# Monetary Dynamics in Jamaica 1976-1998: A Structural Cointegrating VAR Approach

by

**Patrick Kent Watson**

*Economic Measurement Unit*
*Department of Economics*
*University of the West Indies*
*St. Augustine*
***Trinidad & Tobago***

Tel: (868) - 645 - 7004
Fax: (868) - 662 - 6295
E-mail: pkwatson@fss.uwi.tt

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## *ABSTRACT*

In this paper, a simultaneous equation model of the demand for money in Jamaica is constructed, estimated and evaluated using the Structural Cointegrating VAR methodology and quarterly data covering the period 1976-1998. The existence and stability of a steady state, long-run demand for money function is of particular interest as well as the relationship between this and other long-run relations with the associated short-run dynamics.

The econometric methodology to be employed is presented and discussed. This is followed by a description of the hypothesized long run relations in the model which are derived from economic theory. Problems relating to the data to be used are discussed and the model is estimated after testing for unit roots and cointegration vectors. The Error Correction form of the model is then derived and evaluated. Persistence profiles based on system wide shocks are derived and discussed.

**Keywords**: Demand for money, Jamaica, structural cointegrating VARs, persistence profiles.

**JEL Classification Numbers:** C51, C52, E41

## 1. Introduction

The stability of the demand for money function has always been a matter of concern to economists. This stability is crucial to the effectiveness of monetary policy in offsetting the fluctuations that may arise in the real sector. Small wonder, then, that the demand for money is one of the most controversial and highly researched areas in macroeconomics. Concern has also been expressed about the dynamics of monetary relations and, in particular, the link between the short and the long run. One of the most influential contributions in this area is Chow (1966) who argued that short-run demand for money adjusted slowly toward long-run equilibrium (his "stock adjustment" principle). The dominant idea at that time was that long-run (secular) growth and short-run (cyclical) fluctuations resulted from separate, independent shocks.

In their seminal work, Nelson and Plosser (1982) questioned this line of reasoning and provided evidence that most economic time series contained important stochastic trend elements and that secular and cyclical components were intimately linked. King et al. (1988a, 1988b) argue that short as well as long run economic fluctuations are seen as responses of a competitive economy to persistent stochastic shocks in its technology. The cointegration framework, first introduced into the literature by Engle and Granger (1987), allows precisely for the analysis of long-run steady state properties together with short-run dynamics within one framework. Economists quickly appreciated the potential usefulness of the new methodology to the study of monetary relations and early applications to developed countries include Johansen and Juselius (1990), Bagliano et al. (1991), Miller (1991) and many others.

The basic concerns about monetary relations discussed above did not escape the attention of Caribbean economists. Pre-cointegration studies of the demand for money include Bourne (1974), Howard (1979, 1981), McClean (1982), Worrell (1985), Watson and Ramkissoon (1987), Watson (1988) and others. See Farrell and Christopher (1989) for a critical review of the pre-1990 literature. An early Caribbean application of the cointegration approach is Craigwell (1991) who looked at the demand for money in Jamaica using the Engle-Granger 2-step procedure.

The cointegration literature has made significant advances since the Engle-Granger article and so too have the corresponding applications. In recent times there has been a veritable explosion in the demand for money literature involving the application of the cointegration methodology to developing country cases. These include Treichel (1997), Ghartey (1998), Bahmani-Oskooee and Rhee (1994), Attingi-Ego and Matthews (1996), Chowdhury (1997), Tan (1997), Arize (1994), Rother (1998) and others. Dobson and Ramlogan (2001) is a recent application of the Johansen methodology to a Caribbean case, that of Trinidad and Tobago.

One of the more promising developments in the recent literature on cointegration is the Structural Cointegrating VAR (SCVAR) approach. See Pesaran and Smith (1998) and Garratt et al. (1999). This method develops and extends on the Johansen methodology by allowing for a simultaneous equation framework with long-run relations specified a priori and short-run dynamics freely determined. ~~The basic elements of the SCVAR~~ methodology are given in section 2 below. There then follows in section 3 a presentation of some of the salient facts about the Jamaican economy and, in section 4, we specify the long-run relations in the system which we hope will be verified by the data. In section 5, we discuss some pertinent data issues, carry out unit root tests for the variables to be used in the model and then conduct cointegration tests. We also test the validity of the long-run relations as specified in section 4. In section 6, we estimate and evaluate the corresponding (dynamic) ECM form of the model. In section 7, we derive and discuss the model's persistence profile and, in section 8, we conclude the paper.

## 2. *Econometric methodology*

A modern VAR analysis may very well begin with a structural VAR of the form:

$$\sum_{j=0}^{p}\boldsymbol{\Phi}_j \mathbf{y}_{t-j} = \boldsymbol{\mu}_0 + \boldsymbol{\mu}_1 t + \boldsymbol{\Psi}\mathbf{d}_t + \boldsymbol{\Theta}\mathbf{f}_t + \sum_{j=0}^{p}\boldsymbol{\Gamma}_j \mathbf{x}_{t-j} + \mathbf{u}_t,\ t = 1,2, .., T \qquad (1)$$

where

- $\Phi_j$, j = 0, 2, ..,p are G×G matrices and $\Gamma_j$, j = 0, 2, ..., p are G×K matrices of fixed coefficients.
- $\mathbf{y}_t$ is a (G×1) vector of endogenous variables
- $\mathbf{x}_t$ is a (K×1) vector of (weakly) exogenous variables
- $\mu_0$ is the (G×1) constant term vector
- $\mu_1$ is a (G×1)vector of fixed coefficients
- t is the trend variable (used also as the time subscript)
- $\mathbf{d}_t$ is a (k×1) vector of "intervention" dummies
- $\mathbf{f}_t$ is a (s×1) vector of seasonal dummies (s+1 is the number of "seasons")
- $\Psi$ is a (G×k) matrix of fixed coefficients
- $\Theta$ is a (G×s) matrix of fixed coefficients
- $\mathbf{u}_t$ is the (G×1) error vector of independently, identically distributed random variables with mean zero and covariance matrix $\Omega$.

See Giannini (1992) and Mosconi (1998).

When the y and x vectors are I(1) and cointegrated, equation (1) may be re-written as:

$$\boldsymbol{\Phi}_0\Delta\mathbf{y}_t = \boldsymbol{\mu}_0 + \boldsymbol{\mu}_1 t + \boldsymbol{\Psi}\mathbf{d}_t + \boldsymbol{\Theta}\mathbf{f}_t + \boldsymbol{\alpha\beta}'\mathbf{z}_{t-1} + \boldsymbol{\Pi}_0\Delta\mathbf{x}_t + \sum_{j=1}^{p-1}\boldsymbol{\Pi}_j\Delta\mathbf{z}_{t-j} + \mathbf{u}_t \qquad (2)$$

where $z'_t = (y'_t, x'_t)$ and $\alpha$ and $\beta$ are (Gxr) matrices of full column rank and $\beta' z_{t-1}$ gives the r linear combinations of **z** that are cointegrated. Johansen (1992), (1994) shows that the dynamics of $y_t$ as well as the asymptotics of the system are affected by the way the constant term and the trend enter into the model. Consider the following decompositions:

$$\mu_0 = \alpha\mu_{01} + \alpha_\perp \mu_{02}$$

$$\mu_1 = \alpha\mu_{11} + \alpha_\perp \mu_{12}$$

where $\alpha_\perp$ is a Gx(G-r) matrix of full rank, orthogonal to $\alpha$. It can be shown that (2) may be re-written as:

$$\Phi_0\Delta \mathbf{y}_t = \alpha_\perp \mu_{02} + \alpha_\perp \mu_{12}t + \Psi \mathbf{d}_t + \Theta \mathbf{f}_t + \alpha \begin{pmatrix} \beta \\ \mu_{01} \\ \mu_{11} \end{pmatrix}' \widetilde{\mathbf{z}}_{t-1} + \Pi_0 \Delta \mathbf{x}_t + \sum_{j=1}^{p-1} \Pi_j \Delta \mathbf{z}_{t-j} + \mathbf{u}_t \qquad (3)$$

where $\widetilde{\mathbf{z}}'_t = (\mathbf{z}'_t, 1, t)$. *In this paper, we will use this form of the model with the restriction that* $\mu_{11} = \mu_{12} = 0$. $\mu_{01}$ and $\mu_{02}$ are unrestricted.

There are two "identification" problems associated with the model as shown in (1) and (2). The first concerns the identification of the short-run coefficients $\Phi_0$, $\Gamma_0$, $\Phi_j$ and $\Gamma_j$, j = 0, 1, 2, .., p. Secondly, there is the identification of the $\beta$ matrix. Furthermore, solving one of the identification problems does not help us to resolve the other. See Pesaran and Shin (1999).

In this paper, we will assume that the short-run coefficients are unrestricted. In such a case, we may work with the reduced form of the Model:

$$\Delta \mathbf{y}_t = \Phi_0^{-1}(\mu_0 + \mu_1 t + \Psi \mathbf{d}_t + \Theta \mathbf{f}_t + \alpha\beta' \mathbf{z}_{t-1} + \Pi_0 \Delta \mathbf{x}_t + \sum_{j=1}^{p-1} \Pi_j \Delta \mathbf{z}_{t-j} + \mathbf{u}_t)$$

which may also be re-written as:

$$\Delta \mathbf{y}_t = \mu_0^* + \mu_1^* t + \Psi^* \mathbf{d}_t + \Theta^* \mathbf{f}_t + \alpha^*\beta' \mathbf{z}_{t-1} + \Pi_0^* \Delta \mathbf{x}_t + \sum_{j=1}^{p-1} \Pi_j^* \Delta \mathbf{z}_{t-j} + \mathbf{u}_t^* \qquad (4)$$

where $\mathbf{x}^* = \Phi_0^{-1}\mathbf{x}$. This is the form of the core model that we are going to estimate in this paper and the SCVAR approach will be used to do it.

Traditional structural VAR modeling, following the lead of Blanchard and Quah (1989), typically employs covariance restrictions on (4) in order to derive some idea about the structural content of the model. This, however, is limited to impulse response analysis and does not seek to derive underlying behavioural equations in the structure. The strategy of the SCVAR approach is quite different in that it allows the short run dynamics to be data determined but at the same time has a coherent long-run equilibrium. A detailed comparison of the SCVAR approach with other approaches to econometric modeling (large scale structural econometric models, unrestricted and structural VARs and dynamic stochastic general equilibrium models) may be found in Garratt et al. (1999).

SCVAR modelling may be carried out in the following 5 steps:

1. The key long run (equilibrium) relationships among the variables, $\beta' z_t$, are hypothesized on the basis of a priori reasoning. In the typical case, these relations will embody overidentifying restrictions. Let the number of such restrictions be equal to q.
2. The data are then used to determine the number of cointegrating relations within the data and to establish in particular if this is equal to the number of relations specified a priori (r).
3. Assuming that the cointegrating rank is indeed equal to r, an exactly identified version of the equilibrium relationships (r restrictions on each equation, i.e. $r^2$ restrictions in all, $r^2 < q$) is then estimated.
4. The overidentified form of the model which was specified a priori and containing a further ($q-r^2$) restrictions is estimated and the validity of the extra restrictions tested using a Likelihood Ratio Statistic which, under the null, is distributed as a $\chi^2$ with ($q-r^2$) degrees of freedom.
5. The relationships verified in step 4 are then imbedded in an otherwise unrestricted vector error correction (VECM) model like (4). The **x** variables in this context may be interpreted as forcing variables and may eventually be assumed to follow the VAR(s) process:

$$\Delta \mathbf{x}_t = \mathbf{b}_0 + (\mathbf{D}\mathbf{b}_1)t + \mathbf{D}\mathbf{x}_{t-1} + \sum_{j=1}^{s-1} \mathbf{R}_j \Delta \mathbf{x}_{t-j} + \varepsilon_t \qquad (5)$$

Persistence profiles which trace out the speed at which the different relations will return to long-run equilibrium following a system wide shock may be determined and analysed. It is also possible to determine the impulse response function as is done in traditional VAR frameworks but that will not be done in this paper.

### *3. Salient economic facts about Jamaica, 1976-1998*

Jamaica is by any standard a small country. Most would say that it is a very small country. Nevertheless, with a population of about 3 million and a land mass of approximately 11,000 km$^2$, it is the largest island in the English speaking Caribbean and one of the larger members of the Caribbean Community (CARICOM). Table 1 below presents some key economic and demographic indicators of CARICOM member states (except for Montserrat for which data were unavailable) in 1998:

**Table 1**

*Some key indicators of CARICOM Member States 1998*[a]

| *Member State* | *Pop. (000s)* | *% Pop.* | *GNP measured at PPP*[b] *(US$m)* | *%Total GNP* | *GNP/Capita measured at PPP*[b] *(US$)* | *Surface area (000 km²)* | *% Total Area* | *Population Density (People/km²)* |
|---|---|---|---|---|---|---|---|---|
| Antigua and Barbuda | 67 | 0.45 | 631 | 1.58 | 9440 | 0.4 | 0.09 | 152 |
| Bahamas | 294 | 1.97 | 3073 | 7.70 | 10460 | 13.9 | 3.00 | 29 |
| Barbados | 266 | 1.78 | 3257 | 8.16 | 12260 | 0.4 | 0.09 | 618 |
| Belize | 236 | 1.58 | 927 | 2.32 | 3940 | 23 | 4.97 | 10 |
| Dominica | 74 | 0.50 | 291 | 0.73 | 3940 | 0.8 | 0.17 | 98 |
| Grenada | 96 | 0.64 | 454 | 1.14 | 4720 | 0.3 | 0.06 | 283 |
| Guyana | 857 | 5.74 | 2302 | 5.77 | 2680 | 215 | 46.48 | 4 |
| Haiti | 8000 | 53.57 | 9600 | 24.06 | 1250 | 28 | 6.05 | 277 |
| **Jamaica** | **3000** | **20.09** | **8300** | **20.80** | **3210** | **11** | **2.38** | **238** |
| St. Kitts and Nevis | 41 | 0.27 | 324 | 0.81 | 7940 | 0.4 | 0.09 | 113 |
| St. Lucia | 160 | 1.07 | 738 | 1.85 | 4610 | 0.6 | 0.13 | 263 |
| St. Vincent and the Grenadines | 113 | 0.76 | 463 | 1.16 | 4090 | 0.4 | 0.09 | 290 |
| Trinidad and Tobago | 1317 | 8.82 | 8854 | 22.19 | 6720 | 5.1 | 1.10 | 257 |
| Suriname | 413 | 2.77 | 685 | 1.72 | 1660 | 163.3 | 35.30 | 3 |
| **Total** | 14938 | 100.00 | 39899 | 100.00 | 2671.689 | 462.6 | 100.00 | 32.3 |

Source: *World Development Report 1999/2000,* The World Bank.

*a. No data was available for Montserrat.*

*b. Purchasing Power Parity(PPP): GNP measured at PPP is GNP converted to US dollars by the purchasing power parity(PPP) exchange rate. At the PPP rate, one dollar has the same purchasing power over domestic GNP that the US dollar has over US GNP; dollars converted by this method are sometimes called international dollars.*

Before the recent entry of Haiti into CARICOM, Jamaica had by far the largest population in that grouping. It now accounts for about 21% of the total CARICOM population but only about 2.4% of the land mass. It contributes about 21% of total CARICOM GNP measured in purchasing power parity rates. Over the period under consideration, Jamaica has had a turbulent political and economic history. The political situation in the earlier part of the period was highly volatile and culminated in a violent election campaign in 1980 in which about 1000 people were killed. The economic situation reflected the deterioration in the politics and may have even been the cause of it. There resulted mass migration of capital and labour and, generally, marked deterioration in all the normal economic indices. The national currency deteriorated by leaps and bounds as Table 2 below illustrates:

**Table 2**

*Average Annual Exchange Rate of Jamaican dollar 1984-2000*

*J$ Per 1US$*

| 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 |
|---|---|---|---|---|---|---|---|---|
| $3.94 | $5.56 | $5.48 | $5.49 | $5.49 | $5.75 | $7.18 | $12.85 | $23.01 |

| 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|
| $25.68 | $33.35 | $35.54 | $37.02 | $35.58 | $36.68 | $39.33 | $43.32 |

Jamaica was once one of the more prosperous islands in the Caribbean before it went into recession in 1973 and output declined steadily throughout the 1970s and 1980s. Deteriorating economic conditions during the 1970s led to recurrent violence and a drop-off in tourism. The Government turned to the IMF for support in 1976 and was a regular customer until 1995. The violent lections in 1980 saw the democratic socialists of the PNP voted out of office and subsequent governments have been open-market oriented. Political violence continues to mar elections up to today.

While the PNP was in office in the 1970s, it initiated a shift in major economic policies. Noteworthy during this period was the imposition of the Bauxite Levy in 1974, which was undertaken to increase Jamaica's share of the income in that industry. The government's aim at that time was to position the state in a leadership role within the process of economic development, with a view to rectifying the inherited economic inequalities.

In the 1980s, the JLP, the other major party in Jamaica, held political office. They were committed to the same free market development policies as the IMF, the World Bank, and the USAID. Because of a special political relationship with the Reagan administration, Jamaica benefited from generous USA assistance in the first half of the decade. The economy was substantially deregulated, the currency was devalued, and many public enterprises were divested in the process of adjustment, which has now been on-going for some 14 years.

The PNP came into political power again in the 1990s. At this time the government sought to implement tight monetary and fiscal policies by eliminating most price controls, streamlining tax schedules, and privatizing government enterprises. During the early part of the 1990s the government's continued firm hold on the country's monetary and fiscal policies did help to slow inflation and stabilize the exchange rate but the economic growth of the country suffered a slowdown moving from 1.5% in 1992 to 0.5% in 1995. The lowering of trade barriers in the North Atlantic Free Trade Area, the common market set up between the USA, Canada and Mexico, drew a lot of business away from the island's economy. For example, garments exported to the USA and other miscellaneous manufactured articles had seen considerable expansion, rising by 23.2% to US$262 mn in 1994. However, several manufacturing plants have since closed because of competition from Mexico for the US market and from imports as markets have been liberalized. The number employed in the garments industry fell from 36,000 in 1994 to 20,000 in 1998.

Jamaica suffered a financial crisis during the 1995-96 period. The country was reeling under rampant inflation - 25.6% in 1995 and 15.8% in 1996. The Government was forced to bail out ailing financial companies to avoid a crisis in the banking sector.

Although Jamaica has made measurable progress in stabilizing the economy since the mid-1990s, the economy has not yet returned to a path of sustainable growth. In 1996, GDP showed negative growth (-1.4%) and remained negative through 1999. Serious problems include: high interest rates; increased foreign competition; the weak financial condition of business in general resulting in receiverships or closures and downsizing of companies; the shift in investment portfolios to non-productive, short-term high yield instruments; a pressured, sometimes sliding, exchange rate; a widening merchandise trade deficit; and a growing internal debt for government bailouts to various ailing sectors of the economy, particularly the financial sector.

Interest rates of 40% stabilised the exchange rate and 1997 was the first year that saw inflation in single digit figures again i.e. at 9.2%. This greatly reduced inflation rate has come at a high price for the nation. The high costs of borrowing choked economic growth and during 1996 and 1997 the economy actually shrank. Many companies collapsed under their debts and went into receivership, were closed or downsized. Internal debt escalated. Money was not invested in productive sectors but was put in short-term, high-interest investments on the financial markets.

The official figures show that Jamaica's economy is dominated by the bauxite, tourism and sugar industries. With the exception of tourism, these industries can be a potential source of economic instability due to their susceptibility to shifts in world commodity prices. Two steady sources of national income are the tourism revenues and the remittances from thousands of Jamaicans living in the United States, Canada and the United Kingdom.

In 1997 bauxite production rose to its highest level since 1981, with a further increase in 1998 to 12.7 million tonnes and alumina production increased to 3.44 million tonnes but lower prices brought a 6% fall in earnings. In 1999 job losses were announced by three bauxite and alumina companies, which tried to cut costs as prices slumped.

Sugar is the main crop, and most important export item after bauxite and alumina. In 1993 four state-owned sugar mills were sold to the Sugar Company of Jamaica, in which the government had a 24% shareholding. However, drought and floods hit the privatized industry, which was also struggling under high interest rates. Despite government grants to enhance efficiency and reduce production costs the industry remained insolvent and in 1998-99 four mills were repossessed

Tourism is the second foreign exchange earner and contributes to approximately 15% of GDP. Stopover arrivals grew by an annual average of 8% and cruise visitors by 14% in the first half of the 1980s until, in 1987, combined stopover and cruise arrivals passed the million mark for the first time. In the early 1990s numbers continued to rise and hotel capacity increased but occupancy is only 60%, with many tourists put off by stories of crime and harassment. In 1999, stopover tourists increased by 1.9% to 1,248,000, including 101,262 Jamaicans living overseas, while the number of cruise ship passengers rose by 13.5% to 764,341.

## *4. Hypothesised long-run relations in the model*

In this paper we consider the following four long-run relations that link together 7 variables:

$$m_t = a_{10} + \beta_{13} y_t + \beta_{14} p_t + \beta_{17} r_{at} + \varepsilon_{1t} \qquad (6)$$

$$m_t = a_{20} + \beta_{22} b_t + \beta_{27} r_{at} + \varepsilon_{2t} \qquad (7)$$

$$r_{Dt} = \beta_{37} r_{at} + \varepsilon_{3t} \qquad (8)$$

$$r_{Lt} = \beta_{45} r_{Dt} + \varepsilon_{4t} \qquad (9)$$

All variables are expressed in logarithmic form and:

$m_t$ = Money

$y_t$ = National income

$p_t$ = Domestic price level

$r_{at}$ = Rate of interest on "alternative" asset

$b_t$ = Base money

$r_{Dt}$ = Deposit rate of interest

$r_{Lt}$ = Interest rate on loans

Equation (6) is the money demand relation. This is a fairly classic specification in which nominal money balances are explained as a function of income, the price level and an interest rate indicative of the opportunity cost of holding money (the rate of interest on an alternative asset). Real income is the chosen "scale" variable as it is in the vast majority of work on money demand. It is positively related to money balance so that $\beta_{13}$ is expected to be positive. The higher the price level, the greater the demand for money balances so that $\beta_{14}$ is expected to be positive. A value of $\beta_{14} = 1$ would indicate that the demand is for real balances. In the Jamaican context, Treasury Bills may be taken as an alternative asset to holding money in which case the corresponding rate is the Treasury Bill rate. This rate is expected to be negatively related to the money balances held ($\beta_{17}$ is expected to be negative). In this study, the Treasury Bill Rate will be assumed to be under the direct control of the monetary authority and indeed may be used as an instrument of monetary policy. For this reason it is assumed to be exogenous to the system.

Equation (7) is the money supply relation. In it, money supply is explained as a function of the monetary base and the alternative interest rate variable. Money supply is expected to be positively related to both the monetary base and to the interest rate (both $\beta_{22}$ and $\beta_{27}$ are expected to be positive). The equality of money demand and supply is implicit in equations (6) and (7).

Equations (8) and (9) are the deposit rate and loan rate relations. They explain the deposit and loan rates of interest as mark-ups: the deposit rate is determined as a mark-up on the Treasury Bill rate while the loan rate is determined as a mark-up on the loan rate.

Most of the money demand studies cited so far in this paper, including the Caribbean studies, have concentrated on single equation studies. This is so even in the case of Dobson and Ramlogan (2001) where the Johansen method was used and where up to 3 cointegrating vectors were identified in some of the cases considered. Surely, one of the most attractive features of the Johansen method is its ability to uncover multiple long-run relationships which may have interesting economic interpretations.

## 5. Unit root and cointegration tests

The long-run relations outlined above involve 7 distinct variables for which data must be collected. Data on money and interest rates were obtained from the IMF's International Financial Statistics. In the case of the deposit and loan rates, we opted for the weighted average rates. The logarithmic form of each interest rate is calculated as:

$$0.25 \log (1 + R_t/100)$$

where $R_t$ is the annual interest rate expressed as a percentage.

There is no existing quarterly series for national income in Jamaica. However, annual series for current and constant price GDP do exist. A quarterly series for current and constant price GDP using a procedure proposed by Goldstein and Khan (1976). From this, we derive the implicit GDP deflator which is used as the price variable in the study.

The estimation method to be employed requires that each of the seven variables in the model be I(1). The summary results displayed in Table 3 below show that this is indeed the case for the variables $m_t$, $y_t$, $p_t$, $r_{at}$, $b_t$, $r_{Dt}$ and $r_{Lt}$.

**Table 3**
Dickey-Fuller Tests

| Variable | $m_t$ | $y_t$ | $p_t$ | $r_{at}$ | $b_t$ | $r_{Dt}$ | $r_{Lt}$ |
|---|---|---|---|---|---|---|---|
| ADF level | -2.654 | -2.157 | -2.500 | -2.967 | -3.016 | -1.400 | -0.9372 |
| ADF 1st diff | -2.623 | -3.171 | -2.830 | -7.533 | -4.061 | -7.314 | -6.565 |

Levels: 95% critical value for the Dickey-Fuller statistic = -3.461, 90% critical value = -3.157
1st difference: 95% critical value for the Dickey-Fuller statistic = -2.895, 90% critical value = -2.584

The test for variables in levels includes a constant and a trend term while the test in first differences includes only a constant term. The order of the ADF is chosen on the basis of the AIC and SBC criteria and only the statistic satisfying that criterion is shown here. Five of the seven variables in first differences are significant at the 5% level while the other two ($m_t$ and $p_t$) are significant at the 10% level. The conclusion is that they are all I(1).

The AIC and SBC criteria are used to select the underlying VAR for cointegraion analysis and we decide on a VAR(6) model. Using this model with unrestricted intercepts and no trends, and using the Treasury Bill rate as a forcing variable, we proceed with the cointegration analysis. The summary results of this analysis appear in Table 4 below:

**Table 4**

Tests for Cointegration Rank

(a) Maximum Eigenvalue Statistic

| Null | Alternative | Statistic | 95% Critical Value | 90% Critical Value |
|---|---|---|---|---|
| r = 0 | r = 1 | 59.9770 | 42.9500 | 40.2100 |
| r<= 1 | r = 2 | 52.8911 | 36.8000 | 34.1000 |
| r<= 2 | r = 3 | 37.1423 | 30.7100 | 28.2700 |
| r<= 3 | r = 4 | 23.0443 | 24.5900 | 22.1500 |
| r<= 4 | r = 5 | 8.2250 | 18.0600 | 15.9800 |
| r<= 5 | r = 6 | 5.2301 | 11.4700 | 9.5300 |

(b) Trace Statistic

| Null | Alternative | Statistic | 95% Critical Value | 90% Critical Value |
|---|---|---|---|---|
| r = 0 | r>= 1 | 186.5098 | 109.5700 | 104.4000 |
| r<= 1 | r>= 2 | 126.5328 | 81.4500 | 76.9500 |
| r<= 2 | r>= 3 | 73.6417 | 58.6300 | 54.8400 |
| r<= 3 | r>= 4 | 36.4994 | 38.9300 | 35.8800 |
| r<= 4 | r>= 5 | 13.4552 | 23.3200 | 20.7500 |
| r<= 5 | r = 6 | 5.2301 | 11.4700 | 9.5300 |

At the 10% level of significance, both the Trace Statistic and the Maximal Eigenvalue Statistic lead to the conclusion that there are exactly 4 cointegrating vectors. There seems, therefore, to be sufficient evidence to support the conclusion that there are exactly four cointegrating vectors which accords with the underlying theory.

The next step is to estimate a model subject to exactly identifying restrictions, in this case 16 (4 per cointegrating vector identified). We did this successfully using Johansen's exactly identifying restrictions. Following this, we must test the 7 overidentifying restrictions implied by the system (6)-(9). The log-likelihood ratio (LR) statistic for the joint test of the overidentifying restrictions is 18.96 with a p-value of 0.01. The data seem therefore to reject the theory underlying the restrictions implicit in the model (6)-(9) unless we are prepared to use a significance level as low as 1%.

Garratt et al. (1998), who themselves obtain a p-value of 0.0001, argue cogently that the null in such cases need not be rejected. They claim that "in view of the relatively large dimension of the underlying VAR model, the number of restrictions considered and the available sample size, it is important that the validity of the asymptotic critical values are (sic) evaluated by means of bootstrap techniques". We applied such techniques and calculated empirical distributions based on a range of re-sample sizes. A fairly stable empirical distribution resulted as is evidenced by table 5 which shows the 90, 95, 97.5 and 99 percentiles for the LR statistic obtained using 500 and 10,000 re-samples.

**Table 5**

Percentiles of the LR Statistic

(a) 500 re-samples

| 90% | 95% | 97.5% | 99% |
|---|---|---|---|
| 22.05 | 25.42 | 28.59 | 30.69 |

(b) 10,000 re-samples

| 90% | 95% | 97.5% | 99% |
|---|---|---|---|
| 21.03 | 24.11 | 26.94 | 29.80 |

The null hypothesis cannot be rejected on the basis of the calculated LR-value of 18.96. The long run relationships of the core model, defined by equations (6)-(9), are therefore properly estimated as:

$$m_t = \underset{(1.05)}{-2.239} + \underset{(0.129)}{1.435}\, y_t + \underset{(0.023)}{1.253}\, p_t - \underset{(2.693)}{13.93}\, r_{at} + \hat{\varepsilon}_{1t} \qquad (6')$$

$$m_t = \underset{(0.196)}{0.973} + \underset{(0.041)}{1.165}\, b_t - \underset{(4.354)}{25.42}\, r_{at} + \hat{\varepsilon}_{2t} \qquad (7')$$

$$r_{Dt} = \underset{(0.025)}{0.687}\, r_{at} + \hat{\varepsilon}_{3t} \qquad (8')$$

$$r_{Lt} = \underset{(0.065)}{1.397}\, r_{Dt} + \hat{\varepsilon}_{4t} \qquad (9')$$

Standard errors (asymptotic) are shown in parentheses. All coefficients are significant and all carry the correct sign except the coefficient of the Treasury Bill rate in equation (7'). This means, among other things, that there is evidence for a stable demand function in Jamaica. In addition, the estimated value of $\beta_{14}$ in equation (6') is 1.253 which, given the corresponding standard error of 0.023, implies that $\beta_{14}$ is significantly greater than one so that we are not dealing with a demand for real balances.

## *6. Error correction form of the model*

The Error Correction form of the core model was then estimated. Selected results of this exercise are shown in Table 6 below. These include the coefficient values associated with the error correction terms and the Treasury Bill rate (the forcing variable), together with the corresponding p-values, as well as some measures of goodness of fit of the individual equations.

Table 6

Error Correction Form of Model (Extracts)

| Equation | $\Delta m_t$ | $\Delta b_t$ | $\Delta y_t$ | $\Delta p_t$ | $\Delta r_{Dt}$ | $\Delta r_{Lt}$ |
|---|---|---|---|---|---|---|
| $\hat{\varepsilon}_{1,t-1}$ | -0.25390 [0.0034] | -0.3353 [0.2618] | 0.0373 [0.0285] | -0.1325 [0.0008] | -0.011375 [0.0596] | -0.011694 [0.0324] |
| $\hat{\varepsilon}_{2,t-1}$ | 0.069127 [0.0976] | 0.3332 [0.0281] | -0.0318 [0.0003] | 0.03847 [0.0415] | 0.003347 [0.2598] | -0.001714 [0.5195] |
| $\hat{\varepsilon}_{3,t-1}$ | -0.11527 [0.9488] | 1.2663 [0.8444] | 0.9548 [0.0107] | 0.49536 [0.5393] | -0.565563 [0.0001] | -0.361574 [0.0030] |
| $\hat{\varepsilon}_{4,t-1}$ | -6.16361 [0.0134] | -5.4434 [0.5306] | 0.7827 [0.1110] | -2.7741 [0.0132] | -0.343137 [0.0001] | -0.575776 [0.0005] |
| $\Delta r_{at}$ | 1.174163 [0.2607] | -6.8179 [0.0723] | -0.2740 [0.1927] | -0.2567 [0.5817] | 0.610337 [0.000] | 0.311526 [0.000] |
| $\Delta r_{at-1}$ | .232018 [0.2291] | 3.81122 [0.5655] | 0.46711 [0.2108] | 2.6217 [0.0026] | 0.20169 [0.1316] | -0.103686 [0.3851] |
| $\Delta r_{at-2}$ | 1.339787 [0.4828] | -6.8919 [0.3167] | -0.0096 [0.9800] | 1.1732 [0.1741] | -0.171948 [0.2121] | 0.308492 [0.0152] |
| $\Delta r_{at-3}$ | 1.628969 [0.4090] | -1.4082 [0.8421] | 0.8936 [0.0277] | 0.86205 [0.3310] | 0.417373 [0.0047] | 0.013985 [0.9123] |
| $\Delta r_{at-4}$ | 1.393914 [0.3785] | -0.4106 [0.9418] | -0.2783 [0.3779] | 1.36561 [0.0566] | -0.136773 [0.2267] | -0.035605 [0.7246] |
| $\Delta r_{at-5}$ | 1.393914 [0.3920] | -4.5386 [0.4379] | 0.14954 [0.6468] | 0.0609 [0.9333] | 0.201729 [0.0881] | 0.208694 [0.0510] |
| $\overline{R}^2$ | 0.480 | 0.215 | 0.547 | 0.73683 | 0.829260 | 0.669 |
| p-value for $\chi^2_{SC}$ | 0.505 | 0.056 | 0.8635 | 0.02088 | 0.000 | 0.571171 |
| p- value for $\chi^2_{FF}$ | 0.128 | 0.045 | 0.912 | 0.11964 | 0.3768 | 0.2203 |
| p- value for $\chi^2_{N}$ | 0.041 | 0.35500 | 0.000 | 0.054618 | 0.0001 | 0.0218 |
| p- value for $\chi^2_{H}$ | 0.131 | 0.11866 | 0.971 | 0.51831 | 0.000 | 0.2927 |

The error correction terms $\hat{\varepsilon}_{1,t-1}$, $\hat{\varepsilon}_{2,t-1}$, $\hat{\varepsilon}_{3,t-1}$ and $\hat{\varepsilon}_{4,t-1}$ are derived from equations (6'-9').

The diagnostics are $\chi^2$ statistics for the Breusch Godfrey test for serial correlation (SC), the Ramsey RESET test for functional form (FF), the Jarque-Bera test for normality (N) and the ARCH LM test for heteroscedasticity (H).
The figures shown in squared parentheses are the p-values associated with the corresponding coefficient estimates.

The overall results appear to be acceptable. The $\overline{R}^2$ values are reasonable given the fact that the regressions explain variations in the changes of the endogenous variables in the model. The long run relations make an important contribution in each of the equations and are significant at the 5% level in at least one instance in each equation. The

Treasury Bill rate (which is the long run forcing variable) intervenes significantly, at least at the 5% level), in 4 of the 6 equations.

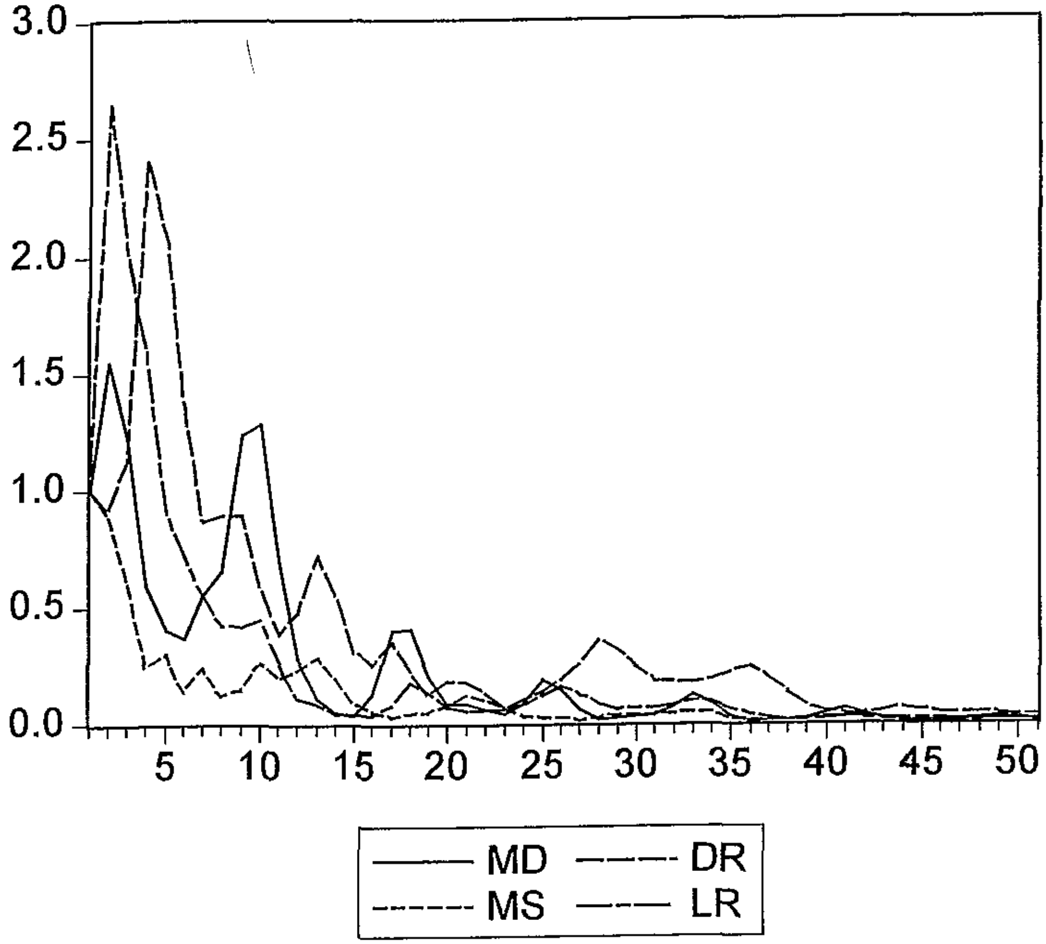
The diagnostic statistics are also quite encouraging except in the case of the deposit rate relation. They show that serial correlation is rejected in all but 2 equations on the basis of the Breusch-Godfrey test. However, when the Box-Ljung test is applied, only the deposit rate relation shows evidence of serial correlation. Five of the six equations show that the functional form is properly specified the sixth one only barely fails the test at the 5% level. Five out of the 6 show no evidence of heteroscedasticity. Only two, however, convincingly pass the normality test.

## *7. Persistence Profiles*

For determination of the persistence profiles it is assumed that the oil price variable is strictly exogenous. Figure 1 below shows the persistence profiles of the 4 long run relations in the model. They show the speed at which the different relations will return to long-run equilibrium following a system wide shock.

**Figure 1**

Persistence Profiles of the effect of a system-wide shock




Garratt et al. (1998) define a half-life measure which describes the horizon over which the profile falls to 0.5. Given that the profile starts at 1 and falls to zero, this gives a simple indication of the speed of adjustment of a profile and makes it easy to compare the response rate of the different profiles. All the relations tend to return to their equilibria following a shock, although some do so much faster than others. The fastest response comes from the money supply relation whose half-life is less than four quarters. The others fluctuate before eventually converging. The second fastest convergence is obtained by the loan rate (LR) relation whose half-life is 8 quarters. The third fastest is the deposit rate whose half life is 11 quarters while the slowest convergence of all is obtained by the money demand relation whose half life is 12 quarters. This is in keeping with established theory that return to long-run monetary equilibrium following a shock is a slow process. See Chow (1966).

## 8. Conclusion

The results provide convincing evidence that the 4 long-run relations hypothesised a priori were empirically verified. In particular, there exists a stable long-run demand for money function. The corresponding Error Correction form had satisfactory diagnostics while the Persistence Profiles, a useful tool for policy analysis purposes, are not at odds with the predictions of economic theory. In particular, it shows that, once disturbed, some considerable time elapses before the money demand function re-converges to equilibrium.

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