Estimating a Small Scale Macroeconomic Model of the Jamaican Economy: Some Preliminary Results

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Abstract

This paper presents some preliminary results from the estimation of a small-scale model of the Jamaican economy. An aggregate demand and a stable money demand function were identified in a cointegrating framework. Further, the analysis of the Phillips curve relation points to the possibility of some inflation/output tradeoff. The model simulations highlighted the potency of monetary policy and the importance of exchange rate behaviour in stabilizing inflation. The main transmission channel of monetary policy was through the exchange rate, with a relatively small role for the credit channel.

Keywords: cointegration, structural break, monetary transmission
JEL Classification: C51,C52

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1. Introduction

The design and implementation of macroeconomic policy require a reliable and objective means of assessing, both qualitatively and quantitatively, the likely impact of various policy options on the behaviour of economic aggregates such as output, employment, consumption and prices. Macroeconometric models, to varying degrees, have proven quite useful in providing such analysis. The construction of such models assists in illuminating the underlying structural relationships in an economy.

In this regard, a number of macroeconometric models have been constructed for Jamaica from as early as the 1960s. These include inter alia, the Carter model, UNDP model and the Planning Institute's Keynesian fiscal year model. During the second half of the 1980s, Bank of Jamaica utilized a Keynesian aggregate demand model. The model is primarily demand driven with GDP computed as the sum of private consumption, private investment, government expenditure and net exports. Consumption, investment and imports are derived endogenously whilst exports and government expenditure are treated as predetermined variables. During the first three years of its operation, the model's simulations closely approximated the actual outcome of the main macroeconomic variables.

Subsequent simulations however revealed some divergence between the model forecasts and the actual outturn. Robinson (1993) highlighted a number of weaknesses of the model, the main one being the instability of the coefficients as a result of the structural shifts in the patterns of consumption, investments, and imports. A number of suggestions has been advanced towards the reorientation of the model. Recent economic developments, however would suggest the need for a more fundamental revision of the model structure.

This paper outlines a revised model and presents the preliminary results of the estimation exercise. The objective is to develop a model, which can be used to assess the impact of monetary policy on the economy and generate medium term forecasts. We however proceeded by first constructing an aggregated small-scale macroeconomic model (SSMM) of the economy. SSMMs have proven particularly useful in analyzing policy due mainly to their simplicity and flexibility but may be limited in their ability to forecast.

In this model interest rates and the exchange rate are determined in the money and capital markets. These prices influence the allocation of resources for consumption, trade and investment, which then determine the output gap. This, in addition to imported inflation, determines the level of inflation. This structure is based on the view that the inflation process within the Jamaican economy is to a large extent driven by changes in the exchange rate, which is itself influenced by the supply of Jamaican dollars,[2] in addition to excess demand.

The rest of the paper is organized as follows. An outline of the model is presented in the next section followed by a discussion of the estimation methodology in section 3. Section 4 and 5 discuss the estimation results and simulations respectively. Some concluding comments are given in section 6.

[2] See Robinson and Robinson (1998)

2.0 Model

2.1 Basic Structure

Given the data limitations, the model is highly simplified, consisting of IS and LM curves, interest parity relation, Phillips curve and a monetary policy rule. For simplicity, government operations are assumed to be exogenous. Given the absence of reliable time series on capital stock and labour supply to a lesser extent, the model is demand driven and potential output follows a time trend, which captures changes in productivity. In this simplified model, nominal rigidities in the labour market are suppressed as labour supply is taken to be exogenous. Economic agents form expectations rationally, using information up to time t-1, and are aware of the policy rule. The structure of the model is outlined below.

Consistent with the traditional open economy IS curve, aggregate demand given in equation (1) is specified as function of interest rates and trading partner GDP. Real exchange rates are excluded as previous studies (eg. Henry and Longmore (2002)) did not find this to be a significant variable in explaining aggregate fluctuations. This result was also confirmed by our pre-testing. Import demand has traditionally been price inelastic while exports to a large extent are sold under preferential arrangements or priced in US dollars.

We extend the conventional IS specification to incorporate a credit channel through the inclusion of banking system reserves, similar to Bernanke and Blinder (1988). The availability of credit facilitates consumption smoothing and investment and

$$y_t^{ad} = y(r_t, R_t \ / \ p_t, y_t^*), \ y_1 < 0, y_2 > 0, y_3 > 0 \quad (1)$$

$$\frac{m_t^d}{p_t} = l(y_t, c(r_t), E_t\Delta s_{t+1}), \ l_1 < 0, l_2 > 0, l_3 < 0 \quad (2)$$

$$\pi_t = \alpha_0 + B(L)\pi_t + \alpha_2(y - \overline{y}) + \alpha_3(\Delta s_t + \Delta p^*) \quad (3)$$

$$\frac{R_t}{p_t} = R(r_t) \quad (4)$$

$$r_t = r_t^* + E_t\Delta s_{t+1} \quad (5)$$

$$y = y^{ad} \quad (6)$$

$$m^d = \left(\frac{1+cd}{rd}\right)R \quad (7)$$

where

y^{ad} = aggregate demand
y = real GDP
$\overline{y}$ = potential output
r = treasury bill rate
r* = US treasury bill rate
$\tilde{r}$ = central bank benchmark rate (30-day rate)
c(r) = opportunity cost
m = M3
p = consumer price index
p* = US consumer price index
s = exchange rate
$\Delta\overline{s}_{t+1}$ = targeted rate of depreciation
y* = foreign GDP (US)
R^0 = banking system reserves
cd = currency deposit ratio
rd = reserve deposit ratio
π = inflation
$\Delta x_i = x_i - x_{i-1}$

hence influences aggregate demand. Robinson and Robinson (1998) find that the credit channel is one of the monetary policy transmission channels in Jamaica. The credit channel amplifies the effect of monetary policy through the response of the external finance premium and the availability of reserves (see Dale and Haldane (1993) and Bernanke and Gertler (1995).

Equation (2) describes the demand for broad money, which incorporates both the transactions and asset motives. The transactions motive gives rise to the relation between real economic activity, measured by GDP[3]. The specification used in this model assumes that the demand function is homogenous of degree one in prices.

Given the availability of alternate substitutable assets there is an opportunity cost of holding money. Opportunity costs have traditionally been proxied using the own interest rate, competing interest rate, the difference between own and alternative interest rates and the return on real assets i.e. inflation. Exchange rate depreciation has been used as an additional measure in open economies (see for example, Domowitz and Elbadawi (1987)). This measure is of particular relevance to countries, which have a history of exchange rate devaluation/inflation and currency substitution/unofficial dollarization. Friedman and Schwartz (1982) and Ericsson, Hendry and Prestwich (1997) suggest the use of an alternate measure defined as $\left(M^0 / M\right) * r$. This captures the fact that all the components of M, except for high-powered money earn interest at the outside interest rate.

Since interest rates were not fully market determined and the number of alternate assets was significantly less in the early part of the sample the definition of the opportunity cost is not straightforward. Craigwell (1991) in studying the demand for money in Jamaica over the period 1953-1986, used the domestic interest rate, inflation and foreign interest rates as the measures of opportunity cost for holding narrow money. Similar to Hamburger (1977), the inclusion of foreign interest rates was intended to capture the degree of substitutability between local and foreign assets. Kent and Henry (1995) found that in more recent years the spread between the treasury bill rate and savings rate is the more appropriate measure for the opportunity costs. In this paper however, the measure proposed by Ericsson et al was found to be the most suitable for the demand for broad money, among the alternatives suggested by the previous studies. As such the results using this measure are reported. We also include expected depreciation, proxied by actual depreciation, given the openness of the Jamaican economy and increasing incidence of currency substitution and unofficial dollarisation in recent years.

Equation (3) is the Phillips curve relation. The relatively high consumer price inflation in Jamaica has to a large extent been influenced by monetary conditions. Further the openness of the economy has given more prominence, certainly in the short run, to exchange rate fluctuations (Robinson 2000). However, with macroeconomic stabilization and increased competition, supply shocks have recently emerged as a major determinant of inflation, relative to monetary impulses and the exchange rate pass through. Against

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[3] Real GDP is used as the scale variable in this paper, although it maybe argued that some measure of permanent income would be more suitable. However the estimates would be sensitive to the method used to calculate permanent income (see Clark (1973)).

this background consumer price inflation is modeled along the lines of an open economy Phillips curve similar to Svensson (1998).

This specification can be derived from a model in which prices are set as a markup over unit labour costs, which are determined contractually in the labour market, and imported costs. The pricing and wage setting mechanisms assume some type of staggered contracts a la Taylor (1979). The pricing mechanism and the wage setting behaviour combine to produce the Phillips curve relation in which inflation is determined by some measure of excess demand, to capture tightness in the labour market, imported inflation and some inertia reflecting the impact of expectations. Excess demand is proxied by an output gap measured by the deviation of output from its quadratic trend.

The appearance of the lagged term implies that agents are backward looking (i.e. backward looking Phillips curve). However this may not be inconsistent with the more recent forward-looking New Keynesian Phillips curve, as the lagged terms may be proxing expected future inflation[4]. The lags capture the fact that there is a short-run trade off between inflation and the output gap. This arises because of *nominal inertia* due to *menu* costs and wage contracts which are fixed for more than a year. However, if the coefficients of the polynomial lag, B(L), sum to one then there is long-run neutrality.

2.2 Monetary Policy and Exchange Rate Dynamics

Following the sharp inflation during the early 1990s, which coincided with the liberalization of the exchange rate regime, the Central Bank adopted a strict anti-

[4] See Gali and Gertler (1999), Fuhrer (1997) JMCB) and Rudd and Whelan (2001) FRB

inflationary monetary policy, in which inflation was explicitly targeted. The framework involved restricting the growth of money supply through the targeting of the monetary base –the Bank's operating target.

The exchange rate, even prior to the 1990s was used as the intermediate target, and has been viewed historically as the nominal anchor for inflation and inflationary expectations. More importantly, with the stabilization of the monetary impulses to inflation over the past five years, the movements in the exchange rate have featured more prominently in monetary policy operations relative to the trends in the monetary base.

Against this background the model is closed with the following *ad-hoc* Taylor type monetary policy rule

$$\Delta \tilde{r}_t = 0.6 * (E_t \Delta s_{t+1} - \Delta \bar{s}) + 0.4 * (y_t - \bar{y})$$

where $\Delta \bar{s}$ is the desired rate of depreciation consistent with the Bank's inflation target. The coefficients were chosen so as to replicate as best as possible the behaviour of the monetary authority. The larger coefficient on the first term reflects the fact that particularly since 1995, the Central Bank has placed increased emphasis on exchange rate/inflation stabilization and the creation of a stable macroeconomic environment as a basis for sustained growth.

3. Empirical Methodology

The empirical approach is similar to that adopted by Watson and Teelucksingh (1997) in that rather than using the structural systems approach, similar to the Cowles Commission, we model each equation in a cointegrating framework. One traditional approach is to estimate a system with the general form

$$A(L)Z_t = v_t \tag{8}$$

where the polynomial lag operator is A(L)=[B(L) Γ(L)], $Z_t = (Y_t, X_t)$, $v_t' = (\mu_t, \varepsilon_t)$ is a vector of random variables, using Two Stage Least Squares, with the critical assumption that ε_t is a null vector (i.e. exogeneity) and v_t is IID.

However following the cointegration revolution (Granger and Newbold (1974), Engle and Granger (1987)), careful attention has been paid to the time series properties of v_t and the restrictions imposed by the structural approach. There is no *a priori* reason for the exogeneity assumption to hold and as Sims (1980) suggests, we should begin from a reduced form, which captures the data generating process, from which the structural relationships are specified as a set of testable over-identifying restrictions. In support of the Cowles Commission approach however, Hsaio (1997) argues that even when variables are integrated, the critical issue relates to identification and estimation and not necessarily cointegration.

Against this background Watson and Teelucksingh (1997) suggested a comprise approach to estimating macroeconomic models in which following an analysis of the time series properties of the data, each equation is estimated using the Johansen (1988) procedure, to ensure that an economically meaningful cointegrating relation exists.[5]

This is the strategy adopted in this paper as it allows for the proper treatment of the non-stationary variables in the analysis of the long run relations. From the Granger representation theorem the information from the long run relation can be incorporated into the characterization of the short-run behaviour, for which economic theory is silent. Using the Johansen methodology we analyse the long-run properties by examining the rank of the Π matrix in the following vector error correction model

$$\Delta Z_t = \Pi Z_{t-1} + \sum_{i=1}^{k-1} \Gamma \Delta Z_{t-i} + v_t$$

where $Z_t = (Y_t, X_t)$ is the vector of I(1) variables, $\Pi = \alpha\beta'$, α is the vector of adjustment coefficients and β the vector of cointegrating relation.

Further, using the Johansen multivariate framework we analyse the relations among the variables in terms of the degree of endogeneity / exogeneity. A variable z_{it} is said to be weakly exogenous for the long run parameters, if Δz_{it} does not contain information about the long run relation. This can be tested by placing linear restrictions on the adjustment matrix, such that the row(s) corresponding to the variable(s) of interest is zero. Provided that there is weak exogeneity, it is possible to condition a short run single equation error correction model on that variable without a significant loss of information. Thus each equation can be estimated by OLS in an error correction form,

[5] This procedure has the added advantage in that it uses FIML, which is more efficient than 2SLS.

using General-to-Specific modeling, whereby restrictions on the lag structure are imposed and tested.

If more than one variable are weakly endogenous then the residuals from the single equation estimates would be correlated. Consequently we model the endogenous variables in a reduced conditional Vector Error Correction system in which the weakly exogenous variables enter exogenously. That is we estimate the following system

$$\Delta Y_t = \Pi Y_{t-1} + \sum_{i=1}^{k-1} \Gamma \Delta Z_{t-i} + \phi \Delta X_t$$

using full information maximum likelihood where X_t is the vector of weakly exogenous variables. It is generally recommended that in order to ensure identification one can impose the long run relations obtained from the original VAR.

3.1 Modeling Structural Breaks

A number of the time series used has exhibited structural breaks (see Figure A1 Appendix). There was the shock to the bauxite/alumina sector in the first half of the 1980s in addition to adjustments in the exchange rate regime. This was followed by a sharp recovery in alumina prices in 1986 and lower international oil prices, which enabled the resumption of strong growth in the economy. The major structural shift, however, occurred in 1990 with the liberalization of the foreign exchange system which was followed by an acceleration in trade and financial liberalization[6].

[6] There were also the problems in the financial sector in 1996, however this did not seem to produce a significant break in the data.

The standard Dickey-Fuller tests and statistics used in univariate unit root tests do not adequately account for such structural breaks. One could conduct the Dickey-Fuller tests on the individual subsamples, however the degrees of freedom would be diminished. This paper therefore employs the Perron (1989) tests for unit root in the presence of a structural break at time period $t = \tau+1$. Perron (1989) shows that when the residuals are identically and independently distributed, the distribution of coefficient on the lag term depends on the proportion of observation occurring prior to the break. This proportion is denoted by $\lambda = \tau/T$ where T is the total number of observation. The test regression for the Perron's unit root test is

$$y_t = a_0 + a_1 y_{t-1} + a_2 t + \mu D_d + \sum_{i=1}^{k} \beta_i \Delta y_{t-i} + \varepsilon_t$$

where t = time trend variable and D_d is a dummy for the structural break where d=L,P depending on the type of break in the data.[7] The t- statistic is then calculated for the null hypothesis $a_1=1$ and this is compared with critical values calculated by Perron for the value of λ at the 5% level of significance. If the t- statistics is greater than the critical value then it is possible to reject the null hypothesis of a unit root.

The known structural breaks are captured by the dummy variables. However with the inclusion of such deterministic regressors the Johansen (1988) and Osterwald-Lenum (1992) (O-L) statistics commonly used in cointegration tests are not always valid because of the nuisance parameter problem. Johansen, Mosconi and Nielsen (2000) (JMN) have provided approximations for the critical values of the Johansen cointegrating tests in the

[7] d= P for a pulse dummy such that $D_P=1$ if $t=\tau+1$ and zero otherwise, and D_L represents a level dummy such that $D_L=1$ if $t>\tau$ and zero otherwise.

presence of structural dummies. Therefore-, for completeness, we report both the O-L and JMN critical values. We use the *Gamma* program supplied by Bent Nielsen to generate the JMN critical values. Similar to the Perron (1989) statistics, the distribution of the test statistics depend on the number of dummy variables and the where the breaks occur[8].

In the case of the Phillips curve, all the variables in the equation are stationary, so as is now common practice in the literature the equation is estimated using GMM[9], with leads and lags of the right hand side variables used as instruments.

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[8] Rahbek and Mosconi (1999) also suggest that a cumulative dummy should be included in the cointegrating space, and after the rank is determined test whether it can be excluded. The cumulative dummy was found to be insignificant for the long run money demand and significant for the aggregate demand, however no sensible theoretical relation could be derived and hence it was excluded.

[9] See for example Rudd and Whelan (2001)

4. Results

The estimates are done using seasonally adjusted quarterly data in logs from 1980:1 to 2000:4[10]. Tables A1 and A2 report the results of the unit root tests. All the variables in levels were found to contain a unit root at the 5% level of significance. The exchange rate however appears to be trend stationary. Both the Dickey Fuller and the Perron's unit root tests suggest that the non-stationary variables are integrated of order one. With the exception of the opportunity cost measure, the Perron unit root test for structural break indicate a structural shift at the time of liberalisation.

Aggregate Demand

Given equations (1) and (2) it is possible that there are two cointegrating relations among output, reserves, interest rates and foreign output. Table (1) gives the results of the cointegrating analysis. The tests for the optimal lag order of the VAR are inconclusive. The likelihood ratio (LR) and the final prediction error (FPE) both indicated three lags while the Schwartz (SC) and the Hannan and Quinn (HQ) information criteria suggested the use of one lag. The AIC, however, indicated the use of six lags.

The HQ criterion is generally viewed as the most robust relative to the SC and AIC, while the SC has the tendency of selecting the most parsimonious model. We therefore examined the properties of the residuals of the system for each suggested lag. The multivariate normality ($\chi^2(4) = 5.39$) and the LM statistic for autocorrelation ($\chi^2(16) = 23.15$) suggested that 3 lags are appropriate. Further at three lags the VAR is stable as none of the AR roots were outside the unit circle. Against this background we settled on three lags in the VAR.

The Johansen trace tests[11] suggested that there were two cointegrating vectors (CIV) at the 5 per cent level and one at the 1 per cent level using the O-L distribution. However the JMN critical values indicated one CIV at the conventional levels of significance. Based on this, and in contrast to our *a priori* expectations, we focused the one cointegrating vector that corresponds to the aggregate demand relation initially. The long run coefficients were found to have the correct signs, with credit availability being the most influential variable. However imposing zero restrictions on the long run coefficients reveal that perhaps US GDP should not enter the cointegrating space. Additionally the weak exogeneity tests indicate that this was the only variable that was exogenous. In fact the joint test that both the long run and adjustment coefficients were zero were not rejected[12].

The unrestricted reduced VECM system was therefore obtained by estimating with this restriction (See Table A3 in the appendix). The coefficients of the error correction term indicate that we should be normalizing on either reserves or interest rates, indicating a possible two cointegrating relations. For our purposes we normalized on reserves in estimating the restricted short run model, the results of which are given in Table 2.

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[10] The data on foreign interest rates, prices and GDP were obtained from the IMF's IFS CD-ROM. The quarterly GDP data is based on estimates from the Statistical Institute of Jamaica and the Bank of Jamaica. See Allen(2001) for a discussion on estimating quarterly GDP in Jamaica.
[11] The JMN statistic applies only to the trace statistic, hence the max eigenvalue statistic is not reported.

Table 1: Aggregate Demand Cointegration Tests

VAR Lag Length

Lag	LOGL	LR	FPE	AIC	SC	HQ
0	17.30	NA	1.99E-05	0.51	1.65	0.97
1	342.89	533.60	3.70E-09	-8.08	-6.436*	-7.42*
2	354.16	17.224	4.30E-09	-7.94	-5.79	-7.09
3	380.73	37.63*	3.32E-09*	-8.24	-5.58	-7.18
4	393.06	16.105	3.86E-09	-8.14	-4.97	-6.88

Unrestricted Cointegration Rank Test

Hypothesis	Eigenvalue	Trace	5 % (O-L)	1 % (O-L)	5 % (JMN)	1 % (JMN)
r = 0*	0.506101	88.39364	47.21	54.46	74.44	82.79
r ≤ 1	0.321849	34.78145	29.68	35.65	51.25	58.38
r ≤ 2	0.066800	5.264150	15.41	20.04	31.83	37.67
r ≤ 3	0.000129	0.009830	3.76	6.65	15.98	20.43

*(**) denotes rejection of the hypothesis at the 5%(1%) level using JMN(2000)

Unrestricted Cointegrating Coefficients β:

y	r	*R*	*y**
-7.106733	9.279069	-0.083199	5.734680
1.369455	3.073919	-0.081520	-10.69915
15.16665	-0.232178	-0.133277	7.875117
-28.31311	-10.45285	0.032077	21.49095

Unrestricted Adjustment Coefficients α:

y	0.004556	0.000161	-0.002873	-0.000178
r	-0.038743	0.024381	-0.001713	-0.000170
R	1.738654	2.495855	0.266367	-0.003432
*y**	0.000135	0.000571	-0.001201	2.57E-05

1 Cointegrating Equation(s):

Normalized cointegrating coefficients (std.err. in parentheses)

y	r	*R*	*y**
1.000000	0.011707	-1.305673	-0.806936
	(0.00299)	(0.22780)	(0.36404)
Log likelihood	396.624		

Weak Exogeneity:

*y**	r*	*R**	*y*
4.91	3.85	13.66	0.045

*(**) denotes rejection of the hypothesis at the 5%(1%) level

[12] i.e. $H0:\beta(1,4)=0,\ \alpha(4,1)=0 \Rightarrow \chi^2(2)=0.195$

Table 2: Short-Run Error Correction Model		
Variable	Δy_t	ΔR_t
c	0.018591**	
ec_{t-1}	0.003196**	-0.018541**
Δy_{t-2}	-0.314529**	
Δy^{*}_{t-2}	-0.907101**	
Δr_{t-1}		0.446203**
INDLIBDUM	0.005676**	
LIBDUM	-0.012290**	
Regression Diagnostics		
Q-Stats $\chi^2(1)$	1.518	0.6058
Q-Stats $\chi^2(4)$	3.5477	4.5835
Q-Stats $\chi^2(7)$	4.115	6.1736
Normality	3.75707	4.1967
ADF	-9.8856**	-7.8998**
Corr($\varepsilon_y \varepsilon_R$)	0.079469	0.079469

*(**) denotes rejection of the hypothesis at the 5%(1%) level

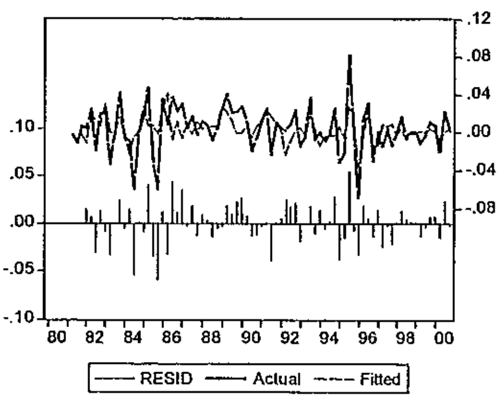


Figure 1: *Δy-Actual vs Fitted*

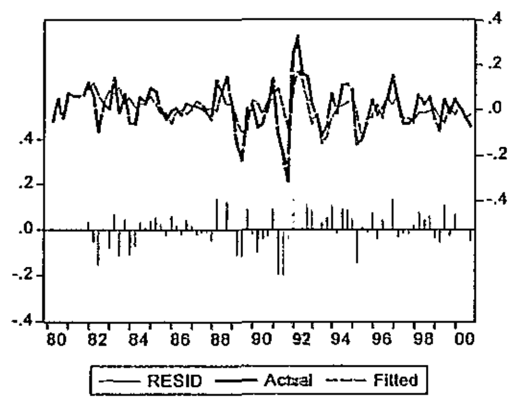


Figure 2: *ΔR- Actual vs Fitted*

The error correction terms in both equations are significant, supporting the hypothesis of a cointegrating relation. While the coefficient in the reserves equation was negative, suggesting that the banking system reduces the available reserves by approximately 2 per cent in response to an excess in the previous period, the sign for aggregate demand indicate that demand responds positively to any disequilibrium. Thus if there is an excess availability of credit it is used up in higher consumption or investment spending. The degree of adjustment in the system, however, is very low, particularly for aggregate demand. While as is expected, the short run behaviour of reserves depends solely on interest rates, output depends on the momentum in the economy as indicated by its own lag and US GDP growth. The influence of US GDP however is more significant, reflecting the importance of trade and the fact that approximately 70% of the tourism market comes from that country.

The regression diagnostics suggested that the estimated system is fairly adequate. The Q-Stats indicated no auto-correlation while the Jarque-Bera and the D-F statistics indicate that the residuals are normal and stationary. The correlation between the residuals are negligible.

Money Demand

The LR statistics, SC and HQ favour a VAR of order one. The trace test rejected the null hypothesis of no co-integrating vector (CIV) at all conventional levels using both the O-L and JMN criteria (Table 3). The test rejected the null hypothesis of at most one CIV at conventional levels using the O-L criteria but could not reject it using the JMN

Table 3: Money Demand Cointegration Tests

VAR Lag Length

Lag	LR	FPE	AIC	SC	HQ
0	NA	0.02473	7.65	8.03	7.80
1	328.0587	0.00025*	3.05	3.93*	3.40*
2	25.96867	0.00026	3.07	4.46	3.62
3	21.40428	0.00028	3.14	5.03	3.89
4	19.18475	0.00031	3.22	5.62	4.18

Unrestricted Cointegration Rank Test

Hypothesis	Eigenvalue	Trace	5 % (O-L)	1 % (O-L)	5 % (JMN)	1 % (JMN)
r = 0**	0.479602	86.54498	47.21	54.46	64.17	71.72
r ≤ 1	0.245338	36.25161	29.68	35.65	43.44	49.85
r ≤ 2	0.165984	14.57720	15.41	20.04	26.44	31.67
r ≤ 3	0.007781	0.601494	3.76	6.65	12.85	16.69

*(**) denotes rejection of the hypothesis at the 5%(1%) level using JMN(2000)

Unrestricted Cointegrating Coefficients β:

rm3	r	*y*	Δ*s*
5.399073	0.126049	-6.406115	0.200769
-6.718333	-0.421664	25.90764	0.008955
6.348782	-0.051906	-17.30967	-0.026027
1.702844	-0.008924	22.56995	-0.012173

Unrestricted Adjustment Coefficients α:

rm3	-0.020908	-0.006219	-0.015034	-0.001768
r	0.391381	0.786268	0.284516	-0.079162
y	0.003456	-0.005279	0.004207	-0.001057
Δ*s*	-2.056281	0.266482	3.376925	0.229556

1 Cointegrating Equation(s):

Normalized cointegrating coefficients (std.err. in parentheses)

rm3	r	*y*	Δ*s*
1.000000	0.023346	-1.186521	0.037186
	(0.00774)	(0.67855)	(0.00436)
Log likelihood	85.13604		

Weak Exogeneity:

rm3	r	*y*	Δ*s*
10.15**	2.07	1.91	3.13

criteria. Based on the JMN statistic we used a unique cointegrating relation. The tests for weak exogeneity reveal that all the variables, except real money balances were weakly exogenous, indicating that the long run relation is consistent with money demand theory.

The system was normalized on real money balances and all the variables had the expected signs and were significant. The elasticity of exchange rate depreciation is almost twice that for interest rates, indicating the significance of the public's perception of devaluation on their portfolio choice. This underscores the importance of maintaining a stable foreign exchange market so as to encourage stability and development in the domestic financial markets.

The income elasticity was marginally larger than one, and although similar to that found in Craigwell (1991), it contrasts with the standard prediction of unitary income elasticity. The restriction tests[13] reject unitary income elasticity and elasticities of ½ and 1/3, thereby rejecting the predictions of the Tobin (1956) transactions model and Miller and Orr (1966) precautionary model. An income elasticity greater than one may not be implausible as GDP may be capturing the trend effect of a high correlation between income and financial innovation, which was particularly evident in the early 1990s.

The results of the conditional unrestricted and restricted error correction models are given in Table 3. We used the same lag order of the VAR for the unrestricted model, from which the restricted model was derived based on the results of Wald restriction

Table 4: Money Demand Short-Run Error Correction Model		
Variable	Unrestricted	Restricted
c	0.012160*	0.014625**
ec_{t-1}	-0.142275**	-0.149988**
$\Delta\Delta s_t$	-0.340483**	-0.328129**
$\Delta\Delta s_{t-1}$	0.148521**	0.151239**
Δr_t	-0.578142**	-0.580555**
Δr_{t-1}	0.047849	
Δy_t	0.212919	
Δy_{t-1}	-0.030173	
$\Delta rm3_{t-1}$	0.080899	
LIBDUM	-0.010566	-0.012641
Regression Diagnostics		
R2	0.6677	0.6461
Sum of squares	0.0891	0.0927
Q-Stats $\chi^2(7)$	3.4676	5.2033
B-G $\chi^2(1)$	0.5608	1.9143
ARCH$\chi^2(1)$	3.9186	2.6569
ARCH$\chi^2(7)$	7.7813	8.8245
HETRO	1.1341	0.2514
Normality	1.5256	1.2596
Reset	2.314	3.1427

tests. The F-statistic in moving from the general to specific was F(3,68)=0.515 below the critical value, suggesting that the restricted model is an adequate representation of the unrestricted.

In both cases the error correction term was negative and significant, which indicates that there is a countervailing adjustment in the demand for real money balances in the subsequent quarter in response to a dis-equilibrium. The speed of adjustment however is low, especially when compared to Craigwell (1991) and Henry and Kent (1996). Cuthbertson and Taylor (1990) argue that a slow speed of adjustment is likely if current portfolio choice of agents is significantly influenced by expected future income

[13] EVIEWS 4 did not report the critical values, it only indicates whether or not the restriction is binding.

and return. In this context, the increasing financial sophistication of the Jamaican investor, particularly since liberalization, could therefore explain the slowing adjustment.

While changes in real GDP do not affect the short run demand, although it is important in the long run, interest rate and the rate of exchange rate depreciation are significant. Changes in the interest rate exert the most significant and immediate effect (the coefficient on the first lag is insignificant.). The rate at which the exchange rate depreciates has a more longer impact, lasting for more than quarter, possibly reflecting the influence of expectations.

The regression diagnostics suggested that both the unrestricted and the parsimonious models were adequate. The Q-Stats and Breusch-Godfrey test indicated that there was no auto-correlation. Engel's test for serial-correlation did not reject the null of no higher order serial correlation. White's test for Heteroskedasticity and Ramsey's Reset test for functional form also did not reject the respective null hypotheses. The Jarque-Bera statistic confirmed that the residuals were normal.

The robustness of the conclusions drawn and their import for policy design depend on the stability of the coefficients. The plot of the CUSUM squared, which is somewhat similar to the Chow structural break test, in addition to the recursive coefficients suggest that the model is basically stable. This is further supported by the Chow forecast test for which the probability of the F-statistic is 0.715, when account is taken of the impact of liberlisation and the financial sector crisis.

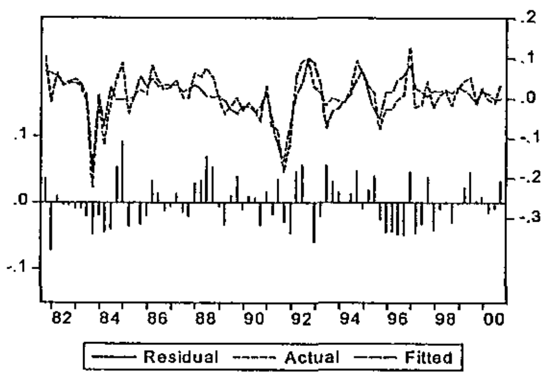


Figure 3: Actual vs Fitted

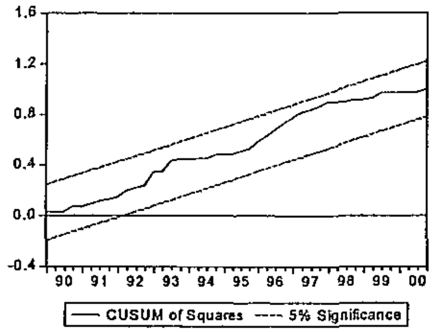
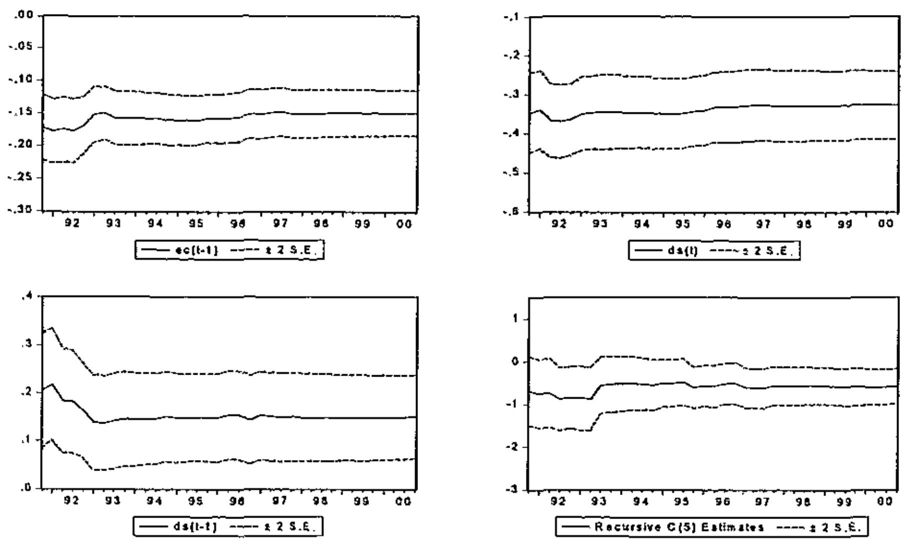


Figure 4: CUSUM

Figure 5: Recursive Coefficients



Inflation

The price equation was estimated using GMM with the Newy-West correction for heterosedasticity and autocorrelation (HAC). The results are given in Table 5 below. The J-statistic, with a p-value at $\chi2(5)$ of 0.52 indicate that the test for over-identifying restrictions was satisfied. The adjusted R-squared however is a bit low. The relative size and significance of the coefficients suggest that the output gap i.e. real disequilibrium may be just as important as imported inflation. However, lagged inflation, which captures either the nominal inertia or proxies expected inflation is the most important determinant and may be pointing to some short run trade off. Test for the restriction that the coefficient was equal to one was strongly rejected ($\chi2(1) = 31.4$), implying that the long run Phillips curve for Jamaica may not be vertical.

Table 5: Phillips Curve				
	Coefficient	Std. Error	t-Statistic	Prob.
constant	0.008821	0.001893	4.659029	0.0000
$\Delta s_t + \Delta p_t^*$	0.204536	0.060173	3.399159	0.0011
$y-\bar{y}$	0.249953	0.115854	2.157476	0.0344
π_{t-1}	0.638573	0.064514	9.898284	0.0000
OILDUM	-0.002857	0.000833	-3.431375	0.0010
R-squared	0.618566	Mean dependent var		0.045642
Adjusted R-squared	0.597077	S.D. dependent var		0.041791
S.E. of regression	0.026527	Sum squared resid		0.049962
Durbin-Watson stat	2.699003	J-statistic		0.055601

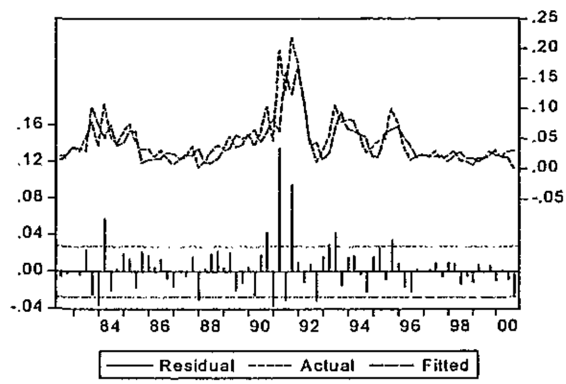


Figure 6: Actual vs Fitted

5. Simulation

In this section we solve the model from which we then study the dynamic response of the main macroeconomic variables to different shocks. In particular, we consider the response of the system to a 1 per cent increase in the central bank's signal rate, which lasts for one quarter. The impulse responses are shown in figure 7.

The impact of the interest rate adjustment particularly on inflation, lasts for as long as two to three years. However, the response of the exchange rate is immediate with an appreciation of approximately 0.42% in the first quarter, lasting two quarters. The effect of the shock on the exchange rate lasts for approximately one year. In its transition back to equilibrium the exchange rate exhibits some overshooting. The appreciation in the exchange rate had a dampening effect on inflation with declines of 0.09%, 0.05% and 0.04% in the subsequent three quarters following the shock. The noticeable appreciation in the currency elicits an immediate rise in real money balances, as it completely offsets the negative impact of the rise in real interest rates. The impact on the output gap has a lag of approximately two to three quarters. The effect however is negligible but persists for a relatively long time (almost three years.)

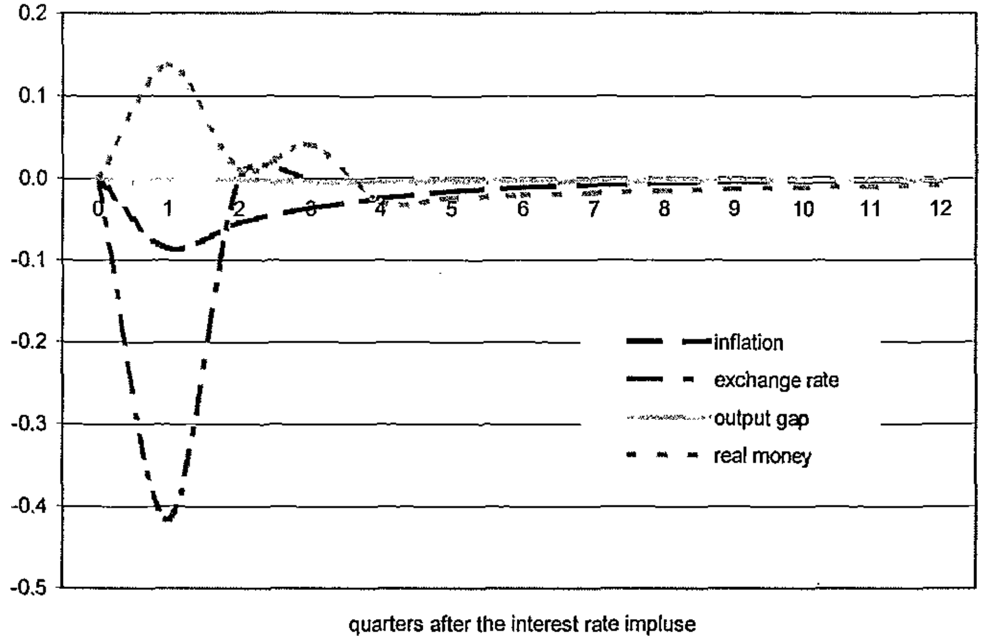


Figure 7: **Response to interest rate impulse**

The transmission mechanism works through different channels in this model. Monetary policy, as defined by changes in the short term interest rates, affects current inflation via its impact on the exchange rate and future inflation via its impact on real interest rates, credit availability and hence aggregate demand –credit channel. In the subsequent simulations we attempted to separate the relative importance of both the exchange rate and credit channels in the transmission process. We must however that methods used to distinguish these effects are rather crude. The response of inflation to the interest rate shock was estimated with the exchange rate fixed, i.e. with the exchange rate channel turned off. The difference between this simulation and the original roughly indicates the effects of the exchange rate channel. Similarly, to identify the credit channel we fixed reserve money. Figures 8 and 9 summarize the results.

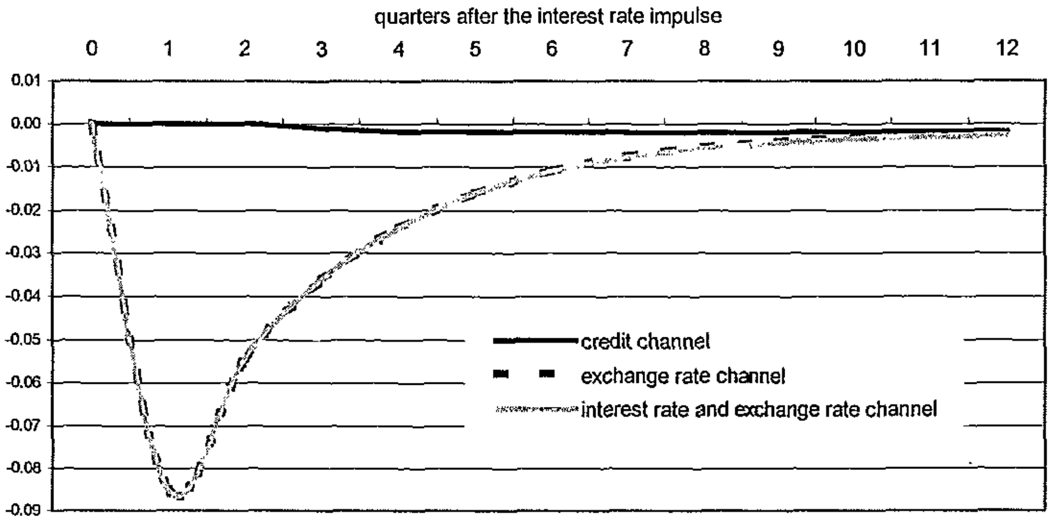


Figure 8: **Transmission channels of monetary policy**

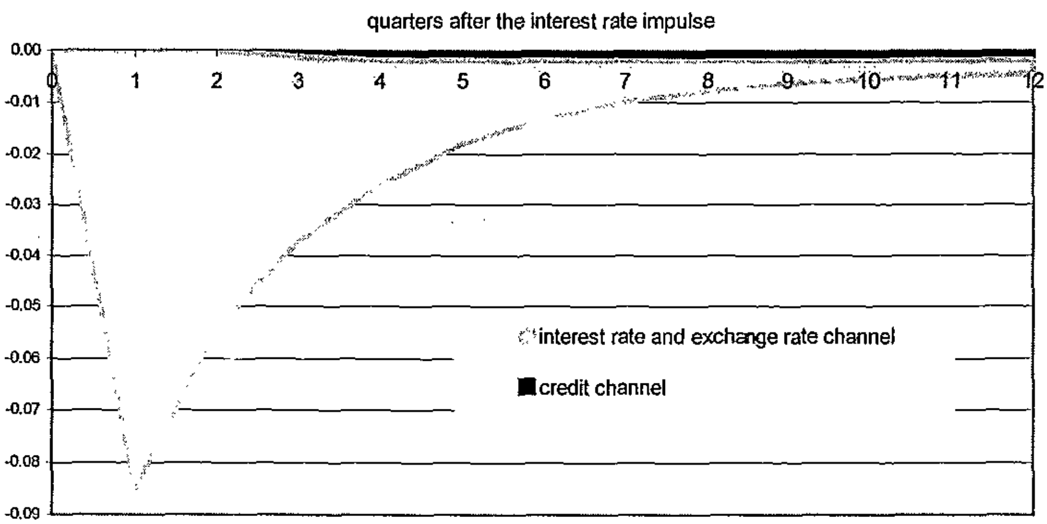


Figure 9: **Relative importance of different channels of monetary transmission**

During the first two quarters after the shock the exchange rate channel constitutes the only conduit through which monetary policy influences inflation. Over longer horizons, beginning in the third quarter, the fall in the output gap, resulting from the credit channel, produces a subsequent slow down in inflation. The graphs demonstrate however that from the third quarter to the fourteenth quarter the effect of the exchange rate channel dominates the credit channel. In the third quarter the fall in inflation amounting to 0.024% can be split into 0.022% reflecting the exchanger rate channel and 0.002% reflecting the influence of the credit channel.

The simulated responses therefore point to the fact that, particularly within the short-run, inflation stabilization is achieved mainly through the inducement of portfolio adjustment between foreign and domestic assets, which via the impact on the exchange rate, lowers the imported component of inflation. However, although relatively small, the persistent dampening effect on aggregate demand, operating through the credit channel, does constrain price movements over the longer horizon.

The dominance of the exchange rate channel as suggested by the model is consistent with the observed behaviour of inflation over the past ten years. Inflation has been influenced mainly by shocks to the exchange rate relative to demand push effects arising from the credit channel. The moderation in inflation over the past five years has coincided with a more stable foreign exchange market, although credit expansion, particularly during the rehabilitation period following the financial crisis was not significant.

6. Concluding Remarks

In this paper we developed and estimated a small-scale model of the Jamaican economy, which could be used to analyze monetary policy and provide the basis for the development of a more comprehensive forecasting model. An aggregate demand and a stable money demand function were identified in a cointegrating framework. The analysis of the Phillips curve relation points to the possibility of some inflation/output tradeoff. The model simulations revealed the potency of monetary policy and the importance of exchange rate behaviour in macroeconomic stabilization.

Although the model presented provides a reasonable framework within which we can analyse the effect of policy, it is nevertheless restricted given the level of aggregation. Further work would therefore require extending the model to account for government, whose demand for resources has been known to have a significant impact on the dynamics of inflation and output. Additionally, real dis-equilibrium is treated in a purely statistical manner, and as such, may suppress the *real inertia* to inflation arising from adjustments in the output gap. Therefore some account should be taken of the supply side. In this context, rather than estimating the Phillips curve separately, it could be estimated along with potential output using a Kalman filter.

Finally, if policy makers' preferences change over time then a more representative policy rule (suppressing the output gap) could be of the form

$$\Delta\tilde{r}_t = \phi_i(\bar{s}_t),\ 0 \le \phi_i \le 1,\ i = L,H$$

where $\bar{s}_t$ is the "fundamental" value of the exchange rate such that if [s_L, s_H] is the "zone of tolerance" then

$$\Delta\tilde{r}_t = 0 \qquad \text{if } s_L \leq \bar{s}_t \leq s_H$$

$$\Delta\tilde{r}_t = \phi_L(s_L - \bar{s}_t) \qquad \text{if } \bar{s}_t \leq s_L$$

$$\Delta\tilde{r}_t = \phi_H(s_H - \bar{s}_t) \qquad \text{if } s_H \leq \bar{s}_t$$

Assuming that expectations are rational, agents know the policy rule and equation (5) holds then the exchange rate can be shown to follow a threshold auto-regressive process.[14]

$$s_{t+1} = \begin{cases} \mu_L + \theta_L s_t & \text{if} \quad s_t \leq s_L^* \\ \theta_0 s_t & \text{if } s_H^* \leq s_t \leq s_L^* \\ \mu_H + \theta_H s_t & \text{if} \quad s_H^* \leq s_t \end{cases}$$

Estimating this TAR model with appropriate identification restrictions would then permit the derivation of a more robust preference parameter for monetary policy.

[14] See Dutta and Leon (2002)

Appendix: *Figure A1*

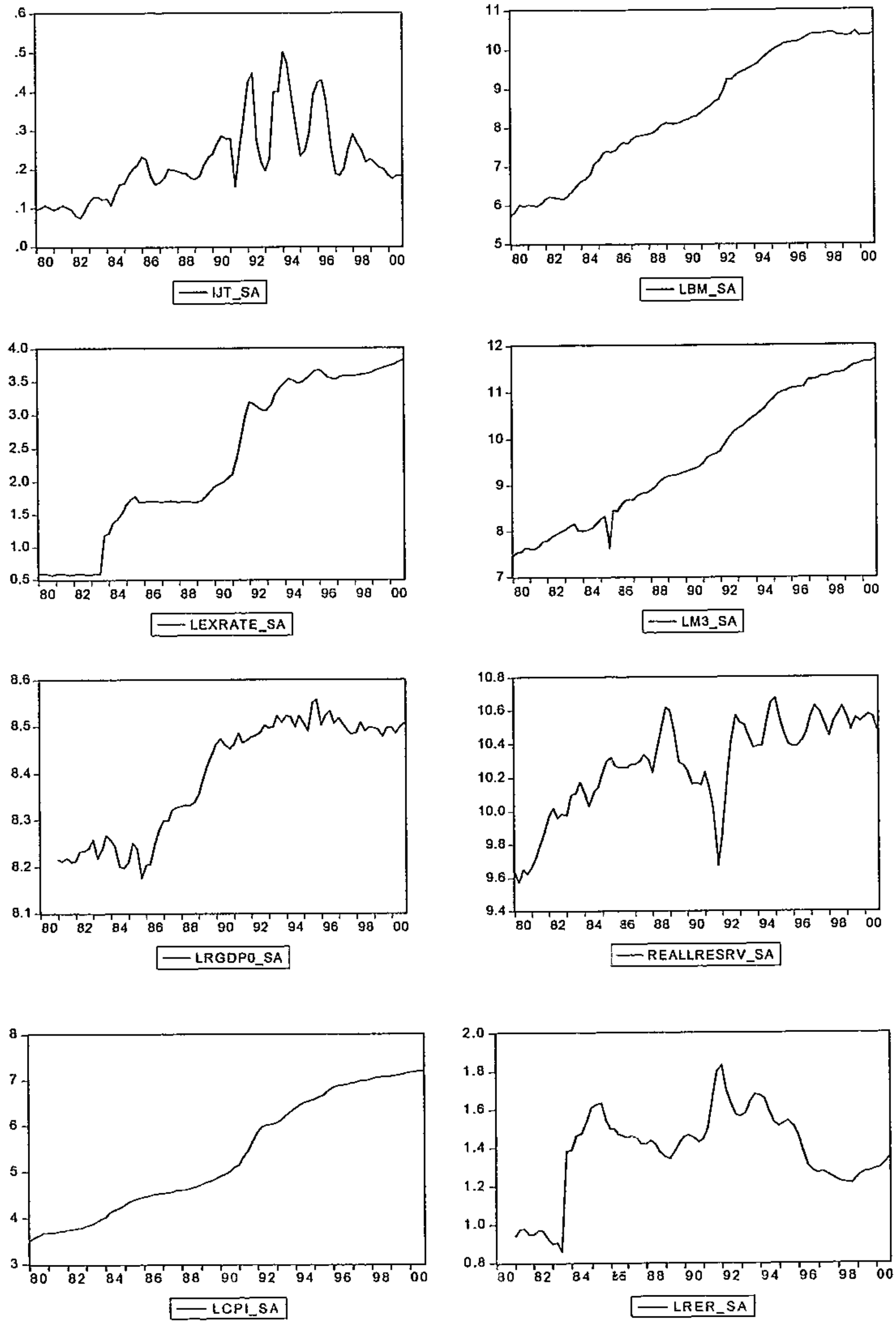


Table A1: Tests for Unit Roots (logs, levels), 1981:1 - 2000:4				
	ADF		Perron	
Variable	Intercept	Intercept and Trend	Intercept	Intercept and Trend
C(r)	-1.78	0.60	-1.14	-0.95
EXRATE	-0.88	-1.93	-3.28	-4.19
IJT	-2.32	-2.50	-2.51	-3.58
GDP	-1.35	-0.69	-1.88	-1.08
CPI	-0.45	-2.24	-3.40	-1.78
M3	-1.30	0.08	-1.36	0.11
RER	-1.84	-1.63	-2.15	-2.11

Note: The ADF is the Augmentented Dickey Fuller and Perron is the Perrons Unit Root test with structural break. The critical values for the Perron test is P(λ, 0.05)=3.76 and is based on Perron, 1989. Asterick denotes the absence of unit roots at the 5% level of significance

Table 1B: Tests for Unit Roots (1st difference) 1981:1 - 2000:4				
	ADF		Perron	
Variable	Intercept	Intercept and Trend	Intercept	Intercept and Trend
C(r)	-8.20*	-7.21*	-6.52*	-6.53*
EXRATE	-6.32*	-6.31*	-12.20*	-12.47*
IJT	-7.20*	-7.57*	-7.89*	-8.07*
RGDP	-10.58*	-10.63*	-9.90*	-9.85*
CPI	-4.18*	-4.15*	-2.88	-3.91*
M3	-6.30*	-6.83*	-5.45*	-6.47*
RER	-7.85*	-7.88*	-3.81*	-3.93*

Note: The ADF is the Augmentented Dickey Fuller and Perron is the Perrons Unit Root test with structural break. The critical values for the Perron test is P(λ, 0.05)=3.76 based on Perron (1989). Asterisk denotes the absence of unit roots at the 5% level of significance

Table A3: Unrestricted Reduced VECM			
	Δy	ΔR	Δr
ecm(-1)	-0.003285	0.036641*	-0.658596*
Δy (-1)	-0.148090	0.181877	18.71788
Δy (-2)	-0.447604*	-0.234256	-17.16131
ΔR (-1)	-0.051449	0.503997*	-7.177739
ΔR (-2)	0.000428	0.019442	-32.85691*
Δr (-1)	9.46E-05	0.002209	0.093742
Δr (-2)	0.000794	-0.004024*	0.205192
Δy^*(-1)	-0.455170	-0.282533	-106.8583
Δy^*(-2)	-0.630962	3.058858	119.8888
C	0.016604	-0.097285	10.00867
LIBDUM	-0.015147*	0.067454*	-2.248853
INDLIBDUM	0.021913	0.042383	14.23299*
INDLIBDUM(-1)	0.022582	0.139063	-7.710479
DUM2	0.005195	0.051678	-9.612038*
INDDUM2(-2)	0.013237	-0.070562	6.866173
INDDUM2(-1)	0.005587	-0.132549	-3.870476
R-squared	0.301575	0.533920	0.375772
Adj. R-squared	0.126969	0.417400	0.219715
Sum sq. resids	0.030400	0.352904	1589.850
S.E. equation	0.022509	0.076692	5.147573
F-statistic	1.727171	4.582217	2.407913
Log likelihood	189.4740	96.30777	-223.3845
Akaike AIC	-4.565105	-2.113362	6.299592
Schwarz SC	-4.074424	-1.622682	6.790272
Mean dependent	0.003840	0.008176	0.098084
S.D. dependent	0.024091	0.100477	5.827413
Determinant Residual Covariance		2.21E-09	
Log Likelihood		361.8558	
Log Likelihood (d.f. adjusted)		325.9252	
Akaike Information Criteria		-6.787505	
Schwarz Criteria		-4.702112	

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