

# Monetary Policy Effects in a Regime Switching Model

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# Abstract

The paper undertakes an assessment of the impact of monetary policy shocks in Jamaica on key macroeconomic variables under three monetary policy stances (or regimes); tight, neutral or loose. This paper complements from previous assessments of non-linearity in the monetary transmission mechanism for Jamaica by exposing the existence of regime switching behaviour associated with monetary policy stance. The method utilized in this study is a threshold vector autoregression (TVAR) model, which allows for the flexibility of the parameters under differing regimes. The results for Jamaica revealed that the effects of monetary transmission to inflation and exchange rate differed depending on whether the central bank is in in a neutral or intervention policy stance. Output proves to be less affected under loose monetary policy stance than in neutral and tight stances. This result proved consistent in part to the study conducted by Choi (1999) on United Sates of America (USA) which found that the liquidity and inflation effects of a monetary policy shock varied across the three regimes.

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<sup>\*</sup>The views and results expressed in this paper represent those of the authors and not necessarily those of the Bank of Jamaica.

# **1.0** Introduction

Research on the monetary transmission mechanism for Jamaica has been a crucial tool in the central bank's attempt to implement effective monetary policy. In Jamaica, the Bank of Jamaica (BOJ) is charged with the responsibility of implementing and managing monetary policy. The Bank's policy objective and policy tools have evolved over the years to reflect a move towards more effective monetary policy. In more recent years the Bank has moved from directly targeting the supply of money to focus on such variables as the policy rate, the 30-day certificate of deposit rate, open market operations and commercial banks' reserve requirement. The Bank of Jamaica in pursuing a policy of low and stable inflation, has embarked on a process for transition to inflation targeting. Research conducted by (Robinson & Robinson, 1997), identify the process by which changes in monetary policy affect macroeconomic variables in Jamaica, specifically, the rate of inflation in the domestic economy. They identify a mechanism which starts from the setting of the bank's policy instrument, the short-term interest rate, to the commercial bank's interest rate, exchange rate which accounts for direct and indirect effect on inflation whereas the indirect channel is through the impact on aggregate demand. A similar transmission process is identified by (Allen & Robinson, 2004); however, there remains a debate as to the number of periods after which a chance in policy may feed through to inflation.

While the literature on the transmission mechanism and the effect of monetary policy in a single regime model abounds, there has been no research investigating the influence of the response to policy under multiple regimes. The paper seeks to do this by examining a regime-dependent model in the form of a threshold vector auto-regression model (TVAR) for the case of Jamaica. This accounts for three monetary policy stances classified as tight, neutral and loose. The study reveals evidence of asymmetric response among agents to monetary policy actions depending on the prevailing monetary policy stance.

The remainder of the paper is organized as follows: Section 2 reviews the existing literature on the effect of monetary policy, in both single and multiple regime models; Section 3 describes the data and presents the econometric methodology; Sections 4 presents further details on the model estimation and results; and Section 5 presents the summary, highlight the policy implications and provides recommendations for further studies.

# 2.0 Literature Review

To effectively implement monetary policy, it crucial to understand the alternate response that may arise depending on the state of monetary policy stance as well as the effect from alternative economic states. As it relates to differing economic states, research conducted by (Mitchell & Robinson, 2009) for the case of Jamaica, reveal that the price and output response to monetary and interest rate shocks clearly exhibits non-linear responses during periods of low and high inflation. Using a logistic smooth transition VAR (Mitchell & Robinson, 2009) demonstrated that the transmission mechanism will reveal a stronger effect of monetary policy action on inflation and output in conditions of low inflation. In specifying the logistic Smooth Transition VAR, the model incorporated feedback from interest rates and money supply on exchange rates, output and prices. The evidence supplied by (Mitchell & Robinson, 2009) confirms the existence of state dependent asymmetric response to monetary policy action and calls for further investigation into the nature and nuances of non-linear interactions that must be considered in the implementation of monetary policy.

The literature on the effect of monetary policy can be traced back to the earlier studies on the transmission mechanism of monetary policy to inflation. This transmission mechanism involves a chain of events that starts from the setting of the bank's policy interest rate, to commercial bank's interest rate, to the exchange rate and later to inflation and aggregate demand. For Jamaica, the transmission of monetary policy has been found to be influenced by the state of the financial system, expectations, and other structural variables that impact the final target inflation (Robinson & Robinson, 1997).

Estimation of the impact of monetary policy on macroeconomic variables is of great importance to policy makers and economists. As such much work has focused on the transmission of monetary policy. In the United States of America (USA) for which there is a myriad of literature seeking to address this is, there is still no consensus on the mechanism and the exact effect of monetary policy shocks on macroeconomic variables. Numerous empirical studies suggest that a 1.0 per cent change in the policy rate in the USA usually leads to 0.5 per cent to 1.0 per cent change in prices and output.

(Bernanke & Blinder, 1992) and (Sims, 1992) were among the first to employ a vector autoregressive (VAR) method to measure the effect of monetary policy innovations on macroeconomic variables. This approach has been extensively adopted given its advantage over traditional methods such as that utilized by (Cagan & Gandolfi, 1969) who measure the liquidity effect by regressing the change in interest rate on current and past money growth. This single equation analysis was unable to capture the endogeneity of the money supply under the Federal Reserve's (FED) interest rate targeting (Choi, 1999). Although the VAR approach delivered quite useful information the approach has come under much criticism. One flaw in the approach highlighted by (Bernanke, Boivin, & Eliasz, 2005), is that the "standard VAR approach addresses only the effects of unanticipated changes in monetary policy, not the arguably more important effects of the systematic portion of monetary policy or the choice of monetary policy rule." Most of this criticism, however, has centred on the limited number of variables used in the estimation. In an aim to address these drawbacks (Bernanke, Boivin, & Eliasz, 2005) estimated a factor augmented VAR (FVAR) which allowed for the use of a wide range of USA data.

Although throughout the literature there has been pervasive use of interest rates as the key policy tool in estimation some authors have investigated or incorporated other policy tools such as quantitative easing (QE). (Cloyne & Huertgen, 2014) explain that while "the effect of unconventional measures is clearly an important topic in its own right, interest rates still remain a key policy instrument." Similarly for Jamaica, interest rate would be the most likely instrument under investigation. One example of this alternative approach, the narrative approach, introduced by (Romer & Romer, 2004) provide qualitative indicators of the FED's policy stance based on reading from the FED's Open Market Committee documents in the USA. This again might be a less suitable approach for use in Jamaica due to the country's less developed systems and inferior quality of communication. The method provided significantly larger effects than the VAR and FVAR methods previously mentioned. For example, in their baseline ADL specification industrial production fell by 4.3 per cent while the level of consumer prices fell by 3.6 per cent.

(Kuttner, 2001); (Faust, Swanson, & and Wright, 2004); (Bernanke & Kuttner, 2005); (Gürkaynak, Sack, & Swanson, 2005); (Barakchian & Crowe, 2013) and Wingender (2011) have attempted to isolate surprises in monetary policy from forward looking financial market data. (Barakchian &

Crowe, 2013) particularly have constructed a measure of policy surprises based on Fed Funds Futures. Using this measure in a VAR model, the authors report that a 1.0 per cent monetary contraction causes a fall in industrial production of around 0.9 per cent, although a small 'price puzzle' emerges. Using historical Bank of England (BOE) data (Cloyne & Huertgen, 2014) recreated historical BOE forecasts, private sector forecasts and real-time data. This was used rather than ex-post data which were not the actually available to policymakers at the time of their decision. The difference was shown to potentially have significant effect on the estimates of the response of monetary policy to macroeconomic (Orphanides, 2001). Following the approach of (Romer & Romer, 2004) they were able to solve the 'price puzzle' and show that a 1.0 per cent contractionary shock to the policy rate leads to a ultimate decline in output of 0.6 per cent and a 1 per cent fall in inflation.

Another segment of the literature focuses on monetary and fiscal regimes that evolve according to a Markov process in a dynamic stochastic general equilibrium model (Chung, Davig, & Leeper, 2004). They consider two regimes; one in which the Taylor rule for interest rates hold and the central bank adjust the short-term nominal interest rate in response to fluctuations in inflation and output; and a second regime in which the Taylor rule fails to hold.<sup>1</sup> The study, however, treats the policy behaviour as exogenous. In light of the inconsistency of such an empirical treatment with theory, (Davig & Leeper, 2006) make the regime changes endogenous. The approach revealed that expectations formation effects are quantitatively important and symmetric policy shocks can produce asymmetric effects. Such studies would be able to identify the effects of the choice of monetary policy rule that could not be identified by the single regime VAR model utilized by (Bernanke & Blinder, 1992), (Sims, 1992) and (Bernanke, Boivin, & Eliasz, 2005).

Another seminal work by (Choi, 1999) estimated a regime-dependent reduced form VAR model that also allows for changes (or flexibility) of the parameters. The study differs from the previously mentioned regime models as it examines three regimes/states of monetary policy stance: tight, neutral and loose using a threshold VAR model instead of a Markov switching process. In this

<sup>&</sup>lt;sup>1</sup> Davig and Leeper (2006) consider two policy regimes; first if the inflation rate is less than some threshold value,  $\pi^*$  at time *t*-1 the usual Taylor rule applies. If, however, inflation equals or exceeds this value a more aggressive policy stance is implemented at time *t*.

case the tight or loose regimes would imply the authorities undertake an interventionist approach, while a neutral regime implies otherwise. The aim is to also account for the role of agents' response in measuring monetary effects on interest rates. Prior to the estimation of the model an index of the FED's policy stance classifying states as tight, neutral or loose is generated using the multiple-indicator multiple-cause (MIMC) model introduced by (Hauser & Goldberger, 1971) and (Avery, 1979). Studies done by (Bernanke & Blinder, 1992) and (Christiano, Eichenbaum, & C, 1996) employed quantitative measures such as the spread between the federal funds rate and long term bond rate or the spread between the six-month commercial paper rate and the Treasury bill rate (Stock & Watson, 1989). These methods, however, capture both the unanticipated and anticipated components of monetary policy and thus anticipated monetary policy has to be abstracted from these measures. (Cloyne & Huertgen, 2014), however, note that the studying countries such as the United Kingdom (UK) have an advantage in that the Bank of England's policy rate is the intended policy target rate. Subsequent to the estimation of the model, the stability of the parameters across regimes is examined. Next, the impulse responses of interest rate, inflation and output growth to a monetary policy shock under each regime are investigated.

## **3.0** Methodology

The estimation methodology consists of three key steps; first an indicator for the monetary policy stance is generated and the threshold values identified, then the index is then used to estimate the threshold autoregressive model (TVAR). Finally, the impulse response functions for key macroeconomic variables, to a one standard deviation monetary policy shock under each regime is generated.

### 3.1 The Monetary Policy Stance Index

Previous studies have utilized indicators such as the spread between the federal funds rate and the long term bond rate or just the federal funds rate. Others have used the spread between the six-month commercial paper rate and the six-month Treasury bill rate. For this paper the treasury bill rates have been used as a proxy for the Bank of Jamaica's (BOJ) policy rate, the 30-day certificate

of deposit (CD) rate, given that these rates typically track the policy rate closely.<sup>2</sup> Additional indicators such as the spread between 30 and 180 day T-bill, the spread between 30-day and Interbank lending rate as well as the excess cash reserve and the reserve requirement ratio are included for robustness and in keeping with the fact that a single indicator of the Central Bank's policy stance is unable to completely measure the central bank's monetary policy stance as demonstrated by (Avery, 1979) and (Bernanke & Blinder, 1992).<sup>3</sup>

Following the procedure outline by (Choi, 1999) who relied heavily on (Hauser & Goldberger, 1971) multiple-indicator multiple-cause model (MIMC), a measure of the BOJ's policy stance that is anticipated by market participants. This is done by extracting information about the BOJ's unobserved reactionary monetary policy stance from a group of known policy indicators. This is done in conjunction with the targeted economic variables that monetary policy actions are known to have a causal influence.<sup>4</sup> If it is assumed that the monetary authority's unobserved policy stance is a linear function of a vector of observable factors we may express this variable as:

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where y is the is a  $T \times I$  vector of unobservable policy stances, X is a  $T \times k$  matrix of observable variables known to be impacted (or caused) by monetary policy action,  $\gamma$  is a  $k \times I$  parameter vector and u is a  $T \times I$  vector of normally distributed error terms with zero mean. A vector of policy stance indicators is then generated using the results obtained from equation (2).

$Z = y\beta + w$		Equation 2

where Z is a  $T \times q$  matrix of policy indicators,  $\beta$  is a  $T \times 1$  vector of coefficient terms, and w is a  $q \times q$  matrix of error terms. X and Z are then transformed to have standard normal distribution. The y in equation (1) represents the variable of unobserved latent policy stance that is implied by

<sup>&</sup>lt;sup>2</sup> The appropriate proxy to be used is determined by examining the strength of correlation between the Bank's policy instrument and a range of interest rates. The rate that was the most strongly correlated was chosen.

<sup>&</sup>lt;sup>3</sup> As noted before it would be challenging to generate a qualitative measure of the monetary policy stance for Jamaica due to its inferior financial systems and poor communication between market participants.

<sup>&</sup>lt;sup>4</sup> See Avery (1979) and Hauser and Goldberger (1971) for more details.

the causal variables (represented as X). Equation (2) therefore expresses the observable indicators of monetary policy stance (Z) in terms of the unobserved latent monetary policy variable (y). (Hauser & Goldberger, 1971) demonstrates that models of this nature suffer from the problem of over-identification resulting in inefficient estimates from standard regression techniques. However, the Maximum Likelihood technique will numerically generate efficient estimates for which there are known approximations. This paper uses the Generalized Least Squares (GLS) approach to derive parameters that approximate efficient MLE results.<sup>5</sup>

#### 3.2 Monetary Policy in a Regime Switching Model and Impulse Response Functions

After obtaining the MIMC indicator from the MGLS estimation, the second stage of estimation will focus on deriving threshold parameters from a grid search on the policy stance variable (MIMC). Using higher values in the MIMC index to reflect a tighter monetary policy stance, the relevant thresholds can then be represented as:

- (i)  $s_t \in \{tight \ regime\} \ if \ \hat{y_t} > \tau_U;$
- (ii)  $s_t \in \{nuetral \ regime\} \ if \ \tau_L \leq \ \hat{y_t} \geq \ \tau_U;$
- (iii)  $s_t \in \{loose \ regime\} \ if \ \widehat{y_t} \leq \tau_L.$

The threshold values used to identify each regime is determined by employing a grid search as outlined in (Choi, 1999). This is done by generating a vector of threshold values for each regime. This *n* length vector of threshold values consists of a benchmark threshold (which is the mean of the positive values of  $\hat{y}$  for the tight regime and the mean of the negative values of  $\hat{y}$  for loose regimes) and values around the means. The pairwise combination of each of these values forms an  $n \times n$  grid.

Identifying the threshold values  $\tau_U$  and  $\tau_L$  used to distinguish between the policy regimes, allows for the estimation of the Threshold VAR Model (TVAR) as guided by (Zivot & Lo, 2001). In order to capture the regime switching mechanism a TVAR model is estimated using the ordinary least squares method. The model takes the following form:

<sup>&</sup>lt;sup>5</sup> Hauser and Goldberger (1971) demonstrates the use of a Modified Generalized Least Squares (MGLS) in deriving efficient estimates of the parameters used to obtain multiple indicator multiple causal unobservable variables.

$(A_1 + B_1(L)Y_{t-1} + V_{1,t}, if \hat{y}_t > \tau_U)$	Equation 3
$Y_{t} = \left\{ A_{2} + B_{2}(L)Y_{t-1} + V_{2,t},  if \ \tau_{L} \leq \hat{y_{t}} \geq \tau_{U} \right\}$	
$(A_3 + B_3(L)Y_{t-1} + V_{3,t}, if \ \hat{y}_t \le \tau_L)$	

where  $Y_t = (Y_t^1, ..., Y_t^2)'$  is a vector of k variables, L is the lag operator and  $V_{i,t} = (\varepsilon_t^1, ..., \varepsilon_t^2)'$  is a k × 1 vector of error terms. All variables are assumed to be endogenous and the monetary growth dependent on its own past values and other variables while the error terms are assumed to be heteroskedastic across regimes. The impulse response function is then generated and the empirical standard error bounds for the response function obtained using the bootstrap method.<sup>6</sup>

# 4.0 Estimation & Results

#### 4.1 Estimating the Multiple Indicator Multiple Causal (MIMC) Variable

The MIMC indicator was derived from the MGLS estimation of the over identified model specified in Equation 1 and Equation 2 in accordance with the methods employed by (Hauser & Goldberger, 1971). The model included five observable indicators of monetary policy and three (3) causal variables deemed to be influenced by monetary policy actions. The four indicator variables include (i) the changes in the 30-day Treasury Bill rate, (ii) the spread between the 180 day Treasury Bill and the 30 day Treasury bill; (iii) the spread between the annualized intraday trading rate and the 30 day Treasury Bill rate where the former was used to proxy competitive rates that corporate entities would be able to source funding for working capital; (iv) the negative of the per cent changes in excess reserves as a measure of realized adjustments to liquidity conditions and (v) the reserve requirement ratio which is infrequently used by the BOJ to influence liquidity conditions.

The three causal variables used to obtain the latent influence of monetary policy on economic conditions are (i) underlying (core) inflation proxied by monthly per cent changes in the consumer price excluding agriculture and fuel (CPIAF) related price adjustments; (ii) monthly per cent changes in domestic currency depreciation vis-à-vis the USD, considering that a major component of monetary policy action in Jamaica has focused on ensuring orderly developments in the

<sup>&</sup>lt;sup>6</sup> See Runkle (1987).

domestic market for foreign currency; and (iii) monthly changes in the unemployment rate to capture the influence of monetary policy on real economic conditions.

The appropriate lags required to capture latent influence of monetary policy on the causal variables was ascertained from the results of multiple granger causality tests at differing lag lengths (see Table 1). The results showed that 15 months (or 5 quarters) would elapse before interest rate spreads begin to granger cause unemployment and the same for underlying inflation. Additionally, while adjustments to total reserves had no recognizable causal influence on real sector unemployment or inflation, there was a direct causal relationship on exchange rate depreciation within a period of 3 months (or 1 quarter).

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Indicators	Causal Variables	t-3	t-6	t-9	t-12	t-15	t-18	t-21	t-24
Spread	Inflation	0.0455**	0.2288	0.3461	0.3593	0.0048***	0.0001***	0.0002***	0.0000***
T-Bill(30day) - T-Bill(180day)	Unemployment	0.2461	0.1140	0.0252**	0.0567*	0.0370**	0.0204**	0.0224**	0.0417**
- Din(100000)	Depreciation	0.1969	0.4458	0.5496	0.5175	0.1287	0.2393	0.3378	0.3638
Spread	Inflation	0.7604	0.8895	0.9094	0.8364	0.0064***	0.0002***	0.0000***	0.0000***
T-Bill(30day) - Interbank Rate	Unemployment	0.1274	0.0374**	0.0070***	0.0506*	0.0101**	0.0037***	0.0097***	0.0155**
(30day)	Depreciation	0.3525	0.4308	0.6213	0.1895	0.2602	0.4302	0.4951	0.5241
%Change	Inflation	0.6494	0.6378	0.4852	0.6795	0.8550	0.9437	0.9895	0.9846
Total Cash Reserve	Unemployment	0.7697	0.8694	0.9404	0.5993	0.9779	0.8477	0.7757	0.9292
TROCOTIVO	Depreciation	0.0222**	0.1339	0.2839	0.3925	0.5958	0.4661	0.4636	0.5849
Note: Statistical significance at 10% 5% and 1% featured as * ** and *** respectively									

Table 1: Standard Normal Probability Values from Granger Causality Tests for Selected Lags

This implies that monetary policy affecting liquidity conditions are likely to transmit speedily to foreign exchange market developments. In light of the granger causality tests, both the inflation and unemployment causal variables were incorporated with a 5 quarter lag while the exchange rate depreciation was incorporated with a lag of 1 quarter.

All input variables reflect monthly adjustments from which the efficient estimate of the (MIMC) is derived. Figure 1 compares the five (5) indicator variables with the MIMC indicator of monetary policy stance. The indexed MIMC indicator reflected in Figure 2 bears close resemblance to modulations in the 30-day Treasury Bill rate (30dtbill) subsequent to September 2003 immediately following the foreign exchange market instability experienced early in the year. In the preceding

period, this type of co-movement was not observed. Rather, the 30dtbill rate tapered gradually while the MIMC indicator climbed with significant accelerations in the period Mar-2003 to Aug-2003 during the height of the 2003 foreign exchange market instability. The adjustment to exchange rate depreciation observed during the period was captured by the mimic suggesting that liquidity conditions during the period tended towards being tight.



Figure 1: MIMC vs (spread\_180dtbill, spread\_intra, %∆cash-reserve)

Figure 2: MIMC & T-bill(30day) vs Causal Variables (Unemp, Ann.Depre, Ann.Core)



#### 4.2 TVAR Model Estimation and Results

The threshold VAR (TVAR) follows the technique proposed by (Zivot & Lo, 2001) as represented in Equation 3. The structural TVAR is specified in Equation 4 below:

$$\begin{aligned} Y_t &= (A_1 Y_t + B_1(L) Y_{t-1}) I[s_{t-d} \le \tau_L] + (A_1 Y_t + B_1(L) Y_{t-1}) I[\tau_L < s_{t-d} \le \tau_U] \\ &+ (A_3 Y_t + B_3(L) Y_{t-1}) I[s_{t-d} > \tau_U] + \varepsilon_t \end{aligned}$$
 Equation 4

where  $Y_t = (Y_t^1, ..., Y_t^2)'$  is a vector of k endogenous variables; *I* is an indicator function which returns a value one (1) if the system is in the specified regime and zero otherwise;  $A_1$ ,  $A_2$  and  $A_3$ represent simultaneous relationships in the three regimes;  $B_1(L)$ ,  $B_2(L)$ , and  $B_3(L)$  are matrices representing the lag operator;  $\varepsilon_t$  is a vector of shocks to the structural TVAR and  $s_{t-d}$  is the threshold variable, which indicates the economic regime that the system is in, given threshold values  $\tau_L$  and  $\tau_U$ . Prior to estimation it is important to determine the appropriate number of lags of the endogenous variables to be used in the estimation of the TVAR model. The Schrwarz information criteria (SIC) and Hannan-Quinn information criteria (HQ) both indicated that a lag order of one was appropriate in the estimation of all models. This lag order was thus applied across all regimes during estimation.

The structural models used to ascertain the reduced form equation that captures the relationship between monetary policy and the reaction from economic agents are reflected in equations x to y. This structure is consistent with the model proposed by (Choi, 1999) consisting of functions that represent (i) Money Demand that accounts for unitary income elasticity; (ii) a Money Supply rule that is expressed as an AR(1) process incorporating parameters of policy adjustments, (iii) Nominal interest rate Fisher equation accounting for liquidity effects and (iv) Aggregate demand response to both an inflation tax that induces substitution away from money holdings as well as the liquidity effect resulting from adjustments to interest rates.

$m_t - p_t = x_t - aR_t + \xi_t$	Money Demand (MD)	Equation 5
$m_t = \mu_s + m_{t-1} + h_t$	Money Supply (MS)	Equation 6
$h_t = \rho_s h_{t-1} + \eta_t$	MS Autoregressive Policy Transmission	Equation 7
$R_t = E_t(\pi_{t+1}) - b\eta_t$	Fisher Nominal Interest Rate Determination	Equation 8

$x_t = -cE_t(\pi_{t+1}) - d[R_t - E_t(\pi_{t+1})] + \zeta_t$	Aggregate demand response Monetary Policy	Equation 9
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Where  $m_t$  is the stock of money represented in logs,  $p_t$  is the underlying price level in logs and  $x_t$  is the real output level also expressed in logs while  $R_t$  is the of interest in nominal terms. The variables  $\xi_t$ ,  $\eta_t$ ,  $\zeta_t$  represent white noise errors and  $\mu_s$  and  $\rho_s$  reflect policy related parameters.

The variables used to identify the structural model include *indusprod*<sub>t</sub> which represents industrial production; *cpiaf*<sub>t</sub> representing the consumer price index without agriculture and fuel components; *xrate*<sub>t</sub> representing the bilateral exchange rate between Jamaica and the USA expressed as JMD:US\$1.00; *cashres*<sub>t</sub> represents total cash reserves; *tbill*30<sub>t</sub> representing the 30 day treasury bill rate that approximates the banks policy rate; and  $m2_t$  which represents the broad money stock. The ordering of variables used for the TVAR are consistent with those employed by (Choi, 1999).<sup>7</sup> Using the notation dlog to represent the first difference of a variable in logs and d to represent the first difference, the three (3) group of ordered variables include

Model A: { $dlog(indusprod_t)$ ,  $dlog(cpiaf_t)$ ,  $dlog(xrate_t)$ ,  $dlog(cashres_t)$ ,  $d(tbill30_t)$ }, Model B: { $dlog(indusprod_t)$ ,  $dlog(cpiaf_t)$ ,  $dlog(xrate_t)$ , dlog(m2),  $dlog(cashres_t)$ ,  $d(tbill30_t)$ },

The orderings for Model A suggests that the 30 day Treasury bill rate (the last variable) is the primary monetary policy tool which generates influence on liquidity represented by excess reserves held by deposit taking institutions. Model B accounts for the influence of Money supply adjustments while also holding the 30 day Treasury bill interest rate as the primary monetary policy tool.

Before estimation, a test was conducted for the presence of threshold effects using the multivariate approach proposed by Lo and Zivot (2001). This test is an extension of the linearity test provided by Hansen (1999). The technique utilizes the Likelihood Ratio test on the Covariance matrix for

<sup>&</sup>lt;sup>7</sup> (Choi, 1999) utilized orderings that were based on empirical results informed by other authors in conjunction with the orderings implied by Wald Causal Orderings. The orderings are consistent with common practice to include non-policy variables before policy variables in a form consistent with a Cholesky decompositions.

each regime with bootstrap distribution as opposed to the linear approach that utilizes an F test to compare measures of the SSR. The results presented in Table 2 demonstrates that the presence of linearity was rejected in favour of both the one and two threshold models with two (2) and three (3) regimes, respectively. These results indicate that there are asymmetric patterns evident in the response of agents to monetary policy actions in Jamaica. This finding supports the use Threshold Vector Autoregression (TVAR) estimation techniques to evaluate the structural relationships outlined in the models outlined in Equation 5 to Equation 9.

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LR test:	1vs2	pval	1vs3	pval
Model A (test)	98.3047	(0.0000)	231.6658	(0.0000)
Model B (test)	136.7429	(0.0000)	303.1957	(0.0000)
Bootstrap critical values for test 1 vs 2 regimes	90%	95%	97.50%	99%
Model A	97.001	97.544	97.815	97.978
Model B	95.773	97.384	98.189	98.673
Bootstrap critical values for test 1 vs 3 regimes	90%	95%	97.50%	99%
Model A	198.104	199.1103	199.6135	199.9154
Model B	199.6066	200.3005	200.6474	200.8556

Table 2: Likelihood Ratio Test of Linearity against Thresholds in VAR using Bootstrap Distribution

Employing Models A and B in estimating the Threshold VAR (TVAR), the grid search for upper and lower threshold values provided fairly consistent parameters across all models (see table K). The results indicate that a neural policy stance is perceived for a narrow distribution of monthly changes in the MIMC indicator about zero that accounts for 10.8% to 12.3% of the small adjustments. Positive changes in the MIMC indicator above the upper bound account for 41.5% to 42.9% of variation in the MIMC while changes below the lower bound account for 46.2% of changes across the three models.

Table 3:Threshold Values and Regime Distribution around variation in MIMC indicator

	Model 1	Model B
Upper Bound	0.000739065	0.000128515
Lower Bond	-0.01823034	-0.01823034
% Tight	41.5%	42.9%
% Neutral	12.3%	10.8%
% Loose	46.2%	46.2%

Using our estimate of the threshold values for each regime, we then estimate the TVAR model. The TVAR model, as mentioned previously, is used to capture asymmetry across different regimes. Thus the suitability of this approach also has to be assessed in comparison to the estimation of a linear model. The Hansen (1996) specification test is adopted to determine whether coefficients are similar across regimes (asymmetry). The null hypothesis of symmetry across regimes is rejected at the 1.0 percent significance level, confirming that coefficient values are different across regimes that are segmented according to the estimated threshold values ( $\tau_U$  and  $\tau_L$ ).

To assess the impulse of shocks to the policy variables within the systems of TVARs, the Generalized Impulse Functions was used which follows the procedures proposed by (Baum & Koester, 2011). The method utilizes a bootstrapping technique that account for 500 repetitions on samples generated from the TVARs estimated for models A and B. The results are provided in Table 4, Table 5 and Table 6, respectively. The results reflect a single standard deviations shock to the 30 day Treasury Bill rate as a proxy for Central Bank policy rate under each of the three (3) regimes.

Money supply response to positive interest rate shocks, as reflected in Model B, is likely to adjust upward by month two in both tight and loose monetary policy regimes. The effect, however, is immediate under a neutral monetary policy stance. This increase however, is followed by a decline by the fourth month which persists, though in an oscillatory fashion within the negative band before returning to a stable growth over the following 18 months. Model B demonstrates that an increase in interest rates will feature a constraining effect on the demand for money for a period of 12 to 15 months. However, the response of money supply is hardly distinguishable under either of the three regimes.

When observing the adjustments of Excess Reserves, as a proxy for corporate sector liquidity, to an interest rate shock, Excess reserves reflected an immediate decline before the transition to stationary growth. Like money supply, excess reserves display no clear asymmetry in the pattern of adjustment across regimes (see table 4). However, while Model B depicts an eight (8) month period for cash reserves to adjust to stationary levels, Model A reflects a speedy adjustment by the fourth (4) month.

The impact of a hike in interest on exchange rate depreciation reveals the anticipated relationship represented by the uncovered interest parity condition. The liquidity effects on the demand for currency across borders in response to potential gains from a hike in interest rates on the domestic market is suggested to trigger an appreciation. This response is reflected in both models A and B and is expected to last for approximate one year before stabilizing. While Model A reflects a sharp decline and gradual adjustment to stationarity, Model B largest decline occurs by the sixth month before overshooting slightly by the year end. Model B also reflects a gradual correction when agents overreacts and also occurs over a period of approximately one year. The response of Exchange rate to interest rate shock is slightly constrained in both tight and loose regimes while stronger adjustments are likely to persist within neutral monetary policy conditions after six (6) months have transpired. The adjustment of any overshooting response is also expected to be speedier within period of neutral monetary policy regime (see Table 4).

The response of industrial production to an increase in interest rate under model A reflects a boost in economic activity which dissipates over a period of nine (9) months. This proves puzzling as it contradicts a priory expectations. However, Model B, while reflecting significant variability in the response of industrial activity to policy action, displays a general propensity for a contraction in economic activity. This leads us to discount Model A and recognize Model B as being more credible as it was able to correct for the price puzzle generally alluded to in the literature. Model B shows that, on average, downward pressures on production should be expected to last for approximately one year before stabilizing. Also, Model B disclosed that the response of industrial production from an interest rate hike is much milder under a loose monetary policy regime than under tight and neutral monetary policy conditions. The response, however reflects greater variation within periods of neutral policy stance.

Table 4: Impulse Response to a Standard Deviation Shock to Treasury Bill Rate.

Model A	Model B



The impulse response of inflation in Model A also reflects the inflation puzzle featured in the literature.<sup>8</sup> However, Model B which included the Money Supply variable in the transmission mechanism, was able to resolve the price puzzle under all three regimes. Following an increase in interest rates, Model A reflected an increase in inflation which gradually adjusted to a stationary level over a period of approximately one year. While Model B featured an initial increase in inflation, this response was wholly offset by the second quarter following which inflation reflected a stronger and prolonged deceleration before taking an additional year (12 months) to return to a stationary level. The response of Model B is consistent with a prior expectations that an increase in interest rates would curtail economic activity thereby inducing deflationary pressures over the near to medium term. Nevertheless, the effect of monetary policy action on inflation reveals a less pronounced effect during intervention regimes. Periods when the BOJ policy stance is considered neutral, an increase in interest rate shows a tendency for persistent deflationary pressures beyond the sixth (6) month after intervention.

<sup>&</sup>lt;sup>8</sup> (Choi, 1999) featured evidence of the price puzzle in his empirical work but noted that he was able to account for this effect in two of his models by incorporating exogenous commodity prices in these models.

# 5.0 Summary & Recommendations

The MIMC indicator was instrumental in identifying significant threshold effects in the feedback of macroeconomic agents as represented in two monetary policy models for the Jamaican economy. The results from impulse responses generated for differing regimes across selected models estimated within a threshold vector auto-regression (TVAR) model provided evidence that economic agents display asymmetric behavioural patterns depending on the perceived state of monetary policy stance. This was also supported by results of statistical tests that confirmed the presence of threshold effects. The results indicated that inflation is constrained by tightening of monetary policy. TVAR estimation revealed that the well-known puzzle was eliminated when the monetary transmission process accounted for variations in the money supply alongside private sector holdings of excess liquidity. Accounting for this result, model B suggests that the inflation effect from a shock to interest rates is largest at the 12 month juncture (4 quarters) before stabilizing by the 18<sup>th</sup> month (6 quarters). Results from the TVAR also reveals that industrial production is curtailed in all three regimes when monetary policy becomes tighter. Exchange rate is also expected to appreciate across all regimes confirming the liquidity influence represented by the UIP condition. The paper confirms evidence of asymmetric response to policy action particularly between periods of intervention as opposed to periods of neutral monetary policy stance. The non-linear response to monetary policy stance was mainly reflected in the response to Exchange rate and Inflation which proved to have larger and more persistent effects under neutral monetary policy regimes.

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# 7.0 Appendix

Table 5: Unit Root Tests

initial Variable	Туре	Transformations	New Variable	ADF	PP
СРІ	level	seas, log	LCPI_SA	I(1) ***	I(1) ***
GDP	level	seas, log	LGDP_SA	I(1) *	I(1) ***
INDPROD	level	seas, log	LINDPROD_SA	I(1) ***	I(1) ***
UNEMP	rate	seas	UNEMP_SA	I(1) ***	I(1) ***
XRATE	level	seas, log	LXRATE_SA	I(1) ***	I(1) ***
TBILL30	level	n/a	DTILL30	I(1) ***	I(1) ***
TBILL180	level	n/a	DTILL180	I(1) ***	I(1) ***
M1	level	seas, log	LM1_SA	I(1) ***	I(1) ***
M2	level	seas, log	LM2_SA	I(1) ***	I(1) ***
CASH_RES	level	seas, log	LCASHRES_SA	I(1) ***	I(1) ***
EX_RESERVE	level	seas, log	L EX_RESERVE _SA	I(1) ***	I(1) ***
REQ_RESERVE	level	seas, log	L REQ_RESERVE _SA	I(1) ***	I(1) ***
CG_RESERVE	level	n/a	CG_RESERVE	I(1) ***	I(1) ***
SPRD_INTERB	level	n/a	SPR_INTERB	I(1) ***	I(1) ***
SPRD_TBILL	level	n/a	SPR_TBILL	I(1) ***	I(1) ***