during January, and spills over on some occasions, to February. To account for this, seasonal dummy variables D^d and D^j are included in the model to reflect the upward and downward seasonal adjustments during December and January respectively.

The tests for stationarity of the currency series indicated that the series was I(1), which when differenced generated the I(0) series used in the analysis. The ARMA model uses the past values of currency to generate the regression (equation 4.1). The process of selecting lag lengths for the estimated process was facilitated by examination of the acf and pacf of the currency series. Observations from the sharp decline in the functions after the first lag indicated the AR(1) process, while the statistically significant spikes at 12-month lags pointed to the need to explicitly model the seasonal patterns in the data. Hence the model component SMA(12) is used, to adequately capture the seasonalities of currency. Subsequent tests on possible higher order AR terms and lower levels of MA terms did not improve the predictive power of the model, therefore the most parsimonious model comprised the specified AR and SMA processes, with the seasonal dummy variables specifically modeled for January and December.

3.2.1. Tests for stationarity

Table 3.1 presents the summary of the stationarity tests of the variables included in the models. The Augmented Dicky-Fuller (ADF) test is utilized, which is based on the following regression:

$$\Delta x_t = \rho x_{t-1} + \phi_1 \Delta x_{t-1} + \phi_2 \Delta x_{t-2} + \ldots + \phi_p \Delta x_{t-p} + e_t ,$$

where Δ is the difference operator, e_t is a stationary random error, a testing whether $\rho = 0$. The null hypothesis is that the tested series is non-stationary. Note that a constant and/or a trend term may be included in the ADF regression according to the tested data.

TABLE 3.1 *TESTS FOR STATIONARITY: 1990:01 TO 1995:12*

	ADF Tests	
	Levels	*1st - Differences*
Variable		
ln m	-1.88	-3.83**
ln x	-2.59	-3.41**
ln p	-2.45	-3.09*
ln i	-2.12	-4.38**
R	-2.77	-3.07*

*** denotes significance at the 1 percent level.*
** denotes significance at the 5 percent level.*

The test results for all the series in levels led to the conclusion that the null hypothesis could not be rejected at the 1 percent or 5 percent levels. However, the differenced series produced stationary I(0) variables, which rejected the null hypothesis of nonstationarity.

Therefore based on the ADF test for stationary, the model variables predominantly exhibited differenced stationarity.

3.2.2 *Cointegrating Equations*

The objective here is to define the linear combination of I(1) variables which generate stationary residuals. Three combinations are explored, and the summary results are presented in table 3.2. In the first instances, two tri-variate approximations are explored with a selected combination of the variables currency demand, exchange rates, inflation, deposit rates, and imports. In the third estimation, a quadri-variate model is tested for the possibility of cointegration among the set of variables. This was done in an attempt examine and to circumvent the potential statistical biases resulting from multicollinearity.

TABLE 3.2 COINTEGRATING REGRESSIONS: 1990:01 TO 1995:12

Variable	Coefficients of Constant	ln x	ln i	lnp	R	Adj. R^2	D-W	ADF
ln m	5.55	1.02	-	-3.19	-0.02	0.94	0.51	-1.32
ln m	3.01	0.68	0.26	-1.82	-0.1	0.96	0.95	-1.64
ln m	5.26	0.23	0.10	0.002	-	0.98	0.96	-2.91

Note: the errors from the cointegration equations are used to perform the ADF based on the regression:

$$\Delta u_t = \rho u_{t-1} + \phi_1 \Delta u_{t-1} + \sum_{i=1}^{6} \phi_{1+i} \Delta u_{t-i} + e_t$$

where u is the error from the cointegration regression, and e is a stationary white noise process. Adj. R is the adjusted R, and D-W the Durbin Watson statistic.

The results of stationarity tests on the generated residuals, could not lead to the conclusive rejection of the null hypothesis of the existence of nonstationary residuals. The results indicated that no linear combination of the I(1) model variables could be generated to produce an acceptable cointegrating equation. However, the Johansen test, which is an alternative test for establishing probable cointegrating rank or ranks was performed, and cointegration was deemed to exist between one selected combination from the set of variables. The test results are presented in Table 3.3.

TABLE 3.3	JOHANSEN TEST FOR COINTEGRATION:1990:01 TO 1995:12	
Tested combination: ln m, ln i, ln x, ln p		
Eigenvalues	*Likelihood Ratio*	*Hypothesized no. of C.E's*
0.462	101.19	r = 0**
0.359	58.411	r = 1**
0.2617	27.62	r = 2
Tested combination: ln m, ln x, R, ln p		
Eigenvalues	Likelihood Ratio	Hypothesized no. of C.E's
0.35	54.29	r = 0 *

**(*) significance at 1% (5%) level.

Based on these results at least one cointegrating rank is identified. The test results indicates that a stationary linear combination of the variables ln m, ln x, ln i and ln p may be generated. Since this test has the testing properties adapted to small samples, the performance of the test relative to the previous test of residuals is more readily accepted, as the small sample size may be causing the non rejection rather than the absence of cointegration (Miller 1991). Further, as noted by Holden and Thompson (1992), use of the Engle-Granger Two step Method, while having some advantages for a two-variable relationship, for multivariate models the Johansen method has better properties.

The accepted result is that the Johansen test has provided the basis for the assumption of cointegration, and hence makes estimating an error correction model a fruitful exercise. The residuals from the corresponding cointegrating regression are retained, and are utilized in estimating the error correction model, in which short-run and long-run dynamics are combined.

3.2.3 Estimating the Error Correction Model

The final stage of the model building process involves the estimation of the currency demand function encompassing short-run deviations from the long-run or steady state equilibrium, and the long-run process of adjustment. This involves regressing the first differences of each variable in the cointegrating equation onto the lagged values of the first differences of all of the variables, plus the lagged values of the error-correction term.

A critical issue in this process is the selection of the lag lengths used in the ECM. The paper uses a selection criterion of the specification with lag lengths that minimize the Akaike Future Prediction Error (FPE).[vi] The criteria involve the comparison of alternative specifications by adjusting the residual sum of squares for the sample size and the number of explanatory variables. The lower the FPE, the better the specification.

4. FORECASTING RESULTS

The results presented include the evaluation of both the SARMA specification and the Error Correction Model based of the in-sample period January 1991 to December 1995. In addition, out-of-sample performance for the specified SARMA and ECM models is presented primarily to generate some conclusive statements on the ability to forecast currency using a more formally specified statistical approach. The evaluation criteria[vii] are the percentage mean square error(PRMSE) and the mean deviation(MD). The PRMSE measures the aggregate percentage squared deviation between the actual and predicted or fitted values, and basically equates to an approximation of the standard deviation of the population. The MD examines the average deviations of the forecast values from the actual values. This evaluation criterion examines the level of over-prediction or under-prediction of actual values by the generated forecasts. Ideally, the MD should be zero, which indicates that the spread of forecast values from the actual values, (above and below) are equally spaced. Each model was estimated for the period January 1991 to December 1995, for which ex-post in-sample forecasts are derived. In addition, out-of-sample ex-post forecasts were generated for the 12-month period spanning January to December 1996. This will facilitate the analysis of the performance of the specifications for forecasting exercises outside of the specified sample range.

4.1 Estimated Models

i. SARMA Representation:

The estimated SARMA(1,12) model on which forecasts are generated is:

$$\Delta m_t^d = 0.021 - 0.480\Delta m_{t-1}^d + 0.194D^d - 0.119D^j + 0.886e_{t-12} + e_t \qquad (4.1)$$

(3.83) (-3.93) (7.77) (-4.90) (8864.31)

Adjusted $R^2 = 0.86$

where

m_t is in logs and, Δ denotes the first difference, i.e. $m_t - m_{t-1}$.

The estimated coefficients for the model specification are all significant, with their expected signs. Monthly currency demand changes which is captured in the AR(1) term indicates the reversal adjustments of holdings relative to the positions of the previous month. The moving average captures the year-to-year adjustments in currency holdings, which from indications, reflect direct proportional movements between months across the period. With the high seasonal component of the currency series, the relative magnitudes of the included seasonal dummy variables indicate that on average, the net currency outflows occurring during December, is not commensurably reversed during January, and supports the observed 12-month annual growth in currency demand.

ii. The Error Correction Specification

The selected model specifications are summarized and presented in Table 4.1. The specifications examine the pure ECM and the specification with seasonal dummy variables to capture the seasonalties observed in currency series and improving the forecasts from this model. Likelihood Ratio tests are performed to test the statistical significance of the combined effects of the model variables to the specifications.

Table 4.1 Summary results for the specified Error Correction Models

TABLE 4.1
ERROR CORRECTION SPECIFICATIONS
SAMPLE PERIOD: 1990:12 TO 1995:12

Model:

$$\Delta m^d = a_1\Delta\tau_{t-1} + a_2\Delta\tau_{t-2} + b_1\Delta p_{t-1} + b_2\Delta p_{t-2} + c_1\Delta x_{t-1} + c_2\Delta x_{t-2} + \delta EC_{t-1} + \beta_1\Delta r_{t-} + \beta_2\Delta r_{t-2} + \lambda_1 D^d + \lambda_2 D^j$$

		Model 1		Model 2	
Coefficients		***Estimate***	***T-statistic***	***Estimate***	***T-statistic***
a_1		-0.022	-1.09	-0.045	-1.36
a_2		-0.038	-1.94	-0.056	-1.70
b_1		0.362	0.79	0.556	0.69
b_2		0.262	0.68	-0.039	-0.06
c_1		0.063	0.44	0.026	0.10
c_2		0.025	0.15	0.403	1.38
δ		-0.199	-2.07	-0.551	-3.96
β_1		-0.042	-0.47	0.029	0.19
β_2		-0.015	-0.18	-0.013	-0.08
λ_1		0.186	9.88	-	-
λ_2		-0.095	-3.84	-	-
$Q(12)^2$			27.17**	28.17**	
LR(2)	$H_o: a_1=0, a_2=0$		3.83**	5.17**	
LR(2)	$H_o: b_1=0, b_2=0$		5.14**	3.36**	
LR(2)	$H_o: c_1=0, c_2=0$		0.26	0.82	
LR(1)	$H_o: \delta=0$		4.28**	16.6**	
LR(2)	$H_o: \beta_1=0, \beta_2=0$		0.40	0.51	
LR(1)	$H_o: \lambda_1=0$		97.7**	-	
LR(1)	$H_o: \lambda_2=0$		14.8**	-	

1. *EC is the error correction term from the cointegrating regression reported in Table 3.2*
2. *Ljung-Box Q test for the presence of higher order serial correlation in the residuals at 12 lags*

*** significance at the 5 percent level*

The coefficient signs are as expected, except for the transactions proxy - food and non-durable consumer imports. This could be noted as being attributed to the selected variable not being an ideal estimation of transaction levels, and therefore ties back to the data deficiencies previously highlighted. The specified model describes the adjustment path for currency demand relative to the selected macroeconomic variables. The ECM term, is negative and very significant, which implies long-run convergence of currency holdings to the steady state equilibrium, through the specified adjustment processes of price levels, exchange rate, and import fluctuations. Of special interest, is the statistical insignificance of the two asset adjustment factors - exchange rate and interest rates. From this, one could conjecture that while the portfolio shifting may exist, the emphasis for Jamaicans, in the short-run, is not relative shifting between cash balances and other assets, including foreign currency holdings. The primary basis for holding currency balances in the short-run is for transactions, as is conjured from the statistical significance of the price, and transaction proxies.

While the model presented as the pure ECM specification summarizes the short-run relationships and long-run adjustment process of currency demand from its steady-state equilibrium. The specification as is, will not facilitate accurate predictions of monthly currency movements. In fact, the model has not been distinctly defined to capture the seasonal components of the data, since in the long-run, the impact of these seasonalities should be nil. However, for the purposes of comparing and evaluating the forecasting ability of the ECM, with the specified ARMA representation, additional dummy variables to explicitly model the identified seasonal effects in January and December are included in the specification (Model 1 in the result summary contained in table 4.1).

Having included the seasonal dummies in the estimated ECM, the significance of the model coefficients does not change, however the magnitudes of corresponding coefficients are smaller. This marginal change in the model specification is attributed to the explicit modeling of seasonal components of the data, for which these effects of seasonality components were captured by the effects of other specified model variables, which would have incorporated the impact of these seasonal demand changes on the public's currency requirements.

4.2 Forecast Evaluations

The evaluation of both models for their performance in generating in-sample and out-of-sample forecasts, is based on the criteria of the percentage mean square errors(PRMSE) and the mean deviations(MD). While PRMSE measures the sum of squared deviations of the forecast values from the actual values, the MD measures the average absolute forecast error. Both criteria are averages, which makes them highly sensitive to large deviations, hence conclusive statements concerning the predictive power of both models are cautioned. Table 4.2 presents the summary of the evaluations for forecasts generated from both models, based on the PRMSE and MD evaluation criteria.

Table 4.2: Forecast Evaluation for In-sample and Out-of-sample Forecasts

	In-sample(1990:12-1995:12)		*Out-of-sample(1996:01-1996:12)*	
Criteria	*SARMA*	*ECM*	*SARMA*	*ECM*
1. PRMSE(%)	*0.17*	*0.14*	*0.11*	*0.092*
2. Mean Dev. (%)	*0.09*	*0.46*	*-1.73*	*-0.095*

Using the PRMSE, to evaluate the forecasts, it is implies that the EC specification demonstrates superior performance relative to the SARMA specification. Both in-sample and out-of-sample forecasts for the Error Correction Model indicates statistical superiority since these forecasts have generated the smallest squared percentage deviations from their actual values.

Further examination of the PRMSE for both specifications demonstrates that for both models the average squared percentage errors are smaller for the out-of-sample period relative to the model sample period. This may be attributed to the relative stability which existed during the latter testing period (1996) during which inflation and exchange rate upheavals were abated; which would have had stabilizing effects on the demand for currency.

The analysis of the Mean Deviation(MD) criterion produces somewhat different results for both specifications. On the one hand, both models (on average), tend to under-predict the monthly currency demand during the sample period 1990:12 to 1995:12. However, the average prediction performance of both models have under-forecasted estimates and is reversed as out-of-sample estimates are generated. Perusal of the in-sample results indicates greater variability in the distances between actual and fitted values is demonstrated in the structural specification. For the SARMA specification however, superiority is demonstrated as the relative distances between forecasts and actual values are more evenly distributed, resulting in such a small measure of relative deviations. However, for the testes sample period, the converse holds, where the ECM, despite over-prediction during this period has produced forecast deviations which are less than the in-sample counterpart.

Preliminary results of the evaluations of the forecasts, would indicate that the ECM specification has basically dominated the ARMA model., thus biasing the choice for this structural specification. However, a third criterion - that of graphical analysis of both in-sample and out-of-sample forecasts are presented to clearly depict the nature of tracking currency movements by each model.

A third evaluation criterion uses graphical analysis of the out-of-sample forecasts, which is presented in figures 4.1(a) and (b). The graphical illustration of out-of sample forecasts demonstrates the high correlation between actual and forecasted monthly currency movements in the SARMA model, relative to the ECM specification. The predictive power of the ARMA model is evidenced by the general tracking and depiction of monthly currency demand changes. Despite the favourable statistical support for the general use of the ECM specification for predicting currency movements, monthly observations of the model performance indicate some degeneration in the model's predictive power during mid-sample to the end of the period. This 'eye-balling' technique does not provide the conclusive support for statistical tests implying full use of the ECM, relative to the SARMA specification. However, one may conclude that both models, used with the caution of observed deficiencies, should provide adequate forecasts for the Bank's operating targets.

Figure 4.1a: Out of Sample Forecasts from SARMA(1,12) Specification (equation 4.1)

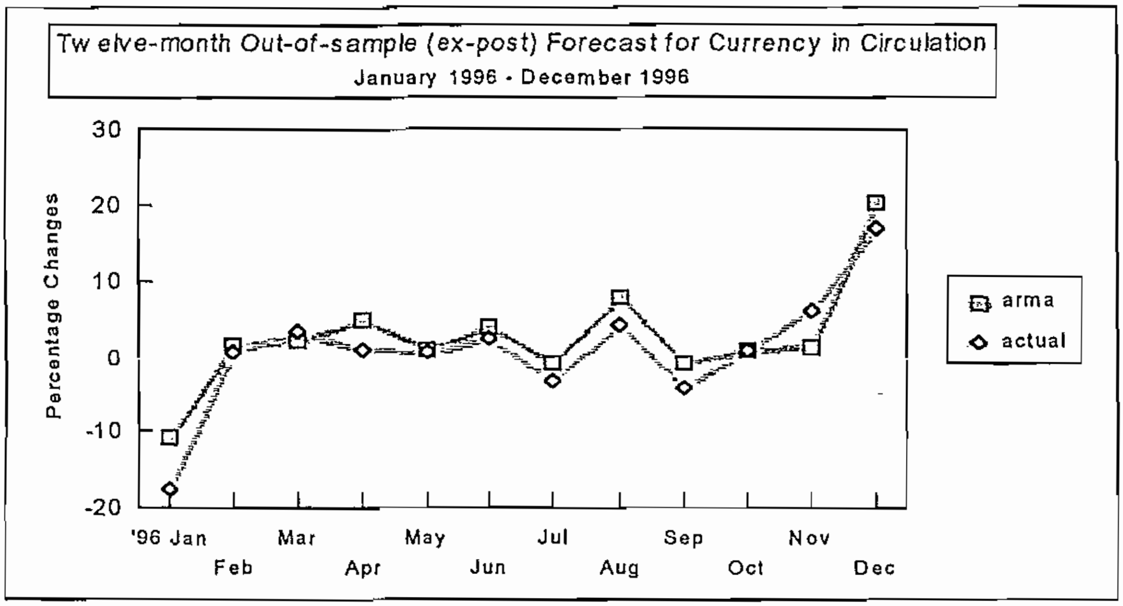
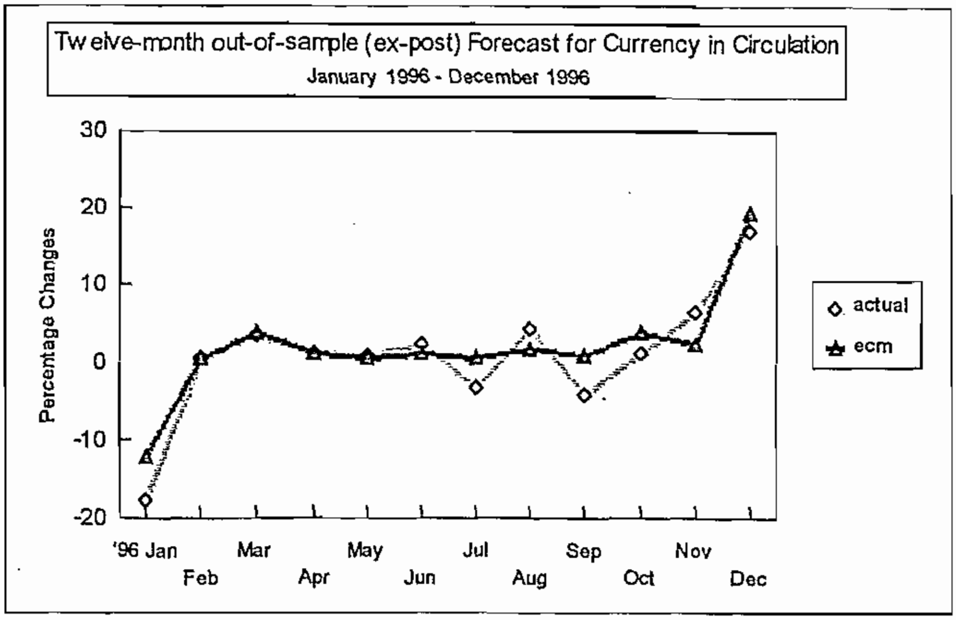


Figure 4.1b: Out-of-sample Forecasts from Error Correction Model Specification (Model 1)



5. *CONCLUSIONS*

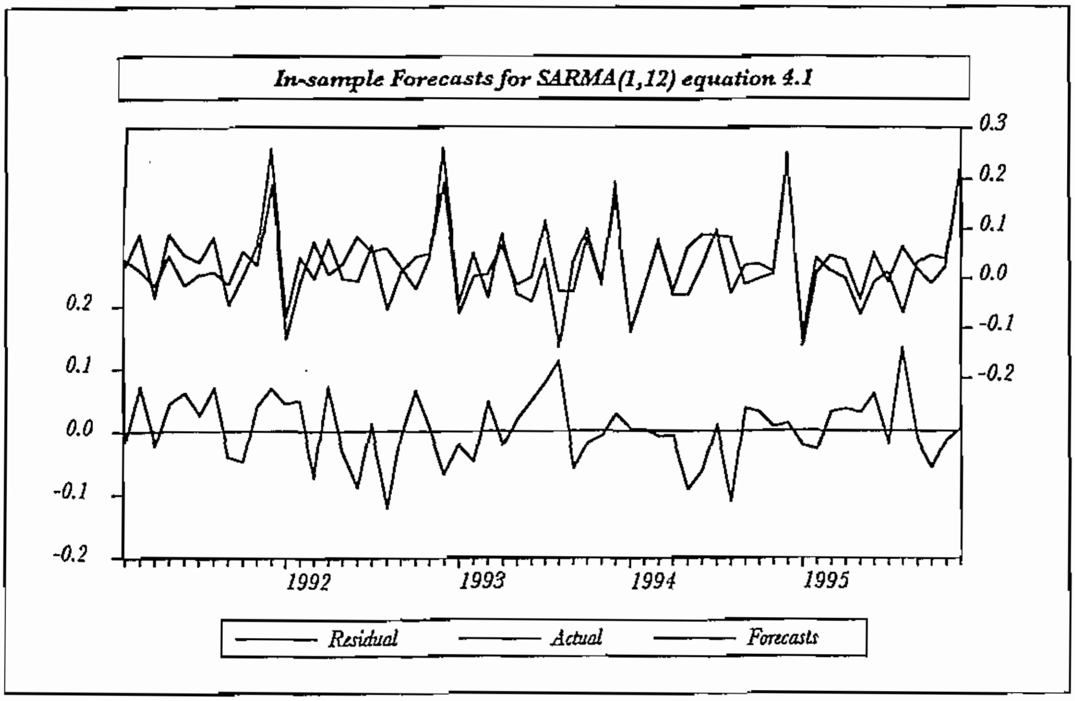
The estimated SARMA (1,12) and ECM models have performed well in and out of sample, despite indications that on average both models tend to over-estimate the monthly currency demand changes. From the presented statistical tests, the results indicate that the ECM specification qualifies as a suitable model to predict future currency movements. However, the noted deficiencies in structural specifications, will warrant the use of the ARMA process, which from the estimated results speaks to the appropriateness of the model specification, based on tracking ability and statistically significant coefficients. The underlying data generation process for currency demand can be sufficient in generating reliable forecasts.

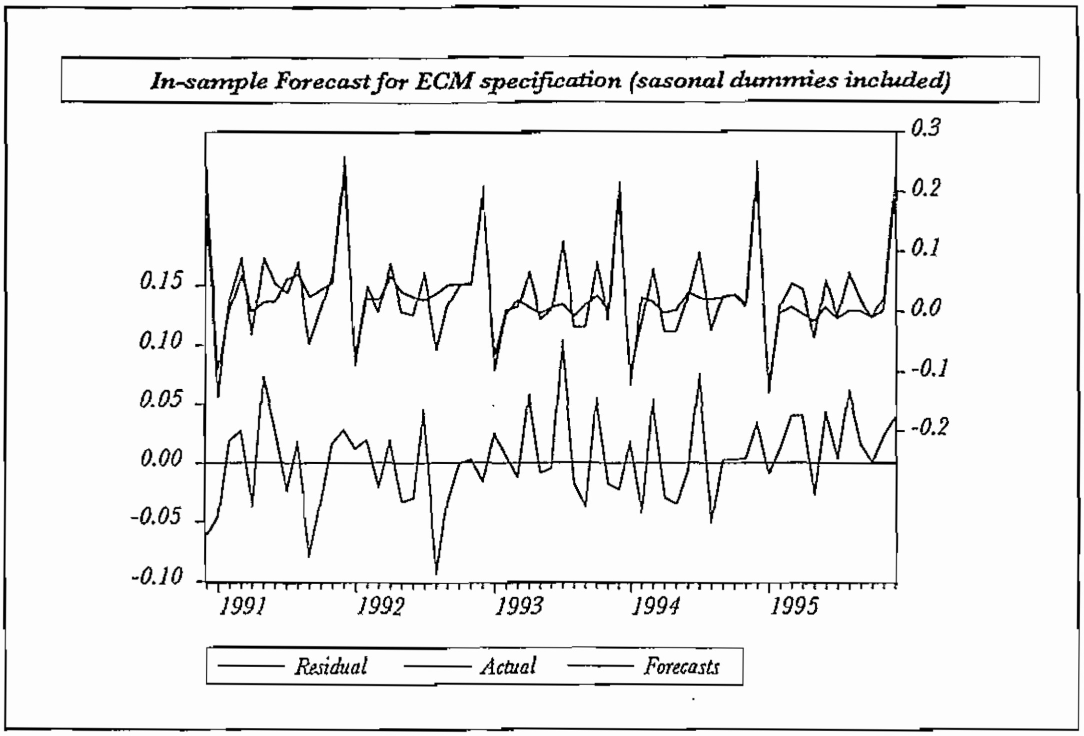
The performance of the models with respect the PRMSE, in deriving out-of-sample forecasts indicates that a necessary condition for generating reliable forecasts is relative stability of major economic variables. Hence, both models have demonstrated superior performance during the out-of-sample period relative to the generated in-sample forecasts, during which economic upheavals of foreign exchange market instability and high inflation persisted. Further, the existence of seasonal components which are statistically significant in both models emphasizes the presence of clear "January" and "December" effects. These effects point to adjustments during these periods of base money management strategies to reduce the potential for ad hoc changes in base money and attendant inflation effects.

Examining the results of other studies, the conclusion is that where predicting future value movements is of essence, the pure time series analysis model (in this case the ARMA representation) generally out-performs structural specifications. Theoretically, this conclusion is reasonable since structural models, although they facilitate other in-depth economic analysis, have noted deficiencies - variable definition problems, omitted variable problems, data frequency problems, to mention a few. However, despite the potential deficiencies in any structural specification, a statistical case is made for the superiority of this structural Error Correction Model specification. This model adequately captures, and explicitly models underlying structural parameters over the horizon, which should influence the public's demand for currency. Hence, the model dominates the extrapolative ARMA specification. In spite of its superior performance relative to the ARMA representation, the problems of lagged data availability for variables of the ECM specification arises, and mitigates against relying on the model to generate the currency forecasts for the monthly base money management target. Hence there is scope for use of the ARMA model to generate such forecasts.

While the estimated error correction model highlights some structural relationships, the need to further investigate the presence of other adjustment processes is required. There is still scope for a possible re-examination and re-estimation of the money demand function using for instance a Vector Autoregressive Process (VAR), to determine and comprehensively analyze the existing economic relationships between currency demand and the range of macroeconomic variables. Additionally, as the financial sector evolves, there is the need for the money demand specification to be transformed to reflect these developments.

APPENDIX I: In-sample graphs of the estimated SARMA(1,12) and ECM.





APPENDIX II

Autoregressive Moving Average Model SARMA (1,12)}
Sample period *1990:12 - 1995:12*

Standard Error of Estimate 0.029

$$\Delta m_t^d = 0.021 - 0.480\Delta m_{t-1}^d + 0.194D^d - 0.119D^j + 0.886e_{t-12} + e_t$$
$$(3.83) \quad (-3.93) \quad (7.77) \quad (-4.90) \quad (8864.31)$$

Adjusted $R^2 = 0.87$

where m_t is in logs; and

Δ denotes the first difference, i.e. $m_t - m_{t-1}$

** significance at the 1 percent level

Serial Correlation check of residuals*

To lag	Chi-square Statistic	Degrees of Freedom
6	12.59 (2.35)	4
12	18.31 (17.10)	10
18	26.3 (19.90)	16
24	31.4 (28.80)	22

* the test is based on the Ljung-Box Q-Statistic, at the 5% level of significance.

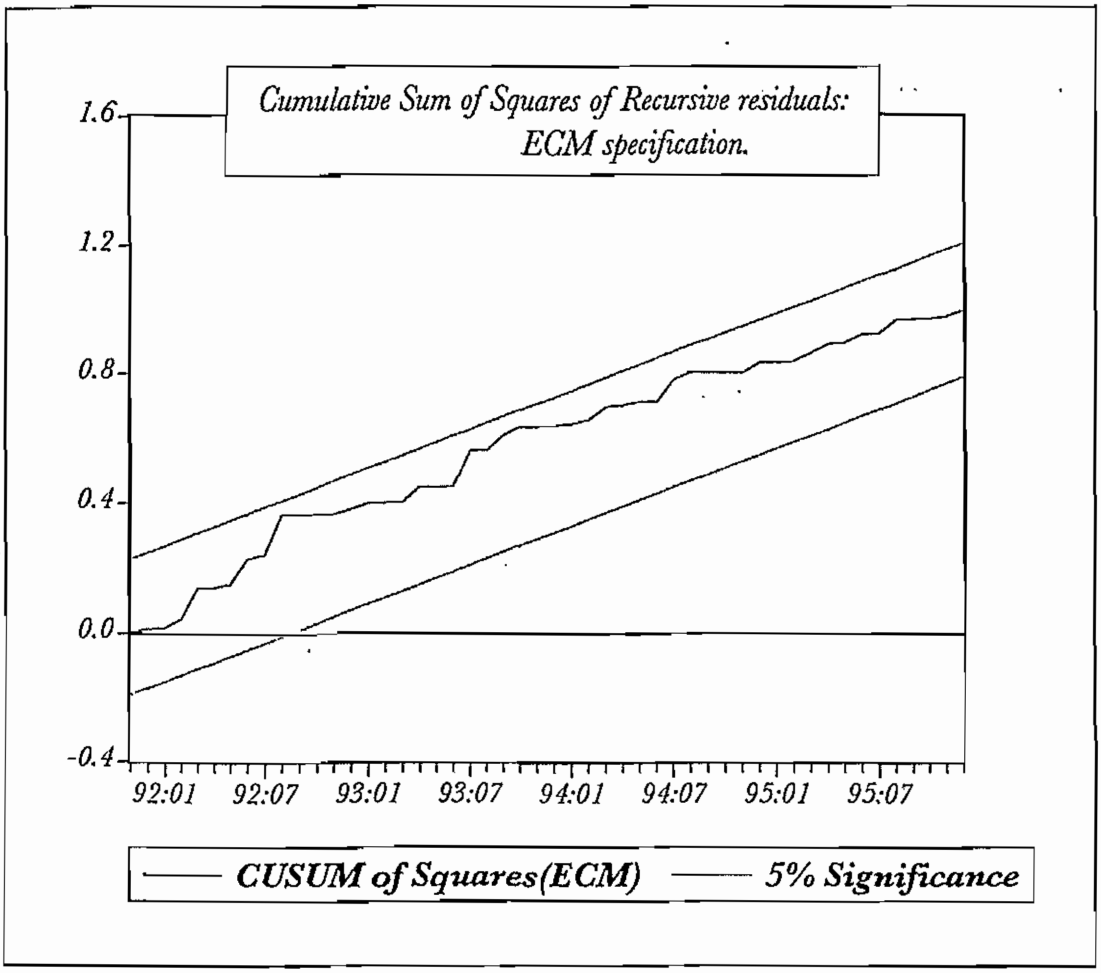
Error Correction Model
Sample period: 1990:12-1995:12

Test for Serial Correlation of Residuals*

To lag	Chi-square Statistic	Degrees of Freedom
12	21.0 (27.17)	12
18	28.9 (32.31)	18
24	31.4 (51.42)	24

* the test is based on the Ljung-Box Q-Statistic, at the 5% level of significance.

APPENDIX II:



Cumulative Sum of Squares of Recursive residuals: ECM specification.
1.6
1.2
0.8
0.4
0.0
-0.4
92:01
92:07
93:01
93:07
94:01
94:07
95:01
95:07
CUSUM of Squares(ECM)
5% Significance

APPENDIX III: Definitions and specific references used in the text.

i. Base money here is defined as currency issue, statutory reserves, and commercial bank cash reserves; both voluntary and statutory.

ii. As mentioned by (Wenninger and Laster, 1995), a brief examination of "electronic purses" in the United States points to the likely displacement of a fraction of smaller denomination currency notes and coins used in routine transactions.

iii. Cointegration means that although many developments can cause permanent changes in the elements of an estimated relationship, there is some linear combination which generates a long-run equilibrium relationship tying the components together. For a detailed analysis of the concept and properties which encourages the appropriateness of the methodological process see: Holden and Thompson (1992).

iv. For further analysis of the Box-Jenkins Methodology see Pyndick and Rubinfield (1991), and Hamilton (1994).

v. As a point of note, GDP was tested for its suitability to the model, and it showed insignificant results that one could explain by its inclusion of a myriad of transaction items that do not utilize currency as the final means of payment.

vi. For detailed analysis of this selection criterion refer to H. Akaike (1970).

vii. The statistical definitions of the selected evaluation criteria are::

$$PRMSE = \left\{ \frac{\sum_{t=1}^{T} \left(Y_t - \hat{Y}_t\right)^2}{T} \right\} * 100 \text{ ; and } MD = \frac{\sum_{t=1}^{T} \left(Y_t - \hat{Y}_t\right)}{T}$$

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