How Vulnerable are Commercial Banks to Macroeconomic Shocks? The Case of Bangladesh

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Abstract:

The aim of this study is to examine the impact of macroeconomic dynamics on credit risk of commercial banks in Bangladesh and also to assess the extent of default rate in the banking system as a result of extreme macroeconomic shocks.

In order to identify the comprehensiveness of structural shocks, applying a VAR model in this study we impose sign-restricted 99th percentile value to disseminate shocks from each variable. The study finds that an extreme adverse inflation situation, contractionary monetary policy, and unexpected increase in exchange rate can boost the default rate by over 1%, 0.57% and 0.92% respectively. In addition, if all the extreme historical events occur for all macroeconomic variables, the default rate would increase by 2.52% after a lag. It indicates, adverse economic situation can threaten the banking sectors.

From the operational and regulatory perspective of banks, our findings are instructive. The results might help the policy makers to focus on the key macro variables for smooth operation and stability of the banking system.

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1. INTRODUCTION

Introduction of innovative financial products and services is continuously exposing commercial banks to vulnerable situation due to increased exposure to liquidity, market and operational risks. This risk is exacerbated for banks in developing economies which have low capital to assets ratio as only a small proportion of their assets are financed by capital. Hence, even a lesser unexpected loss could affect the capital of commercial banks and threaten their survival (Fraser et al. 2001). Banking crises due to financial instability can be very costly for any economy in terms of systematic disruption and contraction of activities in other industries. The impact of these crises includes slower economic growth (as a result of failure of banks and financed projects), lack of confidence in the banking system and re-allocation of investment by investors to more stable economies (Dell'Ariccia et al. 2008). The aim of this study is to examine the impact of macroeconomic dynamics on credit risk of commercial banks in Bangladesh and also to assess the extent of default rate in the banking system as a result of adverse macroeconomic shocks.

The aftermath of the 2007-2009 global financial crisis made financial stability measures and policies as the top agenda of regulatory authorities and public policymakers. Any framework for assessing financial stability should focus on addressing three main factors: risks and vulnerabilities contributing to the instability of the financial system, the shocks that stimulate those vulnerabilities and, the transmission mechanisms that amplify the impact of the crisis. Macro stress test is an effective mode of assessing the impact of shocks to the financial system. It comprises of four core elements which is the recognition of the interconnections and transmission pace across economic

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factors; identification of structural vulnerabilities and risk sources; assessment of the resilience of financial system to shocks; and capability to contribute forward-looking information due to the possible extreme events.

The financial system of Bangladesh is highly reliant on the banking and financial sector similar to the other developing countries. There are presently 54 commercial banks and 31 non-banking financial institutions (NBFIs) operating in Bangladesh. In 2017, the proportion of bank loans to GDP were 47.41% in Bangladesh, which is more or less same as of other neighbouring countries like India (49.54%) and Srilanka (45.55%). The recent global financial crisis did not result in a direct adverse impact on the Bangladeshi banking system due to its limited link with the global financial system in terms of exposure to market to market risk and off-balancesheet activities1. However, commercial banks in Bangladesh are trying to widen their products and services with the help of sophisticated technology2.. The introduction of technology based banking services, e.g., internet banking, mobile banking; operational risk as well as liquidity risk have been increased. In addition, increasing bank participation in security market amplifies the market risk as well as the liquidity risk. Due to macroeconomic adverse conditions, rising credit risk would further augment the liquidity crisis and destabilize the fund management process of commercial banks. In order to ascertain the macroeconomic adversity, detection of macroeconomic dynamics is necessary.

Considering the factors discussed above, the stability of banks is an important feature for their continual existence in an extended risky environment. The Financial Sector Assessment Program, (FSAP) a reform program based on incentives and goals as monitored by the Bangladesh Bank (Central Bank of Bangladesh) and supported by the World Bank, provided the guidelines for stress testto assess the stability of banks. The stress test according to the FSAP guideline covers only a simple sensitivity and scenario analysis on unit to unit basis. Responses of assets and liabilities are measured on the basis of increase in Non-performing loans (NPLs), decrease in forced sale value of mortgaged collateral, changes to interest rate, changes of exchange rate and changes in liquidity3. However, no econometric analysis has been conducted, thus far to capture dynamic relationship among the variables. Since the banking system is one of the most essential contributors to potential growth of a developing country like Bangladesh, macro stress testing is very important to get an idea about the stability of its financial system. This research is motivated by the practical limitations of the stress testing process of the banking system in Bangladesh. The main objective of the study is to examine the impact of shocks to selected macroeconomic variables on the credit risk of commercial banks in Bangladesh using the stress testing process. The specific objectives of this study are: (i) to analyze the impact of macroeconomic variables on credit risk exposure of commercial banks, (ii) the linkage between default rate (a measure of credit risk) and macroeconomic variables using VAR approach; and (iii) to perform stress testing on banks performance in changing macroeconomic environment. By using the Impulse Response Functions (IRFs), this study aims to examine the extent of default rate in the banking system as a result of adverse macroeconomic conditions.

In line with the objectives mentioned above, this study is structured with wider aspect of stress testing in the context of the financial system of Bangladesh. This is the first research, so far known, to present such analysis to find out the performance of commercial banks in terms of the impact on the default rate given the stressed macroeconomic scenarios compared to normal situation Before conducting the simulation on the impact of the particular stress scenario on the credit risk exposure, a link to the macroeconomic variables with the default rate via VAR model need to be established. The VAR is structured and estimated following the earlier works of Hoggarth et al. (2005), Amediku (2006), Filosa (2007), Tracey (2007), Roy and Bhattacharya (2011), and Buch et al. (2014).

Covering data from 2004Q1 to 2016Q2, our study finds that inflation causes a significant reduction in default rate, while a contractionary monetary policy induces the default rate to increase after a lag. A depreciation of exchange rate causes a significant rise of the default rate up to 2nd quarter. The stress test demonstrates that the default rate would increase by 2.52% after a lag if all the extreme historical events occur for all macroeconomic variables. Therefore, adverse economic conditions have the ability to destabilize the banking sectors through an increase in default rate.

The remainder of the paper is designed as follows: Section 2 describes the model along with its theoretical underpinnings and rationales; Section 3 provides a brief about the data; Section 4 describes the estimation method; Section 5 presents the empirical results of the model; and Section 6 is conclusion.

2. LITERATURE REVIEW

Starting with the seminal works of Wilson (1997a,1997b) to examine credit risk under adverse macroeconomic environment, several attempts have been made to measure the flexibility of banking systems to macroeconomic shocks (Vazquez et al. 2012). Among those, Hoggarth et al. (2005), Sorge and Virolainen (2006), Castrén et al. (2010), Buncic and Melecky (2013), Borio et al. (2014), Bouheni and Hasnaoui (2017), Serwa and Wdowiński (2017), Chavan and Gambacorta (2018) have provided a clear overview and different approaches of stress testing. In order to assess vulnerability, several studies have used NPLs, loan loss provisions (LLP) or their composite indices as the indicators of the financial distress.

A number of macro variables have been used in different studies to capture the macroeconomic dynamics. For example, in studies like Hoggarth et al. (2005), Amediku (2006);

1Retrieved from https://data.worldbank.org/indicator/FD.AST.PRVT.GD.ZS.

2Retrieved from http://www.bangladesh-bank.org/fnansys/bankfi.php.

3Guidelines on Stress testing, Bangladesh Bank DOS Circular no. 1 dated April 21, 2010; and Revised Guidelines on stress testing, Bangladesh Bank DOS Circular no. 1 dated February 23, 2011; retrieved from http://www.bangladesh-bank.org/mediaroom/circulars/circulars.php.

macroeconomic variables have been selected on the basis of the findings of small semi-structural models. Many studies have been done on small semi-structural models for different economies; namely Berg et al. (2006a, 2006b), Argov et al. (2007a, 2007b), Pongsaparn (2008), Harjes and Ricci (2010) and, Khan et al. (2019). In most of the studies, along with examining the impact of interest rate, exchange rate, inflation, cyclicality of banks' behavior has also been assessed. In what follows, we discuss brief theoretical hypotheses along with findings of earlier studies linking bank risk to macroeconomic variables.

2.1. Industrial Production Gap

As the intermediary for the real sector, banks are exposed to business cycle conditions. During the economic expansion, increased corporate and household incomes facilitate the borrowers to service bank loans easily and leading to lessen bad loans. Boss (2002) and Kalirai and Scheicher (2002) in Austria have found significant negative relation between credit risk and industrial production. However, most of the studies have tried to find the relationship of credit risk with output gap as an indicator of business cycle. In Italy Quagliariello (2004), Mariucci and Quagliariello (2005) and Filosa (2007) have found strong procyclical nature of credit risk. Similar impact of output on credit risk is also found by Hoggarth et al. (2005) and Vazquez et al. (2012) in United Kingdom and Brazil, respectively. However, Roy and Bhattacharya (2011) have not found any significant impact of output on default rate in Indian banking system.

2.2. Inflation Rate

Inflation is a measure of price stability which affects the real value of cost as well as revenues. During the higher inflation, an economy is expected to operate above its potential growth level and it would be easy for firms to reset prices upwards creating additional profit. Therefore, higher inflation assists the borrower firms in repaying their debt with their additional income. Thus, inflation is expected to have negative impact on default rate. Most of the earlier studies e.g. Hoggarth et al. (2005) in United Kingdom, Athanasoglou et al. (2006) in south eastern European region, Roy and Bhattacharya (2011) in India, Rajha (2016) in Jordan, Makri (2016) in EU countries, and Radivojevic and Jovovic (2017) in 25 emerging countries have found strong impact of inflation on banks' soundness. In Italy however, Marcucci and Quagliariello (2008), have identified a significant impact of inflation on banks' credit risk while Filosa (2007) has not reported such impact. Consistent with the finding of Filosa (2007), Dovern et al. (2008) has found no significant result in Germany.

2.3. Interest Rate

Interest rate, representative of monetary policy indicator, affects the direct costs of borrowing. The cost of borrowing surely increases with the rise in interest rate. Increasing cost of borrowing would rise the possibility of loan default as households and firms are less able to repay their loans. Therefore, a positive relation is expected between loan defaults and interest rates. Interest rates have been used as one of the significant indicators of banks' health. In line with the theoretical underpin, Hoggarth et al. (2005), Marcucci and Quagliariello (2008), Roy and Bhattacharya (2011), Serwa and Wdowiński (2017), Chavan and Gambacorta (2018) have identified significant relationship between interest rates and loan quality. Similar results have been affirmed by Sorge and Virolainen (2006) in Finland, Havrylchyk (2010) in South Africa, Buch et al. (2014) in USA.

2.4. Exchange Rate

With regards to exchange rates, a devaluation of the domestic currency leads to a positive impact for a country's export sector, as the exporter may export at a lower price to international markets. Hence, a depreciation in the nominal exchange rate would lead to decrease the loan defaults. On the other hand, a depreciation of the domestic currency leads to high import cost and consequently production cost. As such, if firms are not in a position to reset their product prices, they would face a loss. So, the association between exchange rates and loan losses is vague. The exchange rate has significant impact on banks vulnerabilities (Marcucci and Quagliariello, 2008; Akhter and Daly, 2009 and Roy and Bhattacharya, 2011). Conversely, no such relationship has been established in the studies conducted by Baboucek and Jancar (2005) and Tracey (2007).

Overall findings of these studies reveal that several macro variables, e.g., GDP, unemployment rate, inflation, interest rate and exchange rate have significantly affected the soundness of the banking system. The results have been different in some cases, most probably, due to different macroeconomic environment in those countries. In most of the above mentioned studies, loan quality of banking system has been found procyclical. In some works, industrial production (proxy for business cycle) has been found as a significant determinant of bank distress. Monetary policy indicator (proxied by interest rate) has turned out as the second most significant determinants of bank health in terms of loan quality. Interest rates have also affected the bank profitability. In addition, a number of studies have found a strong impact on bank soundness due to inflation and exchange rates.

3. DATA

In order to carry out this study, data has been collected from Economic Trend (a publication of Bangladesh Bank). Since, exchange rate in Bangladesh has been floated from 2003, we have considered data for the periods between 2004Q1 to 2016Q2.

3.1. Default Rate

Different indicators have been used in earlier studies as measure of credit risk. Amongst them are NPLs, default rate, loan loss provisions and probability of default. In this study, we consider the default rate as the measure of credit risk based on gross NPLs and gross advances. The Default rate in time t is the ratio of incremental gross NPLs in time t to performing assets in time t-1. The definition of default rate used in this study is aligned to that of Chavan and Gambacorta (2018), Roy and Bhattacharya (2011) and, Marcucci and Qualiariello (2008). The reason for not considering net NPLs and net advances as a proxy of default rate is because a high provisioning for bad debts may induce to reduce net NPLs while, in reality, the gross NPLs would be rising.

3.2. Macroeconomic Variables

In our study, to reflect the macroeconomic dynamics on the basis of the findings of Khan et al. (2013), we have considered four important macroeconomic variables: industrial production gap, inflation, exchange rate and, interest rate. In different countries researchers mostly used quarterly GDP as a proxy for business cycle for their study. However, due to unavailability of GDP data at quarterly frequency for Bangladesh, we use industrial production as a proxy for GDP as used by Boss (2002) and, Kalirai and Scheicher (2002). Industrial production gap is measured as the deviation of actual production from the potential production. We obtained the potential output through the widely used Hodrick-Prescott (HP) filtering approach (with a lambda value of 1600).

In line with most of the earlier studies, we have used CPI for all goods and services as a proxy for inflation and, short term average lending rate is considered as a proxy of interest rate. On the other hand, we have considered the direct exchange rate between Bangladeshi taka and the US dollar to capture the effects of exchange rate. This is because most international trade and other payments in Bangladesh are made in US dollar.

4. ESTIMATION TECHNIQUES

Existing literature provides a broader overview of the macro stress testing process. Sorge and Virolainen (2006) have distinguished between the two methodological approaches on how the macro stress tests can be modeled. Firstly, the balance-sheet models, that analyze the direct link between banks' balance sheet indicators of vulnerability and the macroeconomic condition; and secondly, the value-at-risk (VaR) models, that assigns the multiple risk factors into the probability distribution of mark-to-market losses that could be faced by the banking system under any given stress scenario.

The present study is based on the balance sheet models. Although VaR models are widely used like balance sheet models, we have not used VaR models due to some straightforward reasons. Firstly, the VaR models are basically based on the estimation of conditional probability distribution of defaults of firms. It should be noted here that a firm is expected to default when the value of its assets falls under its callable liabilities. In Bangladesh, to the best of our knowledge, there is no available data regarding defaults of firms. Secondly, VaR analysis assumes that the financial time series are normally distributed while they are actually described by fat tail distributions. This assumption could lead to a serious mistake since the possibility of extreme events is understated while using a normally-distributed loss function instead of a fat-tail distribution (Kalirai and Scheicher, 2002).

Among the balance sheet models, along with linear multivariate regression models, a significant number of studies have followed the VAR (Vector Autoregression) models to assess the impact of macro variables on banks' health and as well as feedback effects. The VAR captures the concurrent and lagged relation between real macroeconomic aggregates and banking sector (Graeve et al. 2008). Therefore, VAR analysis considers each variable symmetrically without imposing any priori theorization such as exogeneity of the variables. Importantly, a key ability of VAR is to predict the effects of a shock (in a variable) to another variable(s). Consequently, the impact of macroeconomic shocks to quality of bank loans can be easily distinguished. We perform the stress test using VAR approach as suggested by Hoggarth et al. (2005), Marcucci and Quagliariello (2008), Amediku (2006), Filosa (2007), Roy and Bhattacharya (2011), Buch et al. (2014), and Serwa and Wdowiński (2017).

4.1. VAR Model

In the line of Hoggarth et al. (2005), Filosa (2007), Roy and Bhattacharya (2011), and Serwa and Wdowiński (2017), the general VAR model can be expressed as:

$$Z_{t+1} = C + \sum_{j=1}^{p} \varphi_j Z_{t+1-j} + e_{t+1} \quad (1)$$

Where, C is a constant vector, Z_{t+1} represents the vector of endogenous variables, φ_j are matrices and, e_{t+1} is a vector of residuals or shocks. Therefore, the equation defining the shock to the default rate is as follows:

$$dr_{t+1} = \gamma + \phi_{dr} Z_t + e_{dr,t+1} \quad (2)$$

In the above equation, dr represents default rate, γ is a constant, $e_{dr,t+1}$ is a white noise shock, ϕ_{dr} is a row vector of parameters. Z_t is the vector of variables included in the VAR including default rate itself.

In a VAR model, we need to spot on few matters. Firstly, order of the variables should be according to their likely pace of reaction to a specific shock. The first variable is a function of lagged values of all other variables as well as itself, while the second variable is a function of the first variable of same period and lagged values of all variables and so on (Roy and Bhattacharya, 2011). Thus, the front variables are to be affected themselves by other variables after a lag, while to affect the subsequent variables contemporaneously. Rear Variables, on the contrary, only affect the previous variables after a lag but are affected themselves immediately. In order to select the order of the VAR, we have followed earlier works of Hoggarth et al. (2005), Roy and Bhattacharya (2011), and Serwa and Wdowiński (2017).

Secondly, for lag lengths selection, we should be cautious enough that if it is too large the degrees of freedom are wasted, and if lag length is too small the model might be miss-specified (Enders, 1995). In choosing lag lengths, a number of cross-equation restrictions tests can be used. Among these tests, Akaike information criterion (hereafter, AIC), Schwarz criterion (hereafter, SC), and Hannan-Quinn information criterion (hereafter, HQ) are widely used. If the selected lag order does not suffer from autocorrelation, it confirms that the chosen lag specification is appropriate.

Table 1: Stationary Test Results.

Panel-A		ADF Test (H_0: Series is nonstationary)			
Variables		Exogenous: Intercept		Exogenous: Trend and Intercept	
		t-statistic	*p*-value	*t*-statistic	*p*-value
dr	Level	-6.649	0.000	-7.818	0.000
ipg	Level	-6.682	0.000	-6.634	0.000
inf	Level	-6.422	0.000	-6.398	0.000
int	Level	-3.069	0.036	-4.173	0.010
exg	Level	-2.819	0.063	-2.782	0.211
	1st Difference	-6.691	0.000	-6.628	0.000

*Lag length selection: Automatic - based on SIC (default set in EVIEWS10).

Panel-B		PP Test (H_0: Series is nonstationary)			
Variables		Exogenous: Intercept		Exogenous: Trend and Intercept	
		t-statistic	*p*-value	*t*-statistic	*p*-value
dr	Level	-6.649	0.000	-8.206	0.000
ipg	Level	-6.694	0.000	-6.648	0.000
inf	Level	-6.418	0.000	-6.392	0.000
int	Level	-1.768	0.391	-2.402	0.374
	1st Difference	-3.362	0.018	-3.381	0.067
exg	Level	-2.920	0.051	-2.895	0.174
	1st Difference	-7.084	0.000	-7.011	0.000

*Bandwidth: (Newey-West automatic) using Bartlett kernel.

Panel-C		KPSS Test (H_0: Series is stationary)			
Variables		Exogenous: Intercept		Exogenous: Trend and Intercept	
		LM-statistic	Critical Values	LM-statistic	Critical Values
dr	Level	0.627	1% level: 0.7390 5% level: 0.4630 10% level: 0.3470	0.206	1% level: 0.2160 5% level: 0.1460 10% level: 0.1190
ipg	Level	0.099		0.087	
inf	Level	0.090		0.036	
int	Level	0.328		0.089	
exg	Level	0.184		0.108	

*Bandwidth: (Newey-West automatic) using Bartlett kernel.

This table reports the stationary test results. Here *dr* indicates the default rate. *ipg* is the industrial production gap. *inf* specifies the annualized quarterly inflation. *int* represents nominal short term interest rate. Lastly, *exg* is the real exchange rate.

Table 2. Results of VAR Lag Order Selection Criteria.

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-381.60	NA*	68.04*	18.41*	18.62*	18.49*
1	-360.63	35.94	83.26	18.60	19.84	19.06
2	-346.18	21.34	145.02	19.10	21.38	19.94
3	-327.06	23.68	220.61	19.38	22.69	20.60
4	-302.30	24.76	298.55	19.40	23.74	20.99

This table reports the results of VAR lag order selection criteria. LR represents modified LR test, FPE is the Final prediction error, AIC indicates Akaike information criterion, SC is the Schwarz information criterion and, HQ represents Hannan-Quinn information criterion.
* indicates lag order selected by the criterion.

4.2. Stress Test – Impulse Response Functions (IRFs) and Forecast Error Variance Decomposition (FEVD)

An examination of causality suggests which variable(s) have statistically significant influence on the dependent variable. However, the causality results do not express two important matters– namely, whether deviations in a particular variable have a positive (or negative) impact on other variables, and how long the system would take to fade away the effect of that variable (Brooks, 2008). The FEVD and IRFs can provide such information therefore, these two techniques have been used to perform stress test in this study.

The FEVD traces the extent of information each variable contributes to other variables in the autoregression due to a structural shock in the system. While the FEVD identifies such amount of information, the IRFs capture the effects of a one-time shock to one endogenous variable disseminated to other variables through the dynamic (lag) structure in a VAR model.

5. EMPIRICAL RESULTS

For the detection of stationarity of different series; ADF, PP and KPSS tests have been performed (please refer to Table **1**). Default rate, industrial production gap, and inflation rate show stationarity according to all the three tests. Interest rate is found non-stationary by the ADF (when intercept and trend are considered as exogenous) as well as by the PP test. In addition, the ADF and PP test show that real exchange rate is non-stationary at level (when intercept and trend are considered as exogenous). However, the first difference of interest rate and real exchange rate indicates stationarity at all significance levels. As a result, for VAR estimation, we should consider interest rate and exchange rate at first difference, while all other series at level.

Lütkepohl (2005) opined that in a small sample, AIC and final prediction error (FPE) might have better properties (by choosing the correct order) than SC and HQ. Also, the former two criteria would minimize the forecast error variance. Ozcicek and McMillin (1999) suggest the AIC usually selects true lags for VAR than other criteria. Table **2** shows that all the information criteria, except sequentially modified LR test statistic, the optimum lag order should be one. Therefore, we construct the VAR with one lag order.

Table 3. Results of VAR Estimation.

Sample: 2004Q1 2016Q2					
Included observations: 58					
	dr	*ipg*	*inf*	*int*	*exg*
dr (-1)	-0.010	-0.168	0.072	0.029	0.067
	(-0.066)	(-0.303)	(0.100)	(0.920)	(0.540)
ipg (-1)	0.006	-0.015	-0.032	-0.013	-0.028
	(0.121)	(-0.089)	(-0.151)	(-1.408)	(-0.763)
inf (-1)	-0.073*	-0.084	-0.099	-0.007	0.073**
	(-1.927)	(-0.625)	(-0.571)	(-0.923)	(2.443)
inf(-1)	0.863	-0.349	-1.946	0.575***	-0.441
	(1.344)	(-0.154)	(-0.663)	(4.394)	(-0.869)
exg (-1)	0.297	0.107	1.596	0.034	-0.231
	(1.401)	(0.143)	(1.650)	(0.778)	(-1.381)
C	-0.366	-0.068	0.275	0.010	-0.009
	(-1.840)	(-0.096)	(0.303)	(0.242)	(-0.057)
R^2	0.12	0.02	0.08	0.37	0.16
Adj. R^2	0.01	-0.11	-0.03	0.29	0.05

This table reports the results for the following VAR(1) model:

$$Z_t = C + \sum_{j=1}^{p} \Phi_j (\mathrm{L}) Z_{t-j} + e_t$$

Where, z_t is the vector of all endogenous variables: default rate (*dr*), industrial production gap (ipg), annualized quarterly inflation (inf), nominal short term interest rate (int) and, real exchange rate (exg).
t-statistics are in parentheses. *, **, and *** indicate significant at the 10%, 5% and 1% levels, respectively.

Table **3** reports the results of the VAR estimation. The results of default rate model (first equation) show that default rate is significantly affected by lagged values of inflation only. As argued by Sims (1980), interpreting VAR coefficients is difficult, because (i) slope coefficients of successive lags show a tendency to oscillate, and (ii) complicated cross equation feed backs exist. Tracey (2007) also indicates that the typical overparamatization of an unrestricted VAR model may reduce the reliability of the t-statistics. As a consequence, it would be better to go for FEVD and IRFs. It should also be mentioned that VAR(1) has passed the validity measures- stability, autocorrelation and heteroskedasticity tests (refer to Tables **4a**, **4b** and **4c**, respectively).

5.1. Impulse Response Functions and FEDV

The responses of default rate to 1-SD innovations are presented in the Table **5**. The responses also graphically presented in the Fig. (**1**). Column II and III of Table **5** and Figs. **1**(a) and 1(b) show that the response of default rate to its lagged value is positive but disappears quickly (within 2 quarters). No cyclical impact is found on default rate like Roy and Bhattacharya (2011).

Our findings are in line with the theoretical explanation that the unexpected increase in inflation reduces the default rate. Fig. **1**(c) and Column IV of Table **5** depict that the inflation cause a significant reduction to default rate with a peak of 42 basis points at 2nd quarter and remains up to three quarters. With some correction in the fourth quarter, the default rate finally dies out at the end of the 5th quarter. Amediku (2006), Filosa (2007), Rajha (2016), Radivojevic and Jovovic (2017) have also got negative impact of inflation on default rate which is similar to our results.

A contractionary monetary policy (increase in interest rate) induces the default rate to increase up to 22 basis points after a lag and thereafter decreases and dies out after 6th quarter (Fifth Column of Table **5** and Fig. **1**(d)). However the impact of interest rate is barely significant. The results are similar to most of all the previous studies, e.g., Hoggarth et al. (2005), Tracey (2007), Filosa (2007), Roy and Bhattacharya (2011), Eickmeier and Hofmann (2013), Buch et al. (2014), Serwa, D. and Wdowiński, P. (2017), and Chavan and Gambacorta (2018).

Table 4. VAR diagnostics Check.

a) Roots of Characteristic Polynomial.

Endogenous variables: ***dr***, ***ipg***, ***inf***, ***int***, ***exg***	
Exogenous variables: C	
Lag specification: 1 1	
Root	**Modulus**
0.630	0.630
-0.528	0.528
0.178	0.178
-0.074	0.074
0.014	0.014

This table reports the results of VAR stability tests. No root lies outside the unit circle. VAR satisfies the stability condition.

b) VAR Residual Portmanteau Test for Autocorrelations.

Null Hypothesis: no residual autocorrelations up to lag h					
Lags	***Q*-stat**	***p*-value**	**Adj *Q*-stat**	***p*-value**	***df***
1	5.92	NA*	6.06	NA*	NA*
2	22.33	0.999	23.23	0.998	46
3	42.21	0.997	44.53	0.994	71
4	70.49	0.977	75.57	0.939	96

This table reports the results of residual autocorrelations tests.

* indicates that the test is valid only for lags larger than the VAR lag order. df is the degrees of freedom for (approximate) χ2 distribution

c) White Heteroskedasticity Test Results.

Null Hypothesis: No residual heteroskedasticity		
Joint test:		
χ^2	*df*	*p*-value
135.8478	150	0.7897

Here *dr* indicates the default rate. *ipg* is the industrial production gap. *Inf* specifies the annualized quarterly inflation. *int* represents nominal short term interest rate. Lastly, *exg* is the real exchange rate.

The relationship between the exchange rate and loan default would be bi-directional: negative and positive. Our findings, as represented in the last Column of Table **5** and Fig. **1**(e), signify a negative impact of exchange rate on default rate. Due to a positive innovation in exchange rate (i.e., depreciation of exchange rate), the default rate significantly rises up to 2nd quarter with a peak of 29 basis points and then with some corrections dies out after 4th quarter. We may explain the results in the way that, due to the depreciation of exchange rate, exporters' performances are better as anticipated. On the other hand, importers' performances may be worse as expected. Since Bangladesh is an import dominant country, we get a net bad impact of exchange rate depreciation to loan quality. Our findings are similar to the results of studies in developing countries like India (Roy and Bhattacharya, 2011) and Ghana (Amediku, 2006).

Table **6** shows the variance decomposition to reveal the relevancy of macroeconomic shocks for banking sector performance. The decomposition is presented from both the short run (one-year forecast horizon) and medium run (five-year horizon) impact. In short run, macroeconomic shocks altogether explain 11.38 percent of the default rate, while exchange rate alone has the highest impact of 4.58 percent variation. At the medium horizons, impact of macroeconomic shocks indicates same nature of impact with a little higher combined impact of 11.88 percent. The biggest variation of 4.65 percent also induced from exchange rate. Table **6** also reveals that the feedback effect of default rate is quite significant to the variation of IPGAP (5.67 percent). Overall

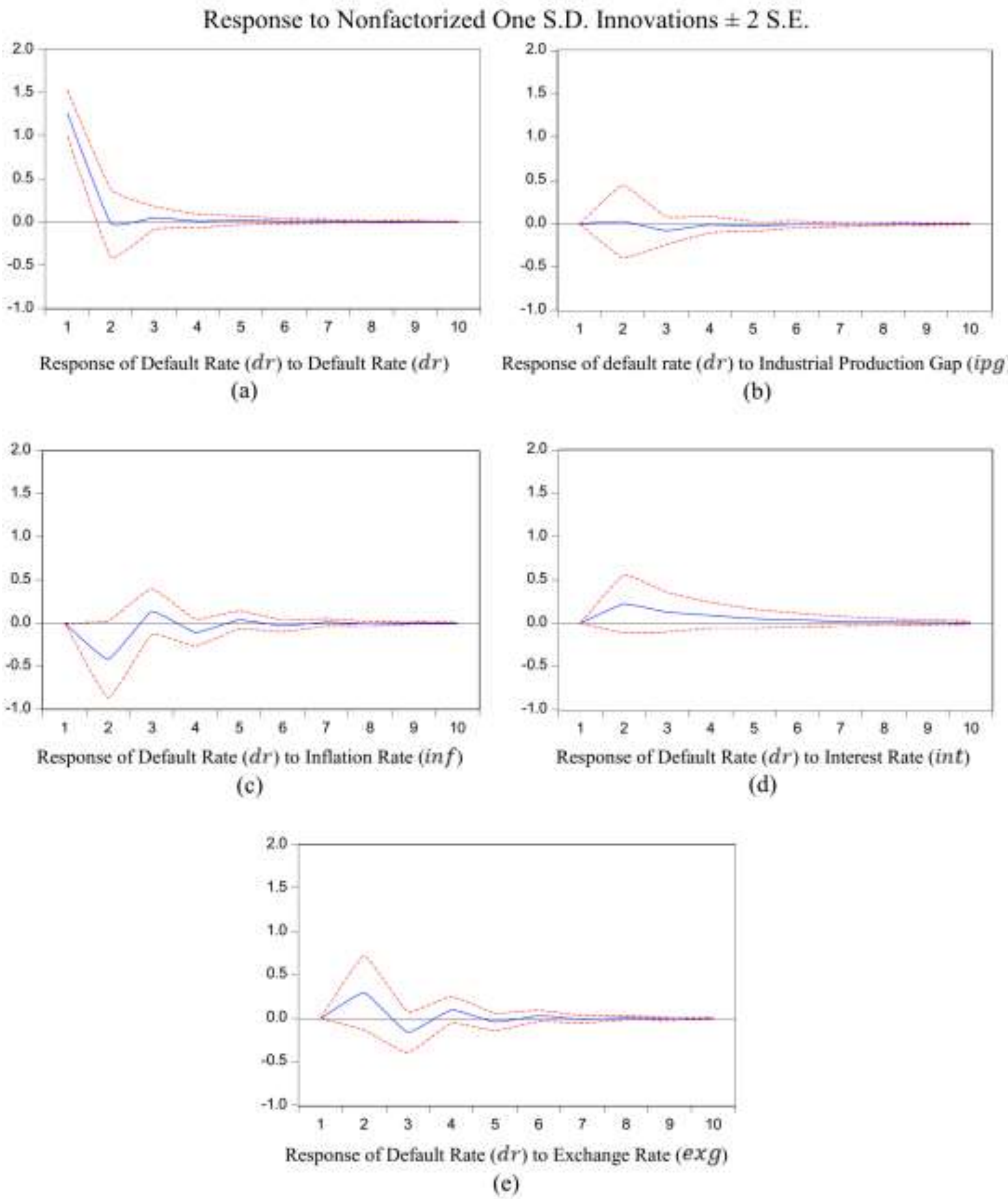

Fig. (1). Impulse Response.

results indicate that though the default rate is largely self-induced, macroeconomic factors have some impact on it.

Table 5. Impulse Response of Default Rate to 1-SD Innovations.

I	II	III	IV	V	VI
Period	***dr***	***ipg***	***inf***	***int***	***exg***
1	1.2628	0.0000	0.0000	0.0000	0.0000
2	-0.0129	0.0252	-0.4216	0.2220	0.2959
3	0.0492	-0.0791	0.1330	0.1277	-0.1582
4	0.0103	-0.0110	-0.1085	0.0901	0.0995
5	0.0200	-0.0305	0.0362	0.0519	-0.0390
6	0.0060	-0.0072	-0.0318	0.0353	0.0297
7	0.0074	-0.0109	0.0089	0.0208	-0.0098
8	0.0028	-0.0035	-0.0096	0.0138	0.0089
9	0.0027	-0.0040	0.0020	0.0083	-0.0024
10	0.0011	-0.0016	-0.0030	0.0054	0.0027

This table reports the periodic (quarterly) impulse response of *dr* to 1-SD shocks of all other variables.

Here *dr* indicates the default rate. *ipg* is the industrial production gap. *inf* specifies the annualized quarterly inflation. *int* represents nominal short term interest rate. Lastly, *exg* is the real exchange rate.

Table 6. Forecast Error Variance Decomposition (FEVD).

		Shocks (1-Year Horizon)				
Variable		***dr***	***ipg***	***inf***	***int***	***exg***
dr		88.62	0.35	3.12	3.33	4.58
ipg		5.67	93.05	0.98	0.06	0.22
inf		0.27	1.84	90.67	1.74	5.48
int		0.73	4.19	2.10	92.12	0.87
exg		1.36	3.73	30.47	2.41	62.03
		Shocks (5-year horizon)				
dr		88.22	0.40	3.14	3.58	4.65
ipg		5.67	93.03	0.99	0.06	0.24
inf		0.27	1.85	90.50	1.83	5.55
int		0.74	4.33	2.06	91.99	0.87
exg		1.36	3.75	30.42	2.51	61.97

Cholesky Ordering: *dr, ipg, inf, int, exg* Here *dr* indicates the default rate. *ipg* is the industrial production gap. *inf* specifies the annualized quarterly inflation. *int* represents nominal short term interest rate. Lastly, *exg* is the real exchange rate.

5.2. Stress Testing – Scenario Analysis

In order to assess more extensive adverse macroeconomic effects on default rate, stress testing is required. Stress testing is concerned with unlikely events, or so-called "fat tail events", could lead to severe consequences (Sorge, 2004). Therefore, we conduct stress test on the basis of extreme values of the respective variables. In order to identify relatively large shocks, use of 99th percentile value to disseminate shocks for each variable would be a better choice (Roy and Bhattacharya, 2011). In addition, we impose sign-restrictions on the IRFs to identify the structural shocks comprehensiveness. Sign-restrictions have been used in earlier studies, e.g., Graeve (2006), Dovern (2008), Buch et al. (2014), and Serwa and Wdowiński (2017). According to IRFs, the default rate is significantly affected by inflation (negatively), interest rate (positively) and exchange rate (positively). Based on these responses of default rate (positive or negative) to macro variables, we impose the sign-restrictions on the IRFs to assess comprehensive adverse effects of macro variables as shown in Table **7**.

Table 7. Sign Restrictions for Impulse Responses.

Response Variable	Impulse Variable	Sign
Default Rate (*dr*)	Inflation (*inf*)	–
	Interest rate (*int*)	+
	Exchange rate (*exg*)	+

Considering adverse inflation situation (99th percentile as shown in Table **8**), Table **9** and Fig. (**2**) show that default rate rises by over 100 basis points. On the other hand, due to extreme unexpected increase of interest rate and exchange rate, default rate rises by 57 basis points and 92 basis points, respectively. If all the macroeconomic variables show extreme effects simultaneously, Table **9** and Fig. **2**(d) demonstrate that the default rate would increase by 252 basis points after a lag if all the extreme historical events occur for all macroeconomic variables. Therefore, adverse economic conditions have the ability to destabilize the banking sectors through the piling NPLs.

Table 8. 99th Percentile of Different Variables.

Impulse Variable	Sign	99th Percentile
Inflation (*inf*)	–	-14.17
Interest rate (*int*)	+	0.662
Exchange rate (*exg*)	+	3.10

Table 9. Impulse Responses of 99th Percentile Shocks.

Impulse Variable	99th Percentile	Response of Default Rate
Inflation (*inf*)	-14.17	1.03%
Interest rate (*int*)	0.662	0.57%
Exchange rate (*exg*)	3.10	0.92%
Combined		2.52%

Despite the consistency of the results, a number of potential caveats should be addressed. At first, we use a linear model instead of a nonlinear one, which may not be able to capture the potential nonlinear linkages during the severe economic distress condition. However, our data range is too small to estimate the required additional parameters for a nonlinear model. Second, as a measure of business cycle use of GDP instead of industrial production, could have better results. In future, with the availability of quarterly GDP data further research could be possible. Given the data condition, these limitations should not be emphasized much.

6. CONCLUDING REMARKS

In this paper, we apply a VAR model to analyze the effects of macroeconomic shocks on the soundness of Bangladeshi banking system. Our attempt can be seen as a first step in the context of Bangladesh economy, thus makes several contributions to the existing body of the literature. First, we model the dynamic linkage of macro variables and banks' credit risk. Second, we identify historical macroeconomic shocks and perform stress testing to measure the effects on default rate to highlight the magnitude of vulnerability of the banking system of Bangladesh.

Loan quality of banking system in Bangladesh is found more sensitive to inflation. It is possibly due to the existence of more volatile inflationary atmosphere in the economy. While inflation causes the highest significant adverse impact on default rate although no cyclical impact is found. On the contrary, due to a positive innovation in exchange rate (i.e., depreciation of exchange rate), the default rate significantly increases. In addition, a contractionary monetary policy i.e. an unexpected rise in interest rate induces the loan default to

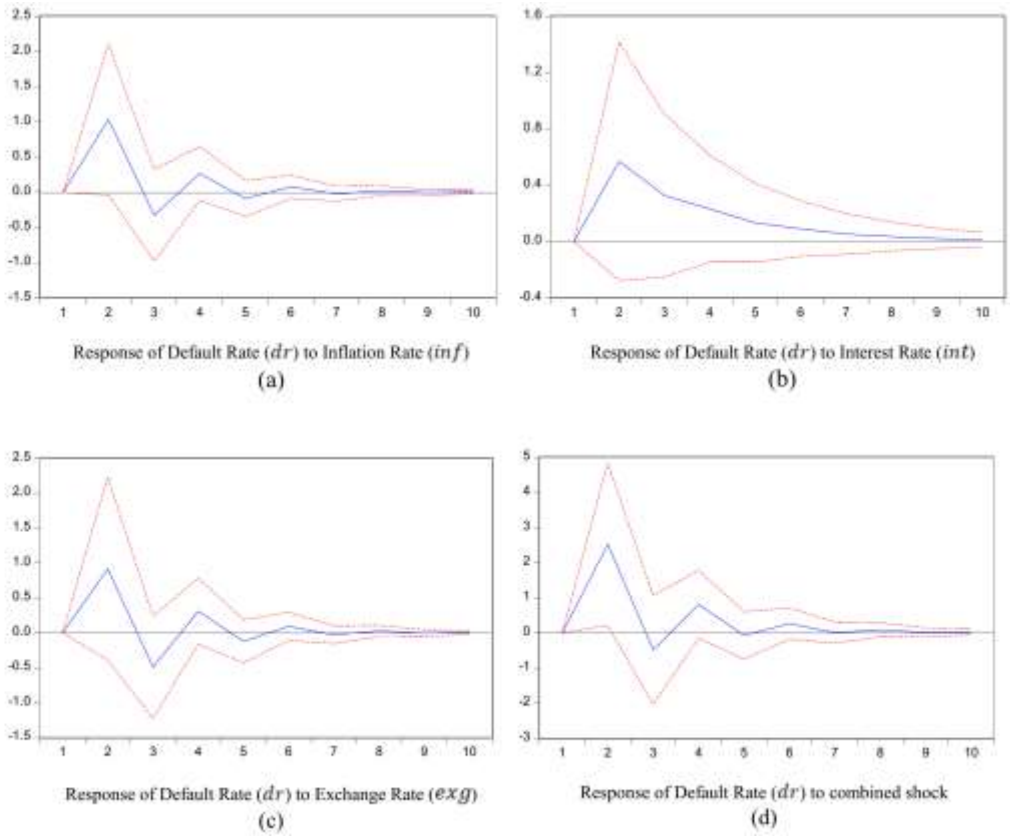

Fig. (2). Stress Test-Historical scenario.

increase. The impact is barely significant. Our findings are almost in line with the theoretical explanation and earlier empirical studies in different economies.

Variance decomposition shows that in short and medium horizons, impacts of macroeconomic shocks on default rate variation are almost same (11.38% & 11.88% respectively), out of which exchange rate explains more compared to other variables.

In order to identify the comprehensiveness of structural shocks, we impose sign-restricted 99th percentile value to disseminate shocks for each variable. The study finds that an extreme adverse inflation situation and increase of interest rate and exchange rate, default rate rises by over 1%, 0.57% and 0.92% respectively. In addition, if all the extreme historical events occur for all macroeconomic variables, the default rate would increase by 2.52% after a lag. It indicates, adverse economic situation can threaten the banking sectors.

From the operational and regulatory perspective of banks, our findings are motivating. The results might help the policy makers to focus on the key macro variables for smooth operation and stability of the banking system. This study also opens the possibility of further studies to assess the individual bank level resilience to macroeconomic shocks.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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