EVIDENCES OF INTERDEPENDENCY IN THE POLICY RESPONSES OF MAJOR CENTRAL BANKS: AN ECONOMETRIC ANALYSIS USING VAR MODEL

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Abstract **-**The study attempts to capture the influence of monetary policy of one central bank on another in the present globalised world. The study used monthly time series data of long-term interest rates of major countries US, India, Japan and Euro Area from December 2011 to November 2017. Based on VAR analysis, Impulse Response and Variance decomposition, found that the monetary policy of countries are majorly influenced by the policy changes made by Federal Reserve System, US. Reserve Bank of India responds almost immediately to a policy change in US, and quiet often it has a sustained impact. Japan and Euro Area also responds to the policy changes made by Fed, but has impact only in the short run. Japan and Euro Area have an increased economic integration and thereby their policies influence each other in a major way. Indian monetary policy was never found to have any impact over the policies of US. The study concluded that while considering the monetary policy reaction, the impact of the policy changes of major central banks should also be considered along with the changes in the macroeconomics variables as advocated by the Taylor rule.

Keywords:Monetary Policy Reaction, Taylor rule, VAR, Impulse Response Function, Variance Decomposition, Federal Reserve System, Reserve Bank of India, Euro Area, Japan.

JEL Classification: E43, E52, E58

Introduction

The impact of inducing changes in the major macroeconomic variables for the purpose of economic stabilization, through the mechanism of interest rates adjustments, has been a predominant subject of discussion in macroeconomic literaturesince the era of the Monetarists. Though the debate revolved around the merit of a discretionary response as compared with a rule based response, there existed no doubt on the vitality of monetary policy reaction in the stabilization process of any economy. In the early 1990s when certain economists[†] advocated the rule-based monetary policy response, the idea was to propagate an appropriate policy reaction towards any deviation from the major macroeconomic goals viz. inflation and output stability.

However, in a globalized world, policy responses of Central Banks need not be restricted solely to what is advocated by Taylor’s Rule or the Augmented Taylor Rule function, thereby limiting the responses purely to manipulations in the major macroeconomic variables of the concerned economy. It must be realized that the Monetary Policy reaction of one Central Bank could also be influenced by the policies of other Central Banks. The chiefcausal factor is the possible creation of an interest rate differential that could lead to massive capital flow between the countries, further causing undesirable exchange rate movements. Exchange rate instability could make the Balance of Payment situation vulnerable and could lead to inflation, thereby propagating output instability.

If recent history is any proof, a few instances can be highlighted to substantiate this argument. A speculation of a policy rate hike by Federal Reserve of the USA hadin 2013led to a huge outflow of capital from India, leading to one of the most historic plummeting of the Indian Rupee vis-à-vis dollar.[‡] On a later occasion, another speculation of a hike in Fed Rates forced the Reserve Bank of India (RBI) to hold on to its high interest rate policy, despite suggestions and proposals to reduce the RBI policy rates to boost domestic economic growth. Though there are such instances as proof of the interdependency in the policy of Central Banks, no empirical evidences were evaluated. It is in this context, that this study looks into the empirical evidences of the interdependency in the policy response of major Central Banks. The rest of the paperwill discuss the methodology, the empirical evidences, and the conclusions derived from a detailed analysis.

The Methodology

To obtain the evidences for the interdependency in monetary policy of major central banks, data of long-term interest rates were sourced for United States, India, Japan and the 19 countries that form the Euro Area. The data for the analyses was takenfrom the OECD database.Since the period of global recession had created considerable distortions in the major macroeconomic data during 2008 to 2010, the analysis used monthly data from December 2011 to November 2017, to free the data from undesirable noises. Augmented Dickey Fuller (ADF) test and Phillips Perron (PP) testwere used to test for the stationarity of the data. Since the study is attempting to capture the linear interdependencies between the policy rates of different Central Banks, a Vector Autoregressive (VAR) Model was used. A basic VAR model can be specified as:

$$Y_{1t} = a_1 + \sum_{j=1}^{k} \beta_{1j} Y_{1\,t-j} + \sum_{j=1}^{k} \delta_{1j} Y_{2\,t-j} + \varepsilon_{1t}$$

$$Y_{2t} = a_2 + \sum_{j=1}^{k} \beta_{2j} Y_{1\,t-j} + \sum_{j=1}^{k} \delta_{2j} Y_{2\,t-j} + \varepsilon_{1t}$$

The optimal lag length for the model was obtained from the VAR lag length criteria. Popular model selection criteria are Akaike Information Criterion (AIC), Schwarz Bayesian Criterion (SBC) and Hannan-Quinn Criterion (HQC). The response of the policy rates of an economy to the shocks from other economies were captured using the impulse response function. In the reduced form VAR model, the shock enters the system through the residual vector.

$$Y_t = \varphi(L)u_t = \sum_{j=0}^{\infty} \varphi_j u_{t-j}$$

Finally, a historical decomposition of the variance in the data wasundertaken to understand the contributions of shocks to the observed series.

Empirical Evidence

As discussed in the methodology, the first step was to check for the stationarity of the variables. The monthly data of long-term interest rates of US, India, Japan and Euro Areawere tested for stationarity using Augmented Dickey Fuller (ADF) test and Phillips Peron (PP) test, the results of which are presented in Table 1.

Table 1:Stationarity Test Results

Interest Rates	Phillips Peron at Level	Phillips Peron at First Difference	Augmented Dickey Fuller at Level	Augmented Dickey Fuller at First Difference
Japanese Interest Rate	-1.262 (0.642)	-7.431 (0.000)	-1.303 (0.623)	-7.557 (0.000)
Indian Interest Rate	-1.362 (0.598)	-5.490 (0.000)	-1.557 (0.498)	-5.733 (0.000)
USA's Interest Rate	-2.053 (0.263)	-6.608 (0.000)	-2.302 (0.174)	-6.634 (0.000)
Euro Area (19 nations)'s Interest Rate	-1.892 (0.334)	-6.378 (0.000)	-1.904 (0.328)	-6.439 (0.000)

Note: Values given in parentheses are *p-value.*

Source: Computed by the Authors

The results showed that allthe variables are stationary in their first difference. The traditional assumptions of the VAR analysis assumestationarity of all the variables at level. For conducting the hypothesis test to examine the statistical significance of the coefficients, it is essential that all the variables used in the system of VAR are stationary (Brooks, 2014). If the variables are I(1) process and are found to have atleast one co-integration equation in the co-integration test, then Vector Error Correction (VEC) model should be applied. Hence, the variables were tested for co-integration using Johansen Co-integration Test, the result of which is provided in Table 2.

Table 2: Co-integration test results

Unrestricted Co-integration Rank Test (Trace)				
Hypothesized		Trace	0.05	
No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob.**
None	0.187216	32.14431	47.85613	0.6042
At most 1	0.116952	17.84135	29.79707	0.5778
At most 2	0.079556	9.259449	15.49471	0.3419
At most 3	0.050003	3.539422	3.841466	0.0599
Trace test indicates no co-integration at the 0.05 level				
* denotes rejection of the hypothesis at the 0.05 level				
**MacKinnon-Haug-Michelis (1999) p-values				
Unrestricted Co-integration Rank Test (Maximum Eigenvalue)				
Hypothesized		Max-Eigen	0.05	
No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob.**
None	0.187216	14.30297	27.58434	0.8012
At most 1	0.116952	8.581898	21.13162	0.8646
At most 2	0.079556	5.720027	14.26460	0.6494
At most 3	0.050003	3.539422	3.841466	0.0599
Max-eigenvalue test indicates no co-integration at the 0.05 level				
* denotes rejection of the hypothesis at the 0.05 level **MacKinnon-Haug-Michelis (1999) p-values				

Source: Computed by the Authors

Since no co-integration was found among the variables, VECM was not adopted for the analysis. The next-best alternative usually adopted in the practice of econometric analysis is to conduct a VAR analysis with first-difference. However, many proponents of the VAR approachhave recommend that differencing to induce stationarityshould be preferably avoided as it poses the risk of discarding important data that might reflect the long-run relationships existing between the series (Brooks, 2014). Since the study is interested in capturingonly the nature of relationships between the variables and not the parameter estimates, non-stationarity of data in the level VAR model can be ignored (Sims, 1980; Sims, Stock and Watson, 1990; Luetkepohl, 2011). Hence, the study went ahead and estimated the following VAR model.

$$Int_{US\,t} = a_1 + \sum_{j=1}^{k} \beta_{1j} Int_{US\,t-j} + \sum_{j=1}^{k} \gamma_{1j} Int_{IND\,t-j} + \sum_{j=1}^{k} \delta_{1j} Int_{EURO\,t-j} + \sum_{j=1}^{k} \mu_{1j} Int_{JAP\,t-j} + \varepsilon_{1t}$$

$$Int_{IND\,t} = a_2 + \sum_{j=1}^{k} \beta_{2j} Int_{IND\,t-j} + \sum_{j=1}^{k} \gamma_{2j} Int_{US\,t-j} + \sum_{j=1}^{k} \delta_{2j} Int_{EURO\,t-j} + \sum_{j=1}^{k} \mu_{2j} Int_{JAP\,t-j} + \varepsilon_{2t}$$

$$Int_{EURO\,t} = a_3 + \sum_{j=1}^{k} \beta_{3j} Int_{EURO\,t-j} + \sum_{j=1}^{k} \gamma_{3j} Int_{US\,t-j} + \sum_{j=1}^{k} \delta_{3j} Int_{IND\,t-j} + \sum_{j=1}^{k} \mu_{3j} Int_{JAP\,t-j} + \varepsilon_{3t}$$

$$Int_{JAP\,t} = a_4 + \sum_{j=1}^{k} \beta_{4j} Int_{JAP\,t-j} + \sum_{j=1}^{k} \gamma_{4j} Int_{US\,t-j} + \sum_{j=1}^{k} \delta_{4j} Int_{IND\,t-j} + \sum_{j=1}^{k} \mu_{4j} Int_{EURO\,t-j} + \varepsilon_{4t}$$

The optimal lag length of two was found through VAR lag selection criteria. The results of VAR lag selection criteria are shown in Table 3.

Table 3: VAR Lag Selection

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-100.1828	NA	0.000339	3.360734	3.497969	3.414616
1	188.9105	531.5586	5.06e-08	-5.448726	-4.762554*	-5.179317*
2	209.6389	35.43893*	4.38e-08*	-5.601256*	-4.366146	-5.116321
3	216.2177	10.39861	6.03e-08	-5.297344	-3.513295	-4.596881
4	227.0484	15.72205	7.36e-08	-5.130593	-2.797607	-4.214604
5	235.9869	11.82189	9.75e-08	-4.902803	-2.020879	-3.771287
6	257.2586	25.38881	8.94e-08	-5.072858	-1.641996	-3.725815
7	281.5174	25.82387	7.73e-08	-5.339271	-1.359471	-3.776701
8	296.7157	14.21779	9.43e-08	-5.313410	-0.784672	-3.535313
9	310.8278	11.38074	1.28e-07	-5.252511	-0.174835	-3.258887
10	335.4377	16.67122	1.36e-07	-5.530250	0.096364	-3.321099
* indicates lag order selected by the criterion						
LR: sequential modified LR test statistic (each test at 5% level)						
FPE: Final prediction error						
AIC: Akaike information criterion						
SC: Schwarz information criterion						
HQ: Hannan-Quinn information criterion						

Source: Computed by the Authors

Post estimation, the stability of the VAR model was checked through AR Roots and AR Graph. The results of AR roots showed that the VAR model is stable (see Table 4 and Figue 1).

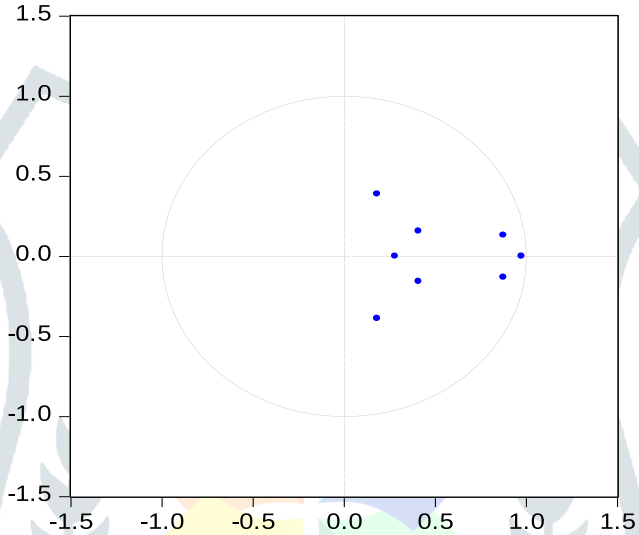
Table 4: VAR Stability Check

Root	Modulus
0.974568	0.974568
0.875437 - 0.130961i	0.885179

0.875437 + 0.130961i	0.885179
0.410582 - 0.157388i	0.439715
0.410582 + 0.157388i	0.439715
0.181661 - 0.387662i	0.428115
0.181661 + 0.387662i	0.428115
0.279950	0.279950
No root lies outside the unit circle.	
VAR satisfies the stability condition.	

Source: Computed by the Authors

Figure 1: AR Roots Graph



Source: Generated by the Authors

Furthermore, to check if the VAR model represents the data generation process of the variables adequately, tests for residual autocorrelation was conducted using Breusch-Godfrey LM test. The results showed no serial correlation among the residuals (see Table 5).

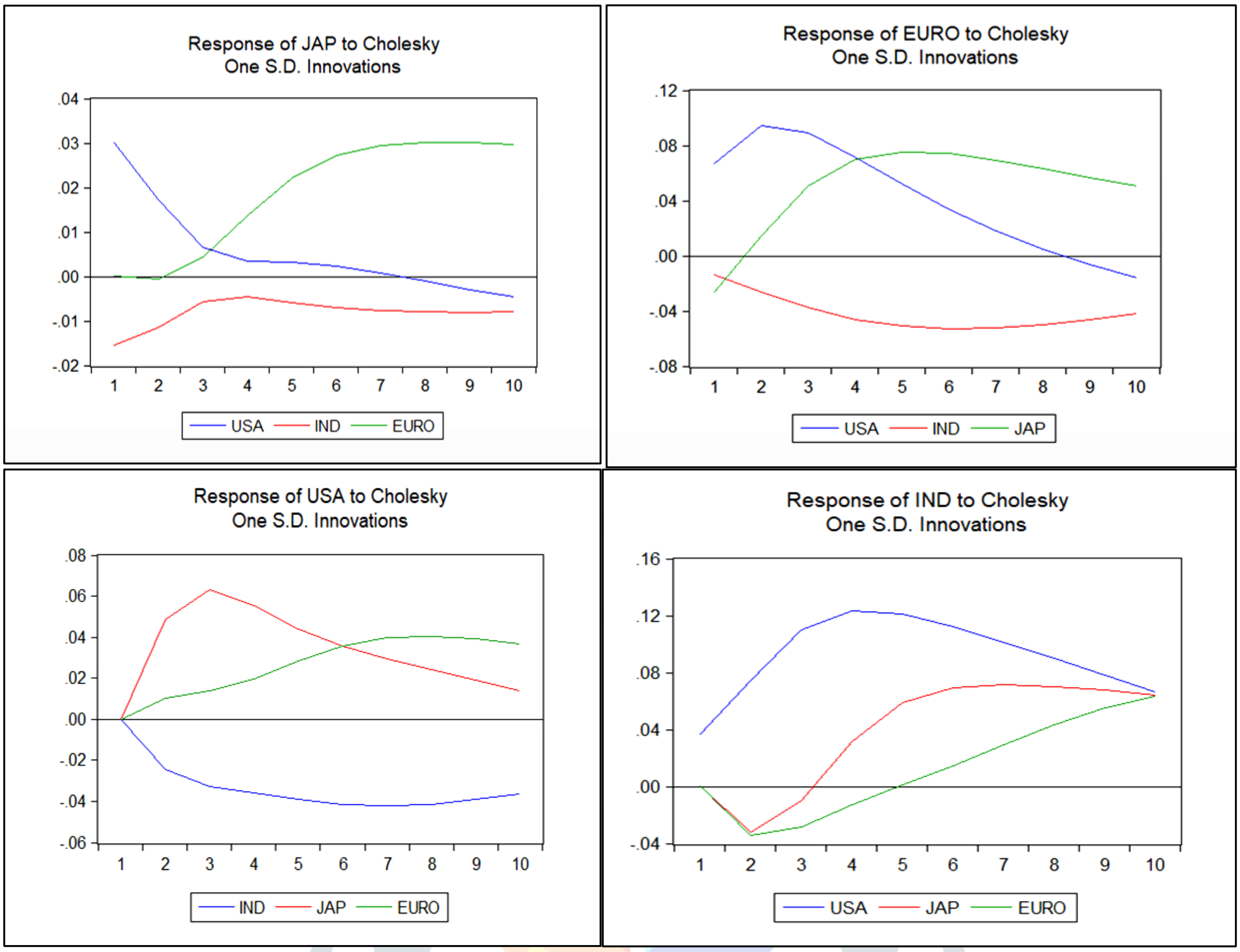
Table 5: Breusch-Godfrey LM test results for Residual Serial Correlation

VAR Residual Serial Correlation LM Tests		
Null Hypothesis: no serial correlation at lag order h		
Lags	LM-Stat	Prob
1	10.20475	0.8557
2	7.989970	0.9492
3	12.59756	0.7019
Prob values from chi-square with 16 df.		

Source: Computed by the Authors

Once the stability conditions were found to be satisfied, the response of the policy rates of an economy to a one standard deviation policy shock from other economies were captured using the impulse response function. The shocks were identified through Cholesky decomposition method. The results of the impulse response function from the VAR estimates are provided in Figure 2.

Figure 2: Impulse Response Graphs



Source: Generated by the Authors

The next part of the analysis involved conducting a Variance Decomposition in order to breakdown the impact that different nations' monetary policies have on a certain economy. The results of the Variance Decomposition test are provided in Tables 6 through 9.

Table 6: Variance Decomposition of US Interest rate

Period	S.E.	USA	IND	JAP	EURO
1	0.141587	100.0000	0.000000	0.000000	0.000000
2	0.218063	93.58419	1.262948	4.935308	0.217553
3	0.266377	88.28557	2.345077	8.956040	0.413312
4	0.296878	85.23847	3.328399	10.66471	0.768421
5	0.318087	82.95857	4.396266	11.18920	1.455961
6	0.334140	80.74322	5.527661	11.27498	2.454138
7	0.346521	78.57326	6.630103	11.20825	3.588387
8	0.355909	76.58656	7.635763	11.08122	4.696451
9	0.362873	74.86927	8.513469	10.92986	5.687410
10	0.367933	73.44929	9.252631	10.77624	6.521835

Source: Computed by the Authors

Table 7: Variance Decomposition of India's Interest rate

Period	S.E.	USA	IND	JAP	EURO
1	0.137478	7.089546	92.91045	0.000000	0.000000
2	0.219579	14.37998	80.99806	2.198087	2.423870
3	0.268402	26.35475	69.28065	1.602516	2.762087
4	0.303913	37.08766	58.23703	2.335181	2.340128
5	0.334075	43.79636	49.21798	5.048489	1.937177
6	0.359700	47.45993	42.60392	8.097394	1.838757
7	0.381651	49.21887	37.84588	10.70250	2.232750
8	0.401032	49.64442	34.39927	12.75851	3.197794
9	0.418449	49.11203	31.90647	14.32450	4.657000
10	0.434094	47.95713	30.11930	15.47789	6.445686

Source: Computed by the Authors

Table 8: Variance Decomposition of Japan's Interest rate

Period	S.E.	USA	IND	JAP	EURO
1	0.065517	21.20846	5.595563	73.19598	0.000000
2	0.094998	13.36717	4.118688	82.51074	0.003402
3	0.107580	10.79408	3.486553	85.55600	0.163368
4	0.114079	9.695500	3.265182	85.44736	1.591958
5	0.119682	8.878364	3.209177	83.04510	4.867363
6	0.125468	8.113846	3.236977	79.54565	9.103523
7	0.131191	7.425206	3.302352	75.94571	13.32673
8	0.136604	6.854241	3.382966	72.63547	17.12732
9	0.141633	6.417947	3.466335	69.68983	20.42589
10	0.146268	6.117246	3.541734	67.09613	23.24489

Source: Computed by the Authors

Table 9: Variance Decomposition of EA's Interest rate

Period	S.E.	USA	IND	JAP	EURO
1	0.188995	12.69053	0.549394	1.892261	84.86781
2	0.287717	16.27910	1.086545	1.066782	81.56757
3	0.351743	17.32301	1.874246	2.820533	77.98221
4	0.396880	16.84779	2.813285	5.314958	75.02397
5	0.431394	15.70702	3.778150	7.565034	72.94979
6	0.459243	14.40697	4.659770	9.280853	71.65241
7	0.482346	13.20431	5.394679	10.48206	70.91895
8	0.501752	12.21240	5.964475	11.27919	70.54394
9	0.518142	11.46704	6.378754	11.78714	70.36707
10	0.532028	10.96350	6.659338	12.09859	70.27858

Source: Computed by the Authors

Conclusions and Findings

This section summarizes all the findings from the various tests conducted, and arrives at a justifiable conclusion regarding the interdependent nature of monetary policies in today's highly interlinked economies.

A careful evaluation of the Impulse Response graphs would highlight an interesting observation: all the countries under study i.e. Japan, India and the Euro Area react immediately to a shock in USA's long term interest rates. However, its impact on Japan and EA's monetary policy reduces over time. It can be concluded from the graphs that India reacts almost instantaneously to a change in USA's monetary policy. Furthermore, the impact is sustained over a long time and influences India's policy decisions for almost five time periods. The impact eventually recedes but remains positive for almost one year.There seems to be a relation between Euro Area and Japan's reactions to an impulse in either of the two economies. Both the nations react to an impulse in the other's economy in the medium term, the impact of which sustains until the long term.

The Variance Decomposition tables confirm our findings from the Impulse Response tests. A keen observation of India's Variance Decomposition table would help one understand the importance of US policy decisions on that of India's. The importance of USmonetary policy increases consistently, and if the shock sustains for a longer period, it starts influencing Indian monetary policymuch more than its own macroeconomic factors in determining the interest rates. This is a rather interesting outcome of this analysis. On the other hand, there seems to be a negligible impact of India's policies on the monetary policy of the US.

The assumed relationship between Japan and EA's mutual responses can be better explained through the Variance Decomposition test as well. While US policies seem to have an immediate impact in the first few time-periods on all nations, the importance of Japan and EA's policies on each other's interest rates are steadily increasing over time. Japan's policy shocks become even more determinant in Euro area's variance in the long run, as did Euro-area's in Japan's policy. Japan's influence in determining EA's interest rates, however, is relatively higher. The explanation for this could be found in the developments in international trade agreements that were developed during the span of our period of study. According to the European Commission, the European Union and Japan have been under trade negotiations since 2013, and EU exports goods and services worth almost 58 billion and 28 billion Euro, annually. This enhances the importance of Japanese markets to the EU. Furthermore, Japan and EU recently signed the Economic Partnership Agreement on December 8, 2017.[§]Therefore, one may notice increased importance of each of their policies on the others', in the future.

The study thereby highlights the importance of factoring in the impact of the policy decision of other Central Banks on a country's interest rates and monetary policy in general, instead of limiting our policy response analysis to the traditional Taylor's rule and the suggestions made based on it.

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