FORECASTING INFLATION USING VAR ANALYSIS

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Introduction

Given the objective of price stability, the ability to predict the process of price adjustments is essential. From a policy perspective, an understanding of the interactions and transmission process between the main macroeconomic variables and prices serves to guide the process of policy formulation and implementation. In understanding and predicting inflation in Jamaica it is necessary to understand the importance of shocks and the underlying process. Critical elements of which are the persistent components such as expectations, indexation and the structural factors such as the openness of the economy, as well as the production function. This paper by exploring these interrelations, attempts to provide an alternate means of forecasting inflation by employing a Vector Autoregressive (VAR) model. In so doing it attempts to elucidate some aspects of the transmission process.

Previously, forecasting and policy analyses have been conducted using structural macroeconomic models. These structural models, using hypothesized theoretical relations, show the main linkages in the economy. These models thus rely on economic theory to determine the number of variables and their influence.

The initial relative success of this approach led to the development of large scale models, the most noted of which were the MIT, Penn State and the Federal Reserve models. During the late seventies, however, these models were criticized by Lucas as being highly inappropriate for policy analysis as they violated the 'policy invariance' property. Structural models have also been criticized on the grounds of their poor forecast performance. More recently, Sims(1980) in a seminal critique argued that the restriction applied to structural models in the estimation procedure were 'incredible' and could not be properly tested. The fact is that in structural models, to achieve identification, often restrictions are imposed which have no theoretical justification. Where single equation models were concerned, the major problem was data mining.

This lead to the development of VAR modelling, which has proven to be quite useful in short term forecasting. VAR models have increasingly been used in macroeconomic research over the last decade or so, especially in the United States. Currently VARs are used by the various branches of the Federal Reserve Bank and the Bank of England for forecasting economic trends.

Because many variables do affect inflation, and are in turn affected by inflation, it is possible to identify a small selection of economic variables, movements in which appear to have been highly correlated with inflation in the past and as such may then be useful in forecasting future inflation. The VAR approach provides a convenient means of accomplishing this, as it relies on the causal and feedback relation amongst variables.

The paper is organized as follows. The first section briefly overviews the inflationary process in Jamaica. A wider discussion can be had from McIntosh (1984), Bourne(1977), Ally (1974), Latibeaudiere (1974), Downes (1993), Robinson (1996) and Barnes (1996). This is followed by an overview of the various models of price behaviour used. This will form the basis of the variable selection process in the empirical analysis. Section three looks at a theoretical overview of the methodology whilst section four looks at the empirical model and its results. In this section a comparison of the forecasting performance of the VAR model with other time series models is done. The paper concludes by looking at the implication of the results.

Inflation and Adjustment

Given the persistence of inflation, which have averaged approximately 20 percent over the past twenty-five years, Jamaica, using Pazos (1972) classification, can be characterized as having chronic inflation. Such economies have been typified by the sluggish adjustment of inflation to stabilization programs (albeit in the Jamaican case, it is the inconsistent application of stabilization programs that may have contributed to these results), current account deficits, periods of real appreciation of the domestic currency or loss of competitiveness and uneven adjustment in output. The response of prices is primarily the result of relatively long memory process and certain institutional (social, economic and political) modalities which have developed as rational economic agents adapt to the current environment.

A number of stabilization measures have been adopted over the years primarily within the ambit of various International Monetary Fund's programmes. Following the initial price shocks in the early 1970s, resulting from both internal sources (such as lapses in domestic policy) and external shocks (oil price increase), monetary policy adopting what Lue-Lim (1988) called a passive stance, relied on the use of bank rates, rediscounting facilities, exchange and credit controls as a means of containing aggregate demand. After 1984 monetary policy became more proactive, relying more on commercial banks reserve ratios and open market operations.

Despite these initiatives however, the annual average rate of inflation during the 1980's fluctuated between 5.2 percent in 1980 to a high of 85.0 percent in 1991. Much of the deviations from the average long run trend however corresponds to shocks from the exchange rate, money stock and structural shocks such as import prices and domestic costs.

Figure i reveals that the variation in the exchange rate has probably the greatest influence on the inflationary path. This is plausible given the openness of the economy. The main exchange shocks occurred in 1973, 1978 to 1980, 1983 and in 1991. These were associated with changes in the exchange rate regimes.

The adjustments during the 1980's involved the introduction of a parallel foreign exchange market, the subsequent unification of the exchange rates and the introduction of a foreign exchange auction system. The subsequent devaluations of the domestic currency vis a vis the U.S. dollar, which were as much as 84.0 percent between 1982 and 1983, saw the inflation rate increasing from 7.0 percent in 1982 to between 20.0 and 26.0 percent over the next two years. The major adjustment however was the liberalization of the foreign exchange market between 1990 and 1991. By 1991 the inflation rate peaked at 80.2 percent as the exchange rate, now subject to a greater degree of influence from market forces, depreciated by some 155.2 percent (in J$ terms). This would suggest that a stabilization policy with the exchange rate being the nominal anchor would be useful.

However, it has been generally accepted that there is also a structural component to inflation, although economists differ as to its relative importance. These structural factors primarily include domestic costs such as labour costs, imported inflation and supply shocks. Figure ii would suggest however that imported inflation had little influence during the 1980s as international inflation was moderate. This is in comparison

fig i
Annual Changes(%)
CPI vs Exchange Rate

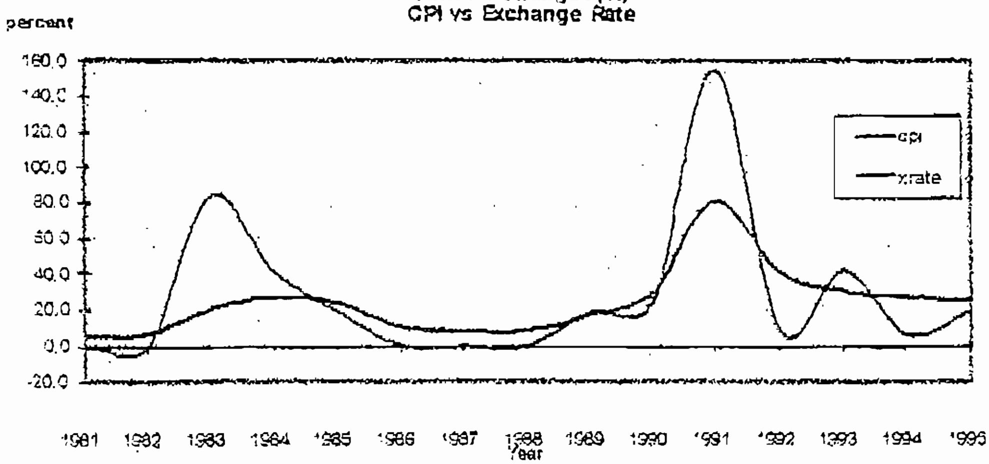


fig ii
Domestic vs Foreign
Inflation

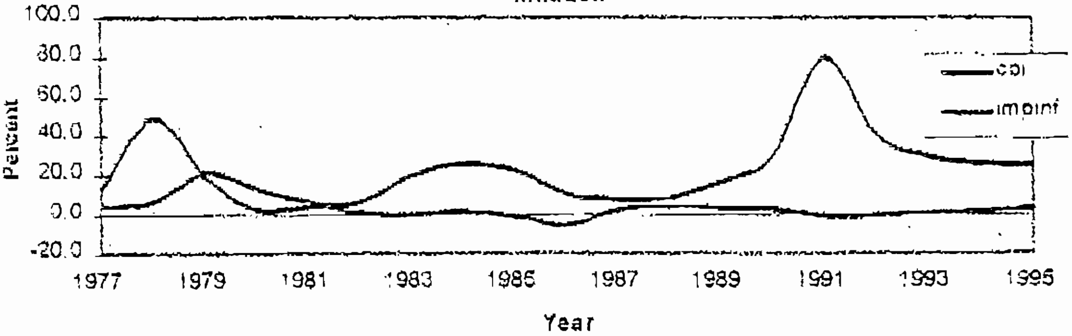
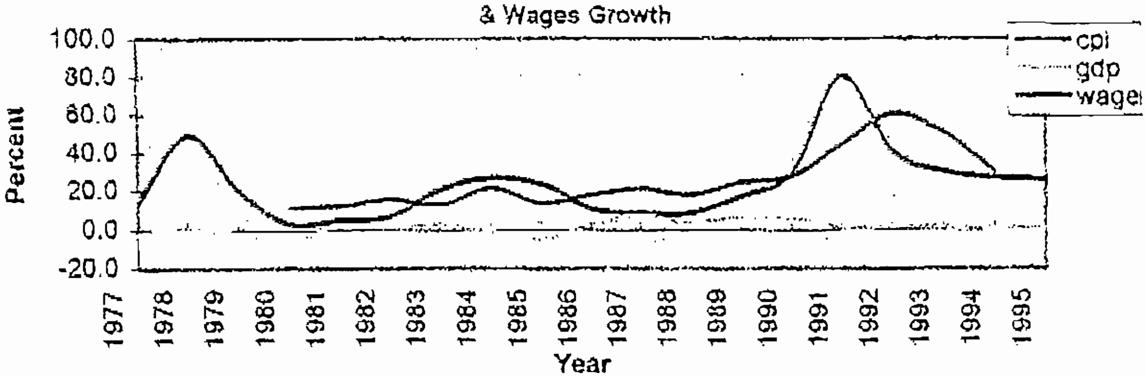


fig iii
Inflation vs GDP
& Wages Growth



to the 1970s where it may be argued that imported inflation was more important. Figure iii highlights the importance of supply shocks, it shows that high inflation occurred when output contracted. The graph also shows some correlation between wages and inflation. Robinson(1996) argues that wages do exert some cost push inflation, though it may not be the sole source of inflationary impulse. Craigwell (1991) examining the wage price causality for Jamaica between 1957 and 1984, found possible feedback relations between wages and prices.

Figures iv through vi show however that the high inflationary episodes also correlate with expansionary monetary and fiscal policies. Changes in monetary policy stance are indicated in fig iv and fig v by the rate of acceleration of the monetary variables (moneybase, domestic credit). Changes in fiscal policy are indicated in fig vi by the change in the overall public sector deficit (inclusive of amortization)[1]. The figures indicate that macroeconomic policy has either precipitated or accommodated the various shocks to prices as both the monetary and fiscal variables peaked at the same time or immediately before the periods of high inflation. Thus we may tentatively conclude that monetary policy has tended to be accommodative, with expansionary fiscal policy exacerbating the problem.

The trends in the 1980s however have to be seen against the background of price and wage controls and subsidies. In which case much of the inflation during this period was suppressed. Consequently the causation amongst the variables over the period has been found to be imprecise.

[1] The 12-month point to point inflation rate at the end of March or the fiscal year inflation rate is used in the graph.

fig iv
Inflation vs Basemoney
Growth

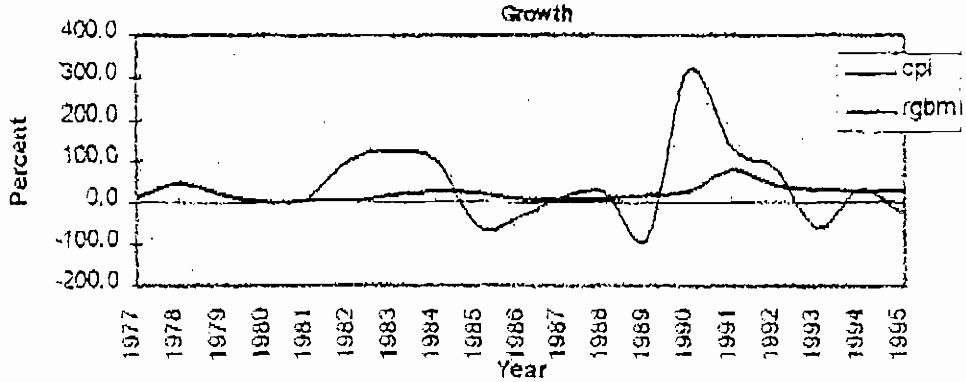


fig V
Domestic Credit vs Inflation

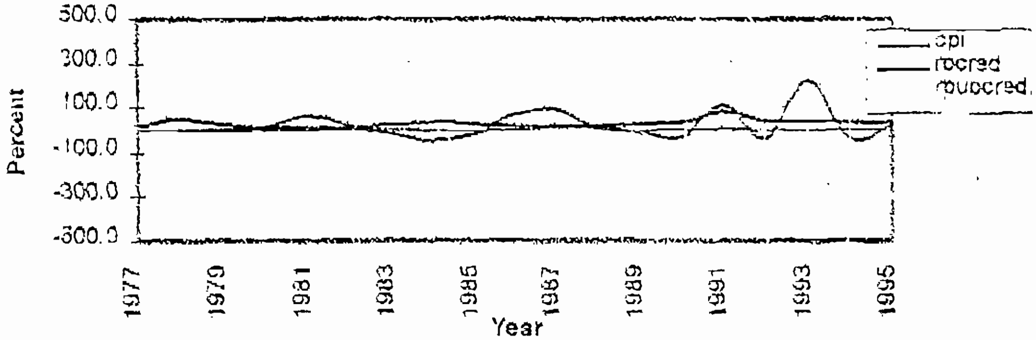
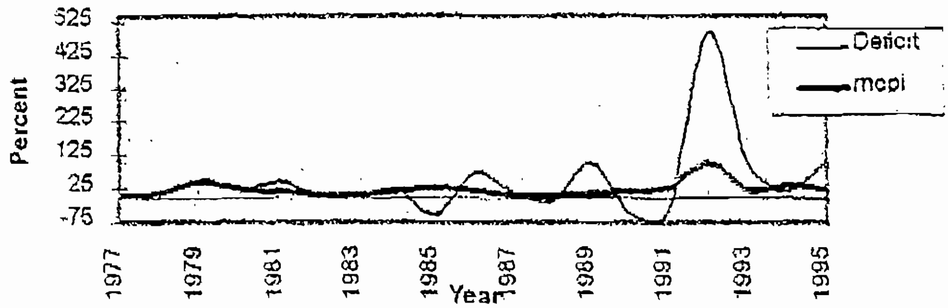


fig vi
Changes in the
CPI vs Overall Fiscal Deficit



It may be argued that the expansionary fiscal policy, which was accommodated by monetary adjustments, resulted in excess aggregate demand which has not only affected the price of non-tradables but has spilled over into the balance of payments and thus forced the adjustments in the exchange rate. This would suggest that stabilization programmes, with (or without) a nominal exchange rate anchor must be supported by prudent monetary and fiscal policy.

It may also be argued that the changes in the fiscal deficit are the result of inflation itself. Thus the significant increase in the deficit in 1991 - 1992 simply reflects the Olivera-Tanzi effect, whereby inflation whilst increasing the cost of government expenses reduces the real value of the tax base.

Recent Models

Various economists have attempted to empirically analyze the issues outlined in the previous section. Earlier studies, such as Bourne and Persaud(1977) and Holder and Worrell(1985), emphasized the role of structural influences and cost push inflation. More recent studies have found that monetary disequilibrium and exchange rate changes are significant in explaining the behaviour of prices in the Jamaican economy[2]. The link between the money stock and inflation occurs via a monetary transmission process whereby the amount of money economic agents desire to hold is less than the available money stock. Assuming a stable demand for money, this serves to reduce the value of money (in terms of goods) thus increasing the price level.

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[2] See for example Worrell, Watson and Scantlebury -Mynard (1992).

Ganga(1992) estimated a model similar to the Harberger model using two-stage least squares. The results using annual data were

$$\ln p = 0.066 - 0.112\ln(ms) + 0.167\ \ln(ms_{t-1}) - 0.137\ln(wg) +$$
$$0.315\ln(pm) + 0.338\ln(xrate) - 0.378\ln(rgdp) + 0.229\ \ln(P_{t-1})$$

Only the contemporaneous money stock and wage rate had unexpected signs and were insignificant. The results suggest that output fluctuations and exchange rate changes had the largest impact on price changes. These results of course are highly influenced by the unique features of the sample period. Using monthly data from 1990 to 1992 the estimated model was

$$\ln p = 0.007 + 0.156\ln(xrate_{t-1}) + 0.285\ln(ms_{t-1}) - 0.006INT_{t-1}$$
$$+ o.554\ln(p_{t-1})$$

which suggest that inflation is highly influenced by lagged money supply and exchange rata changes[3] These results also highlight the significant role of inflationary expectations.

Shaw(1992), starting from the hypothesis of the Quantity Theory, estimated the relationship between money supply and prices in Jamaica between 1982 and 1992. The changes in prices were examined as a function of changes in the money supply(M2), previous price changes and changes in the exchange rate.

Using quarterly data, the estimated model most preferred was

$$p_t = 0.27 + 0.28\Delta ms_{t-2} + 0.38\ \Delta p_{t-1} + 0.24\ \Delta ex_t$$

From this he concludes the inflation rate is influenced by changes in the money supply, but not directly as the Quantity Theory purports. Monetary changes affect inflation

[3] Ghartey (1994) found that changes in the exchange rate can be linked to monetary dynamics. consequently he suggests that monetary policy can be employed to control the exchange rate.

indirectly because of the prevalence of mark-up pricing. This also provides the channel for the impact of exchange rate adjustments (i.e. changes in the exchange rate affect variable cost) and lagged prices.

Thomas(1994) attempts to capture the dynamics of the inflationary process and the relationship with respect to policy shocks in a monetarist framework. He employed a hybrid methodology which combined a distributed lag specification with an error-correction approach. The distributed lag - polynomial lag, was used to capture the short run impact of policy shocks.

Theoretically, he used a small country assumption in which the economy is a price taker in the international market. Thus the domestic price level, by the law of one price is given by

$$P = eP^*$$

where P^* is the international price level and e is the exchange rate Given this his model is specified as

$$P = p(e, P^*, c, f)$$

the steady state long run model is

$$P_t = 80.34 - 6.88e_t + 0.002c_t - 0.80I_t - 0.80 P_t^* - 0.02f_t$$

the short run polynomial lag model is

$$\Delta P_t = -1.67 + 20.34 \sum\Delta e_{t-i} + 0.0003 \sum\Delta i_{t-i} + 1.10 \sum\Delta P_{t-i}^* - 0.32\sum\Delta T_{t-i}$$

$$+ 0.001\sum\Delta f_{t-i} - 0.385 u_{t-1}$$

Thomas concluded from these results that exchange rate changes exert the most dominant influence. This is however against the results of insignificant coefficient estimates for the short run model. The model in itself maybe subject to over paramatization. The model selection criterion used may not be the most appropriate in an ECM framework

Downes, Worrell and Scantlebury-Maynard (1992) estimated an encompassing model of inflation for Jamaica, which incorporated both structuralist and monetarist features. The functional structure of their model is given as

$$\dot{P} = p(\dot{er}, \dot{usp}, \dot{m}^s, \dot{r}, \dot{wr}, \dot{prod}, \dot{s})$$

Changes in the price level (P) are modeled as being positively related to the changes in the money stock (m^s), exchange rate (er), U.S. inflation (usp), lending rate (r), domestic wage rate (wr), factors which cause domestic inflation to deviate from purchasing power parity equivalent (s) and negatively related to changes in productivity (prod).

Using annual data, the results of the static long run equation suggest that cost push variables such as the loan rate and the wage rate do not influence the inflation rate in the long run. Using the generalized instrumental variable estimator technique, the short run dynamic error correction model was

$$dlp = -0.03 + 0.22\ dler + 1.65\ dlusp + 0.39\ dlm1 - 0.15\ HURDUM - 1.03\ ec(-1)$$

which suggests that changes in the exchange rate, U.S. inflation and monetary changes have significant effect on the inflation rate.(HURDUM is a dummy variable for hurricane.) In the short run therefore the model emphasized the role of monetary variables as against structural variables.

For the purpose of this paper a monthly version of this encompassing model (ECM) was estimated. The long run static model in logs was found to be (the t-statistics is given in parenthesis)

$$lp = -0.005 + 1.391p_{t-1} - 0.2381p_{t-2} - 0.2131p_{t-3} + 0.031er + 0.021m2 + 0.0129lwr$$
$$(-0.2) \quad (19.3) \quad (-1.93) \quad (-3.1) \quad (4.6) \quad (3.3) \quad (3.6)$$

adj $R^2 = 0.99$ SER = 0.011 $SC(\chi^2_1) = 0.0038$ D-F = -5.52

and the short run error correction model was

$$\Delta lp = 0.0009 + 0.94\Delta lp_{t-1} - 0.13\Delta lp_{t-2} + 0.098\Delta ler + 0.039\Delta lm2_{t-1} + 0.005\Delta lwr - 0.51ecm_{t-1}$$
$$(0.64) \quad (5.9) \quad (-1.1) \quad (5.9) \quad (1.95) \quad (1.4) \quad (-2.9)$$

adj $R^2 = 0.60$ SER = 0.01 $F(1, 183) = 45.3$ $SC(\chi^2_1) = 3.3$ HET[F(27, 160)] = 1.4 RESET(χ^2_1) = 0.87

M1 was replaced by M2 in this monthly model as it was found to be more relevant. The model maintained the basic characteristics in the short run as Worrell's(1992) model.

It must be noted that whilst these models examine the determinants of inflation it may be argued that they do not fully explore the causal relationship between the variables. Simple correlation does not necessarily indicate causation. Against this background, S. Nichols, J.Nichols and H.Leon(1995) investigated the money price causation in four CARICOM economies. Granger causation was found to run from base money and the narrow definition of money to prices between 1973 to 1995. This did not hold however for intervening periods. Causation from base money and broad money was found in the 1981 to 1989 period. Causation was found also to run from prices to broad money and M2. Ganga(1992) found no causal relation between prices, money supply and exchange rate using annual data from 1970 to 1990. Using monthly data from December 1990 to February 1992, however, he found significant unidirectional causality from money supply and exchange rate to prices.

The foregoing would suggest that whilst certain variables have relatively more influence on the behaviour of prices, the theoretical postulate underlying the behaviour of prices in the Jamaican economy remains partially obscure as the precise causal relations still require further analysis. VAR models as proposed by Sims(1980) circumvent these problems *initially,* as they do not impose strict theoretical priors. That is, VARs avoid any *a priori* endo-exogenous division of variables, consequently the Sims methodology is often referred to atheoretical macroeconometrics. For short run forecasting purposes this approach avoids the need for explicitly forecasting the exogenous variables, a limitation of conventional models.

Empirical Methodology

VAR modelling has its theoretical genesis in the time series analysis of Wold Taio, Box and Jenkins. They basically modeled the moving average and autoregressive components of a time series, which can then be used to predict future movements in the variables. The most widely used model was the Box and Jenkins autoregressive integrated moving average (ARIMA) models.

If x_t is a stationary variable, the moving average process of order p, MA(p), ignoring the deterministic component, is

$$x_t = \varepsilon_t - \phi_1 \varepsilon_{t-1} + \phi_2 \varepsilon_{t-2} + \ldots\ldots - \phi_q \varepsilon_{t-q}$$

$$= (1 - \phi_1 L - \phi_2 L^2 - \ldots\ldots + \phi_p L^q) \varepsilon_t$$

$$= \phi_q (L) \varepsilon_t \qquad [1]$$

where L is the log operator and ε_t is the white noise error. Thus ε_t is expressed as the weighted sum of random shocks. The AR representation is

$$x_t = \alpha_1 x_{t-1} + \alpha_2 x_{t-2} + \ldots\ldots - \alpha_p x_{t-p} + \varepsilon_t$$

This can be expressed in terms of the random shocks to x_t where

$$\varepsilon_t = x_t - \alpha_1 x_{t-1} - \alpha_2 x_{t-2} - \ldots\ldots - \alpha_p x_{t-p}$$

$$= (1 - \alpha_1 L - \alpha_2 L^2 + \ldots\ldots + \alpha_p L^p) x_t$$

$$= \alpha_p (L) x_t \qquad [2]$$

Substituting [2] into [1] we obtain an ARMA(p q) model.

Suppose we have a dependent variable in the form

$$y_t = y_{t-i} + x_t$$

Then this is equivalent to

$$(1 - L)^d y_t = x_t \qquad [3]$$

which is stationary, where d denotes the amount of time y_t would have to be differenced for stationarity to hold. But since x_t follows an ARMA (p q) process then equation [3] can be written as an ARIMA(p, d, q) model by combining equations [1], [2] and [3]. i.e.

$$(1 - L)^d y_t = \frac{\phi_q(L)}{\alpha_p(L)} \varepsilon_t$$

Thus y_t is given as a function of its own lags and a series of innovations in x_t.

VAR models extend this by incorporating similar expressions for x_t (i.e. x_t becomes endogenous), thus forming a system of equations. In matrix form the VAR model is

$$Y_t = AY_{t-1} + e_t \qquad [4]$$

where Y is a vector of variables (y and x in the case above) and A is a matrix of polynomials in the lag operator and e_t is a vector of random errors. Therefore VAR models are simple multivariate models in which each variable is explained by its own past values and the current and past values of all other variables in the system.

Much of the appeal of VAR stems from Sims (1980) critique of structural models. He basically questioned the theoretical validity of the restrictions imposed on the structural models of the time. Sims favoured an atheoretical approach to modelling based on vector autoregressions, in which the data generation process determines the model.

Therefore we may start from a structural hypothesis or model in matrix form such that

$$HY_t + JX_t = k\varepsilon_{it} \qquad [5]$$

and $E(\varepsilon_{it}\, \varepsilon'_{it}) = I$ (i.e. the errors are homoskedastic). Y and X are vectors of endogenous and exogenous variables respectively. If we endogenize the X matrix, we can

Janus quotient (J). The Janus quotient looks at the predictive accuracy of the out of sample predictions against the within sample fit. It is given as.

$$J^2 = \frac{\sum_{i=n+1}^{n+m} (P_i - A_i)^2 / m}{\sum_{i=1}^{n} (P_i - A_i)^2 / n}$$

The numerator gives the deviations in the out of sample period whilst the denominator gives the deviations over the sample period. The higher its value the poorer the forecasting performance. If the structure of the model remains constant over the out of sample period then J tends to one. Thus values greater than one indicates the presence of some structural change. This statistic and its interpretation are affected by the size of the out of sample period.

The VAR model has the lowest mean square error in the predictions. Correspondingly it possesses the greatest predictive power as evidenced by the Theil U statistics. The ECM is only marginally better than the ARMA model in terms its forecasting accuracy. Whilst the J-statistic for the VAR model is acceptable (at this point), the ECM exhibits the greatest structural stability. The other models are highly unstable. This highlights the important point that VAR models are suited for short-term forecasting (one to two years). Medium to long term forecast horizons require the use of models such as error correction models.

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Instead the response to shocks can be assessed using innovation analysis This involves using the Ω matrix to generate variance decompositions and impulse response functions. This however depends on the causal order of the impact or the transmission mechanism. Sims proposed ordering the variables from the most pervasive, in which the shocks to the variables have an immediate impact on all other variables in the system, to the least pervasive. In practice, ordering is done by a Choleski decomposition of the covariance matrix Ω. This produces a lower triangular matrix such that $\Omega = \lambda\lambda'$ holds, where $\lambda = H^{-1}{}_{t}\, k$. This allows the effects of shocks to each variable in the system to be identified. In which case they can then be interpreted as structural shocks. In the case where the possible number of orderings maybe large, 'structural' VAR (SVAR) models have been proposed in which economic theory is used to determine the order.

The exercise will therefore involve the estimation of a compact reduce form system explaining the predictable co-movements amongst the variables. The unexplained portion, is then given a structural interpretation, in the framework of a SVAR, whereby identifying assumptions are placed on the pattern of correlations among the residuals.

The main problem with estimating VARs however, is that the number of variables and lags may lead to over parametization. This causes multicollinearity between the different lagged variables and poor out of sample forecasts (although the within sample fit maybe good). Bayesian vector autoregression (BVAR) has been used to overcome this. Also Gilbert (1995) has suggested combination of VAR estimation and state space model reduction techniques in determining the model.

Alternatively minimizing the Schwartz criterion given as

$$sc = T\ln\hat{\sigma}^2 + n\ln T$$

can be used to reduce the parameters. This paper along with using the Schwartz criterion will employ a likelihood ratio test which tests the appropriateness of one lag length over another. If Ω^* is a M*M covariance matrix based on a lag length 'p', and Ω is a contending residual covariance matrix of lag length 'p-i', then the likelihood ratio statistic is given as

$$\lambda = T(\ln|\Omega| - \ln|\Omega^*|)$$

where T is the number of observations and $\ln|\Omega|$ represents the log determinant of the matrix. T is modified by a multiplier correction, which simply adjusts the statistics according to the sample size. This can be used to test the hypothesis that the coefficients of the i lags are zero. It is distributed χ^2 with M^2 degrees of freedom.

This test is applied iteratively until the most appropriate lag, given the data generation process, is obtained. In the first stage, a hypothetical lag structure[5] is assumed, which is then tested against an alternative to derive an initial lag length. This is then tested against smaller alternatives. The process is repeated until the most suitable length is found.

Cointegration and Error Correction

Traditional economic theory has been applied on the assumption that economic series have a constant mean and finite variance. That is, the variables are stationary. (A non-stationary series on the other hand is characterized by a time-varying mean or variance, and thus any reference to it must be within a particular time frame.) In practice, however, most economic series are not stationary and consequently OLS estimation will lead to spurious results. Recent developments however, notably Engle and Granger (1987), have

[5] This is essentially an unresticted VAR.

shown that OLS estimation may still be valid if a linear combination of any non-stationary series is stationary. In which case the variables are said to be cointegrated.[6]

If the variables are stationary then the VAR can be estimated, in which case any shock to the stationary variables will be temporary. If the variables are nonstationary and not cointegrated, then they have to be transformed into stationary variables by differencing, before the VAR can be estimated. Shocks to the differenced variables will have a temporary effect on the growth rate but a permanent effect on its level. Cointegrated non-stationary variables require the inclusion of a vector of cointegrating residuals (adjustment matrix) in the VAR with differenced variables. This is known as a vector error correction model (VECM).[7] This is necessary as the Granger Representation Theorem notes that cointegrated variables are related through an error correction mechanism.

To test for stationarity[8] or the absence of unit roots, an alternate test for unit roots developed by Phillips and Peron(1988) is used. Consider the autoregressive model

$$y_t = \rho y_{t-1} + \varepsilon_t \qquad t = 1,2.......$$

In the limit, the time series y_t converges to a stationary series if and only if $|\rho| < 1$.

If $|\rho| = 1$, the series is not stationary with its variance being a function of time t. The series is said to follow a random walk or possess a unit root. If $|\rho| > 1$, the series is also non-stationary with its variance increasing exponentially as time passes, that is the series explodes.

[6] Please see K. Holden , and J. Thompson , **Co-Integration: An Introductory Survey**. British Review of Economic Issues June 1992, for a simple overview of stationarity and cointegration theory.

[7] Testing and analysing cointegration in a VAR model is often considered more robust than the Engle - Granger single equation method. See S. Johansen (1991), **Estimation and Hypothesis Testing of Cointegration Vectors in Gaussian Vector Autoregressive Models**. Econometrica 59.

[8] See T. Agbeyegbe(1996) for a discussion on testing for stationarity in inflation.

The Phillips-Perron test, like the Dickey-Fuller test, tests the hypothesis that $\rho = 1$ in the equation

$$\Delta y_t = \mu_t + \rho y_{t-1} + \varepsilon_t$$

Unlike the ADF test, there are no lagged difference terms on the left hand side. The equation is estimated by ordinary least squares and then the t-statistic of the coefficient is corrected for serial correlation, using the Newey-West procedure. All that is required is to specify the autoregressive structure to be used by the Newy-West procedure. This yields the Z_t statistic, where

$$Z_t = (\sum_{2}^{T} y^2_{t-1})^{0.5} (\rho - 1) s^{-1}_{Tl} - (0.5)(s^2_{Tl} - s^2_{k})[s_{Tl}(T^{-2} \sum y^2_{t-1})^{0.5}]^{-1}$$

and

$$s^2_k = T^{-1} \sum_{2}^{T} y^2_t$$

$$s^2_{Tl} = T^{-1} \sum_{1}^{T} y^2_t + 2 T^{-1} \sum_{s=1}^{l} w_{sl} \sum_{t=s+1}^{T} y_t y_{t-s}$$

for some choice of lag window such as $w_{sl} = 1 - s/(l+1)$

Variable Selection

The previous discussions on inflation and recent empirical work suggest that both monetary and to a lesser extent structural variables are relevant to the model. For parsimony however the variables selected are the logs of the consumer price index(CPI) (in which case the difference gives the inflation rate), exchange rate (xrate), gross domestic product (GDP), imported price index[9] (ipi) to capture imported inflation, interest rate on Jamaican treasury bills (ijt) and the money base (bm). Imported inflation and

[9] Imported inflation is derived from an imported price index, which is a weighted average of the export prices of the major trading partners and the price of oil.

GDP represent the structural influences on inflation whilst the interest rate on treasury bills and base money represents the monetary policy stance.

Block exogeneity tests are used to determine how these variables enter the model. Block -exogeneity tests are the multivariate generalization of the Granger causality tests. It has as its null hypothesis, that the lags of a set or block of variables do not enter the equations of the other variables, and thus it is exogenous to the model.

It maybe argued that some measure of fiscal policy, such as the deficit or central bank advances to government, should be included. However to attain parsimony such variables are excluded. Further, it can be shown that changes in base money do capture fiscal policy influences.

Results

Table i shows the results of the unit root tests with the 5% Mackinnon critical values. The table shows that all the variables are non-stationary, specifically, the variables are I(1). Consequently they have to be differenced once to become stationary. Further Table ii shows the results of the Johansen tests for cointegration amongst the variables. The results indicate that there are at most two cointegrating vectors.

Table i

Phillips-Peron Unit Root Test

Variable	Level	1st Difference
LCPI	-1.25	- 7.82
LGDP	-2.19	-10.77
LIPI	-1.39	-13.42
LXRATE	-2.31	- 9.37
LBM	-3.21	-16.25
LIIT	-3.25	-10.38

MacKinnon 5% critical value = -3.4344

Table ii

Johansen Cointegration Test

	Eigenvalue	Likelihood Ratio	5% Critical value	1% Critical value
r = 0	0.274	149.4	102.1	111.01**
r ≤ 1	0.189	89.6	76.1	84.45 **
r ≤ 2	0.135	50.4	53.1	60.16
r ≤ 3	0.068	23.6	34.9	41.07
r ≤ 4	0.036	10.1	19.9	24.60
r ≤ 5	0.017	3.3	9.2	12.97

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

Given the above results a VECM was estimated. Because we are using monthly data an initial lag length of twelve lags (unrestricted VAR) versus smaller lags VARs was tested. Initially the Likelihood ratio favoured seven lags chosen. Further iterations however based on the likelihood ratio and the Schwartz criterion favoured a four lag VAR[10].

The block exogeneity tests indicated that base money, interest rate, exchange rate and gross domestic product should enter the model at four lags. This would suggest that Granger causality runs from these variables to the inflation rate. The most significant variables were base money and exchange rates. The evidence for imported inflation was weak. It was replaced by wages, however the out of sample forecasting accuracy of the VECM declined significantly. This is probably the result of a poor monthly wage series. Imported inflation, to the extent that its impact would reflect structural influences, was therefore retained in the model.

The full VECM results are given in Appendix ii.

Forecasts

Figure viii shows the actual versus the fitted values (within sample) for the inflation rate. Table iii gives a comparison of the forecasting accuracy of the VAR model against an ARMA(4, 3) , Ganga's monthly model and the monthly version of Worrell's (1993) model. The criteria used are the root mean square error RMSE, Theil U statistics and the

[10] The Likelihood Ratio for twelve versus seven lags was χ^2 (112) = 91.1 with a significance level of 0.9267. At Four lags the Likelihood Ratio χ^2 (64)= 62.32 with a significance level of 0.536. We therefore cannot reject the null hypothesis that the restrictions hold, and thus conclude that four lags are sufficient.

Janus quotient (J). The Janus quotient looks at the predictive accuracy of the out of sample predictions against the within sample fit. It is given as,

$$J^2 = \frac{\sum_{i=n+1}^{n+m} (P_i - A_i)^2 / m}{\sum_{i=1}^{n} (P_i - A_i)^2 / n}$$

The numerator gives the deviations in the out of sample period whilst the denominator gives the deviations over the sample period. The higher its value the poorer the forecasting performance. If the structure of the model remains constant over the out of sample period then J tends to one. Thus values greater than one indicates the presence of some structural change. This statistic and its interpretation are affected by the size of the out of sample period.

The VAR model has the lowest mean square error in the predictions. Correspondingly it possesses the greatest predictive power as evidenced by the Theil U statistics. The ECM is only marginally better than the ARMA model in terms its forecasting accuracy. Whilst the J-statistic for the VAR model is acceptable (at this point), the ECM exhibits the greatest structural stability. The other models are highly unstable. This highlights the important point that VAR models are suited for short-term forecasting (one to two years). Medium to long term forecast horizons require the use of models such as error correction models.

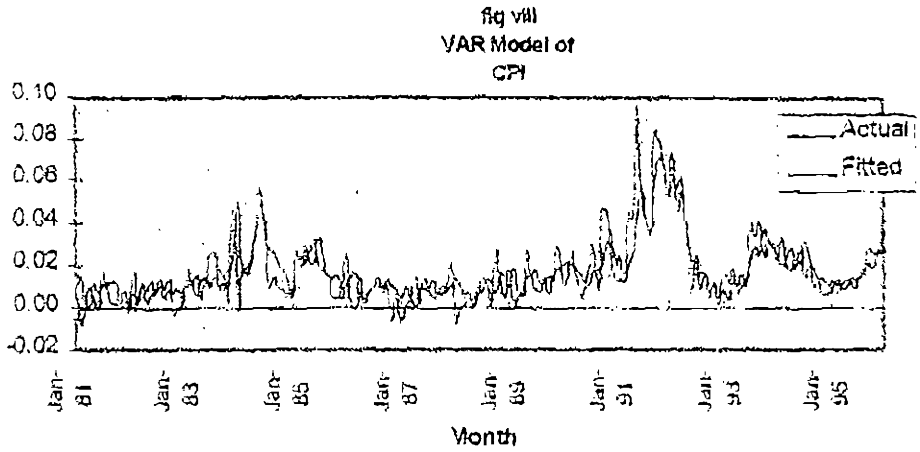


Table iii

Model	RMSE	Theil U	J
VAR	0.004	0.18	0.34
ARMA	0.008	0.38	5.22
ECM	0.009	0.35	0.90
GANGA	0.036	1.70	2.40

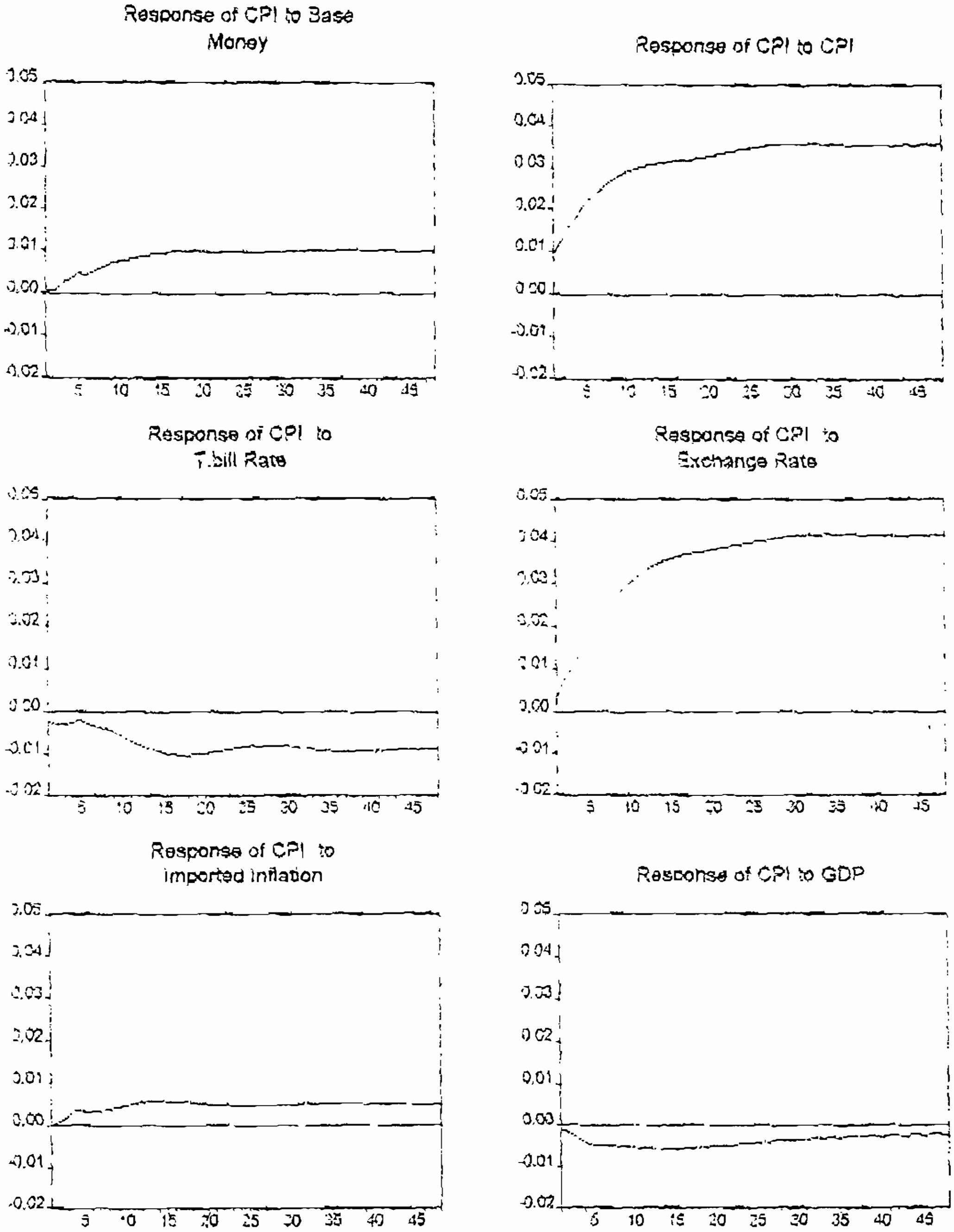
Impulse Response and Variance Decomposition

This section analyses the dynamic property of the model using variance decomposition and impulse response functions. Figure vii shows the response of the inflation rate to a one unit shock to the exchange rate, base money, treasury bill rate, imported inflation and output. The x-axis gives the time horizon or the duration of the shock whilst the y-axis gives the direction and intensity of the impulse or the percent variation in the dependent variable (since we are using logs) away from its base line level.

The impulse responses meet *a priori* expectations in terms of the direction of impact. The graphs show that a positive shock to monetary variables or expansionary monetary policy, has a significant expansionary effect on inflation. *The effect of a unit shock to base money on the inflation rate, occurs after approximately the first one to two months and reaching its peak between ten to twelve months.* Thereafter the cumulative effects of base money stabilize with the monthly inflation rate accelerating by approximately one percent of its baseline level. What is puzzling is that there is no tendency for the impulse generated by a unit shock to the money base to fade.

The impact of the exchange rate is rather immediate and long lasting. A unit shock to the exchange rate causes the inflation rate in the first period to deviate by approximately 0.5 percent from its base level. There is no indication of a tapering off (even over longer horizons), instead the inflation rate accelerates rather rapidly in the first ten to twelve months as it tends to a new equilibrium level. *Increases in the interest rates tend to have a contractionary effect on prices.*

fig vii
Response of CPI to One S.D. Innovations



The more significant impact however manifests itself after five months with the response function trending from zero.

The response of direct shocks to the inflation CPI such as expectations and discrete price adjustments resulting from increase markups, removal of subsidies, etc. follows a similar path to the response to exchange rate shocks. The magnitude of the impact of direct shocks, particularly in the first period, is greater for direct shocks to the CPI. The similarity in the paths may stem from the fact that both sources represent some cost push element. The impulse response of CPI to its own innovation however does highlight the role of expectations and the price setting mechanism which includes indexation.

Increases in output do have a significant contractionary effect although this seems to be temporary as there is a tendency for inflation to return to its previous level in the long run. (This may support the monetarist position that in the long run the price level is determined by changes in the money supply.) Imported inflation exerts a positive influence after the second month. The impact seems to be long lived. This is due to the open nature of the economy and the extent to which domestic production relies on foreign inputs.

The foregoing indicates that both cost push and demand pull elements help to explain prices. Having shown the dynamic effects of each disturbance however the next step is to assess their relative contribution to the fluctuations in prices. This is done by decomposing the forecast variance of the inflation rate over different horizons.

Table iv shows the variance decomposition over the short term (6 months), medium term (12 - 24 months) and over the long term (48 months). The statistics indicate the percentage contribution of innovations in each of the variables in the system to the variance of the CPI.

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Table iv

Variance Decomposition of the CPI (%)

Horizon	Base Money	CPI	IJT	Ex.Rate	IPI	GDP
6 mths	1.964	65.239	1.028	29.065	1.4401	1.214
12 mths	3.724	59.966	1.325	31.585	1.931	1.469
24 mths	4.949	55.068	3.121	31.384	2.757	2.719
48 mths	5.257	52.967	3.716	31.654	2.92	3.487

The results show that shocks to the CPI itself and the exchange rate accounts for most of the variability in the CPI over all horizons. Not much can be attributed to base money, although over longer horizons its relative contribution increases. More importantly, the variance decomposition of the exchange rate (Table v) shows that apart from innovations to the exchange rate itself, base money contributes significantly to the variations in the exchange rate. This supports Ghartey (1995) assessment. *We can conclude that the basic transmission mechanism runs from base money (via interest rates which affect the relative return on financial assets) to the exchange rate and then to prices.*

Table v

Variance Decomposition of the Exchange Rate (%)

Horizon	Base Money	CPI	LJT	Ex.Rate	IPI	GDP
6 mths	7.024	2.538	1.626	36.771	0.742	1.3
12 mths	8.414	6.361	5.889	73.484	2.177	3.674
24 mths	8.420	7.687	7.226	68.774	2.315	5.576
48 mths	8.43	8.9	7.511	66.245	2.399	6.417

Further the greater contribution of innovations in the exchange rate in Table v suggests that much of its volatility is the result of exchange rate speculation (even in the long run). One will also note the increasing contribution of the CPI over time. This maybe reflecting the long run phenomena of purchasing power parity (i.e feedback from the CPI to the exchange rate).

Conclusion

The foregoing points to increased forecasting accuracy when a VAR is applied as against other models. VARs avoid the need for an explicit theory (in the initial stages) and information on the exogenous variables over the forecast period. The foregoing results and the experience of a number of economists using VARs however, suggest that VARs are more suited for short term forecasting. Simultaneous and single equation error correction models are more appropriate for longer horizons.

When applied to price behaviour in Jamaica, the VAR model revealed some interesting, though not surprising results, not readily seen with other conventional models. The innovation analysis showed that a positive shock to monetary variables or expansionary monetary policy has an unambiguous expansionary effect on prices. Assuming asymmetry, the response functions indicate that contractionary policy has a lag effect of 'at least' two months. Further, a decline in the rate of depreciation of the exchange rate will have an immediate dampening effect on prices, particularly in the first twelve months. The response to exchange rate shocks suggests that exchange rate stabilization maybe the most effective way of achieving price stability in the short run. The results of the variance decomposition suggest that monetary stability and the development of an efficient market are essential to exchange rate stability.

The results show that the inflation rate does not return to its original level as there is a tendency for inflationary shocks to be long lived. These shocks maybe perpetuated by the nature of the stabilization process, the structure of the economy, the production function, indexation and other institutional factors. Other factors such as the pricing mechanism, expectations and exchange rate speculation, which are captured in the own innovations of the CPI and exchange rate are also very significant and create very strong inertial tendencies. Stabilization policies must therefore be cognizant of these influences which frustrate the stabilization process.

Appendix i : VECM results

	Δlbm	Δlcpi	Δlijt	Δlxrate	Δlipi	Δlgdp
CointEq1	-0.075302	0.002964	0.146435	0.044753	-0.020258	-0.000165
Δlbm_{-1}	-0.245188	-0.011797	-0.147164	-0.030756	0.025457	-0.005908
Δlbm_{-2}	-0.159482	0.024389	-0.306856	0.020044	-0.031585	-0.004351
Δlbm_{-3}	-0.108646	-0.001719	-0.051006	-0.028488	-0.016533	0.003347
Δlbm_{-4}	-0.100600	0.012345	0.065615	0.049860	0.009226	-0.004181
$\Delta lcpi_{-1}$	-1.142976	1.463842	1.368287	-0.345637	0.115232	-0.015698
$\Delta lcpi_{-2}$	0.280319	0.267643	-0.629099	0.765135	-0.578186	-0.005017
$\Delta lcpi_{-3}$	-1.001608	-0.034955	1.396298	-0.369185	0.638502	-0.014165
$\Delta lcpi_{-4}$	0.409937	0.130851	0.395987	1.161784	-0.253843	0.016390
$\Delta lijt_{-1}$	-0.022102	- 0.010753	0.217460	0.048805	-0.005227	0.001611
$\Delta lijt_{-2}$	-0.006775	0.015486	0.170529	0.046596	-0.037137	-0.000613
$\Delta lijt_{-3}$	-0.069554	0.019427	0.175152	0.018287	-0.022962	-0.000386
$\Delta lijt_{-4}$	0.016762	0.004149	0.029963	-0.063263	-0.038822	-0.001489
$\Delta lxrate_{-1}$	0.198067	0.083270	-0.078436	0.475685	-0.064791	0.001006
$\Delta lxrate_{-2}$	-0.187667	- 0.021281	0.485300	-0.246506	0.069509	-0.000535
$\Delta lxrate_{-3}$	0.204625	0.029813	-0.034734	0.210878	-0.048689	-0.000745
$\Delta lxrate_{-4}$	0.239359	- 0.010273	-0.025574	-0.014115	-0.012678	-0.000120
$\Delta lipi_{-1}$	-0.102374	0.021819	-0.074585	-0.041263	0.147815	-0.001770
$\Delta lipi_{-2}$	0.152281	0.012038	-0.144849	0.059797	-0.108635	0.004301
$\Delta lipi_{-3}$	0.085430	0.018808	-0.136377	-0.054082	-0.082120	-0.000415
$\Delta lipi_{-4}$	-0.019440	- 0.022786	-0.094716	-0.021551	-0.149414	0.000587
$\Delta lgdp_{-1}$	-1.736537	- 0.185210	-0.960204	-0.269209	1.290785	0.379184
$\Delta lgdp_{-2}$	2.209432	- 0.245179	5.805997	0.292302	0.236400	0.169180
$\Delta lgdp_{-3}$	-5.666179	0.104583	-0.017186	-0.367664	-0.228389	0.095328
$\Delta lgdp_{-4}$	-1.217771	0.326404	-2.090249	0.498937	2.037606	-0.005652
C	0.065352	0.002740	-0.037944	-0.011772	0.001324	0.001177
Adj. R-squared	0.175903	0.535369	0.283515	0.259193	-0.005172	0.330951
Akaike AIC	-5.502484	-8.813576	-5.141707	-6.178165	-5.859293	-12.00361
Schwartz SC	-5.05323	-8.364331	-4.692462	-5.728920	-5.410048	-11.55437